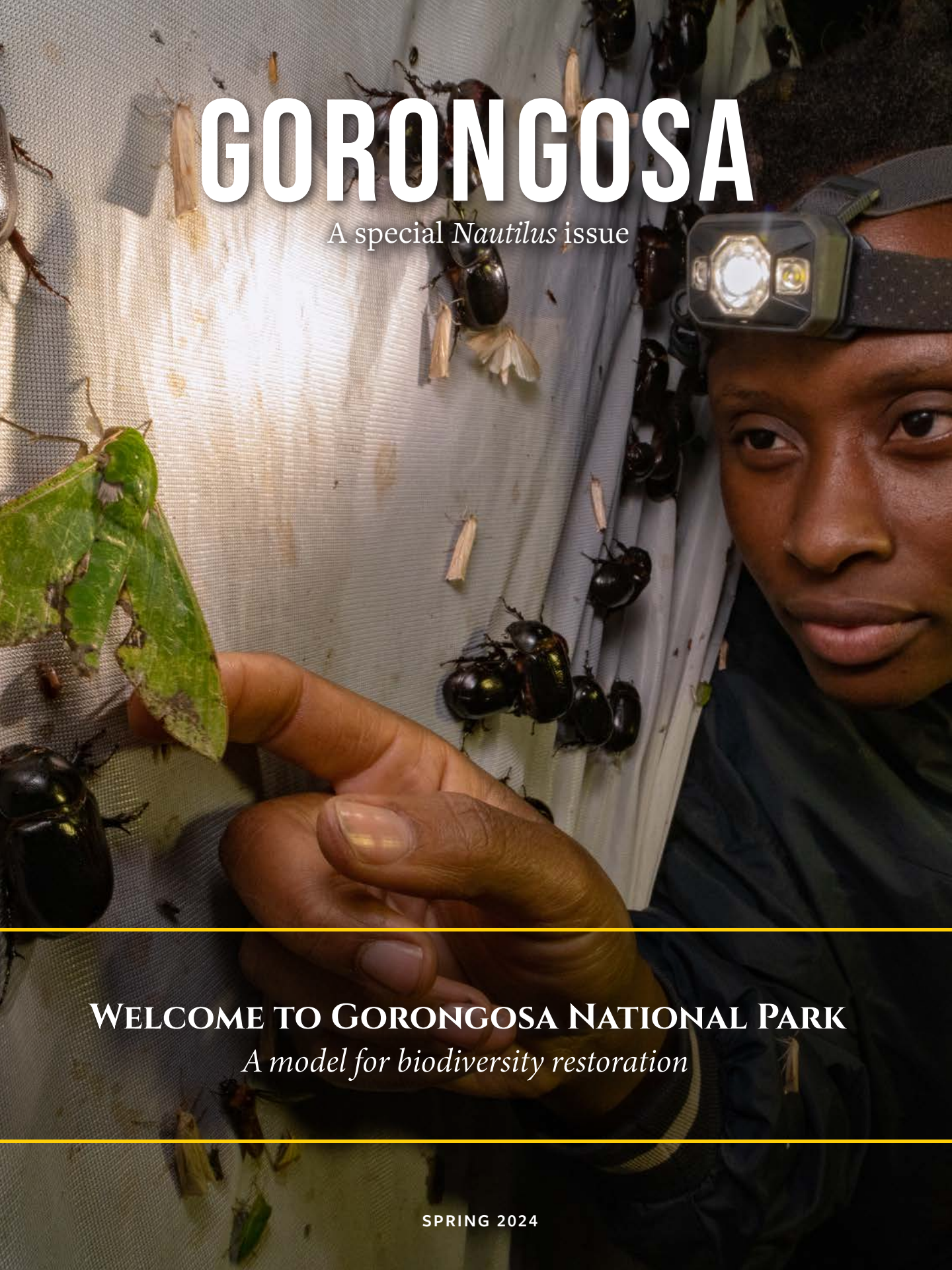

GORONGOSA

A special *Nautilus* issue

Welcome to Gorongosa National Park

A model for biodiversity restoration

SPRING 2024


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NAUTILUS *Next*

EDITOR'S NOTE

The Living Laboratory of Hope

BY ANNA BADKHEN

"IF YOU GIVE A CATERPILLAR A LEAF," writes Katharine Gammon in "The Very Hungry Caterpillar and the Ecosystem," "chances are he's going to tell you about the state of the world."

In this issue, three writers—Gammon, Jori Lewis, and Charles Digges—zoom in on the million-acre living laboratory that is the Gorongosa National Park in central Mozambique. Established in 1960 and devastated during Mozambique's decade-long war for independence and the subsequent 16 years of civil war, which decimated the park's wildlife, Gorongosa is now "a model of wildlife recovery," as Lewis puts it.

Gorongosa's ecosystems bring together rainforests, woodland, savanna, and marshes. Its location at the southernmost part of the great African Rift Valley, which rends the continent north to south from the Red Sea to Lake Malawi, makes Gorongosa a converging zone for southern and eastern African species as well as one of a handful of parks around the world with so many ecosystems in one protected place. This creates an ideal location for collaborative, cross-disciplinary research in biodiversity documentation, ecology, conservation biology, paleoanthropology, climate science, and other fields that are, in the words of the polymath entomologist Piotr Naskrecki, "prerequisite to effective conservation that's firmly based in science."

For six months in 2023, Lewis, Gammon, and Digges investigated the extraordinary scholarship that takes place at the park. They wrote about the scientists' effort to study the language of bats ("scientists believe many species can sing; some can recognize each other's voices; they have dialects; they can alert others to dangers; and they form intense bonds with their young," Lewis writes), understand the needs of species in aftermaths of natural catastrophes, and build a multidimensional map of multi-species interactions that can indicate ecosystems' resilience to change—precious knowledge at the time of unprecedented climate crisis.

As you read their stories, I hope you, too, fall in love with the solitary pangolin ("Think of a cat. Then add scales," writes Digges); marvel at the inventive solutions of the park's Human-Wildlife Coexistence Teams to "facilitate an entente … if not a perfect peace" between wild animals and humans living near the park (Lewis); and hold your breath alongside scientists of the Paleo-Primate Project who are "looking to fill out the pages of humanity's family album" by collecting animal bones from the Miocene Epoch—relics they hope will help them shape "the beginnings of a sweeping narrative involving the life, death, and the shifting landscapes of our cagey hominin ancestors, the creatures with which they shared the planet, and the environment in which they emerged" (Digges).

What do we feel in the face of a drastically changing planet? Despair. Wonder. Grief. Hope. The same, I imagine, as what our "cagey hominin ancestors" felt, or the *Homo sapiens* who faced the East African megadroughts that began 135,000 years ago and lasted 60,000 years, putting humankind at the brink of extinction. The science this issue highlights invites you to peek at what scholars at the Gorongosa National Park are learning as they try to make sense of what it means to be alive on this planet, today.

ANNA BADKHEN is a Guggenheim Fellow. Her seventh book, *Bright Unbearable Reality*, was longlisted for the 2022 National Book Award.

A Park for the People

Behind the creation of Gorongosa National Park

BY GREG CARR

THE GREAT 20TH-CENTURY AMERICAN WRITER Wallace Stegner famously said that "national parks are the best idea we've ever had." I agree with that, but I would add: National parks around the world collectively have improved upon the original idea.

Yellowstone National Park—the world's first example of a formal, national park—was created on March 1, 1872. The goal was to set aside the land for public enjoyment, both aesthetic and recreational. The Act said the land was to be: "reserved and withdrawn from settlement, occupancy, or sale."

How has this "best idea" been improved? I believe there were two important aspects missing in the original conception.

First, there was initially no plan to study the geologic and ecological systems and processes; no plan to conduct science and welcome scientists to Yellowstone. Wildlife had been nearly eliminated from the Park's area by over-hunting. It was a missed opportunity not to study the ecosystem—soil, water, flora, and fauna—as wildlife numbers returned under this new protection. The knowledge gained by studying this restoration would have been useful in restoring other depleted natural areas.

Second, there was no mention of the Indigenous groups who had thrived in the ecosystem for centuries or millennia, who understood how to make a sustainable living there, and whose activities were part of the processes of the ecosystem.

Through the 20th century, national parks across the world began incorporating more science and more local knowledge in their management. Thus, when Mozambique's then-president Joaquim Chissano asked me, in 2004, to help develop a plan to restore Gorongosa National Park, it was clear that these features would be central. We ensured the Park's new iteration would be responsible for "building the capacity of Mozambican researchers, managers, and technicians in ecological research and monitoring, conservation biology, sustainable development, adaptive management, and related skills … [And] improving the ecological management of the greater Gorongosa ecosystem," through scientific research.

As I reflect on these intervening years, I am proud to see how much progress we have made. In these pages, you will read about some of the tremendous work of Gorongosa's Science Department in particular. We now collaborate with 70 universities worldwide, including the major Mozambican universities. We also provide a two-year master's degree in conservation biology with a cohort of 12 Mozambican students in each class—the only program of its kind in the country.

And what about the Mozambicans who have lived for time immemorial in this ecosystem? As the Mozambican government and my team developed our objectives for the Park's relationship with the people who share the ecosystem, we were guided by the ideas of former president Chissano (who held office from 1986 to 2005) and his friend Nelson Mandela, president of South Africa from 1994 to 1999. Those leaders set forth the vision that national parks in their countries must benefit the local people. We established as our mantra: "Gorongosa, a Park for the People." We are the largest private employer in central Mozambique, and 99 percent of these positions (including senior management) are held by Mozambicans, most of them hired nearby.

It is thrilling to read an issue of *Nautilus* overflowing with stories about the science and people in and around Gorongosa National Park. I hope our work can continue to advance the definition, mission, and vision of everything a "national park" can be.

GREG CARR is a philanthropist. He sits on the Oversight Committee of the Gorongosa Restoration Project.

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Welcome to Gorongosa National Park

Nautilus puts a spotlight on Gorongosa National Park, a model for biodiversity restoration

BY JOHN STEELE
PHOTOS BY PIOTR NASKRECKI

GORONGOSA NATIONAL PARK, nestled in the heart of Mozambique, was once a place of thriving biodiversity. Herds of elephants roamed the savannas, lions hunted the plains, and colorful birds fluttered through the air. Created in the 1960s, Gorongosa soon became one of the most important game reserves in Africa. Celebrities like Joan Crawford, John Wayne, and Richard Burton were regular visitors. But two decades of civil war and poaching took their toll. The land was left barren, the animals vanished, and the beauty of Gorongosa faded.

But there were those who would not let it die. The Gorongosa Restoration Project, with tireless efforts, brought new life to the park. They worked to restore the habitats, control the predators, and support the local communities. And slowly but surely, Gorongosa began to bloom again. The elephants returned, their trumpets echoing across the savannas. The lions prowled once more, their roars filling the air. The birds, with their melodic songs, filled the skies. Gorongosa was alive again, and her beauty was once more on display.

JOHN STEELE is the publisher of *Nautilus*.

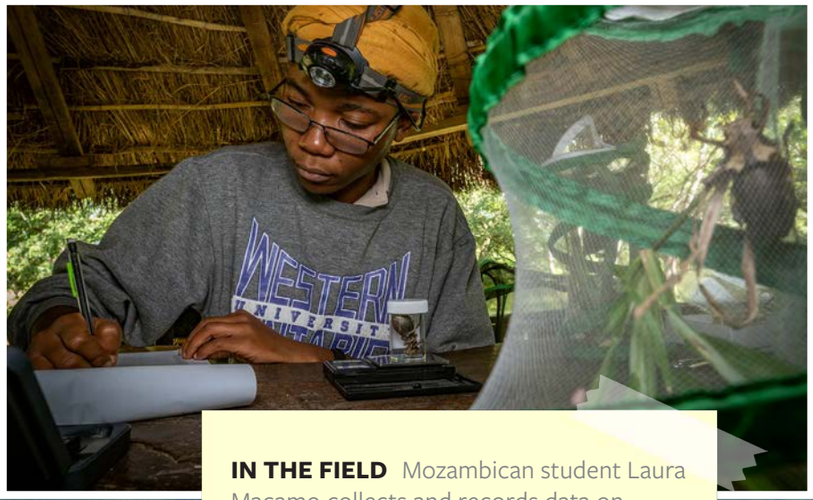
FANCY A DRINK? This photo is a composite that shows every animal that visited one of the last remaining watering holes in one day during the dry season in Gorongosa National Park.

THE PROTECTOR A Gorongosa park ranger wades across the floodplain; water lilies in the foreground. The rangers' anti-poaching work has been key to conservation and the ever-increasing wildlife numbers in the park.

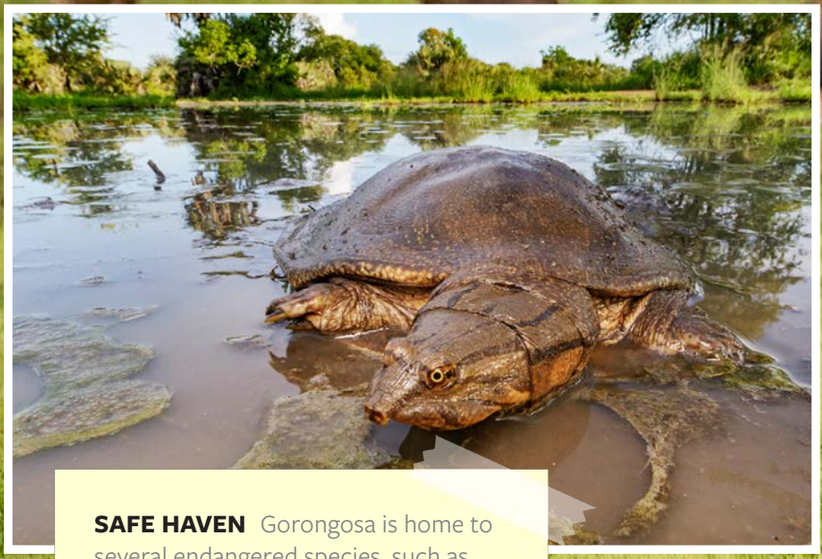
Photo by Jen Guyton

CIVET WATCH As Gorongosa reintroduces top predators, scientists are interested in how the mostly nocturnal African civet, about the size of a housecat, will fare among large cats. The park's recovery allows a rare opportunity to study on a detailed level how an ecosystem returns from a collapse.

MUFFLED ROAR After a civil war ravaged Mozambique for 16 years, from 1976 to 1992, there were only about 20 lions estimated in the million-acre park. Today, the park boasts around 200 lions.



IN THE FIELD Mozambican student Laura Macamo collects and records data on speciation in armored katydids.



SAFE HAVEN Gorongosa is home to several endangered species, such as this Zambezi soft-shelled turtle.

ELEPHANTS IN THE ROOM
Before the civil war, there were more than 4,000 wild elephants in the park. During that time, they were hunted until only about 400 remained, but have since begun to rebound. Today, there are about 1,000 elephants at Gorongosa—and they're vital to the ecosystem. One elephant consumes about 300 pounds of leaves, shrubs, fruits, and roots a day. Their dung helps fertilize soil and spread seeds, furthering cycles of vegetation growth and ensuring plant diversity.

A Map of Life Like None Other

In one of the most biodiverse places on the planet, scientists are charting the amazing web of life

BY KATHARINE GAMMON

THERE'S A PSYCHOLOGICAL PHENOMENON called pareidolia that Piotr Naskrecki, an entomologist from Harvard University, often thinks about on slow walks around Gorongosa National Park in Mozambique. Pareidolia describes an experience when people see a meaningful image in a random visual pattern: faces in a piece of toast, human figures in trees. It has to do with our evolution. In our prehistoric years, humans needed to be prepared for anything hiding in the bushes. Even if a poisonous snake turned out to have been a stick, it was a good idea to have jumped over it. At Gorongosa, Naskrecki harnesses this basic human impulse for science. "I let my mind take the reins of my imagination and guide me toward finding things that I normally would have completely missed," he says.

Naskrecki finds many biological questions can be best answered with a slow walk. Even as an experienced naturalist, he finds the world opens up when he moves slowly and starts to notice things: a dried-up leaf on the side of the path may be hiding a caterpillar on the underside. Or it may not be a leaf at all, it might be a moth. Or a leaf-mimicking insect. Scientific findings are everywhere in the park, underfoot and overhead. Gorongosa is a living laboratory in the wild.

When Naskrecki first visited Gorongosa in 2012, he was completely blown away by the diversity of life. He saw an untold abundance of species interacting on all levels, from millipedes crawling in leaf litter to bugs embedded in the fur of bats. He had worked in other parts of Africa, so he thought he'd be prepared for Gorongosa, but what he found at the park left him in awe and wonder. The international scientific community knew so little about this part of the world that 90 percent of what he was seeing was new to science, he says. "It was just this feeling that I was entering a completely blank spot on the map of global biodiversity, and everything that we can contribute will be beneficial and useful toward understanding the biogeography of life."

FLY AWAY Mozambican student Rosa Félix Tivane releases a Paradise Flycatcher after taking its biometric data.

PAGES 15-17: PIOTR NASKRECKI

I, ZOMBIE This wasp (*Ambulex sp.*) at Gorongosa injects venom into a cockroach, paralyzes it, and lays eggs in it.

Today, Naskrecki is a project leader of the Gorongosa Map of Life project. Its purpose is to document all life in the park, from soil bacteria to elephants and everything in between. Naskrecki and a group of scientists and students from a variety of fields, methodically document a section of the park, recording specimens that might be new to science. Recently, their research took them to a remote area of a limestone plateau dotted with caves. They swept nets to capture insects, turned over rocks and logs to look for reptiles, and used ultrasonic recorders to eavesdrop on bats.

The Gorongosa Map of Life was launched in 2014. Every rainy season, between March and April, the scientists and students sample everything they can, building a multi-dimensional map of interactions. Scientists must know which species make up the park—and how they are related—to conserve them. "Understanding the ecosystem and all its elements is a prerequisite to effective conservation that's firmly based in science," Naskrecki says.

Each group of experts conducts field research for nearly a month at a time, moving every week or so to study a new area. They collect fauna in the soil and leaf litter, trap insects, record

Only 10 to 20 percent of Earth's species have been formally described.

the songs and sounds of bats, birds, amphibians, and insects, and observe the movement and activity patterns of elephants. They also study external processes such as fire to better understand their value in rejuvenating the landscape and in maintaining biodiversity. The Gorongosa Map of Life is the first inventory of its kind in any protected area in Africa.

So far, the project has documented more than 7,700 species, but scientists predict that there are at least 75,000 multicellular organisms in the park, probably more. "Every time we go on a survey," says Naskrecki, "we usually add about 1,000 species to that list." His teams have found a previously undescribed rare spiny crustacean that hasn't yet been named, and a horseshoe bat—at only 5 grams, the smallest in Africa—among other creatures. They have also recorded heretofore undocumented interactions among species, including an earwig that lives on giant pouched rats, crustaceans that thrive inside fungal gardens of termites, and parasitic bugs that nest in the fur of bats.

Traditionally, scientists have studied connections between any two given species. What sets the Gorongosa Map of Life apart is that participating scientists can investigate multi-trophic interactions that involve several levels of life, from plants to herbivores to predators, parasitoids, or pathogens. "The bigger this database becomes, the more data we have, the more powerful it is and the more complex questions you can ask," Naskrecki says.

Understanding natural biodiversity can shed light on what needs to be done to restore degraded landscapes, says Marc Stalmans, a landscape ecologist who directs scientific research at the park. He says it's important to understand how landscapes are destroyed—both to protect what's left and to rebuild a more livable world, especially in the face of climate change.

PIOTR NASKRECKI

HOME SWEET HOME This Mozambican girdled lizard (*Smaug mossambicus*) is endemic to central Mozambique. Most of the known populations of this species are in Gorongosa.

In 2019, a massive cyclone led to unusually extensive flooding in Gorongosa, which knocked out termites in many places in the park. After three years, they haven't been able to recolonize their territory, which has completely changed the dynamics of the woodland savanna where they act as critically important ecosystem engineers. The project's data will be able to show the long-term impact of cyclones on the ecosystem and species, and, more broadly, demonstrate long-term effects of climate change.

When people talk about the untapped potential of the natural world, Stalmans says, they often use the example of undiscovered pharmaceuticals that could be found in the amazing diversity of plants and animals. But there's more to nature than chemical compounds. "The potential of biomimicry, for example, is enormous," Stalmans says. "Nature has evolved form and function that best addresses aspects of energy conservation, protection from the elements, and survival in adverse conditions. We can learn so much from the diversity of life in coping with those challenges."

The scope of the Gorongosa Map of Life is immense. Scientists would love to trace the connection among soil fauna, canopy fauna, river

SURVEYORS Piotr Naskrecki leads a team of young scientists at work on the Gorongosa Map of Life. From left: Berta Guambe, Norina Vicente, Naskrecki, Dennyse Amade, and Mateus Castene.

ecosystems, bacteria, and viruses. Naskrecki estimates there are 10,000 species of spiders and their relatives in the park. What role do they play in the ecosystem? "There isn't one specific goal that we want to achieve with the project," Naskrecki says. "We just want to create a data set that can be endlessly explored and used to make connections between these different elements."

ONE PROJECT UNDERWAY at Gorongosa is investigating what is living in the soil. Naskrecki recently worked with a visiting scientist from Poland, who grabbed a scoop of woodland soil and flew it back to his lab, where he put it under a microscope. It was literally alive, bursting with biodiversity. It included more than 50 species of detrivorous soil mites, which feed on decaying organic material, in just that single scoop. Then there was another group of mites that fed on those detrivorous mites—and yet another group feeding on the predators of the mites. The layers of species and their unexplored interactions in the richness of the soil left Naskrecki with a feeling of astonishment. "It shows how nature in general is so fractal that at any given spatial scale you will find similar relationships," he says.

COURTESY OF GORONGOSA NATIONAL PARK

ENVIRONMENT | GORONGOSA SPECIAL

There are 10,000 species of spiders alone. What role do they play?

Naskrecki is fascinated by parasites, especially the many animals that live off the backs (often literally) or heads of other species. At one point, he was observing a caterpillar who had been parasitized by braconid wasps. The caterpillar's still-living body was paralyzed, having become the host and food for wasp babies, covered with tiny cocoons, something he found both "super cool and kind of cruel." He watched a tiny wasp sitting on top of the cocoons. Was it the moment of emergence from the host? As he looked closer, he realized a different type of drama was happening: The wasp was a hyperparasite, laying eggs in the creatures that had just emerged from the caterpillar. It was a complex interaction, involving several trophic levels: caterpillar eats leaves, parasites eat caterpillar, hyperparasitoids eat the parasites. The relationships between each level are completely unique—each type of caterpillar only eats one type of plant, and so on—and they all rely on one another. Each of these specialized parasites typically represents a new species, and it's one reason scientists now think parasitic wasps are probably the most species-rich group of organisms on Earth.

Those interactions are part of what makes Gorongosa so fascinating. The park's habitats range from rainforests to woodland, savanna, and marshes, which makes it one of a handful of parks around the world with so many ecosystems in one protected place. It's located at the southernmost part of the great African Rift Valley, which rends the continent north to south from the Red Sea to Lake Malawi. This geologic formation channels life from East Africa to the park in a way that makes Gorongosa a converging zone for southern and eastern African species, an ideal nature-made lab to understand how species interact with their environment.

It's also a location that hasn't been studied deeply until recently. The park was established in 1960 and became known for its vast numbers of hippos, wildebeest, and zebras unique to Gorongosa. But as the park was beginning to gain interest from scientists, Mozambique was going through turbulent times. It gained sovereignty from Portugal in 1975 after a decade-long war for independence, then spiraled into another civil war three years later. That war lasted 16 years, and Gorongosa was a hotspot of fighting, whiplashing between government and rebel control. When scientists were able to return to the park safely in the 1990s, the landscape was there, but up to 90 percent of the wildlife had disappeared.

It's impossible, of course, to do effective conservation without knowing what you're trying to protect, especially when resources are extremely limited. Gorongosa is an enormous space—about 1 million hectares that include, uncommonly for a national park, a peripheral area where people live in settlements and villages—so the park wants to deploy resources in the most targeted way possible. Gorongosa Map of Life focuses on the centers of endemic species because that's where conservation can make the most impact. One of those hot spots is Mount Gorongosa, elevation 6,112 feet, an isolated mountain that, at 18.4 degrees south of the equator, holds the remnants of one of the southernmost tropical rainforests in Africa. "Having this type of a map, knowing exactly what we have and where, allows us to make wiser and better decisions about how to do conservation," Naskrecki says.

In 2008, the park entered into a public-private partnership with the Carr Foundation to rewild the area, and has since gone through a renaissance. The park also works with local communities to promote opportunities in an area that has struggled economically. Vitally, the scientists studying Gorongosa also live and work on site. "Particularly in Mozambique, there have been huge gaps in the history of natural research, so there are many things we do not know about yet," says Bart Wusten, a botanist based in Belgium who has been working with Gorongosa for decades, doing surveys of vegetation. The data he has collected can now help set a baseline for future studies.

SO FAR, THE GORONGOSA MAP OF LIFE has collected approximately 210,000 individual observations across different habitats and across different timelines. The participating scientists discovered over 200 species new to science—from mammals to invertebrates and plants. Other species that exist only in the park include a katydid whose loud nocturnal serenades dominate the mountain soundscape yet are undetectable by humans, and a new species of long-fingered bat. It's the most extensive scientific biodiversity work in Africa, with samples and data points stored in a lab at the park and also sent across the world to nearly 70 partnering universities.

The map also allows scientists to see deeper into the hidden connections between organisms. They have documented insects that change their behavior in response to bat predation. The scientists have been able

to create a library of echolocation calls of bats, and recordings of singing insects and frogs. They are currently putting together a dictionary of verbs, phrases, and words used by bats to convey certain messages. "Everybody knows about echolocation," says Naskrecki, "but bats actually have a very complex social language and we are trying to understand it."

Another place to see interactions among species is in carcasses. On an impala antelope, there might be 250,000 fly larvae, and those flies are being preyed upon by hister beetles. The contents of an antelope's stomach will be food for dung beetles. Parasitoid wasps that come and start parasitizing the larvae of other insects on the carcass. In biomass, those insects can reach about a third of the body mass of that mammal—which means that a single dead antelope can nurture about 60 pounds of insects—insects that will feed songbirds or lizards, continuing the map of life.

As the world experiences a mass extinction, humans are racing to catalog our neighbors before they disappear. A larger Map of Life project, a collaborative, multi-university platform that combines satellite imaging with ecological data to determine the location of species across the globe, is working to pinpoint where the most undescribed species may be found. Scholars estimate that only 10 to 20 percent of Earth's species have been formally described.

Conservation also has a practical side to helping prevent climate warming beyond 1.5degrees Celsius. A growing body of evidence shows that wild animals and their habitats can enhance natural carbon capture and storage, and scientists are calling for protection and restoration of wild animals and their ecosystems as a key component of natural climate solutions.

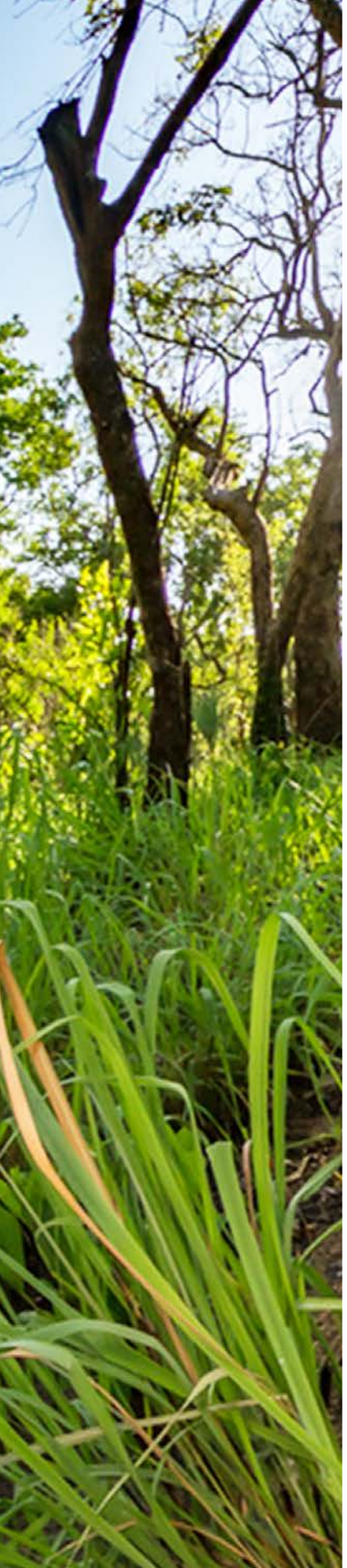
Species-mapping is taking place in national parks around the globe. In the Great Smoky Mountains National Park in the United States, a group of scientists in 1998 started a park-wide biological inventory of all life forms, known as the All Taxa Biodiversity Inventory, or ATBI, to figure out which species live in the park, where exactly they live, and to identify their ecological community. ATBI has since discovered 10,000 species that previously had not been known to exist at the park, and about 1,000 that were new to science. Now the ATBI is looking to speed up conservation science by creating genomic barcodes, which use DNA to figure out species and their relationships. Gorongosa's project has similar goals, though its environment is even more diverse, Naskrecki says. ATBI "have been doing it for the last almost 30 years," he says. "They've already beat us in terms of species, but we will meet them eventually."

KATHARINE GAMMON is a freelance science writer based in Santa Monica, California, who writes about environment, science, and parenting. She is presently reporting from Gorongosa National Park in Mozambique. You can find her on X (formerly known as Twitter) @kategammon.

The Perilous Life of the Solitary Pangolin

Poached to the edge of extinction, the bashful animals are getting by with a little help from their friends in Africa

BY CHARLES DIGGES



THINK OF A CAT. Then add scales.

That's how Mercia Angela describes the pangolins she cares for at the Gorongosa National Park in Mozambique, where she runs the country's only rescue center for the world's most frequently illegally trafficked mammal. "They sleep a *lot*," she says.

Pangolins are nocturnal by nature and elusive in the wild, preferring to burrow in savannas and floodplains, or scrabble up trees in wooded areas where they can remain out of sight. Yet, despite their demure ways, they are the focus of a harrowing drama, their species poached to near extinction by a massive and illegal worldwide trade.

That's where Angela's rehab center—and the lush sprawl of Gorongosa as a whole—come in. It's been a little more than three decades since the ravages of Mozambique's 16-year civil war, by which time Gorongosa's population of large mammals had shrunk by 95 percent. Antelope had been slaughtered to feed troops and hundreds of elephants had been killed, their tusks traded for guns. Pangolins didn't fare any better. For centuries, their meat has been prized as a delicacy in Southeast Asia, and their scales valued in traditional medicinal practices in China. In the West, pangolins barely had a public profile until they were briefly but incorrectly implicated as a possible origin of the COVID-19 virus. Now, because populations in Southeast Asia have been decimated, the pangolins native to sub-Saharan Africa are being caught in poachers' snares.

After 30 years of restoration, Gorongosa has become a leading African conservation project, the pangolin rescue one of its central missions. Encompassing 1,500 square miles at the southern end of the Rift Valley, the park may host as many as 75,000 different species of flora and fauna. Among them, the African ground pangolin plies its lonely nighttime trade, its excavations making it a sort of gardener providing invaluable rejuvenation of the soil.

PAGES 24-25: JEN GUYTON

The stunned animals roll up and become as compact as a medicine ball, making them easy to scoop up and shove in a sack.

Currently, Angela, a wildlife veterinarian, is caring for two pangolins—a baby of only a few months who was rescued from traffickers by Gorongosa's rangers, and an adult, brought to the center by locals living near the park who were concerned that it, too, might end up ensnared in the trade. The baby—a male who Angela calls Tembo—arrived in September 2022 hungry and traumatized. Angela kept him on a diet of milk for three months to help him gain weight before he graduated to ants, which he siphons up at a rate of nearly half a pound a day. She forecasts that in the next few months he might be ready to join the other 98 pangolins Gorongosa has rescued since her center started work in 2018.

The addition of Tembo to that number will be significant. So pervasive is the poaching that the world's population of pangolins is thought to have dropped by as much as 80 percent over the past two decades alone, the Swiss-based International Union for Conservation of Nature (IUCN) has warned.

As rare a find as pangolins are, they're unmissable. Adult pangolins can be as big as racoons and weigh as much as 40 pounds, but they bear a striking resemblance to an artichoke with legs. Their heads and bodies are riveted with an armor of thorny scales, making them look reptilian. Despite their otherworldly appearance, their scales have a characteristic familiar to every human—they're made of keratin, the same protein that makes up our fingernails and hair.

IN ZOOLOGICAL LITERATURE, pangolins are loosely referred to as scaley anteaters because of that armor and their diet, but they aren't related to true anteaters. Rather, they belong to a group all their own—one of the strangest orders of mammals—the *Pholidota*, which contains only eight living species.

Four of these are found across much of Asia, in countries ranging from India to China, and farther to Malaysia and the Philippines. The other four—including the African Ground Pangolin—are native to sub-Saharan countries stretching from Sudan to South Africa. All of them are at risk of extinction, the IUCN says. The grandest international effort taken against the illegal trade in pangolins came in 2016, when 183 nations signed the Convention on the International Trade in Endangered Species, known as CITES, which placed all eight species of pangolin in the document's Appendix I, giving them the strictest protections.

Similar to carnivores by descent and armadillos by convergent evolution, pangolins are most closely related to bears and—yes—cats. But they are almost monastic when compared to those more outgoing cousins. The male and female pangolin come together only to mate, with females capable of giving birth to one baby about every two years. Angela says the single offspring then spend about four months riding on their mother's tail as they get the hang of hunting. Then they separate and set off for a solitary life all their own, sometimes living as long as 20 years.

And it's the lonely foraging and burrowing of the African Ground Pangolin that Angela says makes them so essential to the recovery of Gorongosa's ecosystem. Making quick work of ant and termite hills, pangolins burrow after their prey with deft foreclaws and long, slithering tongues. And where they sniff and nudge the soil by night, nutrients can penetrate more deeply by day, helping to replenish food stores for Gorongosa's other animals and encouraging rejuvenation of the vegetation.

This appetite has other benefits. Angela says that most adult pangolins can eat about a pound of their quarry in their daily feeding, guarding against destructive termite and ant plagues.

But for all the waste they lay to their prey, pangolins are almost entirely harmless to any other living creature. When this bashful animal is frightened, it curls up into a tight ball, the scales offering its first—and, really, only—line of defense.

Sadly, it's that defense mechanism that Mercia says makes them so susceptible to capture by traffickers. As poachers drive pangolins into the open by setting fire to their burrows or battering them out of trees with sticks and clubs, the stunned animals roll up and become as compact as a medicine ball, making them easy to scoop up and shove in a sack.

Often, when poachers are interested only in the scales, they drop the curled-up pangolins into pots of water and boil them alive to make the scales easier to pluck. From there, the scales make their way to Nigeria, where smugglers bundle them with other wildlife contraband like elephant tusks and ship them off to Asia.

TO THE RESCUE Gorongosa rangers patrol the park, dismantling snares and keeping tabs on GPS-tagged pangolins. Here they release a pangolin rescued from poachers.

HITCHIN' A RIDE Female pangolins can give birth to one baby about every two years. Here a mother takes her baby for a drink during the first rain of the season in Gorongosa.

PAGES 28-30: PIOTR NASKRECKI

Nearly a million pangolins have been trafficked from African and Asian countries in the past two decades.

OWING TO PANGOLINS' RECLUSIVE night-time routines, naturalists have famously been unable to settle on an exact worldwide census for the animals. But the scant handful of national figures that researchers have managed to assemble suggests that there may be fewer than 150,000 left on the African continent, though the question is still open to debate and ripe for more study. Similarly, putting exact numbers to the illegal pangolin trade is challenging, but the most authoritative study, published in 2020 by German biologist Sarah Heinrich and Oxford zoologist Daniel Challender, among others, documented that at least 895,000 had been trafficked from African and Asian countries in the two decades before their study was written, though they conceded the actual number is likely much higher.

Heinrich and others shed light on the history and dynamics of the pangolin trade in another paper published in 2016. For centuries, various parts of the pangolin anatomy have featured prominently in traditional Chinese medicine—particularly the scales. If those were ground to powder or burned to ash, the old texts held, they could ward off evil spirits and midnight hysterias, provide a salve against ant bites, hemorrhoids, and malaria, stimulate lactation in women, and aid in circulation. Western science doesn't support these claims, but the traditions proved persistent, with more than 200 Chinese pharmaceutical firms offering medicines based on pangolin scales. Indeed, it wasn't until 2020 that Chinese health insurers stopped covering these remedies.

Pangolins are also a prized delicacy in Vietnam. Challender describes visiting an upscale Ho Chi Minh City restaurant in 2012, where he watched a group of diners pay $700 for a meal consisting of about 4 pounds of pangolin meat. The animal was brought to their table alive, its throat slit in front of them, and its blood was mixed with wine before its flesh was grilled.

But the 2016 study by Heinrich highlighted another historic pangolin consumer—the United States. Between 1975 and 2000—when CITES set the export quota for Asian Pangolins to zero, essentially banning the international trade—America was a voracious client of the pangolin's striking diamond-patterned skin, using it for wallets, handbags, and high-end cowboy boots. Many of these items can still be found on the grayish markets of the internet, though for a stiff price. University of Adelaide professors Joshua Ross and Phill Cassey, in a 2019 paper co-authored with Heinrich, described tracking down a pair of pangolin skin boots for sale on the U.S. eBay site for $13,000. (By May 2023, they had apparently been sold.)

In the years since the COVID pandemic, China has established a raft of prohibitions meant to curtail the illegal pangolins trade. But as those focus mainly on pangolin meat, they have not so much dampened the trade as changed its character. Xu Ling, China coordinator for the wildlife trade monitoring group Traffic, told the *Guardian* that there has been a drop in the number of frozen pangolin carcasses arriving in the country for consumption as meat. Instead, it's the scales that are smuggled in, which Ling says are harvested in Africa.

And the quantities are on the uptick, a study published in *Nature Conservation* shows. Researcher James Kehinde Omifolaji of Federal University Dutse in Nigeria and his coauthors combed through arrest records, seizure reports, and other law enforcement data on China's illicit imports to reach some startling numbers. According to their research, a total of more than 400,000 pounds of pangolin scales made their way to 27 different Chinese provinces in 2021.

Pangolins are lucrative even at the point of sale—or, rather, theft. Angela says that poachers in Mozambique can fetch between $450 to $750 per animal they capture and sell onto the black market.

PIOTR NASKRECKI

PLAYING PANGOLIN When startled or frightened, pangolins curl up into a tight ball, making them easy prey for poachers. This photo was captured before the panglin felt the need for defense, though it was still cautious.

That may not sound like much, especially considering that Mozambique legislation from May of 2017 establishes a 16-year prison sentence for traffickers, as well as fines dictated by their place in the trade. But in a country that ranks as the eighth-poorest on the Human Development Index, and where average salaries hover around about only $300 a month, the illicit trade in pangolins can seem enticing despite the threat of punishment. Nonetheless, Angela's charges have fewer worries about smugglers than their brethren outside the park. Watching over them are more than 250 locally hired rangers trained in law enforcement, who patrol the park dismantling snares and keeping tabs on several species with the help of GPS tags. Though the system isn't fool-proof, park officials say the number of traps they find within park confines has dropped by 60 percent in recent years.

Because of that, Angela sees the task of her center—and of the Gorongosa Park at large—as something that encompasses more than triage. The Gorongosa Park has worked hard to cultivate such community involvement. Some 200,000 people live around the refuge in what park officials call a sustainable development zone that includes education, employment opportunities, and health service. It is for these people that the 15 vets and rangers working in Angela's center have compiled a how-to guide on caring for distressed pangolins found in the wild, complete with first-aid instructions for animals rescued from poachers. The education and involvement of the community, she says, is critical. An informed public can help alert Gorongosa rangers to vulnerable pangolins located outside the haven of the park, and even point them in the direction of smuggling bands. She points out that the majority of the pangolins that her center has helped rehabilitate were brought to her doorstep by concerned local residents.

Even against long odds for all eight species of *Pholidota*, it is this communal tendency that gives Angela hope. Ideally, both of Angela's pangolins will eventually be fitted with GPS trackers and released into the safe haven of the park—a paradise for such threatened creatures.

America has been a voracious client of the pangolin's diamond-patterned skin, using it for high-end cowboy boots.

Picture this: On a recent late afternoon toward sunset, the baby pangolin Tembo and his older bunkmate Mercio (Angela did point out that the elder pangolin's name is the male spelling of her own) wake from a day of slumber and are ready for food. Angela takes them out of their enclosure and brings them to a nearby grassy field, setting them loose to forage. African ground pangolins, unlike the other species, can stand upright on their hind legs, and Tembo and Mercio do—sniffing the air with their sensitive noses for the scent of dinner. Recent rains have brought a bumper crop of ants, and the two burrow in the moist ground and get down to business.

"Yes, there is a light at the end of the tunnel," Angela says. "A light of hope that with a lot of effort and joint work it is possible to avoid the extinction of this species that is so important in Mozambique."

CHARLES DIGGES is an environmental journalist and researcher who edits Bellona.org, the website of the Norwegian environmental group Bellona.

PIOTR NASKRECKI

The Very Hungry Caterpillar and the Ecosystem

Caterpillars are a remarkable bellwether of environmental changes

BY KATHARINE GAMMON

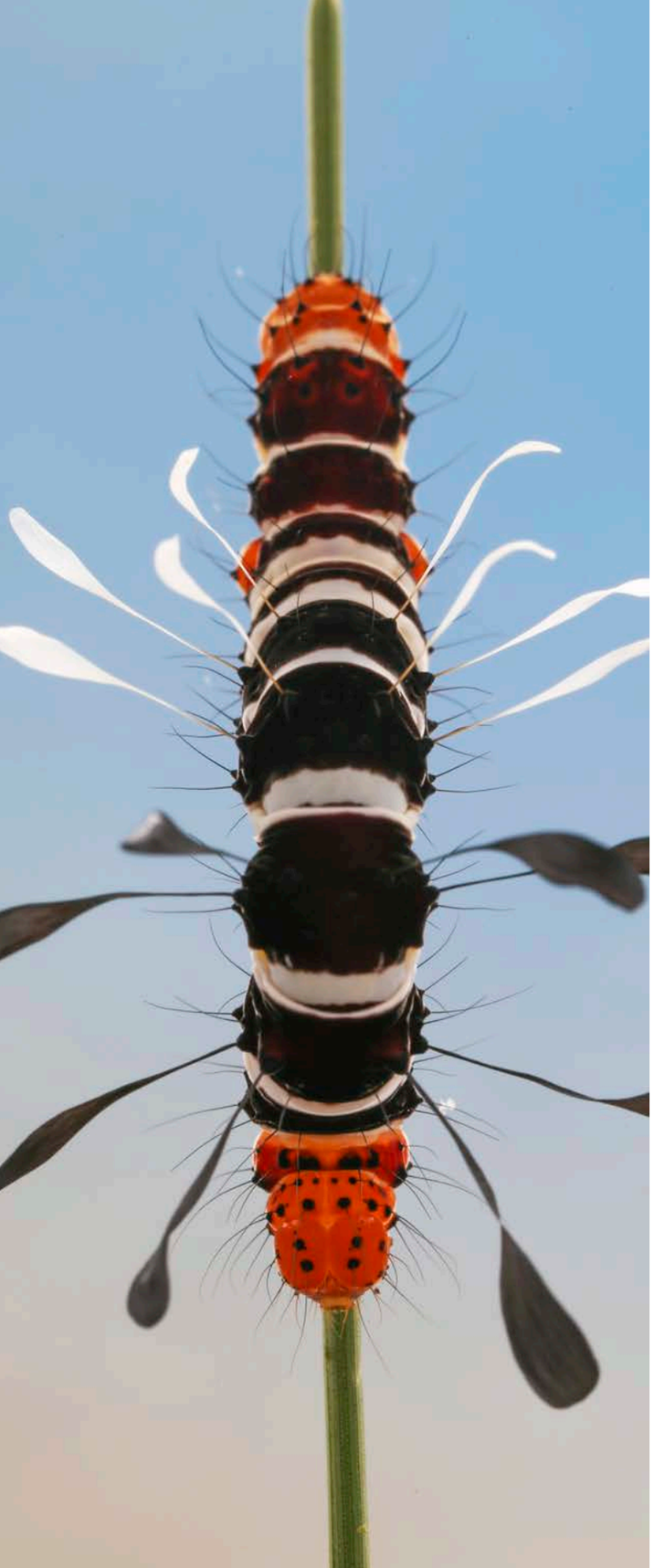
IF YOU GIVE A CATERPILLAR a leaf, chances are he's going to tell you about the state of the world.

This is what chemical ecologist Tara Massad has learned from collecting thousands of caterpillars in Gorongosa National Park in Mozambique. Her work is part of the Gorongosa Map of Life, an ambitious project to build a multi-dimensional map of interactions between species. Documenting which species make up the park—and how they are related—is the path to conserve them.

"Understanding the ecosystem and all its elements is a prerequisite to effective conservation that's firmly based in science," says Piotr Naskrecki, associate director of the E.O. Wilson Lab at Gorongosa, which performs long-term research in biodiversity documentation, ecology, and conservation biology.

For years, Massad has scoured Gorongosa for caterpillars' favorite munching leaves—bristly or smooth, brightly colored or blending into their surroundings—and popped them into bags with the voracious larva. In the lab, scientists observe a classic life-cycle drama: Plants get eaten by caterpillars, caterpillars get eaten by parasitoids—insects whose larvae live as parasites that kill their hosts—and parasitoids get eaten by hyperparasitoids, parasites that feed on parasites. "It's a very intricate interaction, and often these interactions are incredibly species-specific," says Naskrecki.

Documenting which species make up the park—and how they are related—is the path to conserve them.



PIOTR NASKRECKI

BEHOLD THE CATERPILLAR
Stunning to look at, the *Rhanidophora ridens* is helping scientists like Tara Massad branch together the tree of life in Gorongosa National Park.

For every plant-eating insect, there are often one or even two parasitoid wasps that feed on it.

Understanding these interactions is important because caterpillars are a food web connector. In addition to being hosts for a variety of parasites, they eat plants, and are eaten by bats and birds. The ones that get to complete their life cycle become moths or butterflies, which pollinate more plants and often, too, become food for many different animals.

Massad came to Gorongosa in 2014 from Brazil, where she was a post-doctoral student studying plant-eating animals and plant defenses in the South American rainforest. Today she is a mentor to master's students in Gorongosa, and an instructor in environmental assessment and tropical ecology and conservation at Oregon State University.

She explains that more than half of all the described species of organisms in the world are directly involved in plant–herbivore–parasitoid interactions, though very little is known about the actual diversity of parasitoids in tropical ecosystems like Mozambique's. To understand diversity in Gorongosa, Massad says, one has to understand the ecosystems of the park—which means creating a baseline chart of interactions between its incredibly diverse species.

In Massad's case, this has meant a very basic task: matching caterpillars with their adult forms as moths or butterflies, something that hasn't fully been done in many parts of Africa and other tropical areas, as well as matching caterpillars to plants, and parasitoids to caterpillars. Massad has found, for example, that for every plant-eating insect, there are often one or even two parasitoid wasps that feed on it. Her research, she says, can "answer questions about specialization, which is important ecologically because we know the tropics are more species-rich than other areas of the world."

One of the hypotheses about why the tropics are more species-rich than other areas of the world is that life here has become more specialized. In the tropics, a particular kind of caterpillar will often feed on just one kind of host plant, whereas in the temperate zone they might feed on multiple host plants. This creates more species over time as plants evolve to protect themselves from herbivores, and herbivores evolve to tolerate new plant defenses.

Massad's ecological research offers a peek into climate change. "We studied how changes in precipitation can affect parasitism rates," she says. "And so, if you interrupt the parasitism, you interrupt that top-down control, and you have more herbivory and natural systems that might be able to be affected."

This kind of work has previously been done by Lee Dyer, Massad's doctoral advisor at Tulane University, who has studied caterpillars in Arizona, Ecuador, and Costa Rica. Dyer is a coauthor on a 22-year caterpillar collection study from Costa Rica that shows 40 percent of common caterpillar groups and their parasitoids were in decline—with effects throughout the ecosystem.

This type of research is valuable beyond Gorongosa, Massad says. It adds to our knowledge of the diversity of ecological interactions, which is a more informative metric of ecosystem diversity and health than species richness on its own. The data help us understand how simple or networked food webs are, which indicates how resilient to change ecosystems may be. In the long term, these data can show how climate change affects ecological interactions, and also provide information on insect decline.

"Any time we can gather more data on ecological interactions from ecosystems that haven't been studied yet, we are gaining knowledge about the ubiquity or particularity of patterns in nature," Massad says.

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A Fragile Equilibrium

Inside one national park's quest to make peace between humans and animals

BY JORI LEWIS

COURTESY OF GORONGOSA NATIONAL PARK

BRAD AND BECA OFTEN CROSS the Pùngué River from Mozambique's Gorongosa National Park to visit the village of Vinho, although they never go together. Their rambles to explore the countryside are solitary and often nocturnal. And if they come across something tasty to eat, they just swipe it up without a second thought. These rascally male elephants often run afoul of the villagers whose crops they take, though the villagers use less diplomatic language: They say "pillage" or "steal."

Brad M5542 and Beca M5550 are a part of the Gorongosa herd, and are satellite-collared so rangers, veterinarians, and scientists can keep track of their movements. But they don't believe in the boundaries humans have drawn on a map. The people in Vinho and in the necklace of villages along the Pùngué River, which forms the southern boundary of the park, often wish that the pachyderms could learn to respect those limits, those frontiers between the wild and domestic, since interactions between the two parties range from the benign-but-annoying to the deadly. As do the villagers' dealings with the buffaloes and the hippos, and, of course, the crocodiles.

Gorongosa National Park prides itself on being a fenceless park. Fences can reduce human-wildlife conflicts in many cases, but they come with their own ecological and social costs by separating ecosystems and alienating the people who live around such protected areas. The lack of a physical perimeter fence around its 1,500 square miles of wilderness creates a sense of boundless landscape both for animals and visitors. But this also means that animals such as Beca and Brad are free to seek their fortunes or meals in the nearby villages of the park's 2,000-square-mile buffer zone, where approximately 200,000 people live. Marcelino Denja, who manages the park's reaction team of rangers dealing with human-wildlife conflicts, said that it's a dynamic situation, since the animals are moving and the people are moving, too. Any area outside the park has the potential of becoming a locus of potential conflict. "In the village, we have the farms and crops," Denja said. "We have the houses, we have people interacting with [animals] on the roads, we have school children."

Every day, Denja and the rangers on his team receive alerts from villagers about a wild animal in their communities. Occasionally, the distress call tells of an active conflict: an elephant destroying a traditional granary to get at the corn, who might knock down that villager's house, possibly with the family inside; a buffalo in a bad mood who decides to charge at a passerby; a crocodile stalking the people who linger by the river. In response, Denja dispatches a ranger from a nearby outpost to investigate and, if necessary, intervene.

In 2022, nine people died in conflicts with the animals in and around the park, principally with elephants but also with buffaloes and crocodiles. Elephant attacks strained the park's relations with some communities, and some park staff were confronted by villagers. The park also supported a ceremony in one village, a ritual to calm the elephants. Maybe the ritual worked, but some people still wanted more accountability. Denja told me that, to appease some of the affected communities and over the objections of some researchers and park rangers, national parks authorities selected two elephants to shoot and kill from a helicopter last year. He said the bodies of the pachyderms were butchered, and the meat distributed to neighboring villages, a boon for communities whose crops had been compromised by elephant appetites and attacks.

But Denja believes that encounters between humans and animals do not have to end in tragedy. "They can coexist," he said.

Across the world, people who live next to protected areas or wild spaces in forests, mountains, and savannas face similar challenges. Communities are grappling with gray wolves in Montana, elephants in India, crocodiles in the Philippines, exploring possible solutions. Gorongosa National Park's human-wildlife coexistence teams both react to animal crises in progress and work with communities—all to facilitate an entente between the two parties, if not a perfect peace.

ON MY FIRST DAY in Chitengo, where Gorongosa National Park has its main administrative offices and principal hotel, everyone reminded me to lock the door to my room because animal criminals were afoot. The Chitengo baboons regularly try all the locks and windows, and if they find one unlatched, they sneak in and flip the room, opening closets and unzipping suitcases in search of something to eat. During my visit, they often tried their luck at the breakfast buffet table, too, the one covered with fruit, bread, and pastries. The table was guarded by one or two men, the *homens da fisga*—men with slingshots—from neighboring villages. Whenever a baboon peeked over the banister and started reaching a hand toward a plate of cake, one of the slingshot men would ping the animal with a pebble to chase it away.

Elephants don't even need to be stung but are scared off just by the buzz and hum of a beehive.

One night at dinner, I overheard someone saying that a baboon had popped into their room while they were out, taking advantage of a window slightly ajar. It trashed the place, ate a whole bottle of medicine, and disappeared into the bush. (I don't know what kind of medicine it was, only that its owner said the baboon was probably dead as a result of eating the entire bottle.) I went back to my room and checked the windows again. I thought about the baboon's visitation when I traveled to Vinho, the closest village to the park, about a kilometer beyond the Pùngué River. What must it be like to live every day in such a state of vigilance?

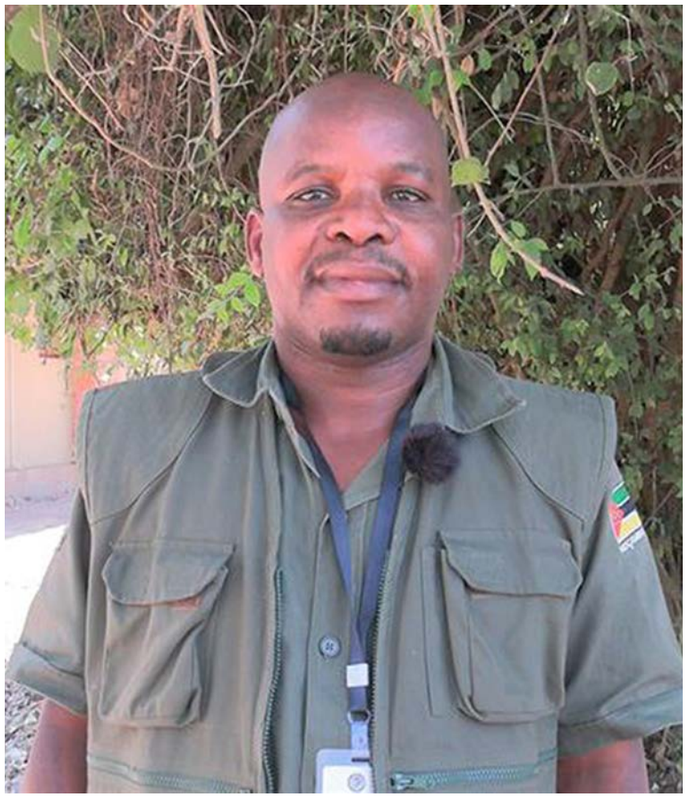
This is where the Gorongosa human-wildlife coexistence program comes in. Piano Jantar, who works with the nearby villages as part of the program, said the park is implementing a multi-pronged strategy to help people in Vinho and the other villages feel more secure. They are building grain silos made from cement reinforced with metal rods that elephants would have to work harder to knock down than the traditional ones made from wood and straw. Jantar said that the program has constructed more than 500 of these across the region, and at least 150 in Vinho alone. The silos cut down on accidental trampling by elephants eager to get at those stocks of grain during the dry season. It's the equivalent of people in Chitengo locking their doors to keep the baboons from temptation.

"Another strategy is to strengthen the fences around the river," said Jantar, as we walked from the boat launch through a path lined with a tangle of reeds and shrubs, and then a grassland that slowly transformed into cropland. The fence, when I finally spotted it, was like no other fence I had ever seen—not an impenetrable barrier at all, but a series of posts connected by ropes and, hanging from these ropes, either bits of metal

sheeting or long rectangular boxes full of bees. Some ropes had nothing hanging from them but were coated with foul-smelling creosote.

Each variation, Jantar explained, is thought to dissuade elephants, buffaloes, and hippos from entering human territory. The bits of metal trick the elephants into believing there's a larger barrier and the creosote smell is thought to be a deterrent. But the bee boxes are the most interesting and most promising approach. Researcher Dominique Gonçalves, who is finishing up her doctorate at the University of Kent in the United Kingdom and is the manager of the park's elephant ecology project, said that the idea is simple but effective.

"It actually comes from an African folktale that elephants are afraid of bees, but it was actually observed and proved and tested again and peer reviewed and everything," she said. If an elephant should try to pass, it would shake the hive, which is suspended in the air, and the African honeybees would emerge and attack. Some elephants don't even need to be stung but are scared off just by the buzz and hum of a beehive.



COURTESY OF GORONGOSA NATIONAL PARK / TREASURING

PEACEMAKER Marcelino Denja manages Gorongosa National Park's team of rangers, who react to animal intrusions into nearby communities and create strategies to reduce the conflicts between the people and animals.

Encounters between humans and animals do not have to end in tragedy.

"It's a beautiful idea," said Gonçalves. "Because it's not only stopping elephants from getting into the crops and destroying everything, but it gives [humans] also that sweet reward that is the honey."

She said the park worked with community members who wanted to try this kind of fencing. But while some are happy with it, others want a more aggressive strategy.

Querida Flautoñe, a Vinho farmer, is one of the latter. She told me that the day before our visit, an elephant came to the village and was eating bananas in someone's fields. She heard her neighbors making loud noises and setting off firecrackers to chase the elephant away. Then they called the rangers. Flautoñe said she has lost more than a few harvests of her maize, sesame, bean, and sweet potato fields to elephants over the years, and sometimes had to resort to sleeping in her fields at night, when it's almost time to harvest, to dissuade the elephants from devouring her livelihood.

The park states that "the most vulnerable within our buffer-zone communities—women, widows, the elderly—are selected as primary recipients for measures such as elephant-proof silos for food storage." However, Flautoñe said the silos don't protect the crops before they are harvested. During my visit, she told Jantar that she would prefer to have an electric fence, one on the park side of the river, to better protect villagers. Jantar responded that the animals need the river, too. And no one can split the river down the middle. He insisted that the alternative fences work, though not 100 percent of the time. There are gaps in the fencing, and, of course, elephants are notoriously smart and learn about those weaknesses.

The cleverness of escaping elephants could be a problem in areas where there's a push for more human settlement—more houses and more fields—and both humans and elephants will need to give each other a wide berth. Despite the so-called "peace-building" work of the human-wildlife coexistence teams, it's clear that there is still some work to do within the park and the communities around it to support more positive interactions between people and wildlife.

Karen Bailey, an assistant professor in the Department of Environmental Studies at the University of Colorado, Boulder, has been studying human-wildlife interactions in Africa, Asia, and the United States, and is interested in how, "when communities have the desire to figure out alternative ways to coexist and to share the landscape with wildlife," she said, they can partner with researchers to find solutions that are adapted to their needs and their vision of the future. She points to her ongoing research in Thailand, where a community with elephants is considering a switch from farming pineapples, which elephants love, to farming lemongrass and galangal, which elephants don't like as much and which are still useful and appropriate for their cuisine and economically viable. Or to her experiences in Colorado, where bear problems abound, and the state is supporting community-led efforts to create bear-smart communities.

"Maybe it's policies or mandate, or maybe it's resources to make it easier for people to take those actions," she said, "but always focusing on the community and doing something in a way that's responsive to their ideas around coexistence."

Gonçalves, manager of Gorongosa's elephant ecology project, said coexistence is not a static ideal, not a static thing. "Coexistence is such a fragile thing," she said. "In one moment, you are there, elephants and people are fine. There's no crop raiding. There's nothing. We're coexisting. And in another moment, one thing happens, and everyone is crying out to announce that there is conflict and there is not coexistence anymore. We need to start understanding that it is about a balance and an equilibrium."

JORI LEWIS writes about the environment and agriculture mostly from the Global South. In 2018, she received the Whiting Grant for Creative Nonfiction for her new book, *Slaves for Peanuts*. She is also a contributing editor with *Adi Magazine*, a literary magazine covering global politics. She splits her time between Illinois and Dakar, Senegal.

KEVIN BERGER

Elephants Are Total Scaredy-Cats Around Bees

The buzz on preventing elephants from plundering communities

BY CHARLES DIGGES

IS THERE ANY KIND OF FENCE that can make humans and elephants good neighbors? It's a question Dominique Gonçalves has had to ponder as she leads the elephant ecology project at Mozambique's Gorongosa National Park, which is not surrounded by a physical barrier.

A number of pioneering studies throughout Sub-Saharan Africa over the past several years showed a solution that was simple and natural: bees. As it turns out, the tiny, ubiquitous honeybee has the power to terrify a mammal that's 22 million times its size.

In fact, even the sound of the insect's buzz is enough to send a family of elephants into a panic, showed studies by Lucy King, an Oxford zoologist and preeminent researcher in human-elephant coexistence at the nonprofit Save the Elephants. Upon hearing the telltale hum, elephants will run, kick up dust, and shake their heads as if trying to swat the bees out of the air, trumpeting distressed warnings to other elephants as they flee.

Of course, a bee's stinger can't penetrate the thick hide of an elephant. But when bees swarm—and African bees swarm aggressively—hundreds of bees might sting an elephant in its most sensitive areas, like the trunk, the mouth, and eyes. And it hurts.

Building on King's insights, Paola Branco of the University of Idaho conducted a massive two-year-long experiment in Gorongosa that culminated in a 2019 paper she co-authored with King, Marc Stalmans, Gorongosa's director of scientific services, Princeton zoologist Robert Pringle, and others.[1] Their research aimed to settle tensions between human farmers and the park's growing population of marauding pachyderms—with the help of bees.

Although elephants are peaceful by nature, they can and will trample grain, swipe crops, topple down silos, and knock down entire houses. Given half a chance, elephants from the fenceless sprawl of Gorongosa in the Lower Rift Valley will steal across the Pùngué River—which acts as the southern border between the million-acre park and the rest of rural Mozambique—stomping into villages in search of a meal.

Humans share blame in the squabble. Natural habitats for elephants are rapidly being tilled into croplands, encroaching on food sources, often leaving the animals little choice but to ransack and steal. And while the population of African elephants has been precipitously dropping, the number of humans in Sub-Saharan Africa continues to skyrocket, rising from 930 million in 2012 to 1.2 billion in 2022, data from the World Bank show.

The result is that elephants and people are often competing for the same resources. The animals—which typically eat about 300 pounds of vegetation a day—can decimate an entire farm's harvest overnight.

In a way, it's not a terrible problem to have, says Gonçalves, who grew up in the town of Beira, a few hours away from Gorongosa.

COURTESY OF GORONGOSA NATIONAL PARK

BUZZ OFF Buckets of bees are strung on a fence wire along a river in Mozambique. When elephants trip the wire, bees swarm out of the boxes. The elephants hightail back to where they came from.

The Mozambican civil war, which raged from 1976 to 1992, saw 95 percent of Gorongosa's large animals killed. The impact on elephants was especially profound. Slaughtered by warring troops who traded their tusks for more guns, the park's prewar population of elephants dwindled from 4,000 to only about 200 by the time the conflict ended. Thirty years on, says Gonçalves, that population is bouncing back and now numbers a little more than 1,000. The crop raids are a side effect of that recovery.

But straying elephants cause havoc for small-scale subsistence farmers in Gorongosa's buffer zone, the liminal area that stretches around the 1,500 square miles of the park and is home to more than 200,000 people. The more elephant numbers bounce back, the more of them there are to go on nighttime ransacking missions.

"It's a question of how humans and elephants are overlapping," says Gonçalves. "If there are agricultural plots, that can create situations of conflict, when elephants either eat or trample or destroy. That has a huge economic security impact for farmers."

Most subsistence farmers don't have the resources to surround their plots with expensive wire fences, and often must resort to less effective deterrents like banging sheet metal to scare elephants away, burning tires to produce acrid smoke, or lying in wait in the bushes at night with flashlights and fireworks to startle the animals.

These confrontations can prove lethal for both sides. In July of 2022, five people harvesting their crops in the Mozambican province of Cabo Delgado—870 miles northeast of Gorongosa—were trampled by elephants from the Quirimbas National Park. On occasion, humans retaliate. In Kenya, for instance, wildlife authorities shoot between 50 and 120 elephants per year.

COURTESY OF GORONGOSA NATIONAL PARK

LIVING FENCES Dominique Gonçalves, manager of the park's elephant ecology project, says that using beehives as an animal deterrent is "a beautiful idea." It not only stops elephants from destroying crops, it provides people with the sweet reward of honey.

"That's the worst-case scenario," Gonçalves says. "Both people and elephants end up being dead." So she and her colleagues at Gorongosa decided to intervene to keep the two sides happy.

It began, as many science things do, with an experiment. In 2017, researchers strung a series of fences at well-trafficked elephant crossing points along the Pungwe River. Some of the fences relied on methods of elephant deterrent already popular among small-scale farmers, such as twine soaked in chilis.[1] But between others, the researchers ran bailing twine from which they suspended hives populated by the famously irascible African bee, a species nearly identical to its European and North American cousins—but for its more aggressive tendencies. Still others combined chili-coated twine *and* bee hives.

The researchers then tranquilized and fitted 12 male elephants—males being more apt to forage in croplands—with GPS collars. Satellite data pinged from the collars, combined with the observations of local community members, allowed the researchers to keep exacting tabs on where the elephants wandered and whether the experimental fences prevented them from stumbling into neighboring farmsteads to rummage.

Sure enough, the fences worked. The chili fences reduced elephant river crossings by 80 percent—while the beehive fences thwarted a whopping 95 percent of cross-river forays by the animals. (Beehives strung on twine coated in chilis were, surprisingly, the least effective. King and her co-authors surmised that the coating weighed the twine down, making it easier for elephants to simply step over it.)

The bee has the power to terrify a mammal that's 22 million times its size.

Cameras placed near fences involving beehives showed that the elephants would trip the bailing twine, thus shaking the suspended beehives. Immediately, this would stir the bees to action, and they would swarm and mount an attack. In footage taken at night, shadowy silhouettes of peeved elephants can be seen turning tail and lolloping in unison out of the frame.

The true beauty of this method, write Branco and her coauthors in the study, is that it allows discontinuous fencing to block key corridors used by elephants as they go on crop raids rather than fencing individual farms or entire nature preservers, like Gorongosa—which both for the farmers and the park could prove prohibitively expensive, running into the thousands and even tens of thousands of dollars. To build 15 hives and string them from posts, Branco and her team spent a total of $773.

The results at Gorongosa jibed with those from another field study that King conducted in Kenya in 2017.[2] In that experiment, researchers strung beehive fences around 10 farms that were located near a nature preserve, reducing elephant raids by 80 percent. Bee fences have also been found to be an effective deterrent against crop raiding Asian elephants, showed a 2018 study King conducted in Sri Lanka.[3] In that case, merely playing recordings of angry bees through speakers in the field was enough to cause the elephants to flee.

Gonçalves says the bee barriers set an important precedent for future conservation efforts by offering a nonlethal method of control that doesn't create divisions between the park and the people who live near it.

Bee fences alone aren't enough. Other animals that are less flustered by bees, such as baboons and honey badgers, can be drawn to the honey the bees produce, disturbing the hives to the point at which the bees themselves take flight and move out. King's studies in Kenya, however, suggested that small cages can be placed around hives to prevent them from being disturbed by these other foragers. The dry seasons, too, can dampen bee populations in hives as they flee and search for moister climes.

But the elephant intellect, says Gonçalves, proves the biggest obstacle to a static set of beehive fences. They have not, for instance, deterred clever elephants from seeking out alternative crossing points and taking up near-permanent residence in the buffer zone.

Indeed, Stalmans says, sometimes a traditional, or even electric, fence is the best resort—but even those prove, over time, to be no match to an elephant's keen navigational sense. Just as they are smart enough not to get stung or shocked, they're also smart enough to simply chart routes around most human-made impediments and find their way to nearby farm settlements.

It is here that Gonçalves joins efforts with Gorongosa's human-wildlife coexistence team. Together, they chart the peregrinations of known elephant families that have been collared with GPS devices and can thereby spot areas of potential human-elephant conflict before they erupt.

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We'll Miss the Vulture

Ecosystems are suffering without their invaluable scavenger, victim of a bad reputation

BY JORI LEWIS

IN HIS POEM "VULTURES," the Nigerian writer Chinua Achebe makes the scavenger bird a metaphor for the evil of a concentration camp.

Yesterday they picked

the eyes of a swollen

corpse in a water-logged

trench and ate the

things in its bowel.

Vultures are almost never described affectionately in literature. Instead, they serve as grotesque symbols of the hollowness of death, of exploitation, of benefits gained only by the misfortune of others. In short, vultures give us the ick. And that feeling of general disgust sometimes affects how people think about vulture research and conservation.

But no matter how we collectively feel about vultures, researchers are sure we're going to miss them when they're gone. Despite their gross reputation, vultures serve as the janitors of the bush.

People often think that vultures transmit disease since they feed on carrion, but the opposite is true. If a cow or an antelope should die in a forest or on a savanna, vultures swoop in, pick clean the bones, and then eat the bones, too, all in a couple of hours, says Ethiopian biologist Alazar Daka Ruffo, a consultant for Bird Life International. Even if that cow died of anthrax or hoof-and-mouth, the vulture could digest it and emerge unscathed. Vultures perform the critical function of waste removal and disposal of carcasses that might otherwise spread bacteria and pathogens. At abattoirs near Addis Ababa, where Ruffo studies vultures, the birds feed on offal and viscera. "They are employees who aren't paid a salary," Ruffo says jokingly.

But vulture populations across Africa are crashing. Scientists estimate that populations of several species of vultures in Africa declined by an average of 62 percent over the past 30 years.[1] Among them, the white-headed vulture is a critically endangered species, with only about 5,500 individuals left in the wild.

Many vulture species are social animals—picture a kettle of vultures sharing a meal of a buffalo carcass, joining one another for a snack, and nesting together as a colony. But the rare, white-headed vulture is solitary, almost shy. It prefers to fly and feed in smaller groups, and a brooding couple will often build a nest only for itself and tuck it away on the top of a baobab tree.

"They build a nest cup lined with grasses, and then they reinforce it along the edges with a thick ring of sticks," says Rebecca Bishop, a Boise State University graduate student who has been on the hunt for these solitary nests in Mozambique's Gorongosa National Park for the past couple of years. "White-headed vultures are so rare and understudied that we still lack basic natural history knowledge pertaining to the species, which is unusual in 2023," she says. "So, we've got a gap where we don't completely understand a species in drastic decline."

That's where her research on the breeding ecology comes in. By surveying nests and their locations in Gorongosa and working to characterize them, Bishop and other researchers are creating the baseline data needed to follow the species both in the park and in other ecosystems.

Given how rare white-headed vultures are, Bishop was surprised to find so many of their nests hidden away in Gorongosa's plentiful baobab trees. "My first season, I actually went and collected data on 13 white-headed nests," she says. When she came back the following year, in 2022, she used a drone to get a better view of the canopy and found even more. "Just the fact that we've got such a high density of nesting white-headed vultures is really impressive," says Bishop. "I went to a conference in Zimbabwe last fall and talked to other vulture researchers from Africa. In West Africa, specifically, they note maybe two white-headed vulture nests in some national parks."

PAGES 48-49: PIOTR NASKRECKI

Gorongosa, a haven for vultures, has a smorgasbord of options for the hungry scavenger.

After Mozambique's civil war (1976-1992), vulture researchers like Bishop might not have seen many vultures. The park had been a zone of intense hunting, and the populations of waterbuck, elephants, and baboons—all good vulture food—were in sharp decline. But after nearly 30 years of rest and restoration, big mammal populations have started to rebound. Gorongosa's latest animal census found more than 60,000 waterbuck and nearly 10,000 impala, so the park has a smorgasbord of options for a hungry scavenger bird.

"Gorongosa seems like a stronghold for a few different [vulture] species," says Greg Kaltenecker, director of Boise State's Intermountain Bird Observatory, who has also been studying vultures in Gorongosa for several years. The park is a safe haven not only for the shy white-headed vultures, but also for the more well-studied and more common white-backed vulture, which is also critically endangered. White-backed nesting pairs in the park number in the hundreds.

Bishop and Kaltenecker credit the vultures' success in the park to Gorongosa's biodiversity, including its abundant baobab trees, and its dynamism as a system. In isolation, if they were the only scavengers, vultures wouldn't thrive. Vultures have trouble tearing open tough waterbuck or elephant carcasses on their own, so they sometimes need a little help from a larger predator or scavenger. For vultures, Gorongosa's recent re-introductions of hyenas and side-striped jackals is good news. "As those carnivores increase in numbers and make that food more available, vultures are going to be able to eat and scavenge and raise chicks and thrive," Bishop says.

In previous studies, Boise State researchers helped tag some of these two vulture species, so they could track their movements. White-headed vultures stay mostly within the confines of the park and the buffer zone around it. "It's uncanny; they seem to know right where the park boundaries are with a few exceptions," Kaltenecker says. "Protected areas represent important habitat features the vultures are keying in on." Although white-backed vultures nest in the park, they can forage thousands of kilometers away, crossing Gorongosa's borders and, often, the borders of Mozambique itself.

The Boise State Intermountain Bird Observatory has been researching vultures in Gorongosa for nearly 10 years, a collaboration between faculty members and masters' students from the United States and Mozambique. So far, their discoveries included the white-headed vultures' apparent awareness that they are safer in the confines of the park, and the vast amplitudes of the feeding forays of white-backed vultures. Bishop's research about nest ecology—identifying and characterizing the nests of different species—is significant because the information she has produced can help

JANITOR OF THE BUSH An endangered white-backed vulture feeds on the carcass of a newly deceased waterbuck in Gorongosa National Park. To get the shot, Piotr Naskrecki, a conservation biologist from Harvard University, hid his camera inside the carcass.

PIOTR NASKRECKI

forecast where other healthy breeding populations might occur, within the park and outside of it. And discovering so many in the park when the numbers of both species are critically low across the continent is a good indication of a healthy population.

But the threats beyond the park are many. The transformation of forests or grasslands into farmland and urban areas means vultures have more difficulty finding their favorite nesting trees. Power lines and windmills pose a critical threat to the birds whose superpower is to focus on the ground below but who have trouble seeing dangers in front of them[2]; vultures regularly get electrocuted on power lines and collide with the blades of a wind turbine with fatal results. Although vultures have a stomach of steel—they have a gastric acid level that's nearly the same as pure hydrochloric acid,[3] and can digest botulism, anthrax, and salmonella with no issues—they are felled by anti-inflammatory drugs that are often used on livestock.[4] In addition, across the continent, vultures are sometimes targeted for ritual use.[5,6]

Domingas Matlombe, who finished her master's in Gorongosa's conservation biology program in 2022, and collaborated with researchers from Boise State, also found that some people in the rural communities near Gorongosa are using vulture parts for traditional medicine. Many healers told her that hunters bring them already dead animals, but she was skeptical. "We can't assume the hunters are always so lucky as to find dead animals," she says. "Maybe the hunters know the spots the vultures occur, and they are killing vultures in order to sell them."

Most experts say poisoning is the single largest driver of the decline in vultures across the continent. "Often, it's not that they are targeted directly for extirpation, but they become the secondary victims," says

Vultures have a stomach of steel and can digest botulism and anthrax with no issues.

André Botha, program manager of Vultures for Africa at the Endangered Wildlife Trust in South Africa. If a community has a problem with an animal, say, an elephant or a lion, they might poison it. Once it dies, vultures swoop in for a tasty treat and are unintentionally poisoned as well. "We've had incidents where literally hundreds of vultures have been killed feeding on a single poisoned elephant carcass."

In places where criminal groups hunt elephants to harvest their tusks for illegal trade in ivory, or hunt other animals without authorization, hunters might deliberately poison vultures, nature's narcs, to keep their circling group from alerting authorities. Botha says both conservationists and researchers need to adopt a regional approach to form policies to protect the continent's remaining vultures. Research like Matlombe's on the social perceptions of vultures, which delves into the religious or belief use of vulture parts that is common in some corners of Africa, might help bring in more people into a regional or continent-wide plan on vulture conservation.

Vultures, though, are hard animals to champion in a marketplace of small and large donors who are mostly interested in charismatic megafauna. Kaltenecker tries to explain to donors that vultures are more than just gross bogeymen; they are key actors in the ecosystems they inhabit, the trash collectors of the natural world. As Gorongosa, a model of wildlife recovery, shows, vultures have a lot of work to do.

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Students of the Wild

Hands-on fieldwork, cutting-edge science, and baboons who steal your lunch

BY KATHARINE GAMMON

ZITO BANDE HAS ALWAYS been drawn to water. After completing undergraduate studies in aquaculture at the Gaza Polytechnic Institute in Chokwe, Mozambique, he interned with the federal agency that manages all conservation areas in the country. But that was an office job, and Bande felt the itch to be in the field. So, when applications opened up for the two-year Master's in Conservation Biology program at Gorongosa National Park, during which students live, study, and work in one of the largest national parks on the African continent, he leapt at the chance. Now he is using invertebrates as an indicator of water health to study the impact of land use on water quality.

PIOTR NASKRECKI

Cutting-edge science can be challenging in a remote place.

Gorongosa has the only master's program in the world run entirely within a national park, says Tara Massad, a tropical chemical ecologist who helped start the program in 2017. Training conservation biologists in a protected area gives students a singular perspective on what it means to manage one, says Massad, who directed the program until March. "Beyond everything they're learning in their classes, they know the different challenges that actually face a protected area. They have this kind of first-hand insight that a university student wouldn't have."

Students sleep in safari tents pitched on raised platforms, learn from top experts who fly in from around the globe, collaborate with one another on complex problems, and apply their knowledge to the field immediately.

Amade Martins Mario Real studied forest engineering at Mozambique's Institute of Fauna and Ecotourism in Marrupa, and took part in a weeklong conservation science workshop at Gorongosa National Park after graduation. He quickly applied for the master's program. He was impressed with the fact that the program provides not merely classroom instruction but also hands-on, on-the-ground learning and problem solving: "a world-class tutorial," he says.

Another master's student, Jonata Joaquim Caminho, did his undergraduate degree in ecology and biodiversity conservation at the Eduardo Mondlane University in the capital Maputo. While he was studying there, he kept hearing about Gorongosa: "It's unique in the world. If you want to be a good scientist, you must go to Gorongosa," he remembers people telling him. After attending a workshop at the park in 2019, he figured: If he was loving the place for one week, why not try two years? Caminho now studies the way birds respond to fire and herbivores on the savanna as part of the long-term Gorongosa Savanna Ecology Experiment.

Gorongosa began its education program with a 2015 grant from the Howard Hughes Medical Institute (HHMI), as a series of scientific workshops and a biodiversity internship program that invited young Mozambican university graduates to conduct research in the park for a year. But, Massad says, there really wasn't any postgraduate training for leaders in conservation biology in the country. So, she and her collaborators decided to make one. (The internship program has continued, now aimed at high school graduates from the park's buffer zone.)

The two-year master's program, also funded by HHMI, involves one year of coursework and one of independent research. The first-year curriculum is

TAKING WING Master's student Elsa Candido Caetano focused her second-year research project on butterflies. The project uses the butterflies to measure restoration success on Mount Gorongosa. Above, the large striped swallowtail, a species of butterfly found in Gorongosa.

made of modules—short but very immersive classes, which include topics from organismal level classes—mammalogy or herpetology—to subjects such as statistical analyses and modeling. In this way, students receive a broad educational background that helps them solve a variety of problems in conservation. Instructors come from all over the world, volunteering their time to teach these intensive modules for about two weeks. The students basically "live, breathe, and eat that module" Massad says: It's all they do, working alongside the professor for eight hours a day, then doing homework at night. "It's super intensive, but it's also a good learning model because they're so immersed in the courses, they really engage with and assimilate the material. They also connect what they learn in one module to another, so they are building knowledge throughout the year."

During the second year, each student takes on a research project. This is when students collect data, analyze them, and synthesize their results. They are supported in this work by Massad, the new program full-time director Kris Bal, and Piotr Naskercki, a polymath entomologist who is helping develop a new research facility on site, the E.O. Wilson Laboratory, which is the hub of biodiversity research in Mozambique.

The program is free for the students, says Massad, who currently divides her time as a consultant for the program and continues to advise students, run experiments and teach, while also teaching at Oregon State University.

The best thing about the program, says Atal Vilanculo, a current second-year student who is researching sustainable agriculture in the buffer zone around the park, is that he can learn through experience. "We don't [just] need to read an article … we are seeing it in real life," he says. "And the worst thing is the baboons who come and steal our food."

The students' work contributes to the cutting-edge science that is taking place in the park, filling in gaps in fundamental understanding of ecosystems and human communities. Many of the students are also deepening the work they had begun as undergraduates. Elsa Candido Caetano, for example, studied butterflies as an undergraduate biology student and wanted to continue to learn about them. In Gorongosa, her research project uses butterflies as an indicator of restoration success on Mount Gorongosa, a 6,112-foot inselberg that juts out from the rolling plains of the park. "I want to answer the question: How does the land use change affect the biodiversity on the mountain?" she says.

PIOTR NASKRECKI

He couldn't have imagined any of this as an undergrad, yet the park now feels like home.

Bal, the new director who took over from Massad last spring, would like the program to expand into researching the aquatic species and the water systems of the park—areas that are "less investigated currently in Gorongosa," he says (Bal's own doctoral work at the University of Antwerp in Belgium was on the hydraulics of aquatic vegetation).

Bal is excited to see the students engage with hard-hitting science about less charismatic species, from bats to plants and insects. Their topics echo a priority of the park: to be a model of moving conservation work on "forgotten taxa."

Doing cutting-edge science can be challenging in a remote place: One student, who is studying the ethnobotany of medicinal plants, needs to test if extracts of the plants can kill off or inhibit the growth of bacteria and fungi. To do that, he needs to get samples from outside of Africa. "Everything takes time," Bal says. "I'm currently trying to expedite that process, so that the student can do everything in time."

Master's program graduate Beto Tenente spent his first year in the program during the coronavirus pandemic shutdown, partly studying from home, and partly in the park for studies, surrounded by elephants and antelopes. For his second-year research, Tenente used crickets as an indicator taxon to demonstrate how fire and the presence of large mammals affect insect diversity.

After he graduated in 2022, he was hired by the Pringle Lab at Princeton University, which has been researching large-scale ecosystem restoration and predator-prey dynamics, among other things—and continues to work in the park. He says he couldn't have imagined any of this as an undergrad in forestry studies at the Gaza Polytechnic Institute. For Tenente, the park now feels like home, even though time in the field means that he occasionally has to sprint away from elephants, as happened once when he was out collecting memory cards from camera traps.

"Our students are sought after—conservation organizations contact us wanting to hire them, which is really cool," Massad says. Graduates from Tenente's cohort are teaching at universities, working with international conservation organizations, or working as conservation scientists in other parks. Tenente would one day like to get a doctoral degree, or to work at the intersection of conservation and community development.

Although the students take all their classes in the park—and the park staff develops the curriculum with Mozambican partners from all over the country, the University of Lisbon in Portugal, and an international volunteer faculty—the actual diploma comes from Mozambican partners that are accredited universities. The program itself recently received the highest level of accreditation in Mozambique, even though its approach of rigorous independent inquiry is fairly unique within the country.

"I'm continually impressed with our students," says Massad. She has seen how the program builds confidence in students: Once they realize that they can pass their classes and conduct successful research on their own, they are much better prepared as independent problem solvers. This, she says, is a great model for training scientists across the African continent. "As scientists and as leaders, they need to start thinking and solving problems."

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The Social Life of Bats

They sing, have dialects, reserve special tones for their pups—our reporter journeys to Mozambique to explore the unique communication of bats

BY JORI LEWIS

PHOTOS BY PIOTR NASKRECKI

THE SQUAT ABANDONED CONCRETE STRUCTURE may have been a water tower when this tract of land in the grasslands of Mozambique was a cotton factory. Now it served an entirely different purpose: Housing a bat colony.

To climb through the building's low opening, bat researcher Césaria Huó and I had to battle a swarm of biting tsetse flies and clear away a layer of leaves and vines. My eyes quickly adjusted to the low light, but my nose, even behind a mask, couldn't adjust to the smell of hundreds of bats and layers of bat guano—a fetid reek of urea with fishy, spicy overtones. But Huó had a different reaction. "I don't mind the smell now," she said. After several months of monitoring bat colonies in the Gorongosa National Park area as a master's student in the park's conservation biology program, Huó said she almost likes it. "Now, when I smell it, I know there are bats here."

Since we arrived at the tower during the daylight hours, I had expected the nocturnal mammals to be asleep. Instead, they were shaking their wings, flying from one wall or spot on the ceiling to another, swooping sometimes a bit too close to me for my comfort. But the bats didn't care about me; they were cruising for mates. It was mating season, and we had lucked out to see their mating performances. Huó pointed out that some females were inspecting the males, checking out their wing flapping prowess.

But Huó and her adviser, the polymath entomologist Piotr Naskrecki, did not bring me to this colony to view the bats' seductive dances and their feats of flight, since those behaviors are already known to scientists. We were here to decipher what the bats were saying while doing them. Huó and Naskrecki had set up cameras and audio recorders the night before to learn more about these bats and try to understand the nature of the calls they use, listening for signs of meaning.

Scientists have studied echolocation calls in some bat populations for decades. Echolocation is a kind of sixth sense that allows bats to use reflected sounds to fly blind and hunt in the dark, a superpower that has inspired aspects of human technologies such as sonar and new forms of radar. But we know much less about their social communication, said Naskrecki, who first became interested in the flying mammals while studying the ways some katydids adapted their morphology to avoid being captured by bats. He realized that bats are similar to primates in their behavior, and came up with a hypothesis.

YULIA_OGNEVA / SHUTTERSTOCK

ZOOLOGY | GORONGOSA SPECIAL

Huó would set up devices to record the bat all night and hope it would call out.

"One thing that is interesting about primates is that they have developed this ability to warn other members of their group of different dangers and they have different expressions of different signals to indicate what type of danger that is," Naskrecki said. "So, if it's a snake, that will be one signal, if it's a leopard, that's another signal. I thought, well, I bet you that bats do the same thing. It's just incredibly difficult to show it."

Difficult because bats are skittish, often live in inaccessible areas, and many species are mostly active at night. Further, the calls they emit—echolocation or social—are at frequencies too high for the weak human ear to hear. "Every now and then you will hear a squeak," Naskrecki said. "That squeak is like a roar to them."

Naskrecki's instinct about social communication in bats coincided with the ongoing research of Mirjam Knörnschild, an expert in the field and a professor of evolutionary ethology at Humboldt University Berlin. Naskrecki asked her to join Huó's committee and she was glad to do so.

BAT DANCE During mating season, a male bat—*Hipposideros caffer* aka Sundevall's leaf-nosed bat—shows off his wing-flapping prowess for a female.

"We have over 1,400 different bat species, and we only have vocal information—not complete information, but at least some information on their social communication calls or songs—for less than 100 species," Knörnschild said.

Bats are one of the largest and most diverse groups of mammals. There are bats the size of a bumblebee and bats that weigh around the same as a small rabbit. Most bats live in colonies and many of them have incredibly complex social lives for which good communication is necessary. Scientists believe many species can sing; some can recognize each other's voices; they have dialects; they can alert others to dangers; and they form intense bonds with their young.

"We know that mothers use a specialized tone of voice when they communicate with their pups, like motherese, what we humans do when we're cooing at a baby, using this high pitch," Knörnschild said. And there's still so much to discover. Bats are an ancient group with many phylogenetically distinct species. "They could have come up with different solutions for the same problem," Knörnschild said.

Once Huó and Naskrecki retrieve the audio and video recordings from the bat tower, they feed them to the computer, using a program to transform what sounds to humans like silence into the hum and buzz of hundreds of bats, a cacophony of sounds. "We slow it down, then we look at the spectrogram that shows us the pattern of these calls," Naskrecki said. After screening out echolocation calls, which have already been collected in a database, they look for new patterns, cross-checking the video to see what the bats were doing when they made this or that sound. Naskrecki and Huó are trying to build a kind of

TIME TO FLY A bat flees its roost in an abandoned concrete structure in Mozambique, which may have been a water tower on an erstwhile cotton factory.

dictionary of the calls of the bats who live in the abandoned tower—*Hipposideros caffer* aka Sundevall's leaf-nosed bats—as well as those of the Egyptian whispering bat, *Nycteris thebaica*, who live in a semi-hollow tree in the sand forest inside the Gorongosa boundaries.

A few days after our excursion to the bat colony, Naskrecki showed me how he manipulated the squiggly waveforms on a large screen in his office until the clicks and hisses started to sound like chirping birds. One call of four staccato chirps stood out. "This is just a lonely male calling," Naskrecki said. To correlate the call to the action, and infer its meaning, Naskrecki and Huó also conduct experiments in the lab by bringing bats from the colony into a controlled environment, to see if they make the same calls.

That morning they had brought back a tiny male bat that could fit in the palm of a human hand. It was afternoon and Huó was trying to tempt it to eat fresh meal worms and moths in a room across the hall from Naskrecki's office. But the little guy was refusing. Maybe the room was too loud or too bright. Maybe it was stressed out by the big human (a monster to the bat, no doubt) who was trying to feed it mysterious foods. Huó was worried because this wasn't the first bat they had captured, but at least the eighth, and two of them had gotten so stressed out that they'd died. After feeding it, she planned to release it into the bat room, a small room with walls painted black and a fake tree or two, as well as a cozy fake cave to help the bat get comfortable. Huó would set up devices to record him all night and hope it would call out—perhaps a kind of distress call—so she could add the call to the dictionary.

I expected the nocturnal mammals to be asleep. Instead, they were swooping a bit too close for comfort.

Distress calls are one of the most universal bat social calls, said neuroethologist Angie Salles, who runs a lab studying social communication in bats at the University of Illinois, Chicago. "If you play back the distress calls, you usually attract bats to the area where you're playing those back, and it doesn't necessarily attract only that species of bat," she said.

Salles conducts similar experiments at her bat lab, but with slightly different goals. She uses captive colonies and sometimes attaches little electrodes to their heads to measure variations in their brain activity depending on their behavior or when they are exposed to different sounds. She's especially interested in how bats interpret these auditory communications in different contexts. "Let's say a bat is engaged in a fight with another bat," she said. "Maybe a distress call will have a more salient response than if the bat is doing something else." She hopes to gather ideas about how brains (the bats' but also human, yours and mine) process the sounds that become language.

The morning after I watched Huó try to feed the bat, I went back to the lab to check on it. Huó said it was doing fine. "He's eating OK and I saw him hunting last night," she said. It had hunted some of the crickets and moths she had thoughtfully planted in its room. We found it resting upside down (naturally) on a branch. In the room there was another recorder, poised to capture its sounds and songs, and if the bat lived through this ordeal, he would go back to his colony in a day or two.

Naskrecki said his goal is to create a captive colony in the bat room and compare it to roosting spots in the wild. (They don't plan to maintain a permanent captive colony of bats—only to keep and grow one for the duration of Huó's master's project.) The researchers will then have a listening post to hear what bats say when they are content, sending out messages of social cohesion; when there's a threat and they want to attack or flee; or when they woo their sweethearts or coo to their young. Inaudible to humans, the lab will be alive with the sound of bat talk for scholars to decipher and interpret.

JORI LEWIS writes about the environment and agriculture mostly from the Global South. In 2018, she received the Whiting Grant for Creative Nonfiction for her new book, *Slaves for Peanuts*. She is also a contributing editor with *Adi Magazine*, a literary magazine covering global politics. She splits her time between Illinois and Dakar, Senegal.

Fire on the Savanna

Our writer joins researchers in Mozambique to uncover how fire shapes Africa's grand wilderness

BY KATHARINE GAMMON

PHOTOS BY PIOTR NASKRECKI

ENVIRONMENT | GORONGOSA SPECIAL

IT'S EARLY MORNING in Gorongosa National Park; the heat of the day is still a few hours off. Thick, dog-eared field guides crowd the space between the front seats of our safari truck; *A Complete Guide to the Snakes of Southern Africa* sits on top. The truck jounces over a few kilometers of bumpy roads with science technician Arquimedes André at the wheel.

Soon we see fences that section off the savanna into plots: some accessible to large herbivores, others not. We have arrived at the site of an ongoing, large-scale experiment to determine the role of fire and large herbivores in shaping diversity and structure of savanna ecosystems. The experimental area takes up about 487 acres of the million-acre park, and this morning we are pulling up to study a chunk of it.

Out of the truck tumbles André, a park ranger toting a long-barreled rifle, and two students in the Gorongosa master's science program, Jonatá Joaquim Caminho and Iolanda Greedes Fernando Marcolino. We stand at the side of a plot approximately 100 feet by 100 feet—the size of two basketball courts—and Caminho explains what we are going to do: walk around and count species we see, logging them in a small journal and identifying them as best we can. Suddenly, he falls quiet. A low rumble means a lion is nearby. As soon as I recognize the sound, I feel glad the ranger has come along.

André, Caminho, and Marcolino are taking part in the Gorongosa Savanna Ecology Experiment, which allows researchers to monitor the presence of large mammals through intermittent "exclosures"—a fenced-off area that keeps large creatures out—to test the effects of early- and late-season fires on nutrient cycling in soils and vegetation, and on the insects, reptiles, amphibians, birds, and mammals that populate them. Tropical chemical ecologist Tara Massad, director of Gorongosa Master's Program in Conservation Biology, launched the project in December 2020 as a platform to train students, mostly from Mozambique, in doing high-quality scientific research. But it is also providing invaluable insights into long-standing questions in savanna ecology.

A savanna is an expansive area of mixed grassland and woodland, with scattered trees that don't form a closed canopy. About half of the African continent is savanna—and fire and the herbivory of large mammals such as antelope and elephants drive the ecosystems, "basically shaping our communities and affecting the rest of savanna biodiversity," says Massad. These two major drivers influence such things as nutrient cycling in the soil and which plants grow where, as well as which animals can use the plants to survive, which makes understanding the system fundamental for studying savanna ecology—both in Gorongosa and around the globe.

Caminho's project aims to understand the foraging response of birds in areas of the savanna where large mammals are present and fires have occurred. André is collecting similar data on lizards and snakes, and Marcolino is setting traps for beetles in this area to understand how they react to fires and herbivory.

André sets a cell phone timer for 20 minutes and we begin a slow, meditative walk around the perimeter of the plot, looking for any signs of life. My feet crunch the dry grass and I strain my senses to see what the scientists are observing—tiny turns of a white wing or a fragment of a song, the tail of a small lizard or a wing of a fluttering insect. Their senses seem honed to this environment in a way that takes months of focused practice.

Caminho is looking to identify species of birds but also to observe what they are doing, and how they are using their habitat. Are they foraging? Are they resting? As we walk, he holds a well-worn book with a sky-blue cover: *Roberts Birds of Southern Africa*. He tells me that he has always enjoyed birds. Growing up near the capital city of Maputo, he liked to hear their songs and see

Suddenly, he falls quiet. A low rumble means a lion is nearby.

their colors. But as he has grown in his studies, his love has deepened: "Now it's not only about the singing but their biology and behavior."

The Gorongosa Savanna Ecology Experiment is intended as a long-term study and a research playground that allows Gorongosa students to contribute to a detailed understanding of savanna function. The experimental area consists of 10 blocks, each with six plots: three that are open to large mammal herbivores and three that are fenced off. (The open ones are very much within a lion's range.) Of those six, two are burned early in the season, two are burned late in the season, and two aren't burned at all—allowing scientists to understand how the effects of fire and large mammals interact.

Similar experiments exist in Kenya and in South Africa at Kruger National Park, but they aren't designed to test the effects of fire regimes and the presence of large mammal herbivores in a fully crossed experiment, Massad says. Another aspect of the project in Gorongosa that sets it apart is that it is looking at biodiversity comprehensively, because students are studying multiple species. "Because of these little projects within the big project," Massad says, "we're able to understand not just how these factors influence the big mammals—which are usually what people care about—but also all the smaller and more biodiverse taxa as well."

After one year of the experimental data has been analyzed, Massad is excited to see differences in the results from the plots. Researchers who take part in the project have found that in plots that are burned, there is more grass biomass—which is good for large foraging and grazing mammals. On the other hand, the plots that are open to herbivores have limited grasses—a result that is "not a surprise but it's neat to see that happening within a year, and it's also cool that it's matching results from other parts of Africa," Massad says.

Another finding is that both fire and herbivores limit the abundance and regeneration of shrubs—data that support similar conclusions in other parts of Africa. A big remaining question in savannas is how the balance of trees and grass is maintained. "How is it that it's not just grasses that dominate or just trees?" Massad says. "Fire and large herbivores have different effects on grasses versus woody vegetation, and this experiment allows us to understand their interaction, which is likely to become stronger over time. In the future, we expect to see effects on tree growth as well."

Much of the human management of savannas is done through fire—burning allows for more grass to grow, which is good for tourist areas that want to attract antelope and other photogenic species sought after by tourists. But the experiment in Gorongosa has shown that fire has different effects on different species. While early-season fire was beneficial to small mammals, it led to a decrease in the abundance of amphibians. Massad says there are very limited studies about the effects of fire or large mammals on other animal taxa; in particular, there are few, if any, studies testing burn regimes on biodiversity outside of Gorongosa, making the results notable.

"By focusing just on using fire as a management tool for large mammals, people might not necessarily be promoting biodiversity holistically across savannas," Massad says, "even though you might be giving tourists what they want to see, which is a good view of large grazing animals."

CLEANUP TIME Without dung beetles (above) and their waste removal labor, Gorongosa National Park would sink under layers of dung produced by thousands of mammalian grazers and browsers. Researchers are measuring the impact of fire on beetles and all the ecologically important creatures in the park.

Massad hopes that the experiment will run for 10 years. The longer it lasts, the more scholars will be able to learn about variations in climate and the impact of one-time events such as cyclones, in addition to the fundamental science of the plots.

After 20 minutes are up, I follow Caminho and André to another plot. The heat of the day begins to spread into the cracks between the trees and sweat gathers on my neck and back. At the end of three hours, my ankles are covered in insect bites, and we have seen only a few creatures, including a small blue waxbill and a black-backed puffback: a bird recognizable for the unique clacking noise followed by a whistle between songs. The only reptile André logs in his tally this morning is a skink that Marcolino has accidentally hacked apart when she was digging holes for her insect traps. It was probably hiding underground after the experimental plot was burned. We watch as its tail continues to wiggle, detached from its body.

The team will head back out in the evening to check the same plots at a different time of day, logging every observation. All that data will become part of a corpus of knowledge and lead to a fuller understanding of the intricacies of the savanna—to help conserve the ecological breadth of Africa for, yes, people, but also the animals and plants themselves.

KATHARINE GAMMON is a freelance science writer based in Santa Monica, California, who writes about environment, science, and parenting. You can find her on X (formerly known as Twitter) @kategammon.

Digging for Our Origins in the Bone Beds of an African Park

In their search for the last common ancestor of chimps and humans, scientists at Gorongosa National Park are expanding the picture of early primate life

BY CHARLES DIGGES

COURTESY OF GORONGOSA NATIONAL PARK

PALEONTOLOGY | GORONGOSA SPECIAL

FOR THE PALEOANTHROPOLOGISTS looking to fill out the pages of humanity's family album, a cache of ancient teeth unearthed over the past few years at Gorongosa National Park in Mozambique could be like sepia-toned photos from the old neighborhood.

Yet the original owners of the teeth are far from human. In fact, the most startling specimens among them, discovered at an elevation of approximately 1,000 feet, come from the jaws of the genus *Galeocerdo*—tiger shark—an animal that doesn't even live on land. Another set is from an ancient version of a hyrax, a distant, furry relative of elephants. Others are from the gargantuan *Deinotherium*—Greek for "terrible beast"—yet another relative of elephants, whose ancient tusks protruded from their lower jaws like great inverted question marks. A pair of incisors from an ape comes the closest to something in our evolutionary neighborhood, but they're older than the light flickering from the Andromeda Galaxy and predate the emergence of our genus, *Homo*, by at least an epoch or so.

This mixed snapshot of past life found in a vein of sandstone and clay in the East African Rift System comes from the Miocene Epoch—a window of time stretching from about 23 million to 5 million years ago—that saw enormous development of vertebrates, particularly apes and other mammals.

Yet like most things in paleontology, this trove is only a tiny fragment of a puzzle offered up piecemeal by the earth, at first glance disjointed and haphazard—the commas and consonants, perhaps, of a single stanza from a much, much longer verse.

To Susana Carvalho and her team at Gorongosa's Paleo-Primate Project, these osteogenic antiquities mark the beginnings of a sweeping narrative involving the life, death, and the shifting landscapes of our cagey hominin ancestors, the creatures with which they shared the planet, and the environment in which they emerged.

"Even by looking at these other species that are not hominids, that are not apes, we're also looking at the species that our ancestors evolved with and interacted with," says René Bobe, the head paleontologist on the Gorongosa project.

The original owners of the teeth are far from human.

Both Carvalho and Bobe joined me via Zoom—Carvalho from her office at Oxford University, and Bobe from the basement of the London Museum of Natural History, where he sat in front of a tall bank of metal drawers containing a few million years' worth of fossils.

The project Carvalho has overseen at Gorongosa since 2015 incorporates the hardcore digging, sifting, and dusting of paleontology with training and mentoring for a cadre of Mozambiquan students who are pursuing graduate level studies in the field. Ravaged by a 16-year civil war that ended in 1992, Gorongosa has since undergone a profound revitalization that has seen its large animal populations rebound from near-decimation. Thirty years on from that conflict, the park is bursting with life and is home to as many as 6,300 different species of plants and animals. Carvalho's team has uncovered a rich and strikingly comprehensive testament to what came before the current flora and fauna—and in the process is seeking to add another chapter to the story of humanity.

Within that chapter lies not so much an orderly family tree as a wildly branching bush with roots growing in a swirl from numerous directions. One key character among the thicket, Bobe tells me, is the elusive last common ancestor of chimpanzees and humans. But Bobe says that any study of our roots must push deeper into time than that—to a last common ancestor of humans and *all* other African apes, chimpanzees and gorillas included.

"There are various ideas about what these ancestors looked like, how they behaved, what they ate, and how they lived, but nobody knows for sure because these ancestors have yet to be found," he says. "These ancestors mark the starting point of our lineage becoming different from other African primates. Our research aims not just to find these fossil species of apes but also to document the ecosystems that existed in Africa during a very important time in the evolution of humans and other mammals."

COURTESY OF GORONGOSA NATIONAL PARK

WORLDS BENEATH THEIR FEET
René Bobe and Susana Carvalho consult during a dig at Gorongosa National Park, where they lead the park's Paleo-Primate Project. The project has unearthed fossils that paint a vibrant mural of life surrounding our earliest ancestors.

In 2018, after a long period of surveys, Carvalho and Bobe began an excavation at the so-called Mazamba Formation, which lies on central Mozambique's Cheringoma Plateau, a stretch of upland Miocene sandstone wedged between the Zambezi and Pungwe Rivers. Many were skeptical that such a damp, flood-prone area packed with vegetation would yield any useful fossil finds. But it did.

As a common reliquary for ancient bones, sandstone, as the name suggests, forms when grains of sand are compacted together by the elements over the course of millennia.

When an organism that dies in such an environment is gradually interred, its soft tissue are dissolved and replaced by quartz, feldspar, and other minerals. Preserved in the resulting rock are the firmer remnants—bones, shells, teeth, wood tissues. And there they lie, subsumed by newer and newer strata of rock, each marking a new page on the calendar of geologic time.

The excavation site includes several open-air digs as well as studies of deep limestone caves whose layered sediments offer a sweeping record of specimens dating from a more recent time when our genus *Homo* had already emerged. Carvalho's findings from the caves include a smattering of small silica tools chipped to a fine edge to cut open fruit or husk bark—evidence that some species of *Homo* dwelled here. All told, Carvalho says she and her colleagues exhumed some 2,500 discrete fossils across all the Gorongosa digs.

"This combination of animals is not found elsewhere in the East African Rift system," says Bobe. "So, we're looking at the evolution of an ecosystem that is new to science, and it's very, very interesting."

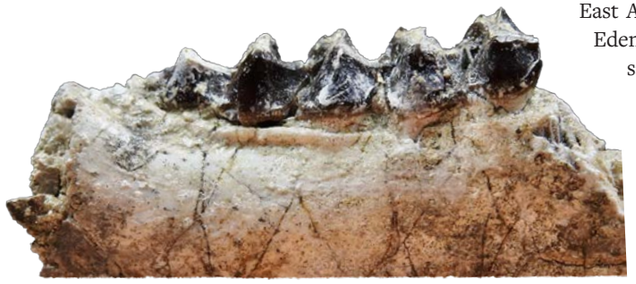
In London, Bobe rummages a jawbone out of one of his drawers at the museum and holds it up to his computer camera to show me—a hyrax specimen slightly larger than a human hand that was unearthed in Kenya in the 1950s by the legendary British-Kenyan paleoanthropologist Louis Leakey. It is similar, Bobe says, to the hyrax remains Carvalho and her team uncovered in Gorongosa.

Carvalho and Bobe's hyrax specimen was found among what Carvalho described as a "bone bed"—a layer of fossils so plentiful that the species found within it must have died at the same time as the result of some catastrophic occurrence. Think Pompeii or the extinction of the dinosaurs.

What local Armageddon befell the organisms on this stratum of the Mazamba Formation remains unknown—Carvalho speculates that it could have been a recurring flood or other major storm—but it was the bone bed that proved Carvalho and Bobe were onto something.

On the basis of their finds at the Mazamba Formation, Carvalho and Bobe led a study for a paper published earlier this year asserting that the part of Gorongosa where their excavation is taking place was once coastal. The site now sits on dry land more than 50 miles due west of the Mozambique Strait—the waterline redrawn by ancient climatic shifts.

"This is the story of a coastal site, not an inland one, which has been the predominant focus of African paleoanthropology," says Carvalho. "These are species that lived along the way between sea and land, and everything we are finding in Gorongosa is completely different from what you would find up north on the Rift or in the caves in South Africa—this area was an estuary."



EARLY BITES Jaw fossils from an ancient tiger shark (top) and hyrax (bottom), a distant relative of elephants, uncovered in Gorongosa, reveal that part of the landlocked park was once coastal, which suggests our primate forbears may have moved inland from the coast.

The discovery of this liminal space between land and sea is an important one that has until now evaded paleontologists working in Africa, Carvalho tells me. An understanding of where ocean and land once met is critical to discerning the footprints of our primate forbears.

"It's in this coastal forest that you are going to find what people have long been looking for but that no one has found yet," Carvalho tells me. "Our hominin ancestors would have moved inland from here."

Carvalho posits that during the twilight years of the Miocene, these ancestors might have followed riverbeds toward the interior of the continent, the humid rainforest vegetation along the way shepherding them toward new environments—and new adaptations.

The spectacular discoveries of *Australopithecus* skeletons in the 20th century—which put East Africa on the map as humanity's Garden of Eden—would seem to support this hypothesis, says Carvalho. Lucy, perhaps the most famous such specimen, was found in the savannas of Northeastern Ethiopia, part of the northerly reaches of the Rift, and well inland from the Red Sea.

At a mere 3.2 million years old, Lucy is much younger than the apes' teeth that have turned up in Carvalho's

What local Armageddon befell the organisms on this rock?

Miocene excavation. But, importantly, Lucy was a generalist omnivore, able to subsist on a variety of nutrients flourishing in her ancient environment. The hominins that would have been common during the Miocene had a more specialized diet and subsisted on soft fruits and other vegetation common along the water's edge—a diet Bobe and Carvalho can analyze by examining patterns of wear on the ape's teeth that they disinterred.

To both Carvalho and Bobe, there is a clear lineage among these earlier versions of ourselves. About 9 million years ago, the Earth became more arid, and the rainforests favored by Miocene primates began to shrink. It is around this time, says Bobe, that the last common ancestor of humans and chimpanzees was thought to live.

The chimpanzee ancestors—and their preference for ambulating with four limbs—remained within the moist forests that they still prefer today. Where in this historic relocation we emerged as a species remains, of course, the big unknown. At some point, we stepped into a more arid landscape as bipedal primates—but whether this happened when we reached the savanna or before is an intriguing question. There's striking evidence suggesting that the apes from which our species of *Homo* eventually evolved were bipedal even before we left the trees.

So, what of these Last Common Ancestors, as the scientific literature calls them in capitalized terms, these theorized transitional species between us and the chimps we left in the forest?

In Carvalho and Bobe's telling, they may well sit among the finds at the Mazamba Formation—all the more present for their absence. It's a little like entering a house whose occupants have just left—here is a half-eaten apple, there an empty cup of coffee with a fresh brown ring at the bottom, the jackets on the rack by the door still astir.

Amid this hoard of fossils and bones from the Mazamba Formation, where will Carvalho and her colleagues find imprints of our shared precursors? "The stone tools might be able to tell us," she says. "Because the hominins that used them could have left DNA samples in the sediments, and DNA preserves well in certain conditions like the limestone caves."

It will be some time before Carvalho can have those sediments sequenced. But when she does, whose photo might she find?

CHARLES DIGGES is an environmental journalist and researcher who edits Bellona.org, the website of the Norwegian environmental group Bellona.

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Marc Stalmans

The director of science at Gorongosa National Park in Mozambique on the history and promise of the park

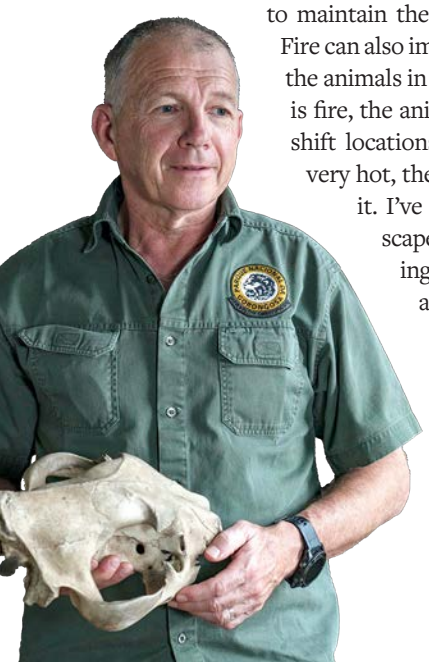
INTERVIEW BY GAYIL NALLS

PARK IN PERIL

When I first started at Gorongosa in 2006, the animals were missing. The park is in the southern part of the Great African Rift with tremendously productive vegetation. Historically, that had supported a huge density of animals. However, those animals got depleted by 90 to 99 percent, depending on the species, during the Mozambican civil war (1977-1992). For example, there were around 14,000 buffalo in that system before the war, but after the war there were fewer than 100 left. So there was a lack of animals to graze the grass and to browse the trees and the shrubs. But it's good for the grass layer to be grazed. That's how those systems have evolved.

BLESSINGS OF FIRE

Fire has historically impacted the park but, contrary to popular belief, it didn't negatively impact the trees and shrubs. The savanna system is very well adapted to fire, and although the immediate visual effects on the landscape may not be appealing, it is part of a larger process that is fundamental to the regeneration of the landscape. In the long run, the fire will allow these plants to maintain their vigor and diversity. Fire can also impact the movement of the animals in the park. Where there is fire, the animals may temporarily shift locations, or if the fire is not very hot, they might move toward it. I've seen animals in landscapes still smoldering, eating ash beds because they are so rich in minerals.



COURTESY OF GORONGOSA PROJECT

LANDSCAPE CREATORS

In the park, termites generally locate their mounds in open savanna. These mounds improve the texture of the soil, improve water flow, and make it a nutrient-rich area. Many times, these areas support little forests of various trees, creating a very different composition that wouldn't be present in the landscape of the open savanna otherwise. And animals prefer to graze or browse on those termite mounds because it offers a better nutrient return for them. The animals, including pangolins, who eat termites and trees like the *Sterculia africana* that grow near the mounds, are making use of these nutrient-rich patches that are so important in the African savanna ecosystem.

NEW LIFE

Even in this time of mass biodiversity loss, new plants are still being found. Since the Gorongosa Restoration Project started in 2004, scientists have described a beautiful endemic plant species called *Impatiens wuerstenii*. This flowering perennial forb is found in rocky shaded areas, in the margins between the forests and the grasslands. There's also a limestone substrate endemic flowering evergreen tree species that was found on the eastern side of the park called *Cola cheringoma*. It's a big tree with a very narrow distribution and was only very recently described.

These new findings are why Gorongosa is an endlessly fascinating place. It has a very rich diversity and is one of those very dynamic places that changes quickly. This is why, with a little assistance, Gorongosa was able to make such an extraordinary comeback.

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To do so, we must Inspire, Unite, Change.

- Dona Bertarelli, Founder of Sails of Change

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GORONGOSA WILSON LAB

The Edward O. Wilson Laboratory is a modern research facility at Gorongosa National Park and a recognized hub of scientific and educational activity in Mozambique. It has been created to explore, document, and protect biodiversity, and to provide training for future conservation leaders in Africa.

The laboratory systematically and continuously surveys the biological diversity of the national park in all its landscapes and habitats, creating a detailed and dynamic picture of the entire Gorongosa ecosystem. This "Gorongosa Map of Life", along with multiple long-term ecological monitoring projects help guide the national park's management and restoration effort. The Wilson Lab regularly hosts external scientists and students, providing support for research that ranges from the soil microbiome to elephant ecology to paleontological studies of primate evolution.

Through its BioEducation Program, the laboratory offers a wide range of educational opportunities to Mozambican students. Its main goal is to improve scientific and conservation capacity in the country, from high school through the graduate level, and train a new generation of conservationists, educators, and scientists. An innovative M.Sc. program, conducted entirely within the national park, provides comprehensive training in both the theory and practice of conservation biology.

Visit **gorongosa.org** to learn more about science and education at the Wilson Laboratory.