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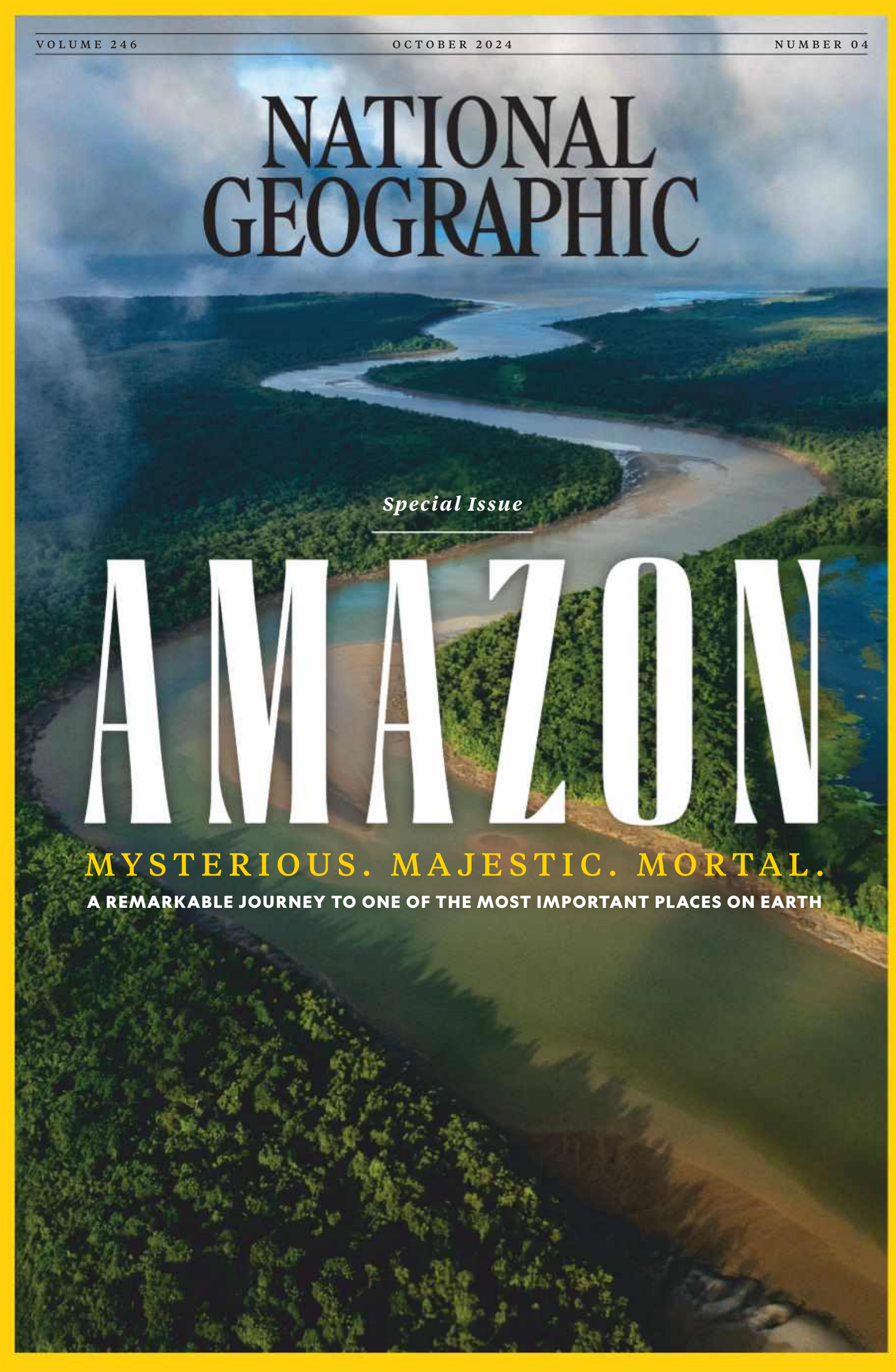
NATIONAL GEOGRAPHIC



Special Issue

AMAZON

MYSTERIOUS. MAJESTIC. MORTAL.

A REMARKABLE JOURNEY TO ONE OF THE MOST IMPORTANT PLACES ON EARTH

STUDYING AMAZON MANGROVES

MODELLING WETLANDS FLOODING

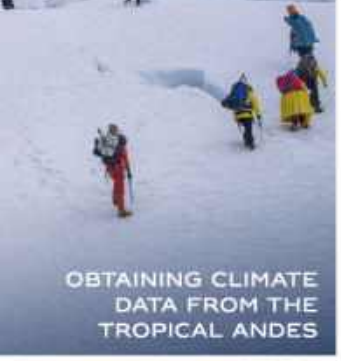
RESEARCHING IN
THE CLOUD FOREST

ANALYZING WATER CONTAMINATION

NATIONAL GEOGRAPHIC EXPLORER
AND PHOTOGRAPHER THOMAS PESCHAK

DESIGNING A CONSERVATION MODEL

WORKING WITH LOCAL COMMUNITIES



OBTAINING CLIMATE DATA FROM THE TROPICAL ANDES

NATIONAL GEOGRAPHIC SOCIETY AND ROLEX: A PARTNERSHIP TO SAVE THE AMAZON

The mighty Amazon helps to regulate the world's climate. For two years, seven teams from the National Geographic and Rolex Perpetual Planet Amazon Expedition have studied the health of one of the world's most important river systems under the watchful eye of photographer Thomas Peschak, who has chronicled their work. Their research will inform decisions on how to protect and restore the river's ecosystems.

#Perpetual

OYSTER PERPETUAL
EXPLORER 40

ROLEX
Perpetual Planet Initiative

NATIONAL GEOGRAPHIC | ROLEX

COMMITTED TO A PERPETUAL PLANET

FROM *the* EDITOR

NATHAN LUMP

THE ISSUE YOU HOLD in your hands is genuinely special. It is the culmination of incredibly deep research, exploration, inquiry, and documentation designed to give us all greater insight into one of our most critical ecosystems.

Amazonia—a popular term for the waterways and terrestrial areas around the Amazon River and its tributaries—is a place like no other. A huge carbon sink of 344 billion trees. A haven of biodiversity that's home to 10 percent of the planet's species. A cultural landscape rich in knowledge and creativity developed over millennia. A source of millions of gallons of water and rich nutrients that feed our oceans. Our planet would simply not be the same without it.

Over the past two years, the National Geographic editorial team has partnered with scientists, researchers, and storytellers in their work across this vast region—from the Andes to the Atlantic—in an effort to shine a light on what Amazonia today is telling us. It's a story of great challenges and threats, and also of hope. One thing is abundantly clear: We need Amazonia, and Amazonia needs our help.

In these pages you'll hear from many members of this expedition, learn what they've learned, and be transported by the stunning photography of Thomas Peschak, who spent nearly 400 days in the field to bring this dynamic ecosystem to life for National Geographic.

I hope you enjoy the issue.

PHOTO: MARK THIESSEN, NGM STAFF

CONTENTS

Reporting in this issue is presented by the National Geographic Society in partnership with Rolex under the National Geographic and Rolex Perpetual Planet Amazon Expedition. Rolex is partnering with the National Geographic Society on science-based expeditions to explore, study, and document change in the planet's unique regions.

ON THE COVER A channel cuts through the coastal mangroves and tropical rainforest of Brazil's Maracá-Jipioca Ecological Station, near the mouth of the Amazon River.
Photograph by THOMAS PESCHAK

OASIS: FARMING THE DESERT

For thousands of years, humans have done more than survive in the deserts of Arabia—they've thrived there. Now archaeobotanists are uncovering the secrets of their success: The crops they learned to cultivate in challenging conditions.

A man climbs a towering date palm tree, his feet nimbly navigating the trunk, also known as a stem, like a ladder until he reaches the canopy. Amid the palm leaves, he pulls a long, curved blade to expertly cut away a cluster of dates that he lowers to the ground. It's a scene almost unchanged for millennia in the oasis of AlUla, northwest Saudi Arabia. The region is renowned for its dates, which have been essential to oasis life for almost as long as humans have lived here. The oasis of AlUla was always more than a vital watering hole for travelers: It was a community and kingdom built on farming the desert.

Main image: *In the oasis of AlUla, dates have been harvested in the same way for thousands of years. The date palm tree remains one of the region's most important cultivated crops.* **Credit:** *Matthieu Paley*

AlUla's oasis was formed by a wadi, a desert ravine that brings water from faraway rains into the valley. Archaeological evidence shows that its soil was originally more fertile than it is today, filled with minerals washed from neighboring basalt plains in wetter times. Migrating birds, drawn to the water, deposited seeds from distant plants and the oasis sprung to life. We're unsure what the earliest humans would have found, but edible plants likely thrived beneath the sprawling canopies of acacia trees. These plants would have attracted animals, including gazelle, that enabled AlUla's first inhabitants to maintain the hunter-gather lifestyle depicted in their enigmatic rock art.

Around 5,000 years ago, the first signs of potential crops appear in the form of cereal grains. The challenge for archaeobotanists, who specialize in studying archaeological plant remains, is the scarcity of material to work with. Most plants decompose and disappear without leaving a trace. But sometimes grains, seeds, and wood survive, especially when carbonized by fire. So, where early humans settled and cooked and discarded rubbish, we find clues to what they were growing and eating.

"Date stones and fragments of date palm trees appear in AlUla around 3,000 years ago."

We don't know if these trees were domesticated locally or introduced, but their appearance coincides with evidence of building in AlUla, perhaps marking the start of the oasis' development. The presence of date palms is significant because these tall trees are an essential enabler for desert agriculture. As well as providing food, they offer shade against a burning sun and help reduce evaporation to preserve precious water. In the wild, this allows more delicate plants to thrive beneath their canopies, and AlUla's inhabitants learned from nature. They developed a three-layer farming system: The tall date palms sheltered shorter trees, and below these trees grew even smaller shrubs and plants. The crops grown at these lower heights changed over time, but a top layer of date palms remains a constant to this day.

Piecing together what was grown at the oasis becomes easier with the emergence of the Dadanite and Lihyanite kingdoms after 800 BCE. Centered on the city of Dadan, these kingdoms hosted substantial populations that

Above: *Whether domesticated locally or introduced from elsewhere, the appearance of date palm trees around 3,000 years ago coincides with the development of the oasis in AlUla.* **Credit:** *Matthieu Paley*

must have been supported by agriculture. Inscriptions in the rocks offer prayers for good rains and harvests, and include references to the seasons, water, produce, and the lease of parcels of land, probably to farmers.

Dadan's archaeobotanical record suggests that date palms were widespread at this time, and there were grapevines, pomegranate, and fig trees. Also found here were annuals, including lentils and cereals identified as barley and wheat—though a variety closer to durum wheat used for pasta.

Sometime after 500 BCE, the town of Hegra began to emerge. The same plants discovered at Dadan were here as well, but with the addition of olive trees. At this time, the people were probably using wild plants more than cultivated crops for their fuel needs. After the Nabataeans arrived and made Hegra their regional capital, the townspeople became more reliant on agriculture. Fruit trees were more numerous in Hegra, suggesting they were being actively cultivated. This change was supported by developments in irrigation: 130 wells were dug at Hegra, and huge cisterns stored water for use throughout the year.

"By the end of the first century BCE another crop appears in Hegra —cotton."

Geochemical analyses of cotton seeds and textiles found there confirm that cotton plants were cultivated and processed locally. Modern cotton is a thirsty crop, making it an unusual find for the deserts of Arabia: Modern cotton comes from the U.S., whereas the cotton found in Hegra originated in either Africa or India, and probably arrived along trade routes. A small tree rather than shrub, this cotton was suited to drier conditions and seems to have grown well, its abundance suggesting economic importance until Hegra was abandoned around 500 BCE.

Above: *Beneath the shading canopy of towering date palms, farmers over millennia have cultivated citrus, mangoes, pomegranate, and other fruit along with cereals, vegetables, herbs, and even cotton.* **Credit:** *Krystle Wright*

Above: *Water brings life to the oasis and the oasis brings life to the desert. Across millennia, the cultivation of crops has enabled communities and even kingdoms to emerge and thrive in AlUla.* **Credit:** *Matthieu Paley*

The cultivation of cotton continued at Dadan when it was reoccupied from around the fifth century and into the Islamic period. Again, we find date palms, fruit trees, and cereals demonstrating a logical continuity: AlUla's inhabitants knew what grew well and cultivated plants that met their needs. To these, they added useful new species revealed by tantalizing charcoal fragments belonging to an apple, pear, or quince tree, as well as further remains that are either apricot or peach. That we don't know which species is indicative of the challenge facing archaeobotanists: Many of AlUla's cultivated crops have left little or no evidence.

During the Islamic period, from the seventh century onward, irrigation leaped forward with the construction of qanats, gravity-fed underground channels bringing water from the mountains to the valley, where it was channeled to water large areas of farmland. In the 12th century, a visiting Islamic pilgrim was moved to describe the region as "a valley with lush vegetation" where "freshwater springs irrigate the crops."

Today, 80 percent of AlUla's inhabitants work in agriculture. The oasis is swathed in the verdant green of two million date palm trees producing over 90,000 tons of dates annually. The palms provide shade for thousands of citrus trees laden with fruits ranging from the sweet Jaffa orange to the Bin Zihr lemon used in kabsa, the national dish of Saudi Arabia. Also among these are the wispy-branched Moringa peregrina trees, a native species long cultivated for the luxurious oil extracted from its seeds. But still, towering above everything, remains the date palm tree—the key to farming the desert for thousands of years.

Scan to learn more about AlUla.
To plan a trip to AlUla visit:
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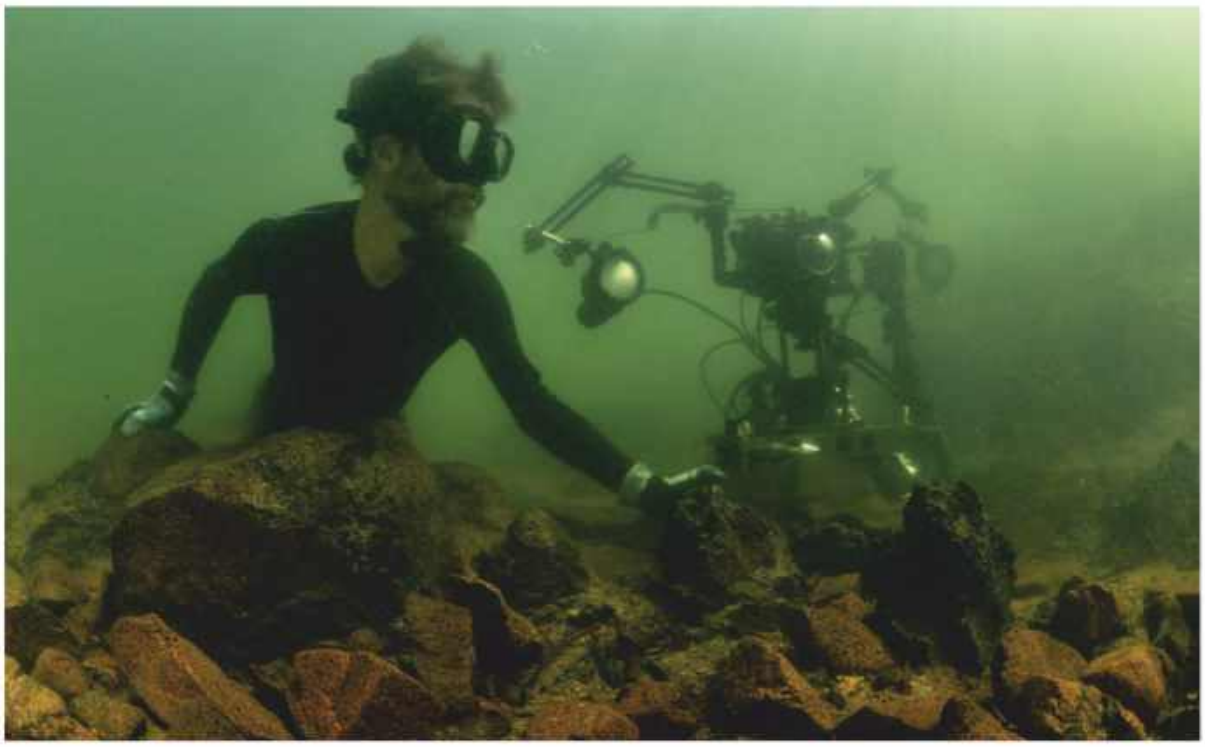
FROM SOURCE TO SEA

A conservation photographer who normally focuses on the ocean immersed himself in the Amazon Basin to reveal its aquatic wonders—and its challenges.



THE DRIVING FORCE behind our Amazon expedition, Thomas Peschak—a National Geographic Explorer since 2017—spent more than a year documenting the world's most biodiverse rainforest and the scientists studying it. He and his team, including videographer Otto Whitehead, embedded for weeks and months in over 30 locations. It was often demanding, says the South Africa–based photojournalist, but his best experiences were "off the charts." Among them: snorkeling with a tapir and diving with human-size catfish. –HICKS WOGAN

Peschak's Amazon Tally

1,931 **Books and scientific papers** he read before the expedition

490,064 **Photographs** he made while exploring the Amazon Basin

6 **Languages** in which he learned how to say hello

396 **Days** he spent on assignment in the field

102 **Bee and wasp stings** he and his team endured

1,200 **Approximate weight** of expedition equipment, in pounds

PHOTO: OTTO WHITEHEAD

NATIONAL GEOGRAPHIC EXPLORERS

These contributors have received funding from the National Geographic Society, which is committed to illuminating and protecting the wonder of our world.

João Campos-Silva, p.76
An Explorer since 2021 and founder of the Brazilian nonprofit Instituto Juruá, he leads a team that's developing and implementing community-based conservation solutions in rural Amazonia. He specializes in the once endangered arapaima, a gigantic fish crucial to the culture of flooding lowlands, the subject he wrote about for this issue.

Angelo Bernardino, p.120
This oceanographer at Brazil's Universidade Federal do Espírito Santo led a research team that recently identified a new kind of mangrove forest at the mouth of the Amazon, an area he covers in this feature. An Explorer since 2018, Bernardino is also a dedicated ocean paddler—on the water by dawn every morning in his outrigger canoe.

Ruthmery Pillco Huarcaya, p.30
Raised in a Quechua village in the Peruvian Andes, Pillco is a biologist helming a research team high in the cloud forest. For this issue, she wrote about the focus of their studies: the elusive Andean bear and its vital role in the ecology of the Amazon Basin. A favorite collaborator? Her rescue dog turned bear tracker. She became an Explorer in 2021.

Eduardo Neves, p.11
The professor, archaeologist, and museum director at Brazil's University of São Paulo has spent 35 years researching the Amazon's early cultures, knowledge he drew on for this issue's introduction. An Explorer since 2012, he now directs the Society-funded Amazon Revealed project, which identifies and maps ancient human occupations in the rainforest.

Cynthia Gorney, pp.30, 76, 120
A former South America bureau chief for the *Washington Post,* Gorney is a journalism professor emerita at the University of California, Berkeley. She's written for *National Geographic* since 2008, reporting from Saudi Arabia, Uganda, and Bosnia. Her feature on the sense of touch ran in the June 2022 issue.

Jordan Salama, pp.54, 104, 118
Salama's features on pink river dolphins and the headwaters of Bolivia's Sécure River are some of his latest stories on South America. For his recent book, *Stranger in the Desert,* the New York–based writer traversed the Argentine Andes in search of his family's lost history.

PHOTOS (CLOCKWISE FROM TOP LEFT): ANDRÉ DIB; PABLO ALBARENGA; FLORENCE GOUPIL (NATIONAL GEOGRAPHIC FOR PREVIOUS THREE); MARK THIESSEN, NGM STAFF; LUIS ALFREDO CEBALLOS; ELÍAS CONDORI

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SPECIAL ISSUE

INTRODUCTION

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Photographs by THOMAS PESCHAK

In a forest flooded by Brazil's Rio Negro, an Amazon tributary, guide Roberto Abdias Gomes da Silva points toward the high-water line on the massive buttress roots of a kapok tree, a species that can grow over 200 feet tall. Its trunk acts like a water tank, storing moisture during seasonal floods to sustain it through dry periods.

Words by
EDUARDO NEVES

RELEARNING THE AMAZON

For 500 years, outsiders have misunderstood the world's largest rainforest. That's finally changing.

The story of how the Amazon got its name begins on June 24, 1542. Francisco de Orellana was praying for an escape from the green world that had swallowed his beleaguered expedition. The Spaniard's two boats, containing fewer than 50 starving men, were nearing what the crew hoped would be their salvation. After seven months of navigating a series of tributaries beginning at the foot of the Andes, they'd finally reached the largest river any of them had ever seen, and Orellana hoped it would soon lead them to the Atlantic Ocean.

He was accompanied by Gaspar de Carvajal, a Dominican friar, who kept a detailed chronicle of their journey. The priest recorded the Europeans' astonishment at the advanced cultures they encountered—densely populated villages along the riverside, including one that stretched on for many miles. He described networks of wide roads, beautiful plazas and fortified palisades, carefully cultivated farms, and painted pottery as fine as any in Spain. Along the way, some communities welcomed them with generosity—feeding them manioc, yams, corn, and turtles. But on this June day, still some 600 miles from the end of the enormous river, they were attacked by an army of warriors led by ferocious women "who fought so courageously that the Indian men did not dare to turn their backs." Carvajal, who came out of the battle with an arrow in his side, compared the women to the Amazons of Greek legend. His accounts of the voyage, the first by a European to traverse South America, would later be dismissed as fantasy by Spanish authorities. And yet, the term "Amazon," however inapt, would come to identify this vast and complex region. Since then, the Amazon has been defined by many myths, which only in recent years archaeologists, like me, and other scientists have begun to unravel.

CLICK ON A SATELLITE IMAGE of the Amazon, and it's easy to fall prey to the myth that it's a pristine jungle. It appears like a green mantle, composed of 344 billion trees covering much of the northern half of South America. Zoom in, and you find a labyrinth of river valleys; more than 6,200 rivers and tributaries drain an area roughly the size of the contiguous United States. It's the planet's largest, most biodiverse tropical rainforest. Roughly

Reporting in this issue is presented by the National Geographic Society in partnership with Rolex under the National Geographic and Rolex Perpetual Planet Amazon Expedition.

10 percent of all Earth's plant and animal species live there. The Amazon shelters 40,000 species of seed plants, 2,400 species of fish, 1,300 species of birds, and 1,500 species of butterflies. Such a place, it would seem, must have been left largely untouched by humans. But this is one of the enduring misconceptions that over the past four decades scientists have been methodically debunking.

Thanks to rock art, stone tools, and other remains found in remote areas in Colombia and Brazil, we know the human presence in the Amazon Basin extends back at least 13,000 years. Ancient Amazonians were depicting Pleistocene creatures, including mastodons and giant sloths, around the same time ancient Europeans were painting mammoths and woolly rhinos. Over time, those Amazonian populations grew, and by 1492, scientists estimate, the region was home to as many as 10 million people.

So why have so many people gotten the Amazon so wrong for so long? In the centuries that followed Orellana's journey, Portuguese efforts to colonize the heart of the Amazon and extract its resources decimated the populations. Smallpox and other diseases introduced by Europeans are believed to have wiped out upwards of 90 percent of the Native peoples. And the practice of slave raiding drove most of the survivors into the far reaches of the interior, effectively converting settled farmers into nomadic hunter-gatherers. So in the 1700s, when the first European naturalists arrived, they found large areas covered in dense jungle vegetation with few people around and assumed it had always been like this.

Because of this depopulation, the large

An ancient mural on a rock wall in Colombia's Chiribiquete National Park depicts jaguars, large rodents called pacas, and piranhas. More than 75,000 paintings have been found in the region, portraying scenes from the prehistoric Amazon.

settlements Carvajal had described, built from wood and straw (there's not enough rock in the Amazon for masonry), had long since rotted away in the wet tropical environment. Large human-made mounds were labeled as natural formations, and the region's staggering number of languages was attributed to successive waves of immigrants that came to the rainforest from elsewhere on the continent. By the late 1800s and the apex of the rubber boom—a period of extreme violence against Indigenous peoples—anthropologists were erroneously describing Native societies as small, nomadic groups. That picture consolidated during the 20th century and still shapes the image that many outsiders have about the Indigenous history of the Amazon.

This was the prevailing view when I graduated from college in the 1980s, but then I met two American anthropologists working with Indigenous groups in the eastern Amazon. Darrell Posey told me how he'd documented the Kayapó planting "forest islands" in savanna areas as they hunted and collected fruits and nuts. William Balée described how the Ka'apor used fire to foster the growth of palm groves. Both groups were clearly engineering their landscape to suit their needs. This idea led me into a career looking for new answers about the history of the Amazon.

Nearly four decades later, researchers have uncovered an overwhelming body of new evidence. The trees tell us part of the story. By surveying the rainforest, we find that half of the Amazon's trees come from only 299 species. These so-called hyperdominant species are especially useful to humans—including acai, rubber, Brazil nut, and cacao. We tend to find these trees in abundance near pre-Columbian archaeological sites, which points

Pilgrims dressed up as *ukukus*—mythical bear-humans—climb glaciers above Peru's Sinakara Valley during the Qoyllur Riti festival. The once plentiful ice, considered sacred, is now receding.

NATIONAL GEOGRAPHIC

THEIR FUTURE CAN BE YOUR LEGACY

For many of us, creating or updating our will is one of those tasks that always seems to fall to the bottom of the pile. In fact, the average person takes more time to plan their vacation than to plan for their future. You owe it to yourself and your family to be prepared. When you leave a gift to the National Geographic Society in your will or trust, or by beneficiary designation, you can protect critical animal species for generations to come.

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PHOTOGRAPH BY FRANS LANTING

24PGAD10INTL

to a long-standing practice of Indigenous people curating the Amazon forests.

But it wasn't just the trees that the early Amazonians were curating; it was the soil too. Beginning in the 1970s, scholars argued that the "Amazon was a counterfeit paradise." Despite the lush jungle, its highly acidic soils lacked nutrients crucial for intensive agriculture and, therefore, couldn't have yielded enough food to support large, concentrated populations. But scientists noticed Indigenous people growing crops on plots of something called *terra preta*—dark earth—which is soil mixed with charcoal and organic matter and often pieces of broken ceramics. Not only are such spots highly fertile, but they can remain so for centuries, with little or no fertilizer added. Archaeologists have found terra preta throughout the Amazon and have dated some as far back as 5,000 years.

But what about the Amazonian cities that Carvajal and other early Europeans described? As recently as 2008, my colleague Michael Heckenberger was criticized for suggesting that there was widespread urbanism in the Amazon. But then came lidar—a laser scanning system—that has allowed us to peer through the dense rainforest canopy and see how early societies shaped the land. While I was working in Bolivia in 2019, colleagues were using lidar to map complex urban settlements belonging to the Casarabe culture, which lasted from around A.D. 500 to about 1400. The settlements were linked to each other by causeways several miles long and included canals and reservoirs and earthen pyramids. Lidar has revealed about a thousand large, intricate settlements throughout the Amazon, effectively rewriting its history and showing us that, as in Europe and Asia, there wasn't a single Amazonian culture but many.

Now my work, partly funded by the National Geographic Society, focuses on partnering with Indigenous communities to do lidar surveys of their land, especially near areas that have been deforested or are threatened. By finding archaeological sites, we're able to apply for stricter protections from the Brazilian government. The hope is to use archaeology to build a firewall around the rainforest.

As this revised historical picture is emerging, scholars continue to make discoveries in the natural world. On average, a new Amazonian species is described for science every other day. Just this February, scientists announced a new species of anaconda, the world's heaviest snake. Every day new parts of the story come into sharper focus.

It's in this spirit that the National Geographic and Rolex Perpetual Planet Amazon Expedition was launched, supporting the research of 16 scientists—11 of whom are from South America—working in a range of disciplines with local collaborators at sites spread from the Andes to the Atlantic coast. In the following pages, you'll find their discoveries, documented by photographer Thomas Peschak and his assistant, Otto Whitehead, who in visiting their research sites traced a path from the river's source in the Andes glaciers all the way to its plume extending into the Caribbean.

It's desperately important work. Since I began working in the Brazilian Amazon in 1986, 12 percent of the forest has been destroyed, much of it by illegal logging. Meanwhile, illicit gold mining is out of control in many countries, and organized crime is increasingly using it and other unlawful activities in the Amazon to launder money from drug trafficking. At times, the future seems dire, but I am sure that we can find ways to change it. Scientists and politicians have a lot to learn from Indigenous peoples and the ways they have managed and shaped the complex natural systems of the Amazon through the millennia. The first lesson they can teach us is that to chart a sustainable future for the Amazon, we should look to its past.

Pink dolphins navigate a flooded forest in the Rio Negro's tannin-tinted waters. Supreme hunters, these dolphins feast on 50-odd fish species, using cone-shaped front teeth to grab their prey. Scientists believe stiff hairs on their snouts give them a sense of touch when foraging in mud for turtles, crabs, and shrimps.

Nevado Ausangate, the highest mountain in the Andes of southern Peru, looms above a waterfall fed by glacial melt. Communities and ecosystems hundreds of miles downstream rely on glacial melt as a primary freshwater source, especially during dry seasons and times of drought.

THE AQUATIC AMAZON

Spanning the continent, the basins of the mighty Amazon River and its tributaries contain and support the world's largest rainforest and countless species of flora and fauna. Originating in the high Andes, then swiftly flowing into the basin, the waters cycle from ice melt and cloud to torrential rains that seasonally flood the densely forested valleys—a perpetual exchange between the terrestrial and the aquatic.

MATTHEW W. CHWASTYK AND DIANA MARQUES, NGM STAFF
SOURCES: ANA P. BARROS, UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN; SCIENCE FOR NATURE AND PEOPLE PARTNERSHIP; ESA; NASA/JPL; OPENSTREETMAP

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Mouths of the Amazon

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Marajó Bay

Bragança

Belém

São Marcos Bay

Portel

Tocantins

Paragominas

São Luís

ucuruí

Serra do Tiracambu

Tucuruí Reservoir

Santa Inês

Fortaleza

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Imperatriz

Teresina

Presidente Dutra

Natal

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Araguaína

Floriano

Crato

Balsas

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Maceió

Palmas

Aracaju

Gurupi

Barreiras

Alvorada

R A Z I L I A N

Salvador

Niquelândia

Ilhéus

Goianésia

Formosa

Brasília

Goiânia

G H L A N D S

Uberlândia

Belo Horizonte

Hydrology

Area subject to inundation

Amazon discharge plume

Limit of the Amazon Aquatic Ecosystem

The freshwater system of climate, life, and landscape drained by the Amazon and the adjacent rivers that flow into its discharge plume

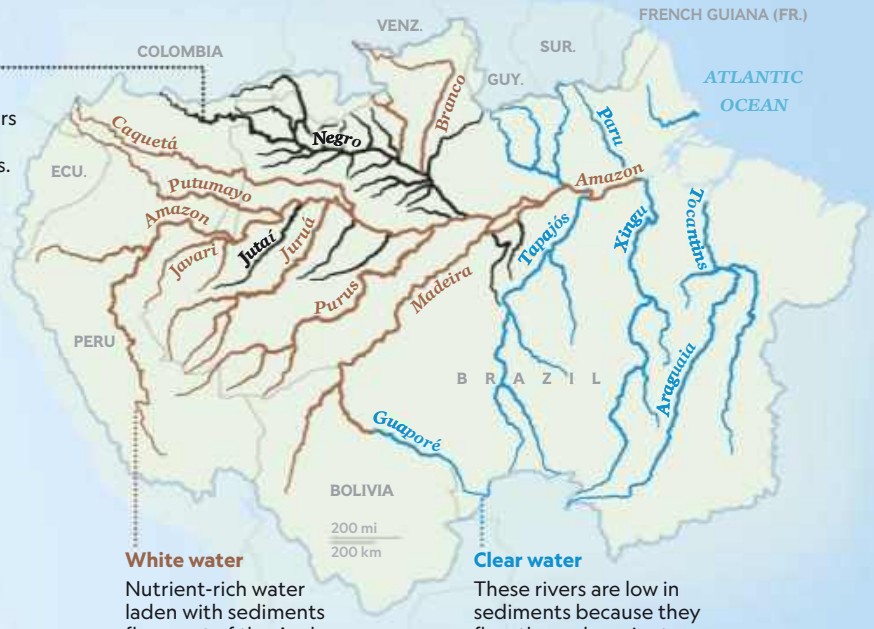
100 mi
100 km

ANDES TO ATLANTIC

From mountain headwaters to tributaries, water takes on sediments and chemicals that change its appearance and characteristics as it flows over different terrain. More than 58 million gallons, enough to fill 88 Olympic swimming pools, flow from the Amazon's mouths into the Atlantic every second.

Black water

Acidic and low in nutrients, these rivers are darkened by decomposing plants.



White water

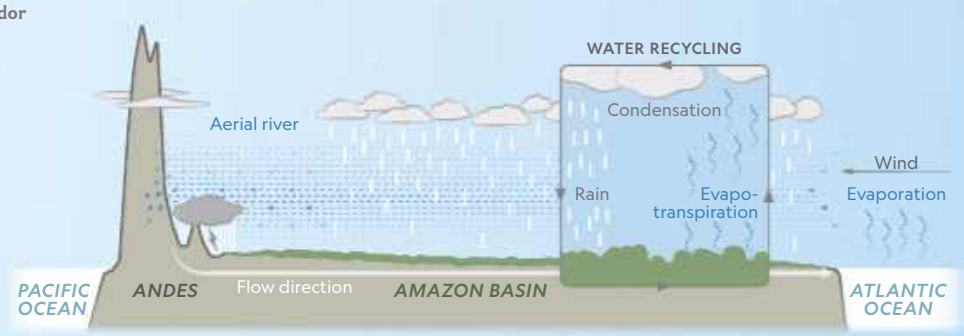
Nutrient-rich water laden with sediments flows out of the Andes, clouding these rivers.

Clear water

These rivers are low in sediments because they flow through ancient shields of hard rock.

WATER CYCLE OF LIFE

Much of the Amazon Basin's water is returned to the forest as rain. The remainder is carried by east-west winds as an aerial current—a mix of moist ocean air and some transpiration from the forest—that is directed south when coming up against the Andes.



THE SOURCE

Photographs by THOMAS PESCHAK

Words by RUTHMERY PILLCO HUARCAYA

THE FLYING RIVERS

High in the Andes, a land of towering glaciers, dense cloud forests, and elusive bears shapes the Amazon River Basin.

Combining a traditional skirt with alpine gear, Senobio Llusco, a member of Bolivia's Aymara people, accompanies a National Geographic team to install a weather station atop Nevado Ausangate, a 21,000-foot peak in the Peruvian Andes. Among the new station's tasks: recording moisture of the glaciers, whose high-altitude melt helps feed the Amazon River.

Icy condor feathers shine in the mist of a cliffside spring atop Nevado Mismi in the Peruvian Andes. While streams and tributaries coalesce from many directions to become the Amazon River, this volcanic peak is the farthest source of uninterrupted flow from the river's mouth at the Atlantic.

MOST MORNINGS, INSIDE MY FIELD STATION BEDROOM IN THE PERUVIAN ANDES, I WAKE UP BEFORE DAWN.

The bats on the ceiling start skittering, and as the light comes up, I can watch the clouds slide along the steep forested ridges outside. They're rivers in the air, these clouds. *Ríos voladores,* flying rivers, they carry moisture that will make its way into soil, and then creeks, and hundreds of miles of river on the ground, all the way out to the sea. I grew up not far from here, but what truly taught me the ríos voladores lesson was a single day of desperation: me stuck amid the dense foliage of these mountains, parched with thirst.

Let me back up. I came to this station and laboratory, a few hours' drive east of Cusco, to study the Andean bear, an elusive animal whose critical role in the Amazonian ecosystem we're just now coming to appreciate. It was May of 2021, and I'd been living here for two weeks with Ukuku, the shelter dog I'd adopted and trained as a bear tracker. A crew of helpers lived here too, most from nearby villages, and our first big mission was a multiday trek to put in place four dozen cameras, at spaced intervals, along a wooded mountain stretch of what we hoped was bear territory. At first, we had horses for the cargo, but the treacherous slopes were too much for them. The horses were sent home, and we put everything on our backs: cameras, tents, food, water, hammocks for overnighting on the steepest slopes, and machetes for clearing the way.

Those packs were heavy. I'm a small person, and with 60 pounds on my back I stepped carefully, one footfall at a time. Even as one of us cut brush with the machete up ahead, the

A Peruvian artisan weaves an image of an *ukuku,* the South American bear venerated in Quechua stories and a vital part of Amazonia's Andean ecosystem.

ground moss and bramble beneath us hid pits that could break a leg. The nights were so cold; when Ukuku started shivering, she nosed into my sleeping bag, and we kept each other warm. By day five the crew had stopped amid the thickest foliage I'd ever seen, not quite sure how far up we'd climbed from the river at the mountain's base. Our food was running low. We were out of water. We could find no rivulets or puddles. We all grasped the grim comedy of the situation: Deep inside the *bosque de nubes*—the cloud forest!—we were frantic for something to drink.

Then Narciso said: The tree beards.

Narciso Llaqta is part of our crew, a Quechua speaker and guide who knows the mountains better than I do. He put his hand on a tree, pulled away some of the moss that covers so much of the bark in these forests, and squeezed the tiny stems and leaves until

Reporting in this issue is presented by the National Geographic Society in partnership with Rolex under the National Geographic and Rolex Perpetual Planet Amazon Expedition.

Biologist Ruthmery Pillco Huarcaya, who was raised in a Quechua village not far from her mountainside field station, holds a flowering bromeliad, a favorite food of the Andean bear. Her research takes her team of scientists and tracker dog Ukuku deep into the Peruvian cloud forest to follow the fast-moving bears.

beads of water appeared—a few, then more, then droplets so fat we could see them splash on the ground. In Quechua these mosses are sometimes called *sachaq sunkha,* the beard of the tree. I knew they act as sponges, moisture receptacles amid Andean clouds, and now I watched as one of our crew members held a cup under the trickle of water Narciso was squeezing from his fistful of moss.

The cup filled. We brought out more cups. Mariano Huanca, who also grew up nearby, thought of the forest's bromeliads—flowering plants with creased leaves straight as daggers. Mariano has worked with scientists who study amphibians, and he had seen bowl-shaped bromeliad centers, from which the leaves fan out, hold enough water to become tiny pools for frogs. Biologists speak of bromeliads as water tanks, in fact, and as we found bromeliads and tree beards collecting water that was

An Andean bear, made famous by the Paddington children's books, blinks back to consciousness after a tranquilizer let scientists fit on a geolocation collar.

brown with silt, somebody else remembered how to improvise a water filter. So there we all stood, exhausted explorers in our swath of Amazonia, curving up the bottoms of our T-shirts to strain cloud forest water into cups.

•

UKUKU IS THE QUECHUA WORD for "bear," and in South America there's only one kind of bear: the round-eyed black Andean. Its range may extend a long way south of the Amazon River; in the past there hasn't been much study of Andean bears, and some of what we think we know about them comes from rumor. Can an Andean bear really bend himself into a furry sphere when he wants to make a quick exit and roll like a ball straight down a hill? People here swear they've seen this. We know that even though they're not big bears, maybe 250 pounds as adults, they're tremendously powerful. An Andean bear can pull a dead cow up a 60-foot tree, hiding the carcass from other bears, to store it in the treetop canopy as food.

When I was a child, though, listening to my grandmother explain the world to me in Quechua, "ukuku" conjured a being more ephemeral than animal. Village dogs and chickens were animals. *Cuys,* the guinea pigs that trotted across our kitchen floor before being turned into part of our diet—those were animals. The ukukus of our stories were not exactly divine, but they were bound to us in mystical ways that we still honor. They were guardians of the Andean glaciers, the stories told us, occasionally taking women as brides. Their bear-human children carried glacier ice from the highest mountaintops to deliver water to the villages.

My research is teaching me that there's serious science in that idea, the Andean bear as life-protecting delivery system here. But in my childhood imagination the ukukus just hovered, part of the physical and spiritual Quechua landscape. To be clear, I was a tough little rebel; my parents started me in kindergarten when I was four. They said I was ready. Maybe they just wanted me out from underfoot. My given name was Edyflor, which I disliked—too much like *coliflor,* the Spanish for "cauliflower," no four-year-old girl wants to think of herself as a cauliflower—and on the day they first walked me to school to sign me up, we passed a house in which I knew, from overhearing the residents' calls to each other, that one was named Rosemary.

"I want that name," I announced, and stopped walking. "I will only go to school if you let me change my name to Rosemary."

SIZING THEM UP

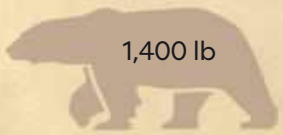
Not all bears climb, and most of the world's eight species of bears are omnivores.

Main diet

Plants Insects Meat

Large adult shown. Weight varies within a species.

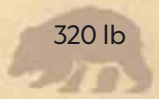
NON-CLIMBER



Polar bear
Ursus maritimus

INFREQUENT CLIMBERS

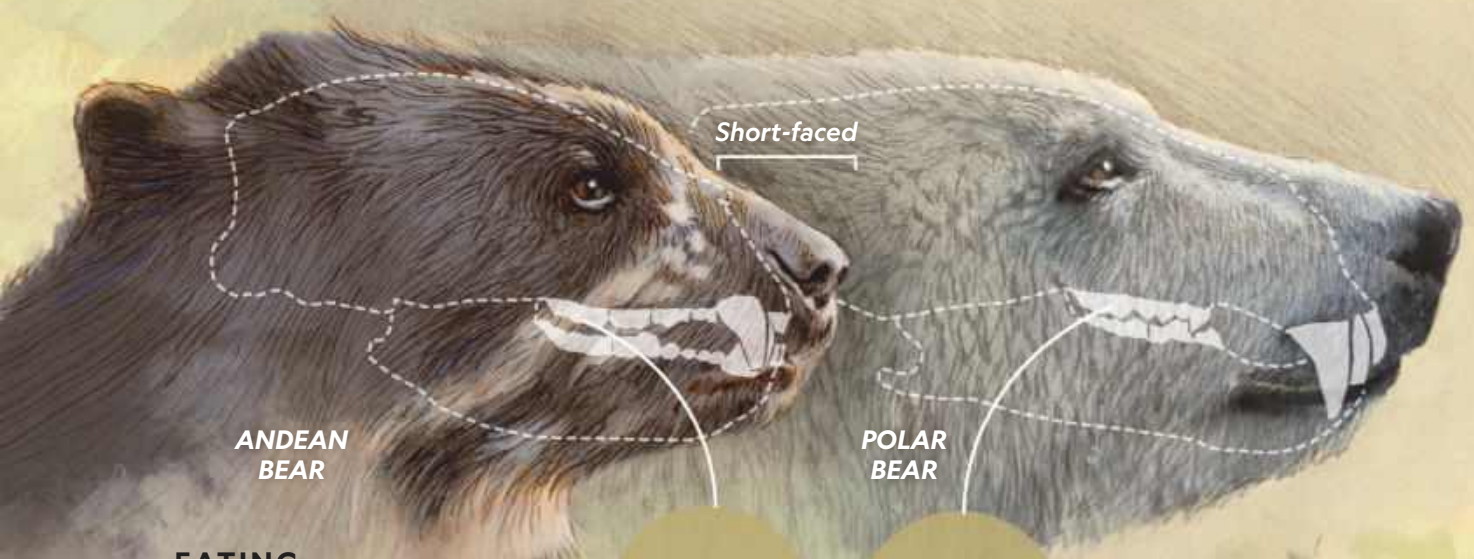
Brown bear
Ursus arctos



Sloth bear
Melursus ursinus

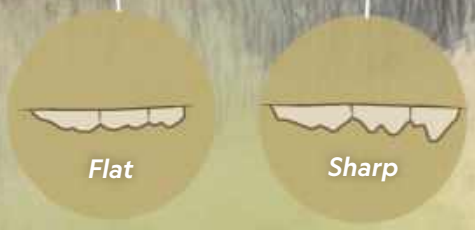
LAND OF THE ANDEAN BEAR

The only bear species in South America, these stout, striped-face bears are adapted to the misty mountains of the Andes, where they're believed to play a key role in forest regeneration.



EATING

Strong jaws and wide, flat molars are an adaptation for chewing tough vegetation, unlike bears with sharp teeth adapted for biting flesh.



NESTING

Females create nests for their small litters of cubs by piling up leaves and branches. Cubs are dependent up to two years.

Bears build nests on cliff ledges.

Letting in light
Breaking branches to make platforms for resting also benefits the forest by allowing light onto the forest floor.

Leaving their mark
Clawing, biting, and rubbing body scent on trees are different ways they might communicate.

7.2 ft tall

LESS FREQUENT CLIMBERS

FREQUENT CLIMBERS

330 lb

Giant panda
Ailuropoda melanoleuca

440 lb

Asiatic black bear
Ursus thibetanus

500 lb

N. American black bear
Ursus americanus

190 lb

Sun bear
Helarctos malayanus

130-390 lb

Andean bear
Tremarctos ornatus

CLIMBING

Andean bears are excellent climbers and spend much of their time in trees. Foraging for food takes up to 70 percent of their active time.

Longer front limbs

Bromeliad, a favored food

Wild avocado

Brown bear (grizzly)

Andean bear

Gripping claws
Curved claws make for a firm grip when climbing trees to forage, rest, or nest.

Spreading seeds
The bears help regenerate the forest by dispersing seeds of the plants they eat, including fruits, in their waste.

200 mi
200 km

VENEZUELA

COLOMBIA

ANDES

ECUADOR

PERU

BOLIVIA

ARG.

WHERE THEY'RE FOUND

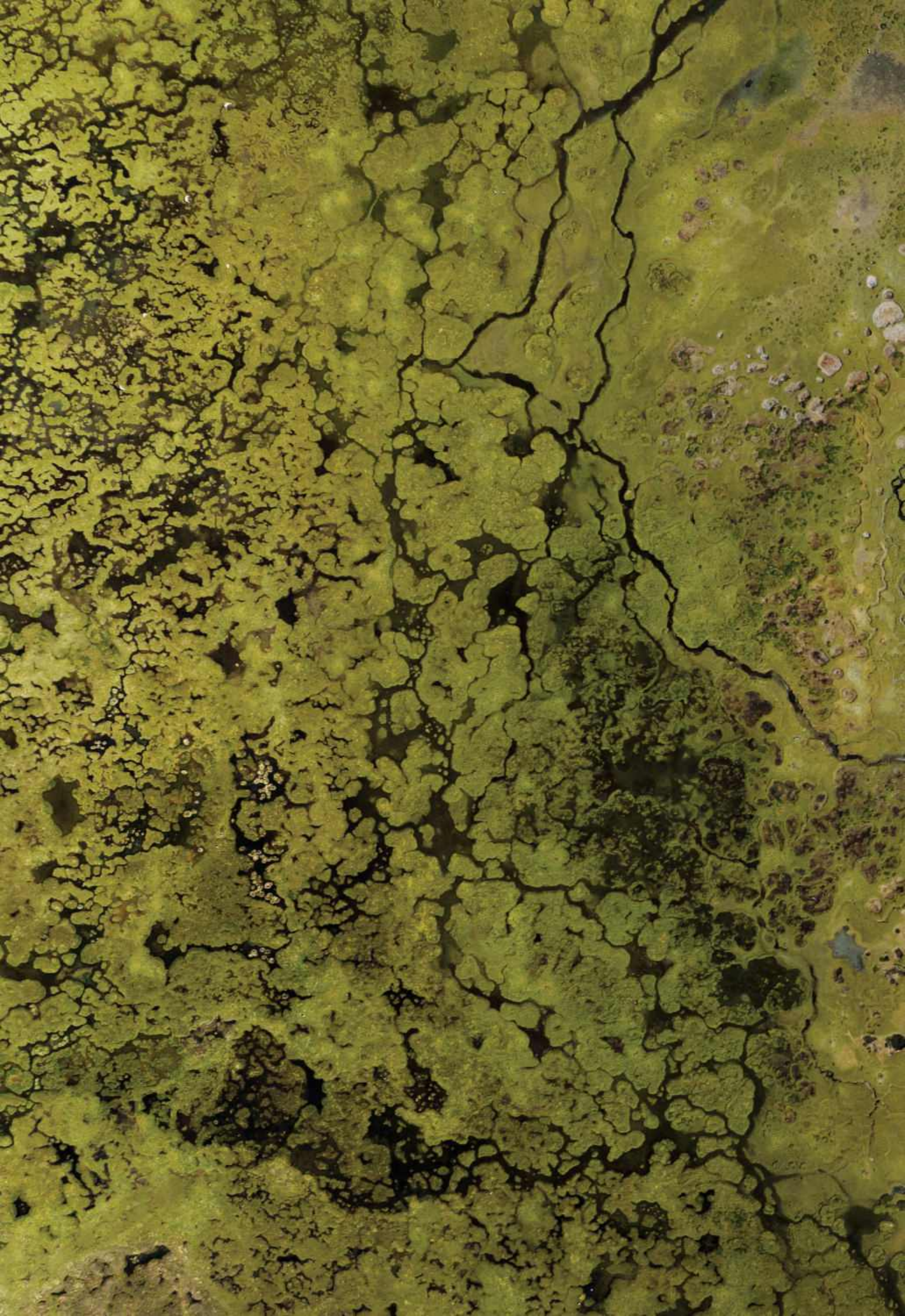
Inhabiting grassland and forest from 650 to 16,000 feet, they seem to prefer food-abundant, high-elevation cloud forests.

Andean bear range

Wayqecha Cloud Forest Biological Station

Fur patterns are as individual as human fingerprints.

GRAPHIC: FERNANDO G. BAPTISTA, PATRICIA HEALY, EVE CONANT, LUCAS PETRIN, AND SOREN WALLJASPER, NGM STAFF. SOURCES: ARMANDO CASTELLANOS, ANDEAN BEAR FOUNDATION; BORJA FIGUEIRIDO, U. DE MÁLAGA; DAVE GARSHELIS, IUCN SSC BEAR SPECIALIST GROUP; TERESA HSU, SMITHSONIAN'S NAT. MUS. OF NAT. HIST.; RUTHMERY PILLCO HUARCAYA, CONSERVACIÓN AMAZÓNICA-ACCA



High above the Peruvian Andes, patterns of life are etched into a valley. On the left, a web of watery veins courses through a mossy peat bog at the valley bottom. The lines to the right are trails scored into the hillside by herds of alpacas and vicuñas.

A rebel, as I said. There were two younger kids at home, and my father was away a lot working in the fields or other villages, so my parents had more urgent matters to deal with. They gave in—OK, Rosemary, whatever—and then the teacher misheard the name and misspelled it in her ledger. So I became Ruthmery, and the school made me tougher; we were forced to speak only Spanish inside, and I was always the smallest among my friends. I used to find lizards around the schoolyard and drop them into the boys' backpacks. We'd run around the village together, making nuisances of ourselves; the women would scold us in our more familiar Quechua. *Heqas!* Brats!

And the bears? I don't know how to explain this, but they kept reappearing. Not literally, I mean, but in my spirit, in my life. There was a videocassette player in the town secondary school, and one day when I was maybe 14, somebody put in a dubbed version of the animated Disney movie *Brother Bear.* It's set in Alaska, where bears, humans, and spirits all interact, and as I watched, I swear I felt something happening in me—some powerful tie, me and the animals. I remember it to this day. I'm connected to bears. I want to be a bear.

I told nobody. Tucked it away in my head. But as I made it to the national university in Cusco—*llaqtamanta lloqsinayki!* my grandmother used to urge, leave this town! go off to learn and explore—that conviction of connection stayed with me. My developing interest in biology would eventually take me to London, for conservation research at the Kew Royal Botanic Gardens; when people there learned where I was from, they would nod and say, "Ah! Paddington Bear!" You might recall that in the children's book, the hero Paddington, when he appears in Britain (wearing an old hat), is from "darkest Peru." That means Paddington would be a "spectacled" bear (his real-life counterparts often have facial fur that makes them look as though they're wearing glasses), or, more formally: *Tremarctos ornatos.*

There was so much other animal and plant life to absorb during those years, of course. My parents only now are coming to see why I always wrote *biología* on the forms that asked us to choose our college major—they assumed that if I really was going to leave my village and family, it would be to train as a medical doctor, a professional career they better understood. But biology fascinated me. I loved the science of the natural world. When I was awarded a spot on an undergraduate expedition, multiple weeks in the mountains and jungles of central Peru, I had to scrounge secondhand stores for basic equipment; I owned no proper hiking shoes, no proper backpack. And as difficult as remote field research proved to be—there were tears, I was so tired sometimes, I felt so completely far from home—I loved that too.

OVER THE YEARS, as more opportunities came, I worked with birds, monkeys, mushrooms, rare trees in Costa Rica. The village school had made me learn Spanish; as a graduate student, with offers from abroad, I had to learn English as well. Then in 2020, my mentors and fellow biologists—Andrew Whitworth, also a National Geographic Explorer, and Adrian Forsyth—told me the Peruvian nonprofit Conservación Amazonica, which Forsyth had co-founded, wanted a researcher to take over an isolated station in the cloud forest. The new project: Andean bears. Their role in the forest's ecology needed deeper study, especially under the urgent pressures of climate change. *"Vamos,"* I said.

Wayqecha, as our station is called, is a cluster of wood buildings—a laboratory, a dining hall, a dormitory. The road to reach us twists cliffside into the cloud forest, too narrow in places for two cars to pass; drivers honk as warning at the blind curves. When the clouds are low, long drops of foliage disappear into the mist. When there's a break and a bit of blue, we can see the far-off depths of forested

valley and then more mountains, their peaks still shrouded, undulating into the horizon.

It may be strange, for someone trying to take in a full Amazonia map, to imagine mountain-scrambling bears fitting in along with everything else. But like monkeys, macaws, and dolphins, the bears of the cloud forest are part of the cycle sustaining this whole river basin, even when the closest real waterway seems a long distance away. Every time an Andean bear eats a plant, climbs uphill for hours, and excretes the seeds miles higher than where it started, that bear is spreading foliage. Seeds often germinate more quickly when they've been partially digested, and these seeds are landing amid a dollop of bear scat fertilizer. Which means more new plants and trees absorbing moisture from the air, which means more water seeping into the soil, which means more rivulets trickling down to the tributaries that feed the Rio Amazonas, where, eventually, hundreds of miles later, surface water evaporates as the river meets the ocean and winds carry back to us our flying rivers of cloud.

And as climate change accelerates, raising temperatures and making rainy seasons less predictable, our research is showing that the bears may be helping fight it by redesigning their terrain. Other seed-spreading animals live here, but the Andean bear is one of the few mammals to cover such long distances uphill, from lower forest to high-elevation grassland in a single day's ramble—helping the forest adapt, we believe, by expanding and moving it, pushing the tree line up to higher and cooler levels.

So, with my dog Ukuku alongside to sniff for traces, my team and I try to follow bears. Their lives up here make it challenging work: Andean bears are solitary, fast, and clever. We find their routes by spotting food leavings or bear scat or markings on tree trunks—communication signals to each other, we think. Our field video cameras are triggered by motion sensors; we've also set out five box traps, baited with rancid meat. Once in a long while—four times, as of this past spring—a bear investigates one of these traps and pushes in just far enough to drop the door behind him, which triggers a loud alert on our phones. It sounds like a bugle flourish, and as soon as we hear it, day or night, we're grabbing our packs and headlamps; we don't want that bear caged any longer than necessary. I call Ukuku, and we all start running—I mean *running*—in our high mud boots, hauling our equipment up the narrow dirt trails.

WHEN PEOPLE LEARNED WHERE I WAS FROM, THEY WOULD NOD AND SAY, 'AH! PADDINGTON BEAR!'

Excitement pushes us. With the adrenaline, you don't feel the weight.

At the trap we shoot in a tranquilizer dart so we can measure, check health, and attach a temporary collar that will geolocate the bear for us once it's on the move. The collars are lightweight; remote commands make them fall away in places we know we'll be able to get to for retrieval. A couple of the collars contain tiny video cameras, and that's how I came to be sitting at my lab computer late into several nights this past spring, staring at the cloud forest as observed from the eye-level—well, technically, neck-level—perspective of a bear.

We had given this bear a name before he dropped his camera collar: Chris, after one of our donors. Now we were fascinated, watching the life of Chris the bear as he crossed rivers, chomped bromeliads, napped in the treetop canopy, shouldered through brush in the rain.

UPLAND WETLAND

High in the Andes are fragile habitats saturated with water. The region's flora and fauna have adapted to thin air, winds, intense solar radiation, and wide swings in daily temperatures between warm days and freezing nights.

GLACIERS

Glacial meltwaters feed the Amazon's rivers. These frozen reservoirs are slow to form, and are receding.

Snow precipitation

Sublimation (solid snow and ice to vapor)

Andean condor
Vultur gryphus

AERIAL RIVER

Snow line

RIVERS IN THE AIR

Water vapor flowing from the lowlands rivals the volume of the Amazon River's discharge.

BOFEDAL (wetland)

MISTY MOUNTAINS

Above the tree line are wetlands characterized by lakes, grasses, and shrubs.

Animal refuge

Water in these wetlands supports wildlife through the dry season.

Andean fox
Lycalopex culpaeus

Vicuña
Vicugna vicugna

Distichia muscoides

White-winged cinclodes
Cinclodes atacamensis

Viscacha
Lagidium viscacia

Deschampsia chrysantha

Glacier finch
Idiopsar speculifer

Water catchers

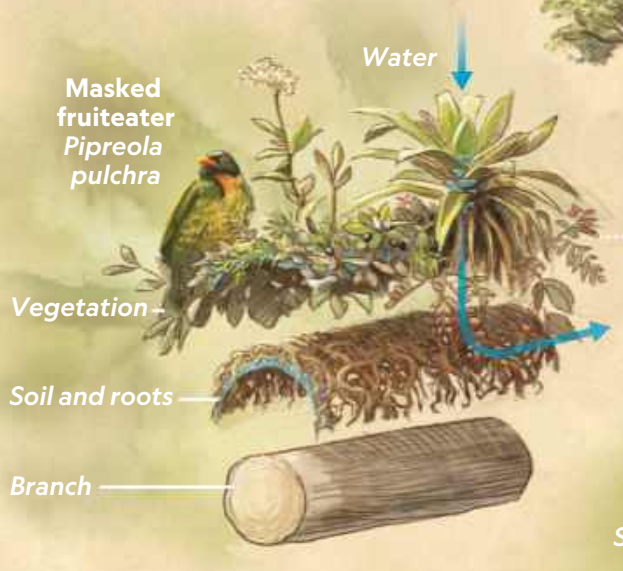
Glacial meltwaters are slowed and stored in thick peat under clumps of cushion plants and grasslike vegetation.

NOTABLE SPECIES

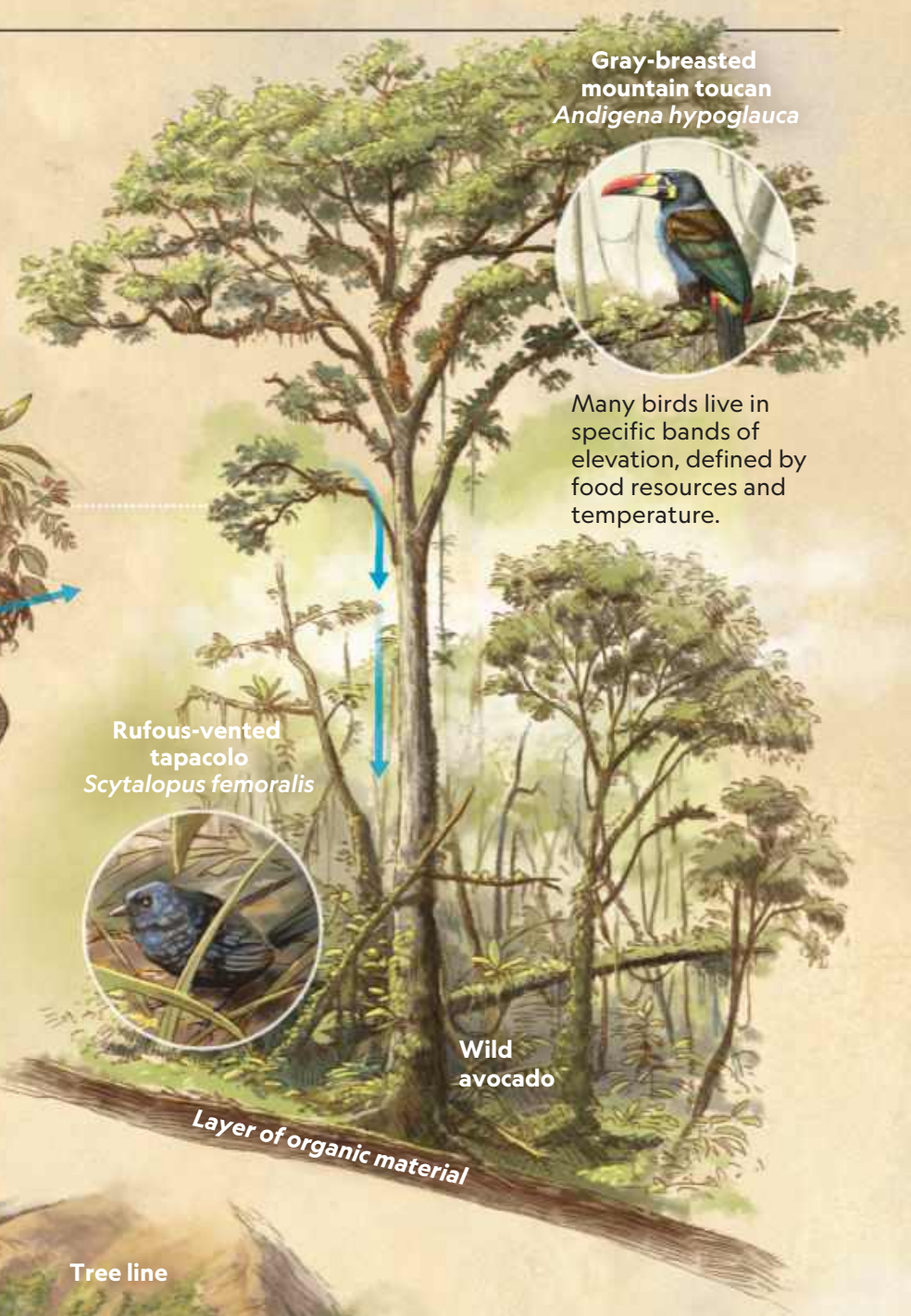
Torrent duck
Merganetta armata
Its blood can carry large amounts of oxygen, a high-altitude adaptation.

SOIL IN THE TREETOPS

Branches are covered with vegetation that has rooted in canopy soils, accumulated matter that can capture more than twice its weight in water.



Forest floor
Fallen leaves, slow to decompose in cooler temperatures, create a thick layer of organic material on the forest floor.



CLOUD FORESTS

Short trees on landslide-prone slopes are drenched daily by clouds that ascend as temperatures rise on lower slopes.

GRAPHIC: MONICA SERRANO, PATRICIA HEALY, AND EVE CONANT, NGM STAFF. ILLUSTRATIONS: MATT TWOMBLY. SOURCES: IAN AUSPREY, FLORIDA MUS. OF NAT. HIST.; ANA P. BARROS, U. OF ILLINOIS URBANA-CHAMPAIGN; MAURICIO DIAZGRANADOS, NEW YORK BOTANICAL GARDEN; SYBIL GOTSCH, U. OF KENTUCKY; RUTHMERY PILLCO HUARCAYA, MARLENE MAMANI SOLORZANO, CONSERVACIÓN AMAZÓNICA-ACCA; THOMAS PESCHAK

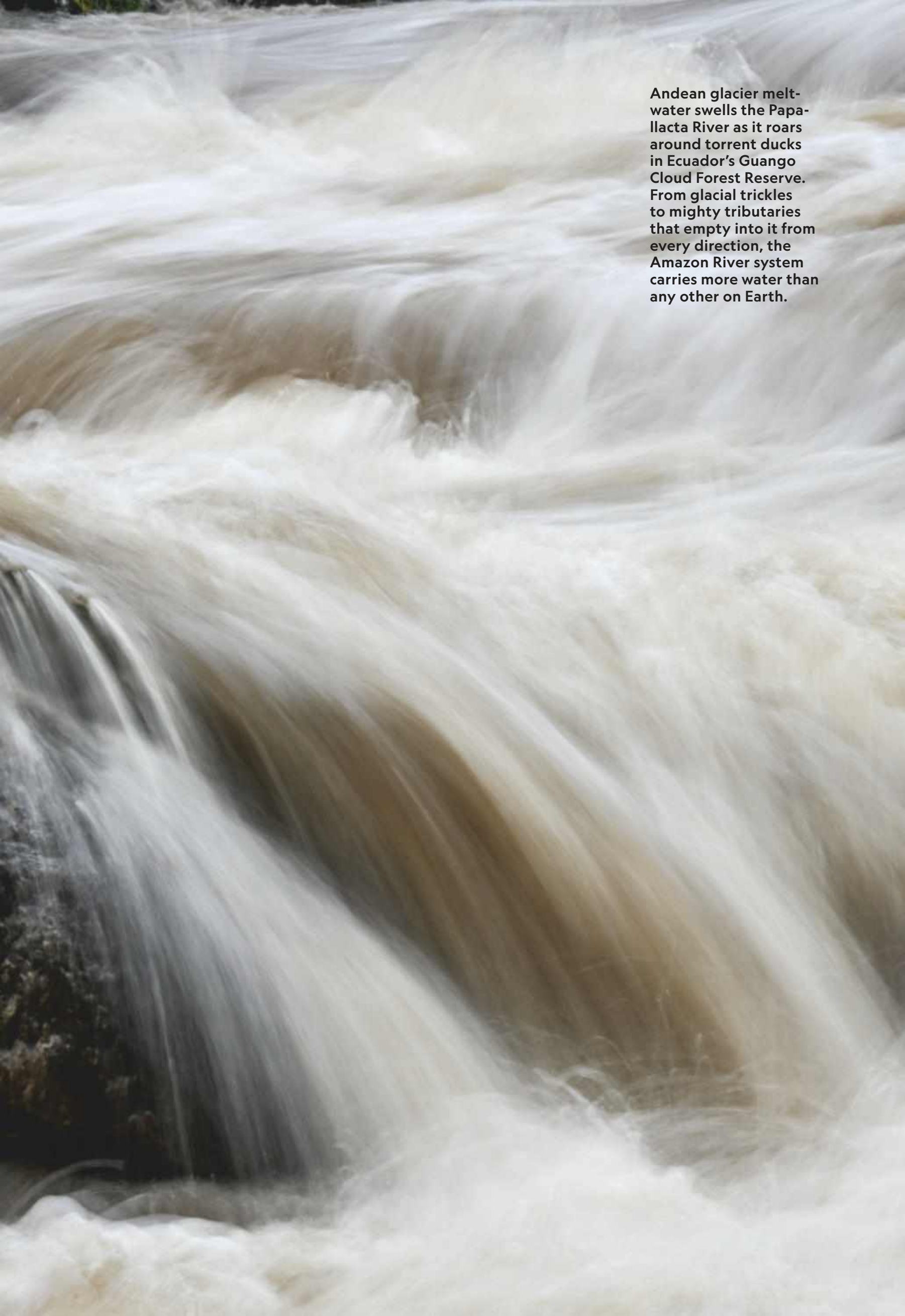
A local alpaca farmer relies on water from the nearby Carhuasanta, a river that forms part of the Amazon's headwaters and is fed by winter snows on Peru's Nevado Mismi.

And before this starts feeling too much like another children's story: We also watched as he ate … a bear. It was a small bear, so this may have been infanticide; adult male brown bears sometimes kill cubs they have not fathered and then proceed to mate with the mothers. We saw Chris eat a monkey too.

He may have good hunting skills, in other words. Bears are omnivores, and part of our mission at Wayqecha is working with the people who live here, like my family, to help recover our connection to a wild animal—a charismatic, sometimes lethal wild animal—that belongs to Andean culture and history. We've talked with farmers about their frustration over slain cows and ravaged cornfields. This is bear habitat, but it's also human habitat, and together we're examining conservation strategies that reflect that reality. Maybe farmers could be compensated for lost livestock or receive support for planting crops less enticing to bears. Maybe "approaching animal" warning systems, like the lion alerts being tested in Africa, would make it easier to scare away bears, rather than shooting them.

There's forest-expanding work for humans, as well. Alongside local people from all around this area, we've planted almost 300,000 shrubs and trees—more bear habitat and food. There's much more planting to come, and over the past three years we've joined village celebrations of our ukukus, both mythic and real, with music, storytelling, poetry, and children's drawings, like the one I can most vividly still call to mind. *"El último oso en mi pueblo,"* the boy had titled it: "The Last Bear in My Town." With pencils and careful coloring, he had drawn a tree, a stream, a purple flower with pointy leaves, and a small white-faced bear, nosing in to take a bite out of those leaves, and smiling.

—AS TOLD TO CYNTHIA GORNEY



Andean glacier meltwater swells the Papallacta River as it roars around torrent ducks in Ecuador's Guango Cloud Forest Reserve. From glacial trickles to mighty tributaries that empty into it from every direction, the Amazon River system carries more water than any other on Earth.

PEAK OBSERVATIONS

Scientist Tom Matthews (in yellow) and others test a weather station before taking it up Peru's Nevado Ausangate mountain.

RISING NEARLY 21,000 FEET above the Peruvian plateau, the snowbound Andean summit of Nevado Ausangate may seem like a strange place to study the Amazon Basin. Yet the frigid peak and its neighbors play a pivotal role in the water cycle, and this region is where insights about climate change and its systemwide impacts often come into focus, say National Geographic Explorers Baker Perry and Tom Matthews.

Photograph by THOMAS PESCHAK ● *Words by* FREDDIE WILKINSON

DATA COLLECTED BY THIS HIGH-ELEVATION WEATHER STATION ARE REVEALING THE EFFECTS OF CLIMATE CHANGE NEAR THE HEADWATERS OF THE AMAZON RIVER.

"There is a coupling, a relationship, between the Amazon and the Andes," Matthews explains. "The snow that falls on tropical Andean peaks comes from water that has evaporated from the leaves of trees in the Amazon ... the winds carry it farther west, and this relay keeps going until the clouds make it to the Andes and the water falls as snow, and that snow melts and flows back to the Amazon."

In July 2022 Matthews and Perry co-led an expedition to Ausangate to place an automated weather station (AWS) near the summit, one of the highest installations of its kind in the tropical Andes. A 10-foot-high aluminum pole stabilized by tripod legs, the station houses sensors and instruments measuring solar and long-wave radiation, snowfall, temperature, wind speed, and humidity—vital signs that will eventually dictate the pulse of life across the vast riverine landscape far below.

Getting to the top of Ausangate was no joke. The mountain's crux—an almost 650-foot headwall, with 70- to 80-degree pitches—demanded technical rope skills, stamina, and a steady mind. It's got longer stretches of verticality than does Mount Everest, on which Matthews and Perry placed a weather station in May 2019. For assistance, the scientists turned to Quechuan and Aymara guides from Peru and Bolivia, as well as members of the Cholitas Escaladoras, a mountaineering club of Aymara women who climb in traditional dress.

National Geographic Explorer Ruthmery Pillco Huarcaya also joined the team, as did scientists from universities in Cusco and La Paz, and Peru's National Service of Meteorology and Hydrology. For Perry, who grew up in Peru and Bolivia and later played professional basketball in Bolivia, the expedition felt like a homecoming.

The AWS installation began to yield results right away. Initial findings indicate eyebrow-raising levels of solar radiation on the summit. And forest fires in the Amazon produce black carbon, which, combined with bright sunlight, can have serious implications for Ausangate's glacial ice. "The more black carbon on the snow, the more of the sun's energy is absorbed; that results in more melting," Perry explains.

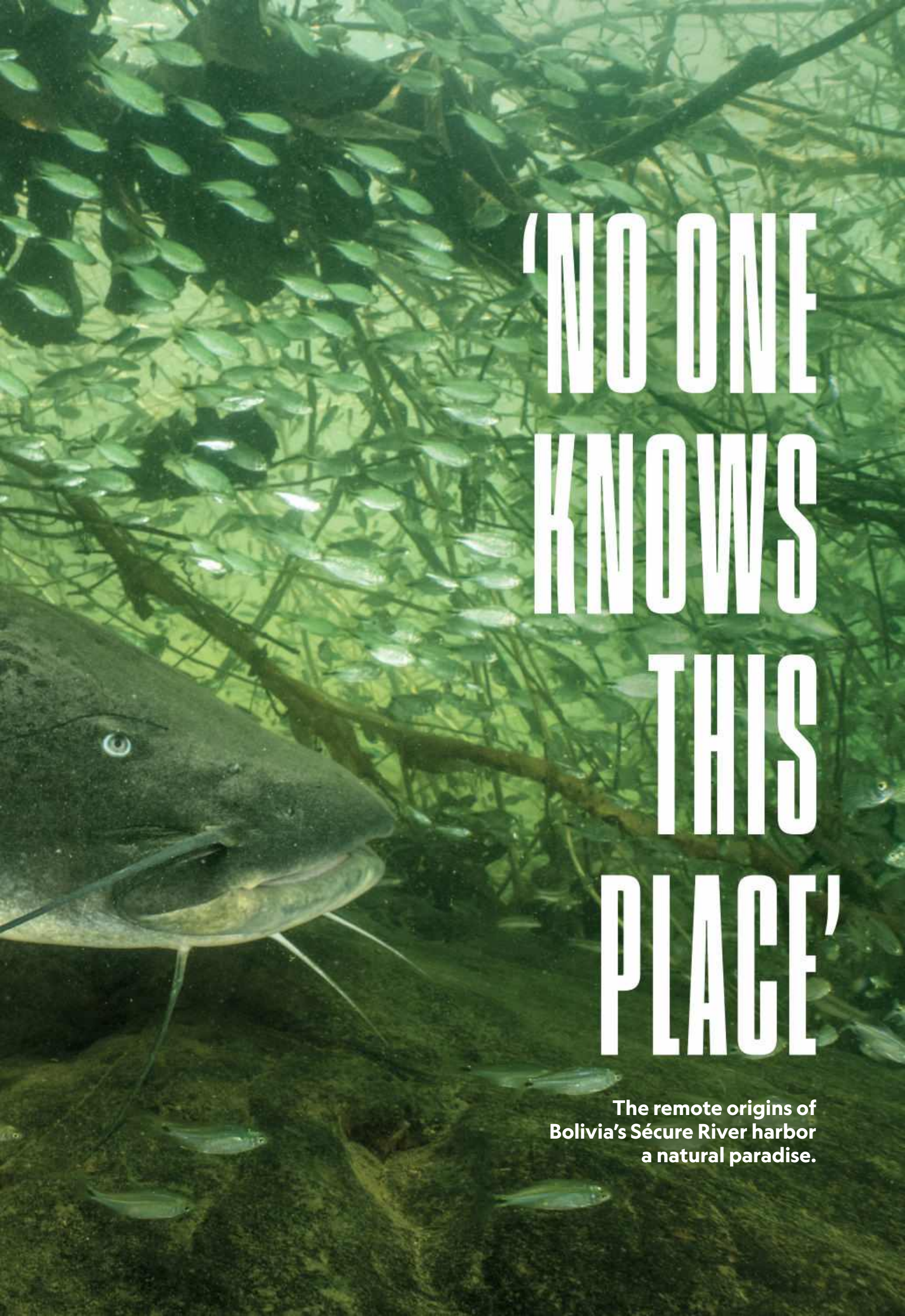
Thanks to cloud reflectivity, it's routinely brighter at Ausangate than it is on the edge of the atmosphere in near space. "The sunshine," Matthews says, "is extraordinary." ▯

NGM MAPS

HIDDEN HEADWATERS

Photographs by THOMAS PESCHAK ● *Words by* JORDAN SALAMA

A gilded catfish cruises the shallows of a river in Bolivia's Isiboro Sécure National Park and Indigenous Territory. Here, the hard-to-reach headwaters of the Sécure River are home to one of the best-preserved aquatic habitats in the Amazon. During winter, low water flows allow for remarkable underwater visibility.



‘NO ONE KNOWS THIS PLACE’

The remote origins of Bolivia’s Sécure River harbor a natural paradise.

The Isiboro Sécure highlands are nearly impossible to reach by foot or boat. Even nearby communities believe that their ancestors never hunted or fished there. "The degree of pristineness is impressive," says Guido Miranda, a Bolivia-based biologist with the Wildlife Conservation Society. "These are places where very few humans have ever set foot."

A South American tapir swims in a tributary stream as a giant cowbird feeds on flies overhead. Because of the headwaters' geographic isolation and lack of human activity, wildlife sightings are numerous, and animals, like the famously shy tapir, are uncharacteristically curious about people.

NESTLED WITHIN ISIBORO SÉCURE NATIONAL PARK AND INDIGENOUS TERRITORY,

where the Andean foothills meet the lowland rainforest in Bolivia, is a place so difficult to access that few humans, until recently, have ever set foot there. The Tsimané, Mojeño-Trinitario, and Yuracaré Indigenous groups have hunted and fished the lowlands for millennia, but locals say that, in living memory, nobody has ventured upstream to the headwaters of the Sécure River, an Amazon tributary. “No one, no one knows this place,” said Roycer Herbi, a member of the Yuracaré community. “You cannot

get there by canoe—it's very risky, and the water is very fast."

"The jungle defends itself with thunder, with heavy rain, with wind, and with lightning," agreed Félix Herbi Moza, Roycer's cousin and the mayor of La Asunta, the nearest Tsimané settlement to the headwaters. "There was always fear of dangerous animals too. That's why our ancestors never went to these places."

This hidden corner holds a stunning amount of wildlife. Neotropical otters ply rivers thick with fish. Capybaras rest in the brush, and macaws perch in the trees. Jaguar tracks crisscross the riverbanks. Animals like the South American tapir, famously elusive, show unusually naive behavior around people. "You get the sense that you're in a place unlike anywhere else," said Guido Miranda, a biologist with the Wildlife Conservation

In partnership with Indigenous communities, the locally run fly-fishing outfitter Untamed Angling offers limited catch-and-release trips during the dry season. Roycer Herbi (below) is a Yuracaré guide on these trips, which range throughout Isiboro Sécure. "Before the fly-fishing team arrived here, nobody knew us," he said. "We grew rice, yuca, plantains; we fished, and that's how we lived." Popular targets include fish like the golden dorado (left), being measured before release.

Reporting in this issue is presented by the National Geographic Society in partnership with Rolex under the National Geographic and Rolex Perpetual Planet Amazon Expedition.

LIFE IN THE HEADWATERS

Turbulent white water rushes through many Amazonian tributaries, but in Bolivia's Isiboro Sécure National Park and Indigenous Territory, clear water flows along the piedmont below a sub-Andean range. Scientists are beginning to study this largely unexplored landscape.

Yearly rainfall
Annual precipitation may surpass 200 inches. Water levels can quickly rise several feet but stay within the riverbed.

Neotropic cormorant
Nannopterum brasilianum

Fruit

CONNECTIONS

Terrestrial and aquatic species form a complex food web with myriad linkages.

Prey → Predator

Trompillo
Cabralea canjerana

Example: **Palma real** *Mauritia flexuosa*
Role: **PRODUCERS**
Make their own food

Water clarity
Nutrient-poor water with a low sediment load is clear in the dry season, murky in the wet one.

Leaves →
Fruits →

South American tapir *Tapirus terrestris*
PRIMARY CONSUMERS
Eat producers

Seed in tapir stool

Sardina *Astyanax lineatus* →

Dwarf caiman *Paleosuchus palpebrosus*

Mayfly →

Pacú *Piaractus brachypomus*
SECONDARY CONSUMERS
Eat primary consumers and producers

Rocky riverbed
Forest shade limits plant growth.

Sábalo *Prochilodus nigricans* →

Circular mouth
The *sábalo* uses this specialized adaptation to feed on biofilm of algae, bacteria, and decaying organic matter.

Golden dorado *Salminus brasiliensis*
TERTIARY CONSUMERS
Apex predators

NOTABLE SPECIES

Great black hawk
Buteogallus urubitinga

Abundant in the region, this apex predator stalks its prey in the sky and on foot.

Pachiuba
Socratea exorrhiza

Shady river

Humid evergreen forests, with trees reaching more than 100 feet high, provide shade along the river.

Blue-and-yellow macaw
Ara ararauna

Giant gladiator tree frog
Boana boans

Amazon kingfisher
Chloroceryle amazona

Neotropical river otter
Lontra longicaudis

Variable habitat

Fallen debris from the forest canopy creates microhabitats, altering the water's flow, adding nutrients, and providing shelter and foraging areas.

Darter characin
Characidium bolivianum

Amazon river prawn
Macrobrachium amazonicum

Beneficial migration

Fish migrating for food and reproduction link freshwater ecosystems by transferring nutrients and dispersing seeds.

Gilded catfish
Zungaro zungaro

SOME SPECIES LISTED IN THEIR COMMON BOLIVIAN NAME

GRAPHIC: MONICA SERRANO, AMANDA HOBBS, AND EVE CONANT, NGM STAFF. ART: MATT TWOMBLY. SOURCES: GUIDO MIRANDA AND GALO ZAPATA-RÍOS, WILDLIFE CONSERVATION SOCIETY; MÓNICA MORAES, UNIVERSIDAD MAYOR DE SAN ANDRÉS; THOMAS PESCHAK; MILES SILMAN, WAKE FOREST UNIVERSITY; A. JOSHUA WEST, UNIVERSITY OF SOUTHERN CALIFORNIA

Society. “There is no evidence whatsoever of the presence of humans.”

It’s also the only place in the Amazon Basin where *National Geographic* photographer Thomas Peschak found such clear water. A two-year search covering eight countries led him to an Argentine fly fisherman named Marcelo Pérez, an owner of Untamed Angling. The outfitter has been running catch-and-release trips along the lower reaches of the Isiboro Sécure Park’s rivers with special permission from Bolivian authorities, arranging a profit-sharing partnership with the Tsimané, Mojeño-Trinitario, and Yuracaré people to encourage conservation. In 2021 Pérez began to fly helicopters to the hidden headwaters for the first time. In 2022 he invited Peschak to join him.

The headwaters did not disappoint. The water’s clarity allowed Peschak to capture some of the first ever underwater images of this extraordinary place. Hundreds of giant *pacú*—a cousin of the piranha—schooled around him. He swam alongside human-size catfish and the stunning golden dorado. “I’ve gone up and down the maps, I’ve had a look for similar sorts of geographical systems, and I’ve spoken to literally hundreds of people,” Peschak said. “I’ve

Trini Cari, a Tsimané guide (left), hunts *sábalo,* a keystone species of the Amazon Basin. The fish migrate in the millions upriver to these headwaters every year, where local fishermen harvest them from dugout canoes and even from shore. Mayor of the Tsimané settlement La Asunta, Félix Herbi Moza (above) sits among canoes similar to ones that haul supplies and fuel for fly-fishing trips to the headwaters.

not come across anything equivalent to this. Nothing. You hop in the water there, and it's like you're in the ocean … you cannot believe you're in an Amazon river."

While Pérez's outfitter now regularly runs trips by helicopter to the area during the dry season, the hidden headwaters of Isiboro Sécure have not yet been scientifically surveyed, and biologists are eager to start. "Without a doubt, there could be new species," said Miranda. Those who have seen the place for themselves hope it might become a national treasure for Bolivians and protected from future exploitation. "I'm proud that my community has this landscape," said Roycer Herbi. "It should be kept exactly how it is." □

A sábalo feeds on algae in the clear water of a stream in Isiboro Sécure. Biologists say that creating an official species list would be the critical first step toward a better understanding of the known wildlife—and any new discoveries—found in these remote ecosystems.

A long-exposure photograph captures the glowing flight trails of cicadas, moths, and mayflies emerging at night in Isiboro Sécure. Scientists are hopeful that collecting data on these insects, as well as the other fauna, flora, and funga present in and around the region, could lead to more national resources earmarked for conservation.

A school of *pirapitinga,* a large species of *pacú* related to piranhas, swims in a stream pool. Known also as red-bellied pacú because of juveniles' colored undersides, pirapitinga have two rows of sharp, flat teeth and can grow up to three feet long and weigh 55 pounds as adults. "The schools of pacú can be so dense that they block out the sun," says photographer Thomas Peschak.

PHOTOGRAPHED WITH OTTO WHITEHEAD

GOLD'S UNSEEN COST

AS PROSPECTING RAZES PARTS OF THE AMAZON, RESEARCHERS INVESTIGATING THE DAMAGE LOOK FOR WAYS TO BRING ABOUT THE BEST POSSIBLE FUTURE FOR THE RAINFOREST.

PERU'S MADRE DE DIOS region is lush and biodiverse, but the quest for gold is reshaping it. Miners clear-cut swaths of rainforest and sift the soil for precious metal. When they've exhausted a location's potential for gold, they've exhausted its soil as well—and altered the flow of local waterways. The miners move on to other areas while the terrain they leave behind languishes, strewn with sand mounds and contaminated ponds.

Now a trio of National Geographic Explorers are aiming to mitigate the damage. For more than two years, Josh West, Hinsby Cadillo-Quiroz, and Jennifer Angel-Amaya have been examining the environmental consequences of gold mining in Madre de Dios and developing strategies for reducing pollution at these sites—and later, revitalizing them. Mined areas may never revert to rainforest, but perhaps they can be healthy in a different form, such as wetlands.

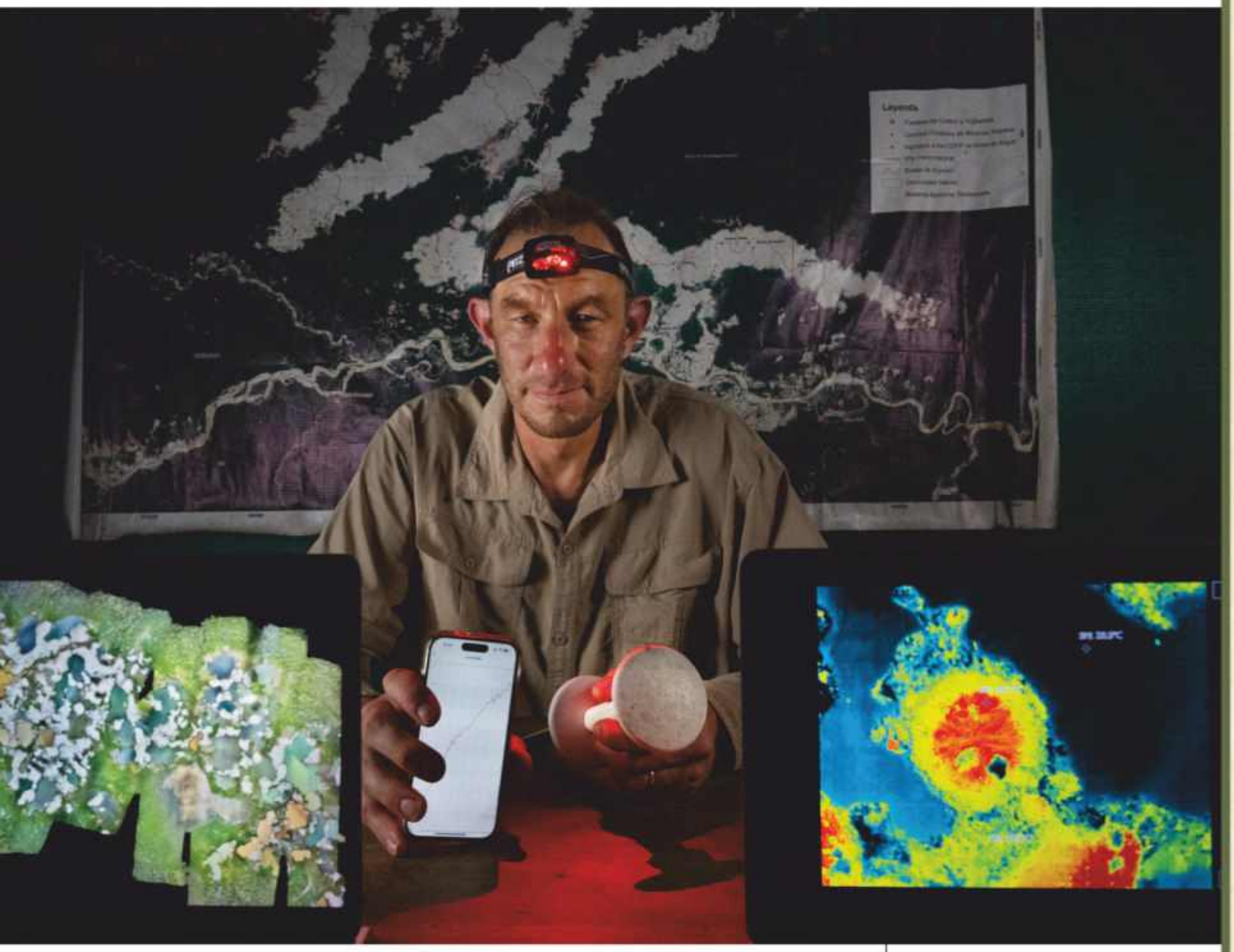
NGM MAPS

An environmental scientist at the University of Southern California, West uses drones equipped with lidar (laser-based remote sensing) and thermal imaging cameras, as well as electrical resistivity tomography, a method of injecting current underground to learn where water is present. He and his research group are characterizing how deforestation has changed the landscape and its ecosystem, including how water moves through it. They're finding, he says, that water "ends up in all the wrong places."

Cadillo-Quiroz, a native of Peru and a microbial ecologist at Arizona State University, focuses on Earth's smallest and by far most abundant organisms. Normally, microbes consume carbon and methane, removing them from the environment; but in degraded soil, like that at a mined site, they can instead release greenhouse gases. Cadillo-Quiroz is examining the relationship among microbes, plants, and heat-trapping emissions.

For Angel-Amaya, mercury is the target. She's measuring and mapping the distribution of the toxic metal, which is widely

Photograph by THOMAS PESCHAK ● *Words by* HICKS WOGAN



used in the region's gold-mining industry (see page 74). A geologist and a Ph.D. student in environmental science at Columbia University, Angel-Amaya is also testing a device for determining whether gold was extracted without mercury. If a market develops for mercury-free gold, it could draw higher-paying consumers and incentivize producers to eliminate the toxin.

Local communities are integral—Cadillo-Quiroz calls them "the other half of our team." With their participation, and with insights gleaned from the data, these scientists believe that mining sites might adapt and start to reclaim the "visceral feeling of life" that West says is especially palpable in the Amazon. ▯

At the Azul Ranger Station in Peru's Tambopata National Reserve, researcher Josh West sits behind maps of mined areas derived from drone-captured imagery. He holds tools used to log and track soil moisture.

AMAZON IN THE BALANCE

Inhabited by humanity for millennia, the Amazon Basin is increasingly under pressure as development drives ever deeper into remote forest. Leading threats outlined here have the potential to permanently harm fragile ecosystems. Illicit activity exacerbates these problems, disrupting conservation efforts and the lives of those who call the Amazon home.

Impacts of gold mining
Thousands of years of Andean erosion have deposited tiny flecks of gold in the river basin. Miners churn up sites to find the precious metal using destructive extraction and refining practices.

DEFORESTATION
Over the past 23 years, more than 130 million acres of forest have been cleared to make way for human activity.

Amazon Aquatic Ecosystem

DAMS
Nearly 300 operational dams interrupt natural flow cycles and animal migrations. Their reservoirs can also emit methane.

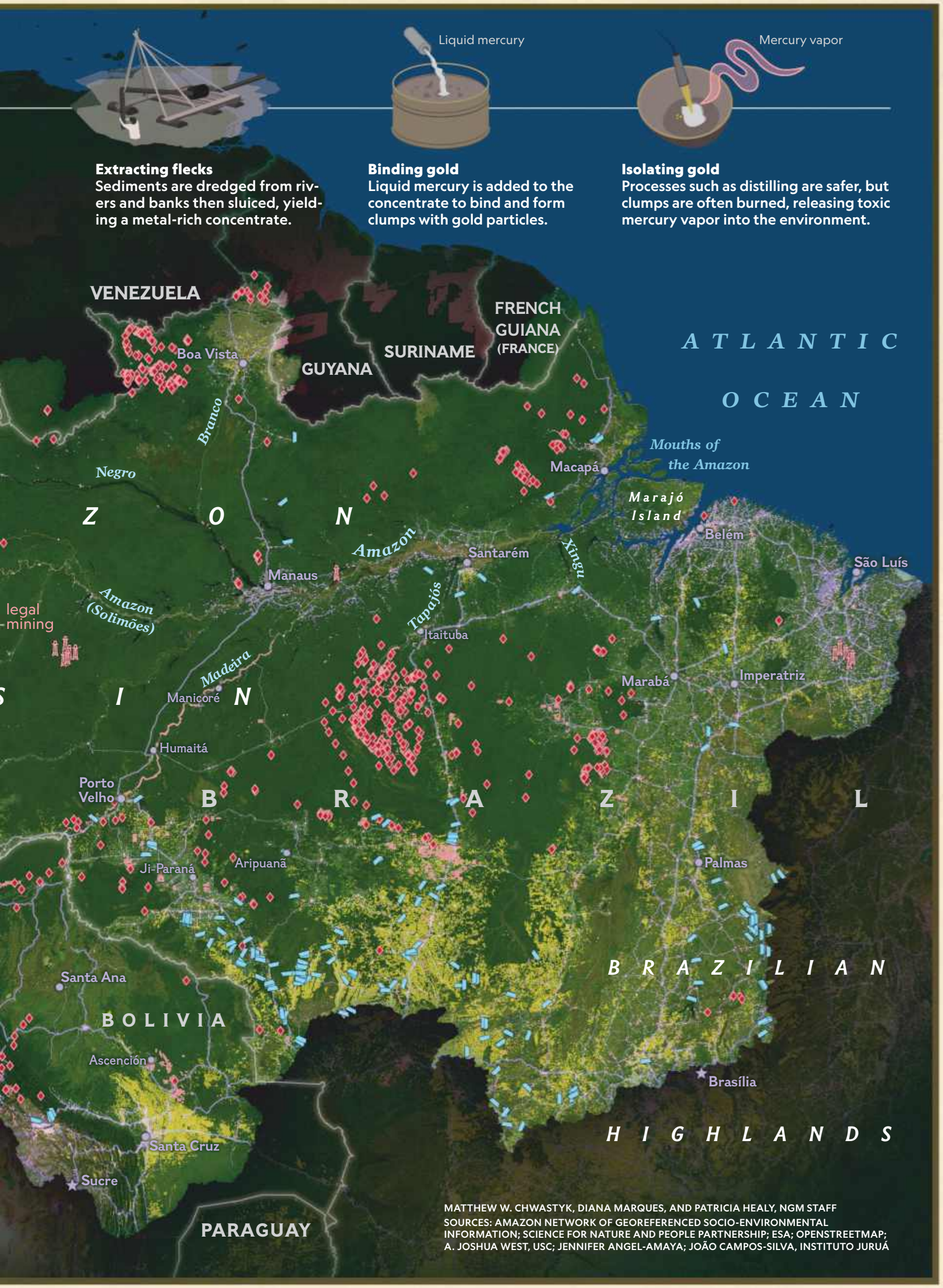
RESOURCE EXTRACTION
Legal permits allow for extraction within the basin; Ecuador, Colombia, and Brazil have active oil leases in production. Illegal mining poses an especially grave environmental threat.

- Illegal mining detected
- Legal mining
- Active oil extraction

AGRICULTURE
Increased land use for monoculture farming, livestock, and illicit crops is a leading contributor to environmental degradation.

POPULATION PRESSURE
Some 47 million people inhabit the Amazon region; population growth has contributed to overfishing and waterway pollution.

COLOMBIA
ECUADOR
PERU
BRAZIL
CHILE
ANDES
AMAZONIA
Quito
Cuenca
Iquitos
Leticia
Pucallpa
Cruzeiro do Sul
Rio Branco
Lima
Ayacucho
Cusco
La Paz
Amazon
Marañón
Ucayali
Juruá
Purus
100 mi
100 km


Liquid mercury
Mercury vapor
Extracting flecks
Sediments are dredged from rivers and banks then sluiced, yielding a metal-rich concentrate.
Binding gold
Liquid mercury is added to the concentrate to bind and form clumps with gold particles.
Isolating gold
Processes such as distilling are safer, but clumps are often burned, releasing toxic mercury vapor into the environment.
VENEZUELA
GUYANA
SURINAME
FRENCH GUIANA (FRANCE)
ATLANTIC OCEAN
Boa Vista
Branco
Negro
Mouths of the Amazon
Macapá
Marajó Island
Belém
São Luís
Santarém
Xingu
Amazon
Manaus
Tapajós
Itaituba
Amazon (Solimões)
legal mining
Madeira
Manicoré
Humaitá
Marabá
Imperatriz
Porto Velho
Ji-Paraná
Aripuanã
Palmas
Santa Ana
BOLIVIA
Ascención
Brasília
Santa Cruz
Sucre
PARAGUAY
BRAZILIAN HIGHLANDS
MATTHEW W. CHWASTYK, DIANA MARQUES, AND PATRICIA HEALY, NGM STAFF
SOURCES: AMAZON NETWORK OF GEOREFERENCED SOCIO-ENVIRONMENTAL INFORMATION; SCIENCE FOR NATURE AND PEOPLE PARTNERSHIP; ESA; OPENSTREETMAP; A. JOSHUA WEST, USC; JENNIFER ANGEL-AMAYA; JOÃO CAMPOS-SILVA, INSTITUTO JURUÁ

THE PULSE

Photographs by THOMAS PESCHAK ● *Words by* JOÃO CAMPOS-SILVA

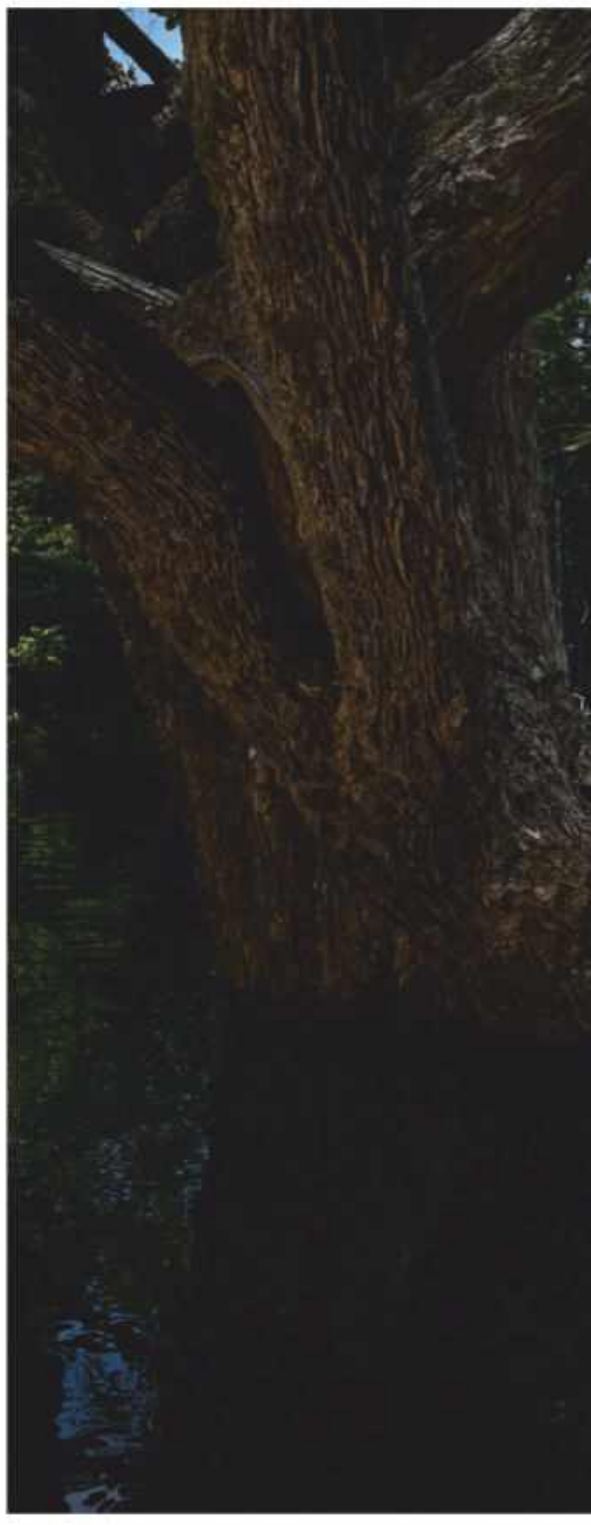
A drone captures the seasonal flooding of Brazil's Rio Negro, the largest tributary of the Amazon, named for its dark waters. Across Amazonia's lowlands, the massive rise and fall of its rivers drown and then reveal forested terrain.

LESSONS IN THE FLOODED FOREST

A Brazilian ecologist learns what he doesn't know from the *ribeirinhos,* or river people, of the Amazon.

Rising as much as 40 feet in the rainy season, lowland floods can submerge some of Amazonia's grandest trees, like this *arabá,* seen here from underwater. When the dry season comes, monkeys and nesting birds return to dwell in limbs that were previously below the surface.

A FISH—A GIANT, PREHISTORIC-LOOKING FISH—IS A WINDOW INTO THE COMPLEXITY OF THE AMAZON.



The cyclic surge and drop of these waters is the region's life pulse—"like a heart," says Brazilian ecologist João Campos-Silva, shown here on the Rio Negro. His favorite place to think: in a boat on a lowland river.

In my work amid Brazil's flooding lowlands, halfway between the Andes and the sea, this is how I have come to think of the arapaima, which is also known as the pirarucu, from Indigenous words for "fish" and "red."

Arapaimas' heads are gray-green, but red scales spread down their backs and brighten at peak mating readiness, as though illuminated from within. There are so many startling things I can tell you about the arapaima: that it breathes air, for example, and must keep splashing up at the water's surface to inhale. That its huge scales are as tough as armor. That its skin makes a fine leather for costly purses and shoes. That one boneless arapaima steak can weigh 150 pounds; it's the biggest scaled freshwater fish in the world. I once included in a science article a photo of a fishing family with an arapaima they had caught, one boy at the tail, another at the gills. Nine people stood side by side along that single stretched-out fish.

If I could transport you through the region to the place where

PHOTOGRAPHED WITH OTTO WHITEHEAD

the photo on this page was taken—where I learned to see the arapaima story as a model for a truly sustainable Amazonia—we would make our way around by boat. We'd have to; in the *várzea,* the lowland forest of the river basin, the transport routes are waterways, and seasonal rains raise surface levels to heights that would be catastrophic elsewhere. Thirty-foot floods, 40-foot floods: normal. Stream and lake boundaries vanishing beneath the high water and reappearing as it recedes: normal. Picture a *sumaúma,* or kapok, the great emblematic tree of the river basin, with fish swimming past branches that a few months earlier held songbirds.

Around the Juruá River, one of the many tributaries winding through the river basin before feeding into the Amazon, houses are built atop stilts. Local families travel by canoe, often with outboard motors. Bigger

Reporting in this issue is presented by the National Geographic Society in partnership with Rolex under the National Geographic and Rolex Perpetual Planet Amazon Expedition.

His reflection eerily clear in the smooth waters of Brazil's Iriri River, guide Djokro Kayapó grasps a yellow-spotted river turtle. Though community programs and anti-poaching laws now protect turtles and their eggs in many parts of Amazonia, Indigenous subsistence hunting is permitted; one turtle can become a meal for four.

Famously slow on land, sloths can be agile swimmers. This brown-throated sloth in Brazil's Lake Acaja-tuba navigates wet and dry seasons by living like an amphibian. The region's people, says Campos-Silva, must do the same. "Half the year they live on land," he says, "and half on water."

motorboats carry goods, fuel, and passengers who bring hammocks on board so they can hang them from hooks and relax. The *Hylea,* the workboat our Instituto Juruá uses to move between research sites, is also our mobile field office, kitchen, and (hammocks again) sleeping quarters. So we'd assign you a hammock space, and we'd pull out of Carauari, the riverside town with a little airport you can fly into. It takes the *Hylea* about three days, up the zigzagging Juruá, to reach the spot where we drop anchor. We're still in transit, though: into canoes now, then another few hours motoring up streams until the first sight of colorful houses and wooden boardwalks, and finally—because this is the village I think I'd like you to see first—the main dock at São Raimundo.

My biology doctorate is from Brazil's Universidade Federal do Rio Grande do Norte, but in the várzea, São Raimundo and other communities nearby have been my true university. Like other examples of the world's apex megafauna—large animals at the top of their food chains—the arapaima not long ago was headed for extinction here in its native habitat. It was Juruá *ribeirinhos,* the people of the river, who taught me how they brought their megafish back from the brink—a lesson for all Amazonia, I believe, and maybe for the future of biodiversity on the planet. Those of us working in conservation live with too much grief these days, and around the Juruá I can see a feedback loop we don't encounter enough in this imperiled piece of the world: people sustaining nature, nature sustaining people. A spot of hope.

PRAY EVERY DAY that I will come to know Amazonia. I want to work there when I grow up." I wrote that in 1992, when I was nine. My mother had given me a book about the wildlife of Amazonia, which was so far from our southeastern Brazil home that we might as well have been on another continent.

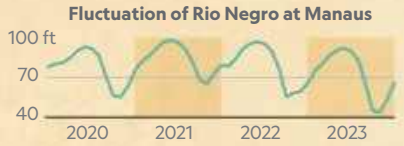
A *Potamotrygon motoro*, a species of freshwater stingray, skims through the shallows in Colombia's Bojonawi Nature Reserve. The Orinoco, Bojonawi's main river, flows north of the Amazon River, but during the rainy season these two great rivers flood the region before retreating with the onset of the dry season.

UNDER WATER

The Amazon and its tributaries rise and fall as waters twist and turn through nearly continent-wide lowlands. Local rains flood large regions of wetlands between rivers, and seasonal influxes of rainfall that start in the Andes and pulse downstream lead to large-scale flooding as rivers overflow their banks into forests, plains, and lakes.

FLOOD PULSE

Water levels change across the basin in an annual cyclic pattern, oscillating with the wet and dry seasons.



MAP: CHRISTINE FELLENZ AND PATRICIA HEALY, NGM STAFF
SOURCES: L.L. HESS AND OTHERS, *LBA-ECO LC-07 WETLAND EXTENT, VEGETATION, AND INUNDATION: LOWLAND AMAZON BASIN, 2005*; RAISG; KYLE C. MCDONALD, CITY COLLEGE OF NEW YORK; THIAGO SILVA, UNIVERSITY OF STIRLING; PORT OF MANAUS

4 Moisture on the move
A concentrated flow of moisture is transported to other parts of the Amazon Basin as an aerial river.

Dust from the Sahara and salt from the Atlantic contribute to cloud formation.

PAC
OCE

DRY SEASON, W

About every six months, the forest
between life on land and

Harpy eagle
Harpia harpyja

WATER RECYCLING

Amazon trees create their own rain by releasing water, more so in the dry season.

Raindrop

Droplet

3 Cloud formation
Vapors condense around particles; droplets gather to form rain clouds over the forest.

Munguba
Pseudobombax munguba

RAIN
28% is recycled.

Brown-throated sloth
Bradypus variegatus

Water vapor

CO_2

Particles

2 Water and particle release
Heated by the sun, pores on leaf undersides capture carbon and emit water vapor and organic particles.

Amazonian umbrellabird
Cephalopterus ornatus

Dry-season survivors
Dormant sponges cling to trees reached in the wet season and regenerate when waters return.

Sponge
Drulia sp.

Acai bears fruit in the dry season.

1 Water pulling
Deeper roots draw up water, redistributing it to shallow-rooted plants and into and up the tree trunk.

Brazilian porcupine
Coendou prehensilis

A rainforest tree can pump 260 gallons of water a day.

Hoatzin
Opisthocomus hoazin

Giant otter
Pteronura brasiliensis

South American tapir
Tapirus terrestris

Capybara
Hydrochoerus hydrochaeris

Black caiman
Melanosuchus niger

Orinoco goose
Neochen jubata

Red-bellied piranha
Pygocentrus nattereri

Waiting for water
Nutrients from the Andes are deposited in the wet season, enriching thin soil for dry-season growth.

Up to 12-in sediments

Roots

Aquatic plants provide food and shelter.

Hig

25 f

Low

NOTABLE SPECIES
Amazonian manatee
Trichechus inunguis
It gorges in the wet season, storing fat for the dry season, when food is less abundant.

VET SEASON

and its inhabitants switch
life in the water.

Ucuuba
Virola surinamensis

Mammal migration
When lowlands flood, terrestrial animals seek refuge in the canopy or retreat to dry forests on higher ground.

Jaguar
Panthera onca

Kapok
Ceiba pentandra

Aquatic spread
Many fruits mature during high-water periods, their seeds dispersed through the water or by fish.

Surviving submergence
Plants such as *Nectandra amazonum* remain intact while enduring months in low-light, underwater conditions.

White uakari
Cacajao calvus

Fishing culture
Fish are a critical source of food and income for local communities.

Sandbox tree
Hura crepitans

Buriti palm
Mauritia flexuosa

Lesser anteater
Tamandua tetradactyla

Neotropic cormorant
Nannopterum brasilianum

Anhinga
Anhinga anhinga

Tambaqui
Colossoma macropomum

h-water level

Fruit

Nectandra amazonum

Tucuxi
Sotalia fluviatilis

Pirarucu
Arapaima gigas

Amazon river dolphin
Inia geoffrensis

-water level

Gilded catfish
Brachyplatystoma rousseauxii

GRAPHIC: MONICA SERRANO, PATRICIA HEALY, AND DIANA MARQUES, NGM STAFF. ILLUSTRATION: MATT TWOMBLY. SOURCES: GUILHERME COSTA ALVARENGA, UNIVERSITY OF OXFORD; ANGELO BERNARDINO, UNIVERSIDADE FEDERAL DO ESPIRITO SANTO; MÓNICA MORAES, UNIVERSIDAD MAYOR DE SAN ANDRÉS; THOMAS PESCHAK; JOÃO CAMPOS-SILVA, INSTITUTO JURUÁ; THIAGO SILVA, UNIVERSITY OF STIRLING; JULIA TAVARES, UPPSALA UNIVERSITY; FERNANDO TRUJILLO, FUNDACIÓN OMACHA

Tree-grazing fish
Some fish, including the tambaqui, have developed molar-like teeth to crush seeds and nuts.

I fell in love then, and permanently, it seems. That third grader's declaration became the preface, a quarter century later, to my Ph.D. thesis about the Amazonian arapaima.

Well, partly about the arapaima. Really, though, my thesis—like all my work since then—was devoted to the ribeirinhos who live where the arapaimas do. These fish have a very long history on the continent; they breathe air because they evolved, millions of years ago, in the shallow, low-oxygen lake then covering what is now the Amazon River Basin. We have archaeological evidence of the region's people eating arapaima long before Europeans invaded, and arapaimas appear in some Indigenous peoples' cosmologies. It remains a fish of tremendous cultural and economic value: Arapaima is an important part of the local diet, and generations of fishing families have depended on income from the sale of its meat and skin.

Arapaima is also a popular delicacy in other parts of Brazil—which is what helped bring it to near extinction. Both within and outside Amazonia are cities whose populations have exploded in recent decades, and by the 1990s, as more and more outsiders' technically sophisticated commercial boats were working the Juruá's waters to meet the growing demand in restaurants and homes, everyone could see what was happening to the catch. In many lakes that had once served as nurseries and harvest sites, the arapaimas were gone.

For ribeirinho villages, fishing collapse means disaster for the whole community. Families were losing both their income and their daily protein; overfishing depleted the supply of smaller food fish as well. There was something else, too, that the ribeirinhos helped me see when I began spending time in the várzea: Regardless of what national data might define as an economic poverty line, they told me, they did not regard themselves or their culture as impoverished. The natural world around them helped create the life they wanted for their children, they said—and hanging on to that was perhaps the most critical thing of all.

They'd talk to me outdoors, the leaders sitting together on the boardwalks, teaching me about their lives. Even as a Brazilian, I was such a foreigner when I first came to Amazonia; my formal education had taken place in the very competitive environment of conventional modern science. Now I was obliged to say to villagers I had just met: "Thank you for insisting I take your sleeping room tonight while you move your hammock outdoors, but no. Please just show me where to go hang mine." I had never experienced such generosity. I had to practice slowing down, quieting myself, and simply listening. And it was from the ribeirinhos that I learned the backstory and details of the powerful accords that completely changed arapaima fishing, two decades ago, across a swath of várzea we scientists call the mid-Juruá—four million acres of Amazonian floodplain.

PICTURE A TREE WITH FISH SWIMMING PAST BRANCHES THAT MONTHS EARLIER HELD BIRDS.

Combining scientific and traditional knowledge, the government-backed Mamirauá Institute for Sustainable Development in 1999 helped work out innovative rules, which are enforced to this day. As a result, most of the community lakes were closed to outsider boats. A few were kept open for recreational and commercial fishing, but on the protected lakes, villagers built floating guardhouses they occupy in shifts, often armed with shotguns, to keep poachers away. Local fishermen

agreed to strict limits on their own harvests, which now take place only once a year, over five intense days.

Fishing accords to conserve game and wildlife are familiar to many of us, I know. But what pulled me into the mid-Juruá communities was the way this conservation plan, the arapaima model, has made shared bounty its centerpiece. It's not coincidental that some of the Juruá leaders are from Amazonian rubber tapper families; their relatives were part of a defiant movement that a half century ago began organizing tappers, the workers who extract latex from living trees. The tappers drew international attention to the threatened rainforest, as the trees they depended upon were being burned away to make room for cattle—and to the semi-enslavement conditions in which most of the tappers worked.

Those tapper campaigns were difficult, sometimes violent. (The most famous of the organizers, Chico Mendes, was murdered in 1988 by a cattle rancher.) But they helped bring about Amazonia's first "extractive reserves," government-protected forest areas managed by and for the benefit of the people who live there. That is the idea behind the arapaima model, which so far has produced spectacular, well-documented results—researchers estimate an almost 600 percent increase in much of the protected area, with the brief harvests now yielding hundreds of fish. In the villages that Instituto Juruá studies and works with, the dividing of the haul is led by families and a ribeirinhos organization called ASPROC, the Association of Rural Producers of Carauari.

There is no private middleman. Keep in mind the size of an adult arapaima and those 150-pound slabs of fish meat; earnings stay in the villages now, with group decisions about how the money will be used. The arapaima lakes function as community savings banks. We see the results every time we visit: new solar panels, medical care, boat motors, social organizations, happiness.

AND THIS, I BELIEVE, is the way to restore and protect the natural resources of Amazonia—by recognizing that one of its natural resources is people.

Look, when I was studying conservation science, I encountered a school of thought that regarded nature in wild and fragile places as something to be shielded from humans. Let's take the people out, I'd hear. Let's put up walls to keep nature pristine. But Amazonia, wild and fragile as it is, has been inhabited by humans for at least 13,000 years. I'm part of a movement insisting that any plan to help conserve it—the forests, rivers, animals, and birds—must begin by listening to traditional knowledge and the needs of its rural communities and including them in the decision-making. For if what we call conservation cannot bring a better life for them, then conservation is a fallacy.

Instituto Juruá both studies and works with ribeirinho communities, documenting benefits from community-based conservation for people and nature. But the challenges are enormous. The market doesn't fairly compensate local communities. If this model is to spread, we'll need global support: a multigovernment fund, perhaps, to ensure economic stability for places like São Raimundo, for people working to keep their land healthy. We need to ask a very fair question: If the world really wants to sustain Amazonia, who is willing to pay?

When I first came to Amazonia 16 years ago, the river basin and the people there made me feel like a child, or an empty glass waiting to be filled. Most of the time, especially when I'm driving the *Hylea,* that feeling stays with me. This is my favorite place to think, standing at the *Hylea*'s helm: I'm wrestling problems in my mind, and sometimes the boat is slow or the river is low, and on this water you cannot be rushed. Patience. Humility. Ribeirinhos taught me that.

—AS TOLD TO CYNTHIA GORNEY

Ydjare Kayapó, like many other men of the Kayapó tribe, wears a headdress while working as a guide on Brazil's Iriri River. He revives a wolffish caught by a client before releasing it. The freshwater predators have canine-like teeth and are prized by sport fishers as a challenging, aggressive catch.

Photograph by T

THE UNDERWATER WOODS

TWO SCIENTISTS MONITOR T
ELEVATION AMAZONIAN FOR
THEM FROM INCREASING EN

In Brazil's Mamirauá Sustainable Development Reserve, Thiago Sanna Freire Silva uses lidar, a remote sensing technology, to study trees growing in river floodwater.

OF THE 2.3 MILLION square miles that make up the Amazon rainforest, more than 320,000 are low-lying wetlands that can survive both above and below the waterline. Every year, the rainy season inundates these areas with up to 40 feet of floodwater, peaking in May or June and subsiding by October or November. Trees there have had to fight to live, either by adapting to the water or waiting it out. For National Geographic Explorer Thiago Sanna Freire Silva,

NGM MAPS

this makes the flooded forests more
esting. By comparison, "terrestrial f
are boring, right?" he jokes. "They
everything they need."

In recent years, these floodplai
ests, known as *várzea* and *igapó* fo
have seen extreme droughts and ex
floods more frequently. This is l
because of climate change and h
electric damming.

Silva and fellow National Geogr
Explorer Julia Valentim Tavares are
ing to discover how this little-under
ecosystem responds to variability
flood cycle. Operating out of a flo
research station in the Mamirauá Su
able Development Reserve, in the r
western part of their native Brazil,
and Tavares are surveying 21 forest
that are 50 meters (about 164 feet)
meters in size and situated at diff
elevations in the floodplain.

A self-described digital ecologis
combines practices from ecology
computer science, Silva scans the
plots with lidar, a technique that u
laser and its reflected light to deter
geography. In this way, he's able to c
three-dimensional, tree-by-tree
els. Returning to the Amazon ann
from Scotland—where he teaches
University of Stirling—and rescan
the plots will allow him to track the
lands' health and identify areas that
greater protection.

Tavares, a postdoctoral research f

HOMAS PESCHAK ● *Words by* HICKS WOGAN

THE FLOOD PRESSURE IN LOW-
RESTS—AND RACE TO PROTECT
VIRONMENTAL EXTREMES.

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at Sweden's Uppsala University, examines tree physiology to learn species' sensitivity to severe conditions. A plant ecologist, she's assisted by professional climbers who ascend into the treetops and sample branches. They start this process in the predawn darkness, when the branches' water content is stable, before the sun rises and photosynthesis resumes. It's an early-morning schedule that Tavares calls an "extra challenge."

As human activity disrupts the Amazon's flood pattern, these Explorers are preparing to forecast scenarios and support conservation efforts. Silva also plans to turn his lidar scans into a virtual reality experience that places users inside the wetlands.

He hopes that seeing this remote ecosystem up close, as he and Tavares do, will help the public understand it and care about its survival. ▯

RAINFOREST HUNTERS

Graphics by FERNANDO G. BAPTISTA, LAWSON PARKER, EVE CONANT, AMANDA HOBBS, *and* LIZ SISK, NGM STAFF

4

BIODIVERSITY
Scientists estimate the Amazon Basin is home to over 10 percent of the world's known plant and animal species.

2,406 SPECIES
Freshwater fish

1,300
Birds

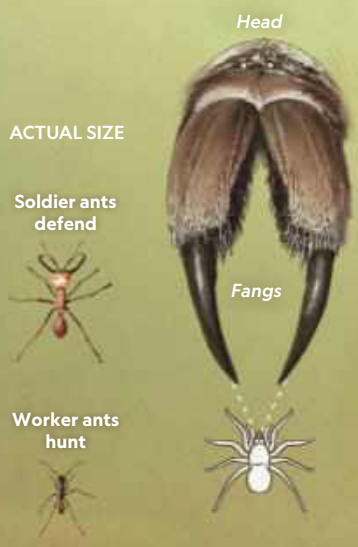
PREDATORS

Rich biodiversity and extreme seasonal changes fuel the relentless evolution of Amazonian predators, giving rise to an astonishing variety of survival strategies and weaponry.

SMALLER

Predators—defined simply as animals that eat other animals—come in all forms. Many are themselves hunted by larger predators.

ACTUAL SIZE



Soldier ants defend

Worker ants hunt

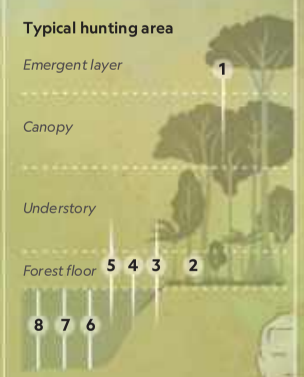
Burchell's army ant
Nomadic carnivores, they catch and carry prey in swarms.

Goliath bird-eating tarantula
The world's heaviest spider has fangs up to one inch long.

Red-bellied piranha
Feared for its teeth, the piranha is mainly a scavenger.

Hunting strategies change as the landscape does. Parts of the Amazon River, for example, can be three or 30 miles wide, depending on the season.

Typical hunting area



Most active time

- Day
- Night
- Day and night

Conservation status

- Endangered
- Near threatened
- Vulnerable
- Least concern
- Data deficient
- Lower risk/conservation dependent

Primary prey

- Mammals
- Fish
- Insects

HUMAN FOR SCALE

LARGE ADULT (MAXIMUM), SPECIES IN APPROXIMATELY RELATIVE SCALE

SUPERPOWER

WEAPONRY

1 Harpy eagle, *Harpia harpyja*

The world's most powerful eagle has short wings and a long tail for extra agility in dense forest.

Wingspan: 6.5 ft
Weight: 20 lb

Facial disk feathers flare around ears to sharpen hearing.

Four-inch talons are capable of exerting hundreds of pounds of pressure.

2 Goliath bird-eating tarantula
Theraphosa blondi

It drags insects, rodents, and other prey back to its burrow, liquefies their insides, then sucks them dry.

Leg span: 11 in
6 oz

Hairlike barbs are flung in defense at would-be attackers.

Leg hairs, sensitive to vibration, warn of danger.

Inch-long fangs act like hypodermic needles to inject paralyzing venom.

3 Jaguar, *Panthera onca*

An opportunistic ambusher, the jaguar can hunt more than 85 different species in water, on land, and up trees.

A confident swimmer, it will cross rivers and dive under water in search of prey.

Body length: 5.6 ft
265 lb

Proportionally wider jaws and thicker canines aid deadly bites to the back of an animal's skull.

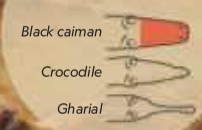
Tiger catfish

4 Black caiman, *Melanosuchus niger*

The caiman lies in wait underwater to conceal its massive frame, exposing only its sensory organs before attack.

Bony plates under the skin protect against attack from teeth and claws.

Blunt, rounded snouts with powerful jaws are built for larger prey, including mammals.



20 ft
770 lb

Capybara

5

Green anaconda, *Eunectes murinus*
A hunter of enormous girth—heavier than the longer reticulated python—it favors shallow, slow-moving waters.

Its muscular body coils around prey, cutting off blood circulation.

Sharp, curved teeth restrain prey before constriction.

Quadrate bone

Teeth

Ligaments

Diameter compared to a python

17 ft
230 lb

Around 400 vertebrae

Jaws attached by stretchy ligaments allow for swallowing prey whole.

6

Amazon river dolphin, *Inia g. geoffrensis*
Its flexible body can move between trees and branches in the flooded forest; a long dorsal fin provides stability.

Sound emitted through a fatty organ called the melon echolocates prey in low light.

Cone-shaped teeth snatch prey; ridged molars crush it.

Ridged *Conical*

Dorsal fin

Click

Outgoing sounds

Melon

Brain

8 ft
450 lb

Unfused neck vertebrae move freely to amplify sonar.

Ear bone

Incoming sounds

Fat-filled cavity

Red-bellied piranha
Pygocentrus nattereri

7

Arapaima, *Arapaima gigas*
Distinguished by its rapid growth and huge size, this air-breathing beast can exceed five feet in just three years.

Surfacing bolsters the gills and helps the fish thrive in low-oxygen waters.

Opening the mouth vacuums in prey, which is then crushed by a bony tongue lined with teeth.

Air bladder for oxygen exchange

Brain

Air pathway through mouth

Armor of thick, enameled (ganoid) scales

10 ft
440 lb

Bony tongue

8

Electric eel, *Electrophorus voltai*
Another air breather, it engages in social predation—swimming in circles to herd groups of fish into a "prey ball."

Sachs's electric organ

Sach's

8 ft
45 lb

Three electric organs offer a range of voltages for diverse, deadly uses.

When ready to strike, it can produce 860-volt shocks, the strongest in the animal kingdom.

Muscle

Main electric organ

Lower-voltage pulses aid in navigation and locating prey.

Hunter's electric organ

Visceral organs

SOURCES: JOÃO CAMPOS-SILVA, INSTITUTO JURUÁ; VERA DA SILVA, INPA; LISA DAVENPORT, U. OF FLORIDA; C. DAVID DE SANTANA, SMITHSONIAN INST.; RADAN KADERKA; EVERTON MIRANDA, TOHOKU U.; GUIDO MIRANDA, WILDLIFE CONSERVATION SOC.; RONALDO GONÇALVES MORATO, BRAZIL'S NAT. SECRETARIAT FOR BIODIVERSITY, FORESTS AND ANIMAL RIGHTS; JESÚS RIVAS, NEW MEXICO HIGHLANDS U.; MIRIAM SCADENG, U. OF AUCKLAND; SCIENCE PANEL FOR THE AMAZON, AMAZON ASSESSMENT REPORT 2021 (BIODIVERSITY DATA); MILES SILMAN, WAKE FOREST U.; RUCHIRA SOMAWEERA, MURDOCH U.; BUCK TRIBLE, HARVARD U.; ADDISON WYNN, SMITHSONIAN INST.

427
Amphibians

425
Mammals

371
Reptiles

Millions
Insects

OF THE AMAZON

Open the flaps to see how Amazonian predators catch their quarry.

BIGGER

At the top of the food chain, apex predators only occasionally make meals of one another.

Harpy eagle
Its talons, the size of a grizzly bear's claws, are the largest found in eagles.

Jaguar
It has the most powerful bite, relative to its size, of all the big cats.

Green anaconda
The heaviest snake in the world bites and then squeezes its quarry to death.

Black caiman
The largest member of the alligator family is also the Amazon's heaviest predator.

RIVER AMBASSADORS

Photographs by THOMAS PESCHAK • *Words by* JORDAN SALAMA

5

TRICKS, ICONS, THIEVES

Whether seen as shape-shifting a fisherman's bane, pink dolphin the Amazon and its estuaries. B region changes, the future of th largest freshwater dolphin is un

TERS, AND

spirits or
s dominate
ut as the
e world's
certain.

A pink river dolphin cruises in the shallows of a flooded forest in Brazil's Ariaú River. Its unique anatomy allows it to swim easily through these waters. Narrow dorsal fins, long snouts, and large, flexible flippers let the mammals slip in and out of submerged branches. "They basically fly between the trees," marine biologist Fernando Trujillo says, "following the fish."

In southern Colombia, Tikuna artisans craft pink dolphin masks from the bark of *yanchama* trees and dance around a fire while singing songs that evoke the animal's role in their cosmology. Dolphins have occupied a central place for generations in the mythologies of Indigenous communities across the Amazon.

ALONG THE RIVERS OF THE AMAZON BASIN, INDIGENOUS TIKUNA PEOPLE TELL STORIES ABOUT DOLPHINS.

These freshwater creatures are mischievous guardians of the aquatic realm that can morph into humans, cover their blowholes with top hats, and charm women away to their underwater cities. They also frequent the shallows of tannin-stained waters close to shore and steal fish from fishermen's nets.

Of the six species of freshwater dolphins, only two are found outside of Asia. Both are endemic to South America, in the Amazon and Orinoco River Basins: They are the Amazon river dolphin *(Inia geoffrensis)*—known in English as the pink river dolphin and in Spanish as *boto* or *bufeo* (range shown on map below)—and the tucuxi *(Sotalia fluviatilis),* its smaller, gray cousin. Both are also classified as endangered, having suffered dramatic

MAP: SOREN WALLJASPER AND PATRICIA HEALY, NGM STAFF. SOURCES: SOUTH AMERICAN RIVER DOLPHIN INITIATIVE & CPSG, 2023 (TAXONOMY); NGS; FERNANDO TRUJILLO, FUNDACIÓN OMACHA; SNAPP

Carved by Ruperto Ahuanare León, a "family portrait" of a pink river dolphin, a woman, and their baby depicts the result of the dolphin's purported magical power to transform into a man.

population declines in recent years as a result of fishing, dam construction, and drought.

The iconic boto is more famous, perhaps because of its unusual look—rosy-pink body, melon head, and toothy, smiling snout. It can navigate nimbly through labyrinths of submerged trees during the Amazon's wet season, when water levels rise up to 40 feet. It's also the largest freshwater dolphin species in the world, with some males reaching nine feet and 400 pounds. It relies on eyesight and echolocation to navigate in search of prey. Small bristles on the snout also help it find its way in close quarters, especially when waters grow murky.

Marine biologist Fernando Trujillo, the 2024 Rolex National Geographic Explorer of the Year, has dedicated his life's work to studying and protecting South American river dolphins. Along with fellow National Geographic Explorers conservation analyst Mariana Paschoalini Frias and veterinarian María Jimena Valderrama, Trujillo leads group excursions to perform health assessments and monitor the status of the dolphins' broader populations—and, in turn, the health of the ecosystems they inhabit. Where dolphin populations thrive, it means that healthy fish populations are sustaining them. Where they suffer, something troublesome is usually afoot—be it high surface temperatures, newly built dams interrupting their migrations, or mercury runoff contaminating their habitat.

In this way, Trujillo likes to say, river dolphins are "ambassadors of the Amazon." Locally and globally, he works to inspire a sense of collective responsibility for the well-being of these animals and their environment. In small fishing communities, it's about changing perceptions too. "When we incorporate fishermen in the capture of dolphins for health assessments, it changes completely, because they know that we are capturing with so much care," Trujillo says. "You create this empathy between the fishermen and the dolphins." □

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Trujillo (at far left), his team of scientists, and community members perform a health assessment of a pink river dolphin near Puerto Nariño, in Colombia. To ensure the animal remains calm, the team must complete all tests in under 15 minutes.

With great dexterity, a pink river dolphin plucks a catfish from a gill net. Stealing fish this way often damages nets and leads to conflicts with fishing communities across the Amazon. “We’re testing a device that aims to keep dolphins away from fishing nets,” says conservation analyst Mariana Paschoalini Frias. “That will both mitigate bycatch … and also allow the fishermen to trap more fish and limit the damage that a dolphin might cause to their nets.”

Trujillo stands alongside a tree holding in its limbs some of the 67 dolphin skulls he has found over the course of his field-work. When the forests flood each year, the dolphins swim at the level of these branches. Trujillo donates most of his specimen finds to Colombia's national collections for further study.

The dolphins' iconic pink bodies can look bright orange beneath the tawny water of the flooded forest. "It's surprising to me that some people still think dolphins are fish," says Trujillo. "The bubbles show that this is a breathing mammal in the Amazon's waters."

DOLPHIN DIPLOMACY

Brazilian Mariana Paschoalini Frias hopes that pingers like the one she's holding will help keep river dolphins away from fishing nets.

ONE AFTERNOON in Lake Acajatuba, along the lower Rio Negro, National Geographic Explorer Mariana Paschoalini Frias was testing a new underwater acoustic device.

It was a pinger that produces sound at 40 kilohertz, which is "the average communication frequency of dolphins and their echolocation," explains Frias, a conservation analyst with World Wildlife Fund-Brazil. The hope is that the noise of the device will keep inquisitive river dolphins away from

Photograph by THOMAS PESCHAK ● *Words by* JORDAN SALAMA

KEEPING THE PEACE BETWEEN LOCAL FISHERMEN AND THE REGION'S RIVER DOLPHINS IS JUST ONE PART OF THE WORK TO PROTECT THIS ICONIC SPECIES OF THE AMAZON.

NGM MAPS

local fishermen's nets and their catch.

It was a routine outing for Frias, who, alongside fellow National Geographic Explorers veterinarian María Jimena Valderrama and marine biologist Fernando Trujillo—both from Colombia—surveys river dolphin movements and migrations in South America.

Since June 2022, the team has been studying the dolphins across Ecuador, Peru, Colombia, and Brazil. So far, they have tallied more than 1,360 dolphin sightings, captured dozens of the animals for health assessments, and tagged 27 with GPS tracking devices.

They've measured levels of mercury contamination in dolphins' blood as well as in the fish the animals pursue and consume. And they have been able to trace the dolphins' comings and goings through their echolocation clicks, detected by underwater sensors.

But they have also documented great loss. Between September and November last year, at least 330 dolphins died in the Amazon region when water temperatures surpassed 100 degrees Fahrenheit—an ominous warning for the 47 million people who live there. River dolphins face numerous challenges—from pollution to overfishing, from drought to warming waters—that threaten humans too.

Besides being experts on the river dolphins' biology and ecology, Frias, Trujillo, and Valderrama have become prominent advocates for the dolphins' protection.

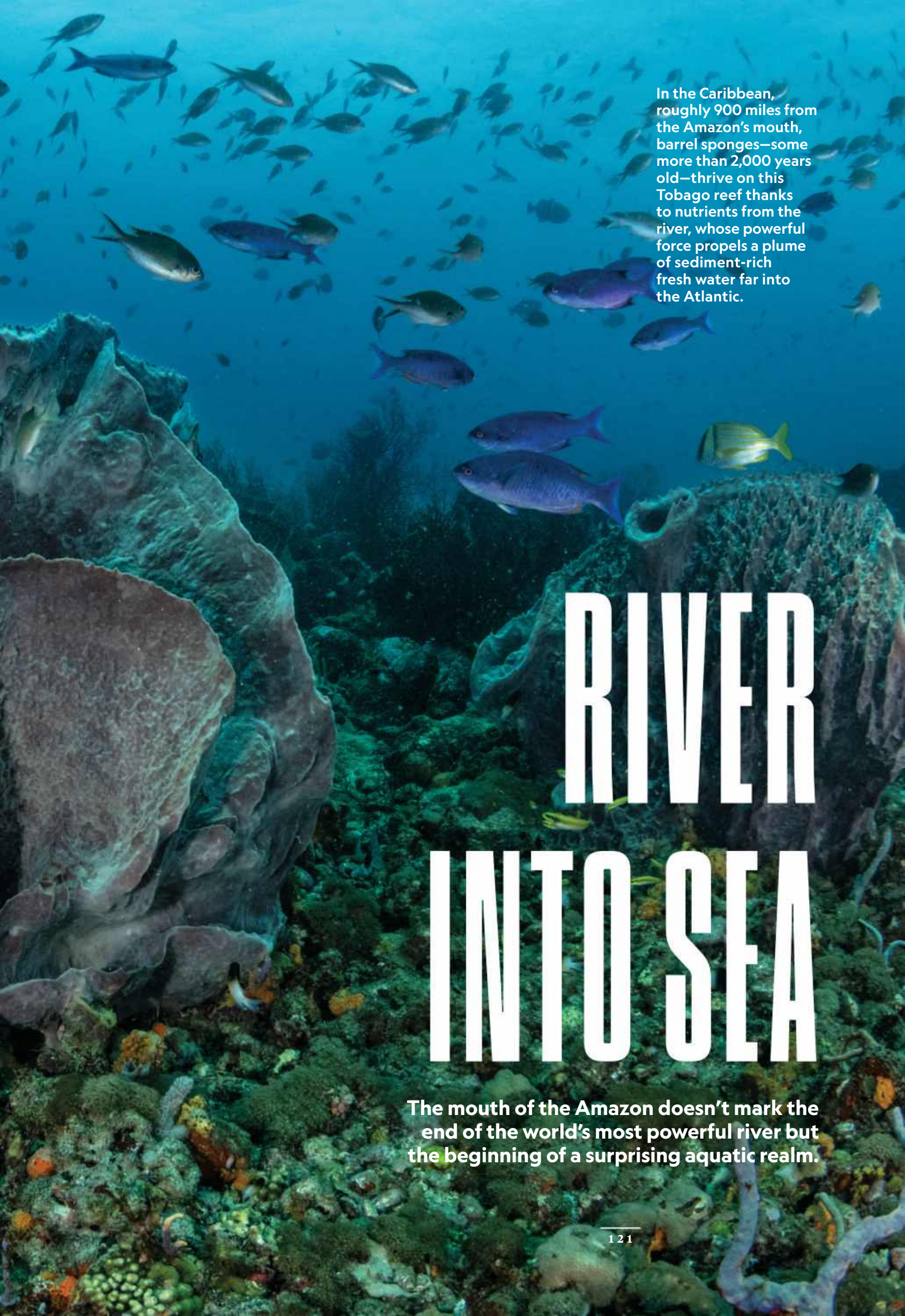
They lead education and conservation projects in South American communities that are frequently in contact with the animals. The team encourages the reforestation of riverbanks, promotes safe wildlife-watching, and fosters empathy for the dolphins among fishermen.

Additionally, Frias, Trujillo, and Valderrama were among the architects of a 2023 international agreement in which 11 nations pledged to protect river dolphins by mitigating numerous environmental threats and collaborating with Indigenous and other local communities.

Such collaboration, the team says, remains paramount, not only to ensure the species' survival but also to protect the Amazon's rainforest and rivers—for everyone's benefit. ▯

THE REACH

Photographs by THOMAS PESCHAK ● *Words by* ANGELO BERNARDINO



In the Caribbean, roughly 900 miles from the Amazon's mouth, barrel sponges—some more than 2,000 years old—thrive on this Tobago reef thanks to nutrients from the river, whose powerful force propels a plume of sediment-rich fresh water far into the Atlantic.

RIVER INTO SEA

The mouth of the Amazon doesn't mark the end of the world's most powerful river but the beginning of a surprising aquatic realm.

IT'S DAY FIVE OF A RESEARCH EXPEDITION TO THE BAILIQUE ARCHIPELAGO,

and nothing has prepared me for the experience of this place, the easternmost end of the Rio Amazonas, where the planet's greatest river pours into the sea.

I'm a university professor, a marine ecologist, and a Brazilian. I know this river discharges more water, when it finally reaches the ocean, than do the next six largest rivers in the world combined. The Ganges, the Yangtze, the Congo, the Mississippi—we could total the volume of all their waters' discharge, add in a few more famous rivers, and we would not yet equal the outpouring of the Amazon.

This trip in February 2024 is my second research expedition to Bailique, the archipelago within the river mouth, where fresh water and salt water meet. It's not like I have never been here before. Still, when I stare at the river from the tough little motorboat ferrying us between one village and the next, I can't comprehend its magnitude. My colleague Felipe Vieira and I keep talking about this, shouting at each other over the roar of the boat engine or sitting on the riverbank after we've tried to wash away the day's sweat and heat in the house where we've hung our sleeping hammocks. Like me, Felipe grew up in this country but so far from here that for him Amazonia was mostly a story, a cause, a part of the national history and imagination.

I say: How can this be a river? It's absurd how huge it is. It feels like the ocean.

Felipe says: The horizon, when I look across, is only water meeting sky.

This is not the Amazonia that most of us—Brazilians, foreigners, nearly everybody except the people who live right here—imagine when we call it to mind. Start with the *colors:* The water's surface appears as strange contrasting strips, precisely separated, blue-gray or brown. The colors swirl past each other like unmixed paint, or stretch side by side with borders straight as broomsticks. The blue-gray is ocean salt water. The brown is river, darkened by natural sediment that has tumbled in for more than a thousand miles along the full breadth of the Amazon Basin, from rivulets in Andean cloud forests to the flooding tributaries of mid-basin lowlands.

Plant detritus. Animal remains. Fragments of rock. It's such loaded river water, and there's so much of it that by the time it's coursing past the Bailique islands toward

open sea, it resists blending with salt water to create the usual brackish estuary. Instead, the fresh water of the Amazon pushes straight out into the Atlantic, pretty much intact, a river within the ocean. It heads north, guided by tidal currents, passing Guyana.

The Amazon River plume, oceanographers call it, or just "the plume."

The plume hurtles along, river water and sediment held together by its own mass and propulsion, all the way to the Caribbean Sea.

Every morning in our explorations here, Felipe and I start by riding the plume—riding in and out of it, to be more accurate, our expert Bailique boatman, Chico da Silva, maneuvering through those weird strips of color. Often, his small boat bucks so hard in the turbulence that we grip the sides to hang on. The questionnaires on our clipboards are printed on plastic sheets to protect from spray and humidity; there are also regular torrents of rain that commence all at once and then stop just as abruptly. The islands' people live in scores of scattered villages, so when Chico drops us at new docks, we walk up muddy wooden steps to the boardwalks that serve as street and sidewalk, and look for a local leader.

Then: *Bom-dia, senhor.* We are from the Universidade Federal do Espírito Santo and part of a project researching ecosystems of the Amazon River. (In Brazil we use the third person to express extra respect.) Will the senhor approve our asking people in the senhor's community some questions?

We get the nod and head down the boardwalk with our clipboards. Calling to people as they rest on porches in the hot, wet air: Would the senhor/senhora like to be part of a study? A few decline, too busy, not interested; more often they motion us over, wary but curious. We sit in doorways or on plastic chairs. The questions are simply worded. How long have you lived here? How do you make use of the river, the ocean, the forest?

Some are simply worded but big. Tell me what worries you. Tell me what is changing. At night, when I'm in my hammock, I see them: the fishermen, the acai berry cultivators, the women with small children at their sides. Their stories keep me awake.

THE RIVER, PEOPLE TELL US, is not as it was. It's meaner. It's ripping out land along its banks. Houses here are constructed to accommodate rising water levels, like those in the flooding forest, but even stilts and elevated first floors are not enough when the ground beneath them washes away. The empty place Felipe and I are renting here in Vila Progresso, the archipelago's biggest village, has a back porch maybe 50 yards from the water's edge. A decade ago, we're told, that porch's view was of another row of houses that stood between ours and the river. All collapsed. *Terra caida,* the Bailique people say: fallen land.

The sorrowful young mother I talked to yesterday knows her family's riverbank house is doomed. Her work is in Bailique, helping run a fishermen's cooperative, but her husband has taken the children to live in crowded Macapá—the nearest city, a 12-hour boat ride back up the river—where schooling is more reliable. There are a few schools on the islands, but attending them now is a challenge. Riverbank damage is undermining the campus grounds of the one K-12 school, which is here in Vila Progresso. And with the river the only real roadway, motorboats can't pick up and deliver schoolchildren when high water wrecks a dock or an access channel unexpectedly fills with riverborne silt. Some school days, even when kids do make it to class, are only two hours long.

Terra caida is not the only slow-motion catastrophe we hear about again and again. The piped-in fresh river water, traditionally brought up for Bailique's household needs, now tastes salty many months of the year. It's only a bit of salt sometimes, but enough to

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Soaring above the Caribbean's St. Giles Islands, these magnificent frigatebirds are part of the marine life likely affected by the long reach of Amazonia's waters. Studies are connecting river basin contaminants, especially mercury from illegal mining, to infectious disease outbreaks in these tropical seabirds.

make the water undrinkable and problematic for cooking and washing. Think of it, Felipe and I exclaim to each other: living here, surrounded by the world's greatest expanse of river, and forced to buy bottled water from a delivery boat or a village shop.

Salinization upends so many people's work lives here. We hear about it in every conversation. The acai cultivators are wondering about the small groves of trees they manage and climb to harvest berries. Will saltier soil damage the roots? they ask us. Will it change the harvest? The fishing families are watching freshwater species they depend on—fish from the *mato,* the jungle—thin out or vanish during the salty months. One second-generation fisherman told Felipe that he has learned how to see when the salinization is high: The water shines differently, he said.

Bailique receives steady news from beyond the archipelago. Solar panels and satellite-carried internet access are proliferating, and we've seen rooms in which the primary piece of furniture is a wide-screen TV. The explanations people give us, as they describe what is happening to them, are essentially what we as scientists believe. In part, it's *mudança do clima,* they say, climate change. As sea levels rise everywhere, violent seasonal changes are also more commonplace; here the river now surges extra high and strong during rainy months, roiling water and taking land. Other

On an island at the Amazon's mouth, marine ecologist Angelo Bernardino sits atop a tangle of mangroves. With colleagues from around the world, he studies these hardy trees, crucial for storing carbon and nurturing coastal life.

months have brought terrible droughts—last year's, across Amazonia, was the worst in recorded history—which weaken the force of fresh water pushing out to sea, making it easier for salt water to infiltrate.

More immediate human intervention is causing trouble as well. Electricity-generating dams, built in recent decades on a mainland river north of here, have disrupted the hydrology of the region and river tributaries that used to join the flow at the Amazon's mouth. And although this soggy region doesn't suit the cattle ranchers who have deforested other parts of Amazonia, it turns out to be fine for water buffalo, which some farmers around Bailique now raise for meat.

So as damming alters the currents and wandering buffalo trample streambeds, a long-standing ecological balance—river against ocean, salt water against fresh—is being disrupted here in Bailique. At high tide we watch chunks of the riverbank crack, and I trudge from one distressing interview to the next, thinking, It's like a window into the planet's future. No! Correcting myself. The planet's present. Rising sea levels have already brought erosion and salinization crises to coastal communities around the world, and Felipe and I can see Bailique people trying, like so many others, to adapt with what's available. They build backyard holding tanks for rain. They abandon broken riverbank houses and move further inland—this haunts me, families watching the river eat their homes of more than half a century. For many of them, the river then takes the next house too. We've met families who have made this move six times.

Some people give up, like the man whose empty house we're renting, and pile all their belongings onto a ferryboat for Macapá. *Mudou a agua, mudou a vida,* a resigned-sounding fisherman told me this morning, recalling friends and neighbors who have left: The water changed, and so did life.

BUT THERE IS SOMETHING ELSE I've learned about this place, something hidden in Bailique's wild terrain. Maybe "disguised" is a better word—for, during my initial expedition in 2022, I was confused at first to see no sign of the foliage that I had expected would crowd the islands' coastlines: mangroves.

I'm part of an international group of scientists studying the ecological benefits of mangroves, those dense tangles of arching trunks and branches that grow in and alongside warm tidal waters. We use "mangrove" as a group name for certain kinds of trees that require these tropical salty conditions, and in recent years we have learned how desperately the

Where the Amazon meets the Atlantic, tidal changes can be ferocious. When the tide rushes in, this channel through Brazil's Maracá-Jipioca Ecological Station can rise 30 feet, generating huge waves. Locals call it Igarapé do Inferno, or Hell Creek.

THE PLUME

The Amazon River doesn't end at its many gaping mouths. Instead, it becomes a massive, fluctuating plume of fresh water that spreads above coastal reefs and fans out across the Atlantic. This colossal flow into the ocean can travel as far north as the Caribbean Sea, covering some 640,000 square miles at its maximum extent.

VISIBLE FROM SPACE

From high above, the plume appears jade green thanks to its composition of sediment, organic material, and chlorophyll a, the primary pigment in phytoplankton, the algae that aid in carbon sequestration.

Concentration of chlorophyll a
July 2022

30
mg/m³
0.03

100 mi
100 km

Anguilla
St. Martin
Barbuda
Antigua
Guadeloupe
Dominica
Martinique
St. Lucia
St. Vincent
Barbados
Grenada
Tobago
Trinidad
Lesser Antilles
Caribbean Sea

ATLANTIC OCEAN

VENEZUELA
Orinoco
Orinoco River Delta
Guiana Plateau
GUYANA
SUR.
FRENCH GUIANA (FR.)
Continental Shelf
Amazon Reef System
Maracá I.
Bailique Archipelago
Vila Progresso
Mouths of the Amazon
Macapá
EQUATOR
Marajó Island
Mangroves
Belém
Óbidos
Amazon
Negro
Manaus
Amazon (Solimões)
Santarém
Tapajós
Xingu
Tocantins
BRAZIL

Fresh find
At the river's mouth around Bailique, scientists discovered something unique for a coastal area: mangroves growing in fresh water.

SEASONAL SHIFTS

The plume's reach varies with winds and river discharge, flowing northwest toward the Caribbean before turning east. The deluge of fresh water creates a lower salinity surface layer that interacts with underlying ocean currents.

May: maximum extent

December: minimum extent

warming planet needs them. The trees' woody underwater architecture makes a safe home for the marine life on which fishing societies depend. On land, the tough root networks help prevent erosion. Mangroves are exceptionally efficient at carbon capture: Within the muddy sediment beneath the roots, they can trap—keep out of the atmosphere—up to 10 times as much carbon as other kinds of tropical trees.

But in many places where mangroves have traditionally thrived—Indonesia and the Philippines, for example—they are disappearing, cleared out to make way for shrimp farms and other development. Brazil has laws protecting mangrove forests, but to enforce those laws, the government needs to know exactly where the mangroves are, which is why our team (including fellow National Geographic Explorers Margaret Owuor and Thiago Sanna Freire Silva) conducted that first Bailique exploration. We knew nobody had yet formally surveyed the foliage of the river mouth islands. I remember our boat chugging slowly through the different channels of the archipelago, nearing one shore after another, and…

No mangroves. Where were they? We saw tall acai palms, bamboos, and coconut trees. We started climbing off the boat to investigate, increasingly perplexed. Finally, we pushed into one beautiful mess of high jungly overgrowth and looked up and around and BOOM, mangroves—but growing in a way none of us thought possible. They were a little distance inland, scattered amid freshwater trees, intertwined with them and sharing their soil. As a marine ecologist, I promise you: This does not happen.

Or so we had thought. Amazonia is not like any other place on Earth, and the river mouth is not like any other place in Amazonia. What we found there may be an ecologically unique kind of forest, with 130-foot mangroves, among the biggest I've ever seen, growing in ground that seems insufficiently salty to sustain them. Another Bailique astonishment, like the plume. Chico motored us over there so I could show the monster stealth mangroves to Felipe, who was not part of the 2022 team.

It took him a minute, craning his neck upward and squinting, to sort out what he was looking at. *"Nossa,"* he said. Wow.

It turns out that unusual stands like these grow all over the archipelago, which means updated maps now include thousands of acres of newly identified mangrove forests eligible for protection. Some of the trees are so big, and probably so old, that the soils trapped beneath them may be profoundly deep carbon sinks—"an unprecedented value to climate mitigation," we wrote in the first science paper published after that initial visit.

Encouraging news, so far. And Felipe and I are discovering that people here don't realize they live amid mangroves. They have their own names for the trees our team recognized; those beneficial mangroves they hear about are the distant thickets up and down the Atlantic coastline, they say. When we ask a survey question about how they use nature, and we mention mangroves, their response is always the same: "We don't have those here."

IT'S WORTH REMEMBERING THAT WATER AND WEATHER HAVE ALWAYS BEEN NATURAL DISRUPTERS AT THE RIVER MOUTH.

MAP: ROSEMARY P. WARDLEY, PATRICIA HEALY, AND ANNIKA HOERNER, NGM STAFF. SOURCES: AJIT SUBRAMANIAM, LAMONT DOHERTY EARTH OBSERVATORY AT COLUMBIA UNIVERSITY; PATRICIA L. YAGER, UNIVERSITY OF GEORGIA; ANGELO BERNARDINO, UNIVERSIDADE FEDERAL DO ESPÍRITO SANTO; ESA OCEAN COLOUR CLIMATE CHANGE INITIATIVE (GLOBAL CHLOROPHYLL-A DATA, V. 6); UNEP-WCMC

A jaguar lounges above a maze of mangrove roots at Maracá-Jipioca Ecological Station, which encompasses three islands north of the Amazon's mouth and is part of a biodiversity corridor designed to conserve coastal wildlife. Jaguars thrive here even as deforestation diminishes their habitat elsewhere in Amazonia.

What will change, as they come to understand that they *do* have them here? We can't be sure. Our job right now is simply to listen and learn, and what we are hearing—along with the worry—is resilience. I like to imagine a future in which mangroves help Bailique adapt: the relabeled forests attracting new government resources, perhaps, or a role in some future Brazilian carbon-exchange agreement. The mangroves will spread as turbulent forces of water keep rearranging river-mouth soil; eventually, I think, these protective trees will be growing within and alongside villages. More roots holding back erosion, that is, in places where the mangroves do settle in. And more underwater nurseries for crabs and fish.

When I say that I hope we researchers can offer information and support, as the archipelago's people learn to make use of the mangroves' presence, I want to be clear: There's no panacea here. Human-accelerated disruption is the most urgent threat imaginable not just in Bailique but across all of Amazonia and beyond. It's worth remembering, however, that water and weather have always been natural disrupters at the river mouth, this giant place of Amazon-Atlantic exchange, and that the wisest people on the islands know it. Felipe and I were in Chico's boat one day, heading into a channel toward our next village, when suddenly the boat stopped moving. Chico sighed. He didn't even look

Below: At the river mouth, mangroves form protective hatcheries for sea life, like the crabs in this fisherman's haul. Left: Egrets flock to fishing boats in Belém, the giant Brazilian river port city. Most Amazonians now live in rapidly growing urban areas like Belém, home to nearly two and a half million residents.

surprised. Then he jumped over the side, landed on his feet, and waded around back to push.

Felipe and me: Wait, what?

Chico: I missed the timing.

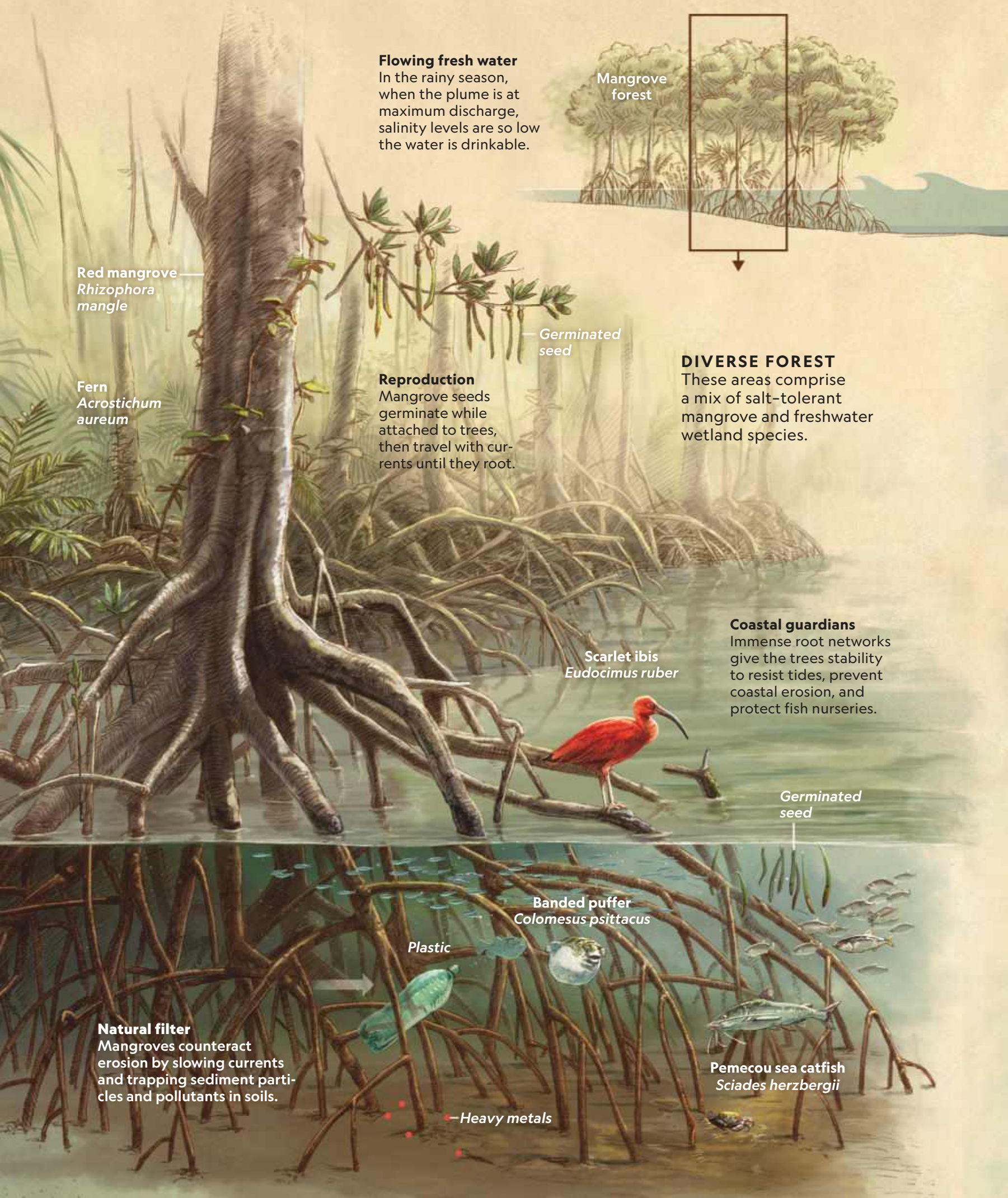
Just barely, he said. This channel now fills and drains so fast that if your boat does not enter it at exactly the right window, you're stuck in watery grass. He'd learned the day's times from what people here call the fishermen channel, the daily conversation among Bailique boatmen—shouted, usually, boat to boat across the top of the plume.

But he'd gotten the times wrong. Or the Amazon had defied prediction, behaving even in this narrow archipelago passage as the most powerful river in the world. Felipe and I climbed over the side too, into warm water up to our ankles. Mudou a agua, mudou a vida, I thought, and Chico nodded at us: Just keep pushing.

—AS TOLD TO CYNTHIA GORNEY

OCEANIC AMAZON

As the Amazon powers into the Atlantic through its estuary on Brazil's coast, the river's massive discharge creates a plume of fresh water extending miles into the salty ocean. Within this transition zone, two unique habitats thrive: freshwater mangroves and a wide reef system.



NOTABLE SPECIES

Mangrove crab
Ucides cordatus
These small crabs pull leaves into their burrows, cycling nutrients into mangrove soil.

Tide
13-26 feet

Macrotides
Monthly tidal cycles and annual rainfall create 20-foot tides. Strong currents lead to riverbank erosion.

Evaporation

The plume
Fresh river water flows over denser, salty ocean waters, carrying nutrients that feed a bloom of tiny plankton.

FRESH WATER

SALT WATER

LOW-LIGHT REEF

In cooler waters from 100 to 300 feet deep under the shadow of the turbid plume is a reef of corals, sponges, and rocklike algae.

Rhodoliths are unattached nodules of red algae.

'Marine snow'
Biological debris, including dead organisms, falls from the freshwater plume, delivering food to reef animals.

Marine snow

Agassiz's parrotfish
Sparisoma frondosum

Scattered pore rope sponge
Aplysina fulva

Rhodolith mound

Fish nursery
Commercially important fish—reef and oceanic species—thrive in this protective habitat.

Spotfin butterflyfish
Chaetodon ocellatus

Elephant ear sponge
Agelas clathrodes

Cleaner shrimp
Lysmata grabhami

Sand tilefish
Malacanthus plumieri

Rhodolith mounds built by sand tilefish

GRAPHIC: MONICA SERRANO AND PATRICIA HEALY, NGM STAFF
ILLUSTRATION: MATT TWOMBLY. SOURCES: ANGELO BERNARDINO, UNIVERSIDADE FEDERAL DO ESPÍRITO SANTO; RONALDO FRANCINI-FILHO; PATRICIA L. YAGER, UNIVERSITY OF GEORGIA

A leatherback turtle crawls ashore to lay eggs at Grande Riviere, Trinidad, a favorite nesting spot more than a thousand miles from the Amazon's mouth. The nutrients collected in the river and carried by its powerful plume far up into the Caribbean help create an environment ideal for leatherbacks.

A boat carries a catch of arapaima, the world's largest scaled freshwater fish, along an Amazon tributary. A key food source, arapaimas are vital to preserving the river economy.

DOCUMENTARY FILM

SEE RIVER DOLPHINS swim among trees and Andean bears roam through cloud forests in *Expedition Amazon,* a documentary presented by the National Geographic Society in partnership with Rolex that brings to your television screen the work of the Perpetual Planet Amazon Expedition detailed in this issue—and more. It airs October 10 on National Geographic and streams the next day on Disney+ and Hulu.

Filmmakers traveled with research teams over two years as they spanned out across the Amazon Basin, following its water cycle from the icy Andes to the giant freshwater plume that pours into the Atlantic and back to the Andes again. Working alongside local communities, the expedition members aimed to understand how one of Earth's most integral resources is changing in real time. Climate scientist Tom Matthews, part of the team that installed a weather station high in the tropical Andes, sums up the project's message: "What we do in the next few years really matters." *—Eve Conant*

DIGITAL INTERACTIVE

Dive into a choose-your-own-adventure experience that explores the animals, terrain, and cultures of the Amazon as never before: *natgeo.com/amazon-special*.

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