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NATIONAL GEOGRAPHIC

BIODIVERSITY

The Fragile Web

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MILLENNIUM IN MAPS

BIODIVERSITY

NATIONAL GEOGRAPHIC SOCIETY

The fragile balance of plants and animals that share the Earth took millions of years to develop. Some life-forms have persisted in nearly their original state, surviving episodes of mass extinction. Some, like ourselves, are relative newcomers. The ones that have perished will not return. Neither will the thousands of species that are disappearing each year due in large part to such human influences as habitat destruction, introduction of invasive species, and overharvesting. If we continue reducing Earth's biodiversity at this rate, the consequences will be profound. The web of life connects the smallest bacterium to the giant redwood and the whale. When we put that web in peril, we become agents of calamity.

2000 NATIONAL GEOGRAPHIC

Ivory-billed woodpecker *Campephilus principalis* ca 1990

Xerces blue *Glaucopsyche xerces* Extinct-circa 1941

Tasmanian tiger *Thylacinus cynocephalus* ca 1936

Round Island burrowing boa *Bolyeria multocarinata* ca 1975

Israel painted frog *Discoglossus nigriventer* ca 1940

Kawaihae *Hibiscadelphus bombycinus* ca 1920

West Indian monk seal *Monachus tropicalis* ca 1952

Falkland Island wolf *Dusicyon australis* ca 1876

Moa *Dinornis torosus* ca 1670

Bali tiger *Panthera tigris balica* ca 1940

Harelip sucker *Lagochila lacera* ca 1910

Aurochs *Bos primigenius* ca 1627

Steller's sea cow *Hydrodamalis gigas* ca 1768

Woolly mammoth *Mammuthus primigenius* Quaternary

European giant deer *Megaloceros giganteus* Quaternary

Glyptodont *Glyptodon elegans* Quaternary

Phorusrhacos Tertiary

Pyracotherium Tertiary

Pteranodon Cretaceous

Around 65 million years ago a meteorite crashed into the Earth, triggering rapid global cooling that contributed to the extinction of the dinosaurs.

Lystrosaurus Triassic

Tyrannosaurus rex Cretaceous

Mixosaurus Triassic

Dimetrodon Permian

Silurian plants Silurian

Dunkleosteus Devonian

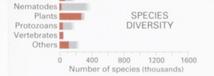
Trilobite *Olenoides serratus* Cambrian

The story of life on Earth—which grew more complex with the appearance of trilobites in the Cambrian period, 540 to 510 million years ago—has been punctuated by numerous minor and several major extinctions.

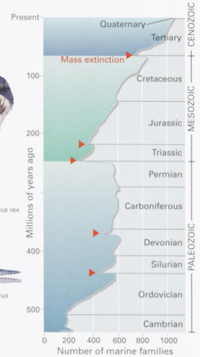
Biologists estimate that species are being lost hundreds or even thousands of times faster than normal. Whatever the cause of earlier extinctions, the sixth major extinction is the first mass dying *driven by human activity*.

DIVERSITY OF LIFE

Since the Swedish botanist Linnaeus published his *Systema Naturae*, a system for classifying living things, in the mid-1700s, taxonomists have identified between 1.5 million and 1.75 million species, some 4,500 of them mammals. Many more species have yet to be named and described. Controversy surrounds the issue of how many unknown species may exist—and how many are becoming extinct before we can count them. Estimates of the total number of species on Earth range from five million to a hundred million. Whatever the sum, insects appear to be by far the most numerous, making up about half of all life. Beetles, in fact, are the most various and pervasive creatures identified thus far.



RAPID EXTINCTIONS, SLOW RECOVERIES



An estimated 99 percent of all species that ever lived are extinct. Yet more kinds of creatures may be alive today than at any other single time in the planet's 4.6-billion-year history.

In the beginning single-celled microbes had a watery, rocky world to themselves. During the Cambrian period, which began 540 million years ago, complex animal life increased dramatically. And later some disappeared. On at least five occasions in the past, mass extinctions destroyed whole families of species across the globe, in relatively short time periods.

The Ordovician extinction, 440 million years ago, eliminated some 75 percent of animal species. (The percentage of families lost—each of which can have many species—is far smaller.) The Devonian, 370 million years ago, was almost as harsh. The worst crash, the Permian extinction of 250 million years ago, claimed more than 90 percent of all marine animals. The Triassic followed 210 million years ago. The Cretaceous extinction, 65 million years ago, ended the reign of the dinosaurs and killed about two-thirds of all animals.

In each ecological cataclysm some species slipped through to the other side, but recovery took millions of years. Biologists warn that we are in another wave, the sixth extinction. It is the first to be caused by and to affect humans. The recovery period, if there is one, has little meaning on the timescale of *Homo sapiens*.

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Sample the biodiversity of the United States and Canada through interactive maps on the Society's website. Explore and compare the worlds of plants, amphibians, butterflies, mammals, and more. See the natural world in a new way at **www.nationalgeographic.com/2000/biodiversity/maps.**

EARTH'S FORESTS

Have We Overdrawn Our Account?

Extinction by machete and fire was to be the fate of *Zea diploperennis* until a researcher identified the wild maize as unique among corn species—a perennial whose disease- and pest-resistant genes, introduced into domestic corn, could boost production by billions of dollars. In this case a finding of great value to humans was rescued from extinction, but the nick-of-time discovery raises the question: What else are we losing as we alter habitats?

Nearly half of Earth's original forest cover has been cut, cleared, or burned. And half of what remains has been so altered by humans that it barely resembles pristine forest. Loss of habitat not only threatens individual species but also brings more widespread ecological consequences.

In the Amazon Basin, for instance, the forest cover underpins the hydrologic cycle, and half the rainfall is generated within the basin itself. If rain forest was replaced by grass cover, temperatures would rise and rains would diminish, greatly affecting weather patterns throughout the region.

In China, protecting the shrinking highland habitat of the panda benefits humans living at lower elevations, as the forest cover prevents erosion and protects watersheds. Recent floods of unprecedented scale in China have been attributed in part to deforested uplands.

We take much of what the Earth's natural systems provide for granted: climate regulation, erosion control, soil formation, nutrient cycling, waste treatment, raw materials, food, genetic resources, habitats, and recreation. Common sense, ethics, economic practicality, and a sense of wonder all tell us that we stand to benefit if we protect what protects us. And nowhere is this lesson written so large as in the plight of the world's forests.

NORTH AMERICA

Heavy human activity has altered the natural forests of eastern North America. The central tallgrass prairies are mere whispers of their former selves. Although more than half the land remains undisturbed, most of that consists of the northern reaches of tundra and taiga.

SOUTH AMERICA

South America has the most undisturbed land, much of it in the biologically rich Amazonian forests. But these forests are being cleared by farmers and commercial loggers at a rapid pace. Each year an estimated 18,000 square miles are leveled.

AFRICA

Historically threatened by slash-and-burn agriculture, in which farmers clear new fields every few years, Africa's remaining forest ecosystems now face increased pressure from commercial logging and hunters seeking bush meat for urban markets.

EUROPE

The European continent has by far the greatest percentage of human-dominated land in the world. In some areas habitat alteration has persisted for so long that the original composition is known only by historical record and pollen analysis. The pie chart includes European Russia, the portion west of the Ural Mountains.

AUSTRALASIA

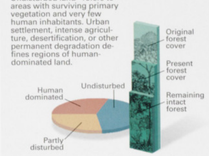
Australia ranks second in undisturbed land, virtually all of it inhospitable arid or semiarid tracts. Logging operations are expanding within heavily forested Papua New Guinea.

ASIA

Nearly two-thirds of all forests on the Asian continent lie within Russia. While the forests of Southeast Asia and the island nations to the south appear to be intact, they include forest fragments, plantations, and secondary growth.

HUMAN LAND DISTURBANCE

"Undisturbed land" refers to areas with surviving primary vegetation and very few human inhabitants. Urban settlement, intense agriculture, desertification, or other permanent degradation defines regions of human-dominated land.



"Remaining intact forests" are big enough to maintain all their biodiversity and are relatively healthy. Present forest cover also includes secondary growth, plantations, degraded forest, and forest fragments.

GLOBAL FOREST DISTRIBUTION

Boreal
Temperate conifer
Temperate mixed
Subtropical conifer
Tropical dry
Tropical moist
Mangrove
Original forest cover

Forest data: World Wildlife Fund, World Conservation Monitoring Centre, CONABIO, Asian Bureau of Conservation, Ecotrust/Interrain, CONAF. Land disturbance data: Lee Hannah, Conservation International

The hooded warbler *(Wilsonia citrina)* migrates thousands of miles each year.

Arriving north in the spring, these songbirds build nests and raise their young in the undergrowth of deciduous or mixed pine forests in the eastern half of the United States.

As woodlands get carved up into islands of habitat by suburbs and farms, hooded warblers must nest closer to the forest edge, where they fall prey to parasitic cowbirds and to predators like raccoons.

Cowbirds—which feed in open areas on insects, including those stirred up by cattle—smuggle their eggs into hooded warblers' nests. Since cowbirds hatch early, they often take food and space away from the younger and weaker warbler chicks.

On their fall migration, warblers face a number of dangers. In cities they fly into the glass windows of skyscrapers. In coastal areas much of their resting habitat has been lost.

The migration route of this songbird, from the eastern United States to the Atlantic lowlands of Mexico and Central America, is increasingly subject to fragmentation.

CHAIN SAWS AND LONGLINES

Threats to Biodiversity

Since the development of agriculture some 12,000 years ago, the human population has grown exponentially. So has *Homo sapiens'* use of the Earth's resources. Today humans consume or directly use nearly half the land's biological production and more than half of all available fresh water.

Humans have long had insatiable appetites and the technology to satisfy them. At present the greatest threat to Earth's biodiversity is habitat loss and degradation stemming from such activities as commercial logging and fishing. Both are destroying environments and stripping them of key species.

Other threats include pollution and invasive human-introduced species.

In the U.S. Pacific Northwest the old-growth forests are cathedrals of controversy, as timber companies and conservationists bitterly argue over cutting or preserving what amounts to less than 10 percent of the original old-growth coverage. Great swaths of forests are being cut and burned in Amazonia, Malaysia, Indonesia, and elsewhere.

In New England and the Canadian Maritimes, fishermen, environmentalists, and government bureaucrats talk and argue and sue, yet the catch of cod, flounder, and haddock diminishes year after year. The fleets of China, Peru, Chile, Japan, India, Russia, and other nations are equally culpable.

Invasions of exotic species, which alter ecological processes and drive native species to extinction, require constant vigilance. Each year Florida spends 11 million dollars to control the water hyacinth that chokes its waterways, a plant introduced there in the 1880s.

When we burn and clear-cut the forests, trail miles of nets through the sea, or drop cyanide near coral reefs to catch fish, we leave places not only impoverished but permanently altered.

SETTING PRIORITIES

Conservation and Research

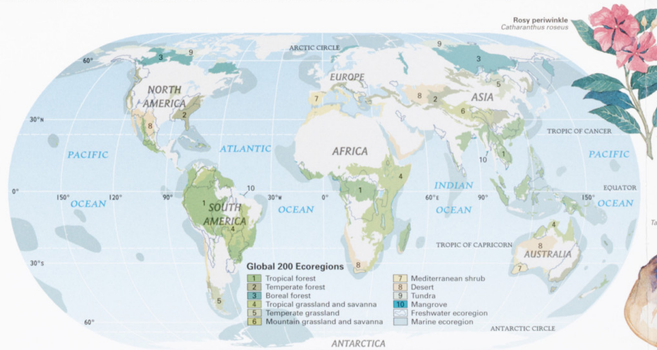
The central question is: How do we get through the next 50 years—when the human population is projected to reach 10.8 billion or more—without losing forever the genetic wealth of biodiversity?

The key to conservation is to identify, inventory, and protect the world's remaining repositories of plant and animal diversity. In 1988 Norman Myers, a British ecologist, used plants as indicator species and adopted the term "hot spots" to describe especially vulnerable, especially rich ecosystems. Conservation International broadened that concept to include animal species, designating as hot spots 24 areas that, although encompassing only 2 percent of Earth's surface, hold over 50 percent of all terrestrial species.

At the World Wildlife Fund, David Olson and Eric Dinerstein have introduced the Global 200, a program to conserve not just hot spots but also representative land, freshwater, and marine ecoregions (below) that harbor globally important biodiversity and unusual ecological phenomena.

Whatever strategies are used to protect species, people with different points of view will have to search for common ground that combines economic and social concerns. An encouraging example can be found in Nepal, which has enacted legislation requiring that up to half of all park revenues be used for local development. At Royal Chitwan National Park, home to one of the highest densities of tigers and greater one-horned rhinoceroses in Asia, villagers are restoring buffer zones to extend tiger and rhino habitat because they now benefit from tourism.

As the Senegalese conservationist Baba Dioum observed, "In the end, we will conserve only what we love, we will love only what we understand, we will understand only what we are taught."



HABITAT FRAGMENTATION

Roads are like daggers into the heart of remaining forests. Build a road and settlers follow, bringing farming, mining, logging, hunting, and other activities that fragment the natural habitat. Even the road itself does damage, exposing the forest interior to wind, sun, weeds, and predators.

Power lines, pastures, and suburbs all create "edge" that can change a forest forever. A pair of warblers, for example, might need only one acre for a breeding territory, but it must be deep within a hundred acres of unbroken forest for their chicks to survive. Their low nests mean easy pickings for raccoons, feral cats, and egg-eating birds like crows and blue jays.

Forced into ever smaller islands of habitat, many native species face a lethal threat.

In both Mexico and Central America, wintering habitat is diminished by slash-and-burn agriculture, especially in dry years such as last year, when the forests also caught fire.

MEDICINAL PLANTS AND ANIMALS

Today some 40 percent of all prescriptions in the United States are either based on or synthesized from natural compounds found in microorganisms, plants, and animals. These substances save lives and alleviate pain and in the process account for billions of dollars for the pharmaceutical industry. Less than 10 percent of known plant species and only a fraction of invertebrates have been examined for their possible medicinal value. Yet from the little we know, consider what we've gained:

• The drug digitalis derives from foxglove. By boosting the pumping function of the heart, digitalis helps many of the 4.8 million Americans who suffer from heart failure.

• Quinine from the cinchona tree, a native of the Andes Mountains, has long been effective against malaria.

• A small pink five-petaled flower called the rosy periwinkle produces two alkaloids that are highly effective against Hodgkin's disease and childhood leukemia.

• The horseshoe crab has a blood-clotting agent that is used to detect potentially fatal bacteria in vaccines, drugs, and medical devices.

• The bark of the Pacific yew tree, found in the ancient forests of the Pacific Northwest, is the source of Taxol, a drug used to treat ovarian and breast cancers.

Rosy periwinkle *Catharanthus roseus*

Cinchona *Cinchona ledgeriana*

Foxglove *Digitalis purpurea*

Pacific yew *Taxus brevifolia*

Horseshoe crab *Limulus polyphemus*

The expansion of citrus groves and coffee plantations contributes to further loss of habitat for the hooded warbler.

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DIVERSITY OF LIFE

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THE NATURAL WORLD

Labeled for their natural vegetation, biomes are defined by their distinctive mix of plants and animals.

1. Tundra
2. Northern coniferous forest (also called boreal forest or taiga)
3. Temperate coniferous forest
4. Temperate broadleaf forest (includes rain forest)
5. Temperate grassland
6. Desert and dry shrub
7. Mediterranean shrub
8. Mountain grassland
9. Flooded grassland and savanna
10. Tropical grassland and savanna
11. Tropical dry forest
12. Tropical coniferous forest
13. Tropical moist broadleaf (includes rain forest)
14. Mangrove
15. Permanent ice cover

SOURCE: WORLD WILDLIFE FUND

CHIHUAHUAN DESERT

Home to one of the richest cactus communities in the world, the desert also harbors a rare example of an inland-desert wetlands—Cuatro Ciénegas. Snails and fish there have radiated into many species, some restricted to a single pool.

Bering Sea

This region is a critical area for migrating marine life, including endangered bowhead whales and gray whales. It also supports huge numbers of murres, auklets, and other seabirds.

Northern Rockies Boreal Forest

The surviving forest sustains one of North America's richest populations of bears, wolves, lynx, wolverines, and caribou.

Tennessee-Cumberland Watershed

This is the world's most diverse temperate freshwater ecosystem.

MEDITERRANEAN REGION

From Portugal to Jordan, from Morocco to southern France, this ecoregion is fragmented and threatened by burning, grazing, human settlement, and tourism. The region is one of five sites of Mediterranean shrub land in the world, which collectively contain 20 percent of all terrestrial plant species.

Várzea and Igapó Forests of Amazonia

These flooded forests include many tree species that depend on fish swimming into them to feed on fruits and disperse their seeds, a unique ecological phenomenon.

ATLANTIC FORESTS

The Atlantic forest region, most of it in Brazil, is a critically endangered ecosystem. Less than 7 percent of the original vegetation remains. Early naturalists found forests draped with orchids and bromeliads and ringing with the sound of animals. The four endemic species of tamarins are all endangered, including the black-faced lion tamarin, which was discovered by scientists in 1990.

Upper Guinea Forests

Although largely destroyed, these forests still house many rare species, such as the pygmy hippopotamus and the dwarf otter shrew.

Taymyr Peninsula

Reindeer by the hundreds of thousands breed on the tundra and winter in the forests to the south.

Lake Baikal

The world's oldest and deepest lake, it harbors 2,600 species of animals and plants, including giant freshwater sponges.

SIBERIAN TAIGA

Earth's largest unbroken forest, this is among the last regions vast enough to allow populations of large predators to interact naturally with prey. A network of wetlands is critical breeding habitat for many species of waterfowl, shorebirds, and the endangered Siberian crane.

NEW GUINEA FORESTS

One of the last great forest wildernesses, long-isolated New Guinea has never been colonized by monkeys or most other large mammals. Their niches are filled instead by reptiles, marsupials, and birds.

WESTERN GHATS

A large number of endemic species, some traced back to forebears on the ancient supercontinent of Gondwana, have evolved on India's long-isolated western mountain ranges. Sixteen bird species and at least 1,500 plant species live only here. Pressure from expanding human population, logging, and farming is intense.

Madagascar

The island has been isolated from mainland Africa for some 130 million years. Lemurs, primitive primates, have evolved into today's roughly 30 endemic species. Eighty percent of the plants are also endemic.

Southeast Asian Mangroves

More than 30 species of mangroves—the most diverse group in the world—flourish along the coasts of Indonesia and Malaysia.

New Caledonia

Home to the largest species of gecko, the only parasitic conifer, and the endangered flightless kagu, the island is a high priority among conservationists.

NEW ZEALAND

The flora and fauna of New Zealand, once part of Gondwana, evolved in isolation for some 80 million years. New Zealand harbors one of the world's increasingly threatened temperate rain forests, where flightless parrots nest. More than 80 percent of New Zealand's plant species are endemic.

INDO-PACIFIC CORAL REEFS

Reefs in the tropical western Pacific are the world's most diverse. Some off western New Guinea harbor 525 species of reef fish and 450 species of coral. The world trade in aquarium fish and large food fish is having a devastating impact, as is sedimentation and pollution.

ANDEAN FORESTS

The rugged terrain of the northern Andes hosts an enormous diversity of habitats. Single peaks or valleys are home to several species of birds, orchids, and other organisms found nowhere else. One of the world's highest concentrations of endemic birds inhabits peaks on the Ecuador–Colombia border.

ANTARCTIC PENINSULA

Large populations of marine mammals, birds, and fish depend, directly or indirectly, on shrimplike krill in surrounding waters. One of the last relatively intact marine ecosystems, the peninsula is a breeding ground for many species. Increased ultraviolet radiation due to ozone depletion threatens the area.

CAPE FLORISTIC REGION

This area in South Africa holds a unique collection of hard-leafed and evergreen shrubs called *fynbos* and harbors more than 8,000 plant species, some 70 percent of which are endemic. The greatest threats to this diverse plant life are invasive alien species and habitat loss.

GARDENS OF LAND AND SEA

Maps of photosynthesis and plant growth (right and far left) reveal the significant contribution of marine plants, which contribute about as much as land plants to Earth's total photosynthesis, though their biomass is less than one percent that of land plants. Plankton blooms in the northern seas mark the annual resurgence of aquatic plant life. The maps are based on the absorption of solar radiation as determined from satellite measurements.

Productivity map data: Michael Behrenfeld, Paul Falkowski, Rutgers University; Christopher Field, James Randerson, Carnegie Institute of Washington

 Printed December 1998

Protecting Earth's "biodiversity"—the word coined by biologists to encompass the variety of all life on our planet—requires understanding the environments that give rise to communities of microorganisms, plants, and animals. Tropical forests harbor more than half of all species. The remainder are distributed in other ecosystems across the planet, as shown above. From deserts to high mountains, from deep volcanic vents in seafloors to the shallow bays of Antarctica, life flourishes. But though superbly adaptable, many life-forms are threatened directly or indirectly by one single species—*Homo sapiens*.

Human population may reach 10.8 billion by 2050, up from 5.9 billion today, and human pressures on natural systems are already extensive. Forests are burned for pasture and croplands. Exotic species are introduced into environments that have no defenses against them. Overharvesting and pollution degrade environments and threaten the life that depends on them.

Biologist Edward O. Wilson has warned, "We are in the midst of one of the greatest extinction spasms of geological history." A growing sense of urgency fuels the effort to identify and conserve major habitats. And if not everything can be saved, it may be possible to preserve representative samples of the world's terrestrial and aquatic environments.

For some places the hour is already late. Mediterranean shrub lands and tropical dry forests are even more threatened than tropical rain forests. And deforestation in each of these areas is of special concern because they harbor large numbers of endemic species, local species that occur nowhere else in the world and often only within small ranges. If we wish to save species, we must first save their habitats.

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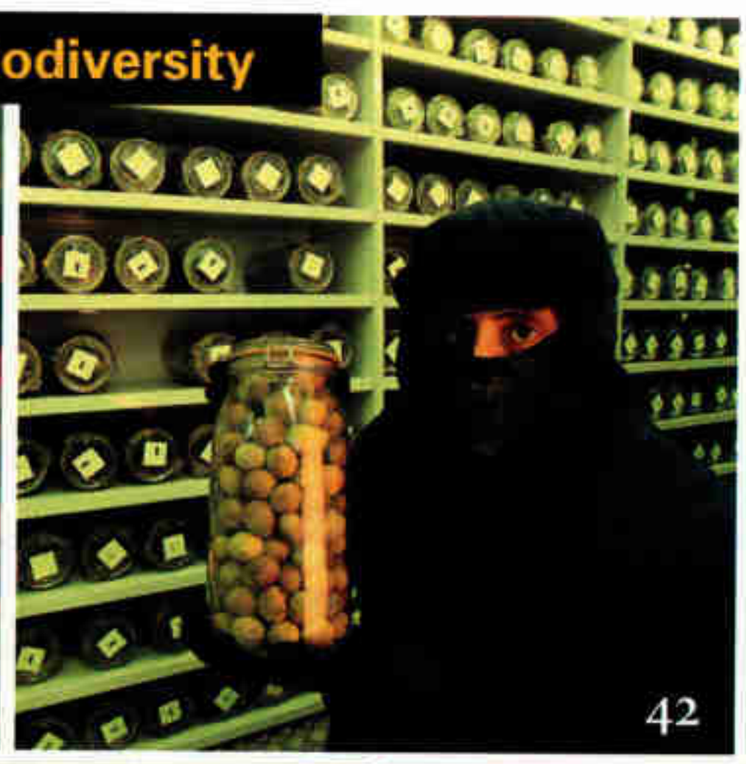
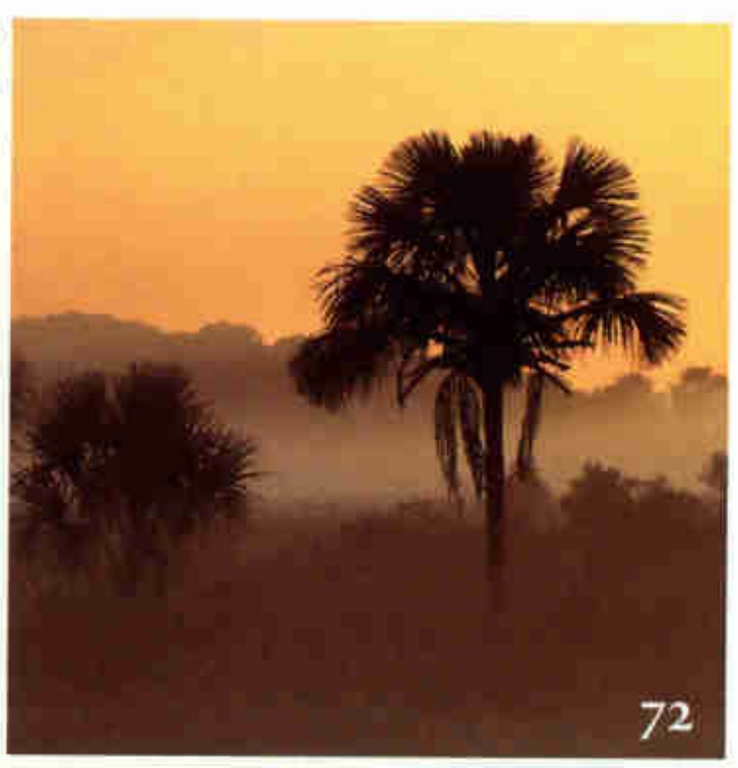
FEBRUARY 1999





The Cover

Peering out from red Australian sands, a desert spadefoot frog emerges for a rare drink of water. Photograph by Frans Lanting

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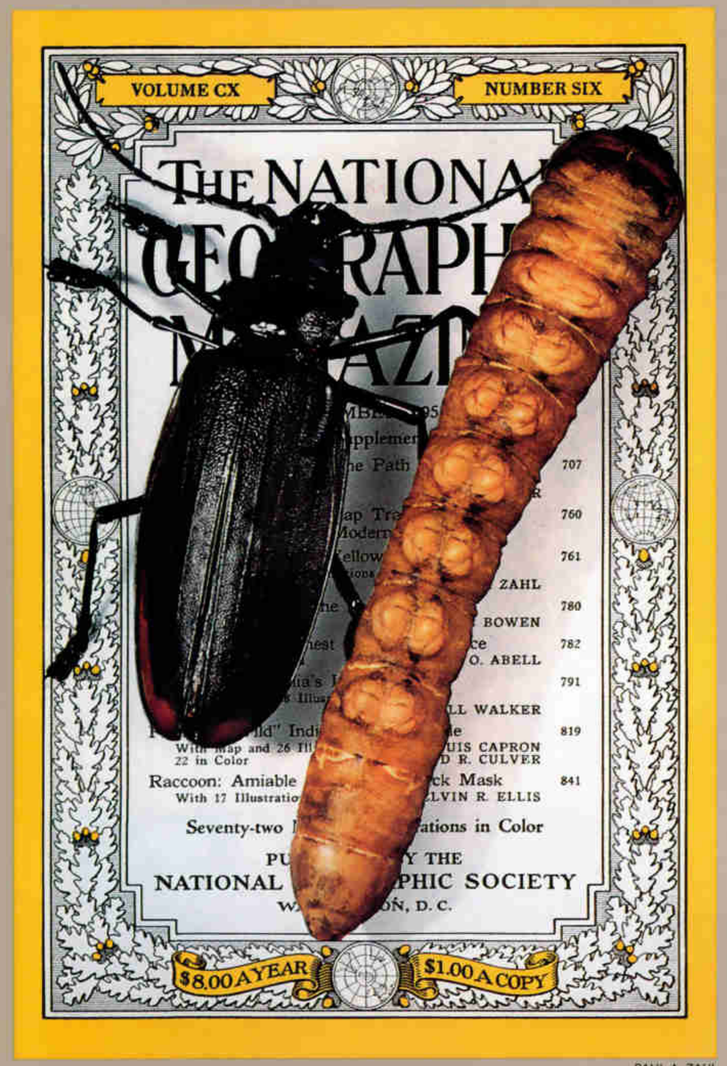
Biodiversity: New Term, Old NGS Concern

"They roam the earth from pole to pole; they are equally at home on a wave-washed coral reef or in an arid desert." The wonder and variety of birds were extolled in the June 1913 GEOGRAPHIC by associate editor and ornithologist Frank M. Chapman. Plants and animals have been a keynote Society subject from its inception. In 1889 Geography of Life, one of five NGS departments, was run by C. Hart Merriam, a Society founder who also launched the forerunner of the U.S. Fish and Wildlife Service.

In the 1930s biologist William Beebe riveted readers by describing deep-sea creatures seen from his bathysphere. His later work in the Trinidad treetops led to today's quest for new rain forest species by scientists such as Harvard's Edward O. Wilson, who has popularized the recent notion of biodiversity—the variety of living things in an ecosystem. "Life is more diverse and more plentiful than anyone had previously known," he wrote in December 1991.



PAUL A. ZAHL

R. W. G. HINGSTON

EARLY FORAYS INTO THE RAIN FOREST
For life-size scale, a *Titanus giganteus* beetle nearly five inches long and an eight-inch-long larva, possibly of the same species, were shown on a mock cover inside the May 1959 issue. The adult was one of 15 collected by staff naturalist Paul A. Zahl in the Brazilian Amazon, nearly doubling the number of *T. giganteus* specimens in the scientific record. In 1932 a member of an Oxford University expedition to British Guiana (now Guyana) climbed a rope ladder into the rain forest canopy (above). There muslin traps were baited to attract specimens of insects, birds, and small mammals.

GEORGE SHIRAS

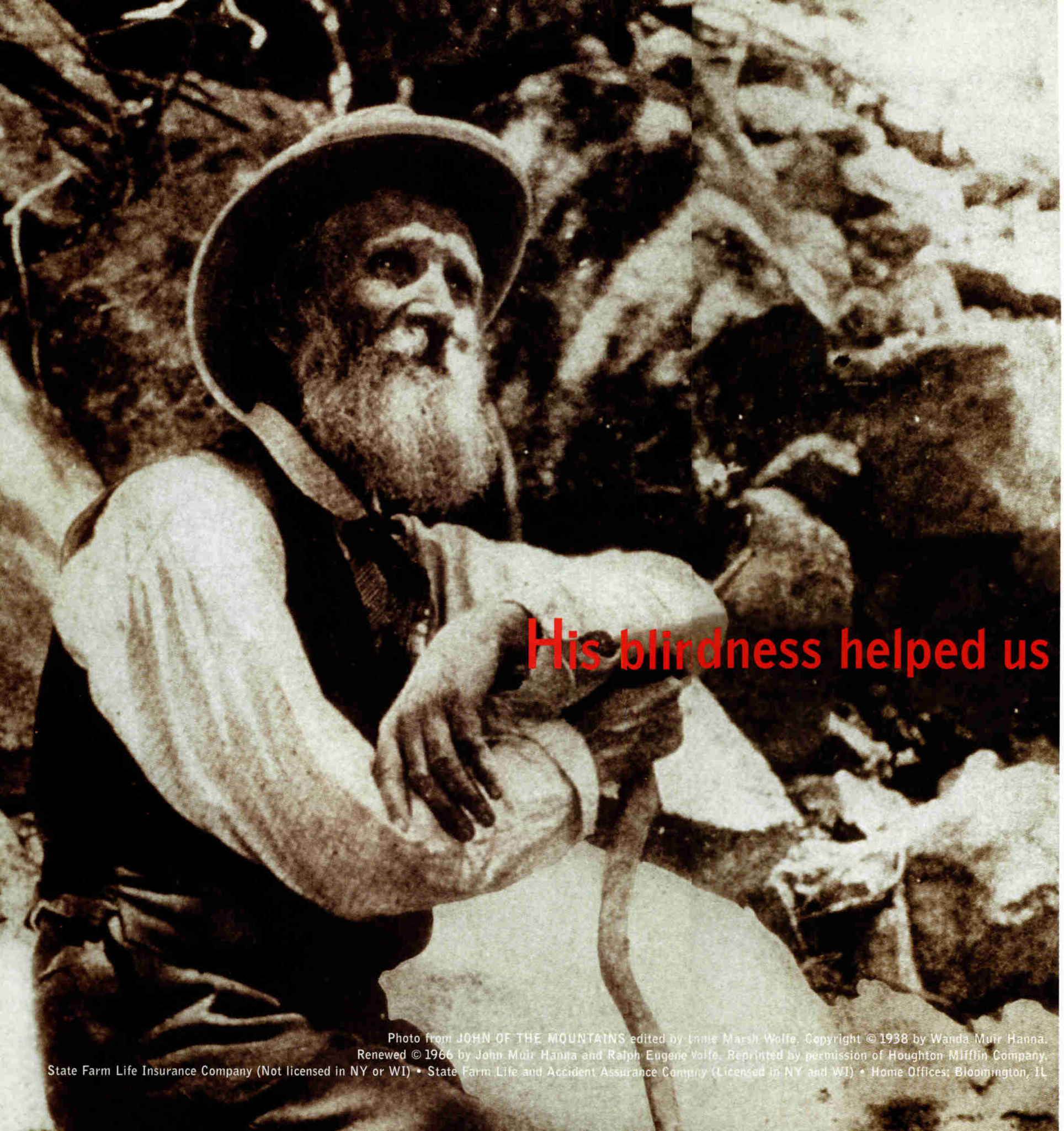
SOCIETY CAMERAS SHED LIGHT ON NATURE
"What is game to the rifle is game to the camera!" Conservationist and photographer George Shiras was among the first to reveal animal night life. In the late 1800s he devised a "flashlight" that reflected ignited magnesium powder onto wildlife in the dark so his film could capture them at a twenty-fifth of a second. Near Lake Superior he rigged a trip wire that these deer snagged, setting off a blank cartridge that startled them. As they bounded away, the delayed flash fired to get their image. Shiras's techniques foreshadowed contemporary photographers' new ways of inducing animals to take their own pictures.

Exploding magnesium involved "nerve-racking suspense," but it produced "The First Autochromes from the Ocean Bottom" in 1927. Ichthyologist W. H. Longley and Charles Martin of the Society's photo lab used a camera enclosed in a windowed brass case. A flash fired a pound of magnesium to capture this hogfish.

W. H. LONGLEY AND CHARLES MARTIN

Biodiversity Milestones

- **4 billion years ago**
  Single-celled organisms, first life on Earth, appear in the sea. More than three billion years will pass before large multicellular life will evolve.
- **540 million years ago**
  During the Cambrian period life proliferates in the ancient seas. Animals with skeletons and shells originate.
- **440 m.y.a.**
  First great mass extinction of animals occurs, wiping out many groups of marine organisms.
- **425 m.y.a.**
  Vegetation colonizes the land, followed by the first land animals, arthropods.
- **410 m.y.a.**
  Insects appear on land.
- **370 m.y.a.**
  In another mass extinction, 70 percent of marine animal species perish.
- **310 m.y.a.**
  Reptiles evolve and become the first vertebrates to live fully independent of the water.
- **250 m.y.a.**
  In the catastrophic Permian mass extinction, more than 90 percent of



His blindness helped us

A Scottish-born machinist blinded in an industrial accident, he swore if he ever regained his sight he would devote himself to the inventions of Nature. And regain it he did. In the 1880s, he became the country's first environmentalist and fought tirelessly to preserve the matchless beauty of places like Yellowstone and Yosemite Valley. With his passion and commitment, John Muir helped establish the world's first national parks, and gave us a vision of the beauty that surrounds us all.

all to see.

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FROM COLLECTING TO CONSERVATION

Filipinos offer a reticulated python, a crested serpent eagle, and other national treasures to an American adventurer who wrote a September 1948 article. Later, concern for vanishing wildlife arose as a strong new theme. In February 1972 a look at threatened African species, especially those under siege by poachers, included this photograph of stuffed leopards near Nairobi (below), captioned "Prey of the ultimate predator—man." The plaintive face of an endangered leopard cat for sale in a Bangkok market (below right) highlighted a March 1981 story on wildlife smuggling. Asked the author: "Who more deserves the shrinking space on earth, animals or people?"

CHARLES H. WHARTON

THOMAS NEBBIA

STEVE RAYMER

SUPPORTING SCIENTISTS IN THE FIELD

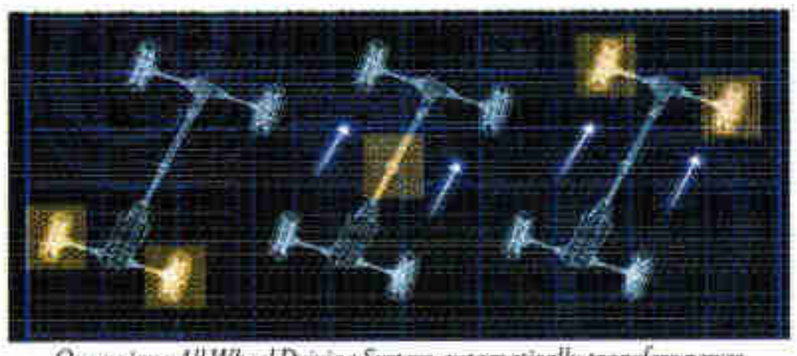
Jane Goodall reaches out to a young Tanzanian chimp named Flint in a December 1965 article. For more than three decades she has also touched Society readers and television viewers with her insights into the lives of these primates. Dian Fossey did likewise with mountain gorillas, as did Biruté Galdikas with orangutans. All were supported by NGS research grants, more than 6,400 of which have been awarded since 1890.

HUGO VAN LAWICK

animal species are wiped out. Some mammal-like reptiles survive, eventually giving rise to true mammals.

- **230 m.y.a.**
  First dinosaurs appear.
- **210 m.y.a.**
  As mammal-like reptiles die out during the Triassic extinction, dinosaurs and early mammals flourish.
- **150 m.y.a.**
  In the late Jurassic period appears an animal with teeth, feathers, and claws—*Archaeopteryx,* the earliest known bird.
- **130 m.y.a.**
  Flowering plants take root throughout the Earth.
- **65 m.y.a.**
  In the Cretaceous mass extinction the end of the dinosaurs comes with a bang as a meteorite's impact changes Earth's climate for millennia. With dinosaurs extinct, mammals proliferate.
- **4 m.y.a.**
  Hominids, ape-like creatures that walk on two feet, arise in Africa.
- **100,000 years ago**
  First anatomically modern *Homo sapiens* appear.
- **11,000 years ago**
  Mastodons and other large mammals become extinct, perhaps victims of human hunting and climate change.
- **350 B.C.**
  Aristotle becomes the first scholar to classify animals—those with blood and those without.
- **A.D. 400**
  With the arrival of Polynesians, Hawaii's flightless birds become easy prey. At least a thousand of the islands' animal species will eventually be erased.
- **1400-1500**
  Intercontinental exploration and trade hasten the exchange of animals, plants, and microbes, in many cases dooming native species.
- **1500-1600**
  Europe's forests are so depleted by 1595 that bakers in France must fire their ovens with bushes.
- **1600-1700**
  Settlers begin clearing North America's forests. Habitat loss and other causes will lead to the extinction of perhaps 500 plant and animal species.
- **1700-1800**
  In 1753 Carl Linnaeus creates a uniform system for naming genera and species, thus globalizing natural science.

The road ahead is merely a suggestion.



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Sailing around the world from 1768 to 1771, naturalist Joseph Banks increases the number of plant species known to science by 25 percent.

■ **1800-1900**
Charles Darwin's *On the Origin of Species* (1859) revolutionizes thinking on how new species arise.

German biologist Ernst Haeckel coins the word "ecology" in 1866.

In 1872 Congress creates the first U.S. national park, Yellowstone, setting an important precedent for protecting nature.

As improvements in health and diet cut death rates, world population surges 70 percent to 1.7 billion by century's end.

■ **1900-present**
A fungus introduced to North America in the early 1900s kills billions of chestnut trees.

Clearing of tropical rain forests escalates during the 1960s, triggering a cascade of extinctions.

The Endangered Species Act, passed in 1973, helps prevent the extinction of dozens of species, from alligators to bald eagles.

CITES, an international treaty banning trade in endangered species, becomes law in 1975.

Discovered in a seafloor vent in 1977, a new organism is classified in 1996 as part of a third domain of life—archaea.

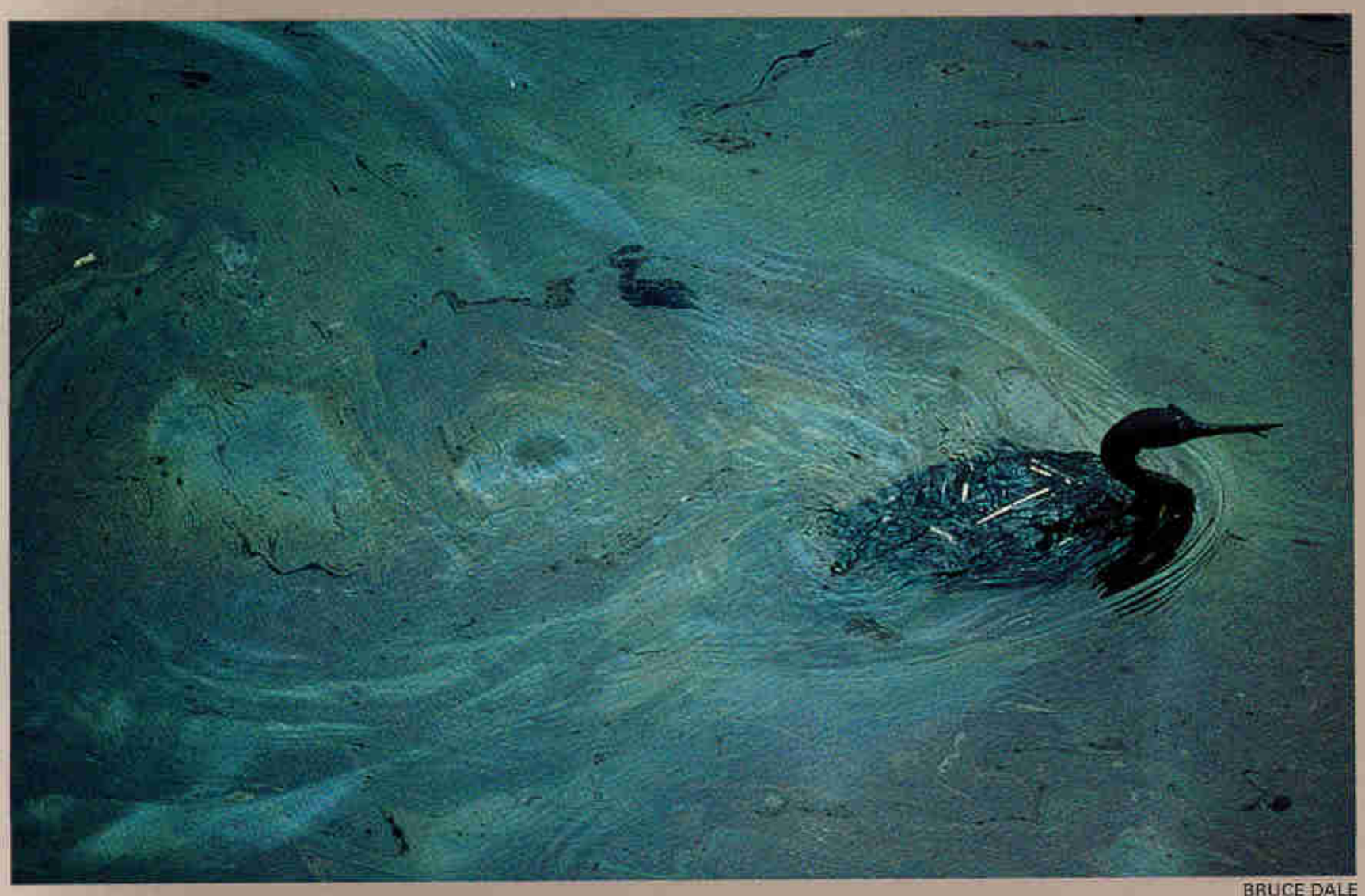
The planet's sixth great mass extinction is already in progress, experts warn.

WILLIAM HENRY JACKSON, COURTESY NATIONAL ARCHIVES

PROTECTING THE PARKS
Few had witnessed the wonder of Mammoth Hot Springs in Wyoming when William Henry Jackson photographed it in 1878. In 1872 Congress had set aside 2.1 million acres of Yellowstone wilderness as the nation's first national park. This photo (above) appeared in a special 1979 issue on the parks that focused on expansion, overcrowding, and other concerns.

Not until 1916 was the National Park Service created—an action supported by GEOGRAPHIC Editor Gilbert H. Grosvenor, who devoted that year's April issue to America's natural wonders.

MARCOS SANTILLI



BRUCE DALE

IMPACT ON THE EARTH
"The oil so damaged his feathers that human help would be of no avail." Thus ornithologist Alexander Wetmore, a Society trustee, assessed the fate of a western grebe caught in an oil well blowout off Santa Barbara, California, in 1969.

Besides pollution, another vexing issue—habitat loss—smoldered in the rain forest of Brazil's burgeoning Rondônia state (above), featured in the December 1988 magazine. With a shattered crystal globe depicted on its cover, that issue posed what remains a critical and as yet unanswered question: "Can man save this fragile Earth?"

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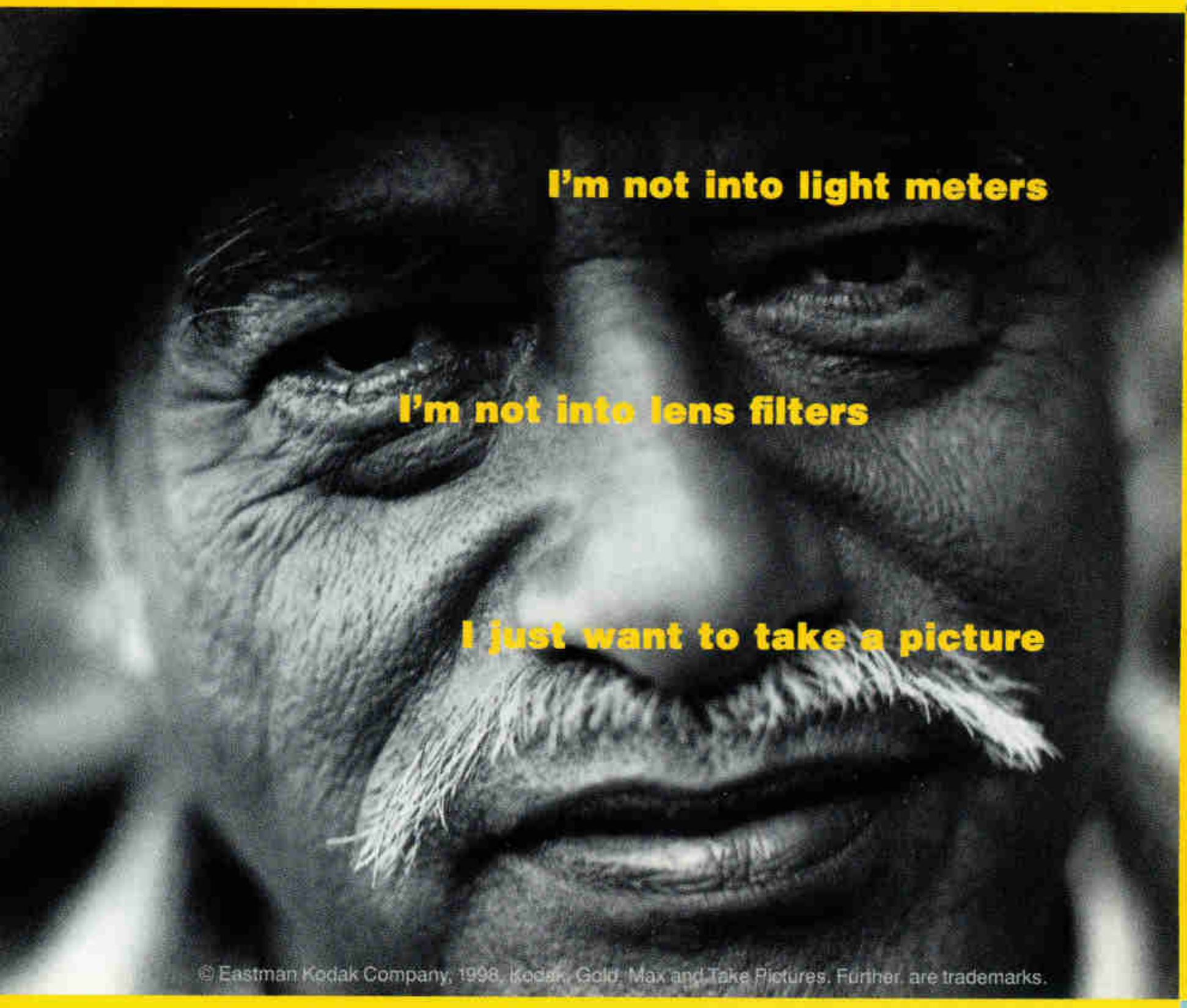

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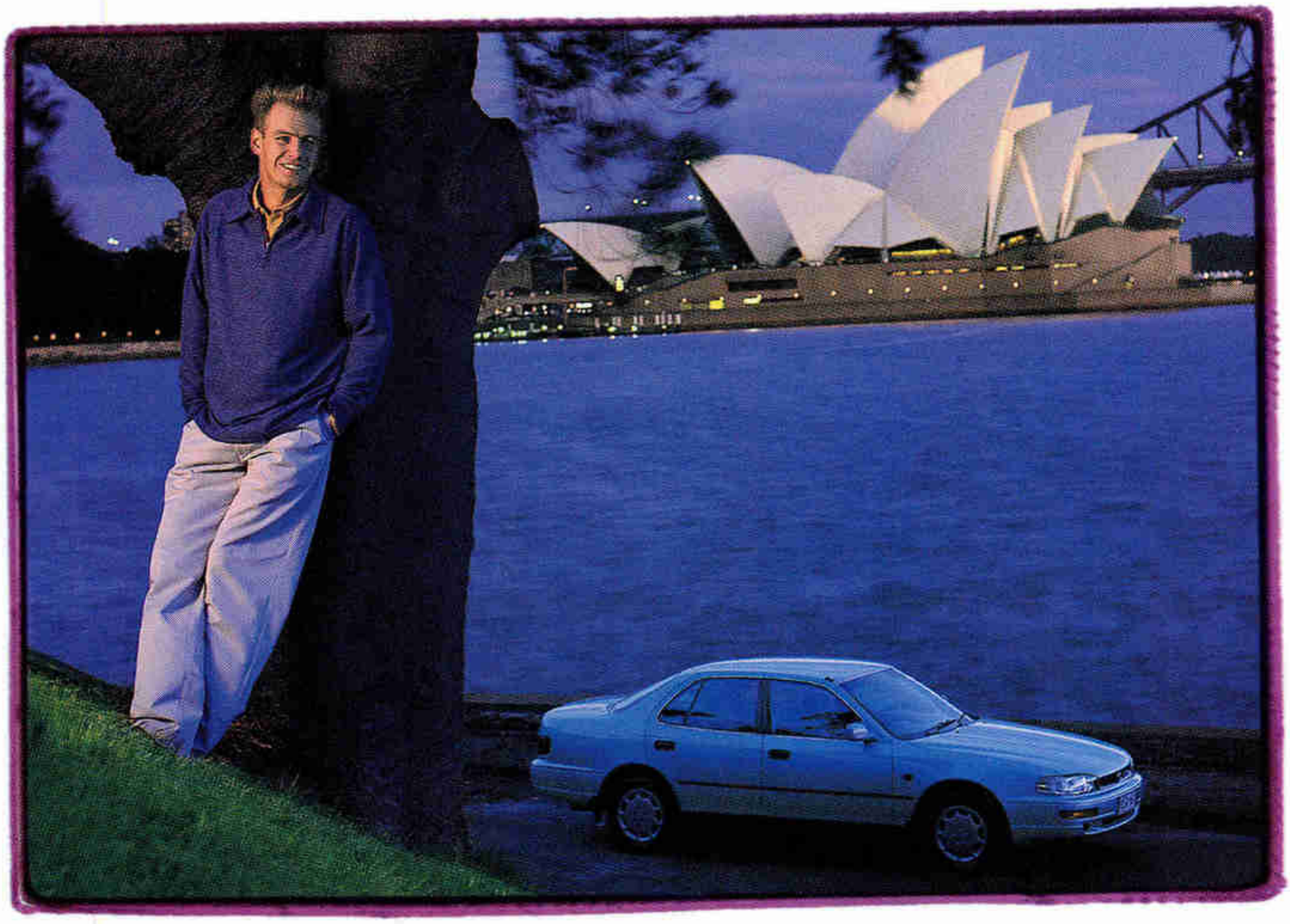

PEOPLE IN AUSTRALIA

BUILD SOME PRETTY AMAZING THINGS

There's one in front of that

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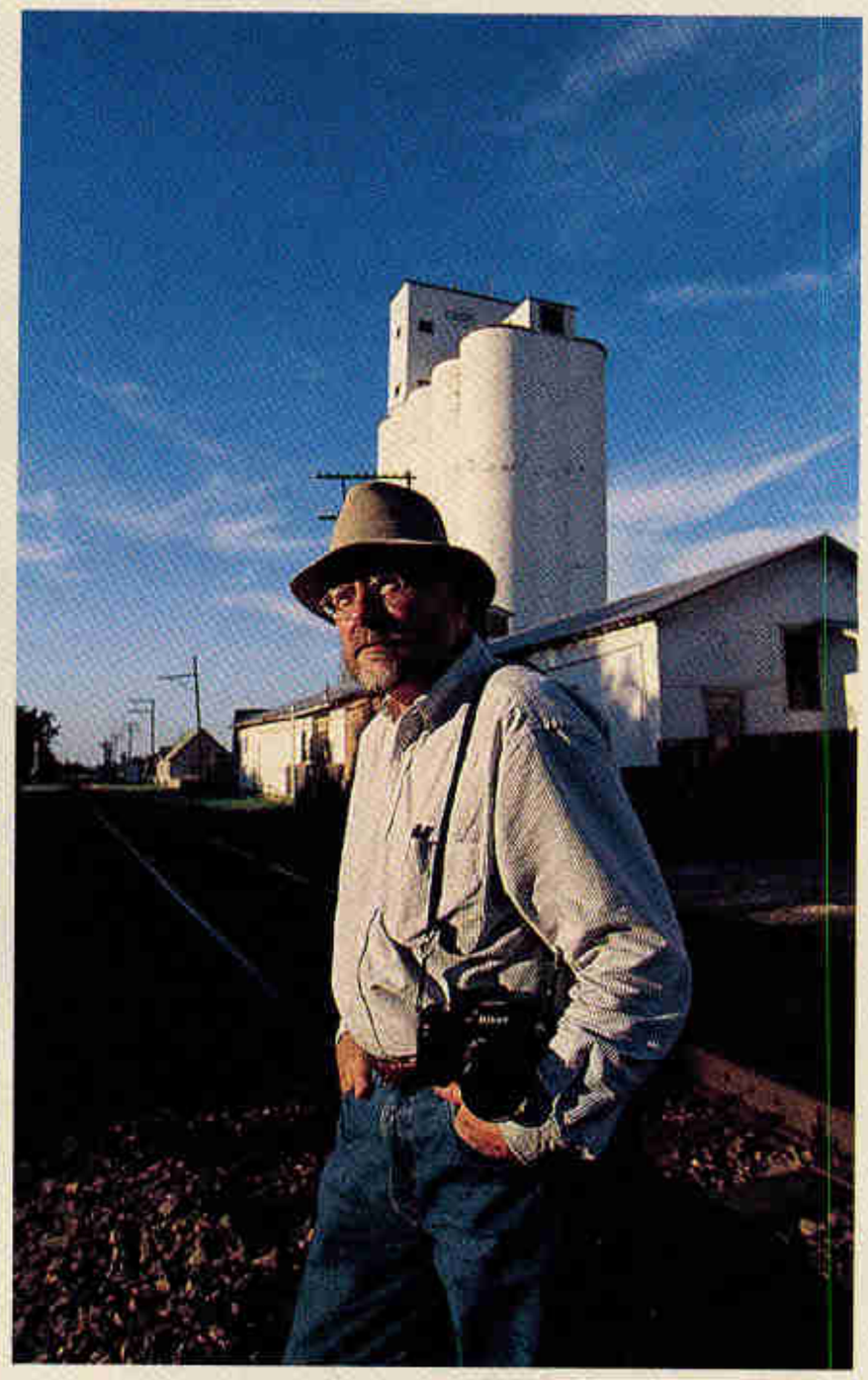
TOYOTA People Drive Us

Behind the Scenes

STEVE RAWLS (ABOVE); KATHY RICHARDSON



Home on the Grange

When you imagine professional photographers at home in their sophisticated urban penthouses—you're not imagining our photographers. A surprising number live, they're happy to admit, in the middle of nowhere.

"I'm a photographer, not a farmer," insists Joel Sartore (right), whose house nonetheless sits smack in the center of prime Nebraska corn country. He relishes the peace and quiet. "I spend so much time making arrangements and dealing with people for my job," he explains, "that when I get home, I just want to sit back and recharge my batteries. On those long international plane flights I dream about painting my porch." Jim Richardson (above right) fled Denver two years ago for tiny Lindsborg, Kansas, where grain elevators count as skyscrapers and the whole town of 3,000 turns out each Easter for Handel's *Messiah*. Jim is from Kansas originally but admits that living in the big city has left its mark. "I still drive to my office from my house. But now my office is only three blocks away." Robb Kendrick (top) calls 200 acres in the Texas Hill Country home. His place is part farmland and part private wildlife preserve. "During hunting season the quail and doves and deer know to come here," he says. Robb points to the local police blotter, reprinted in the weekly newspaper, as one reason he plans to stay put: "May 15 was a high crime day: Four mules and a goat escaped onto Main Street."

KATHY SARTORE

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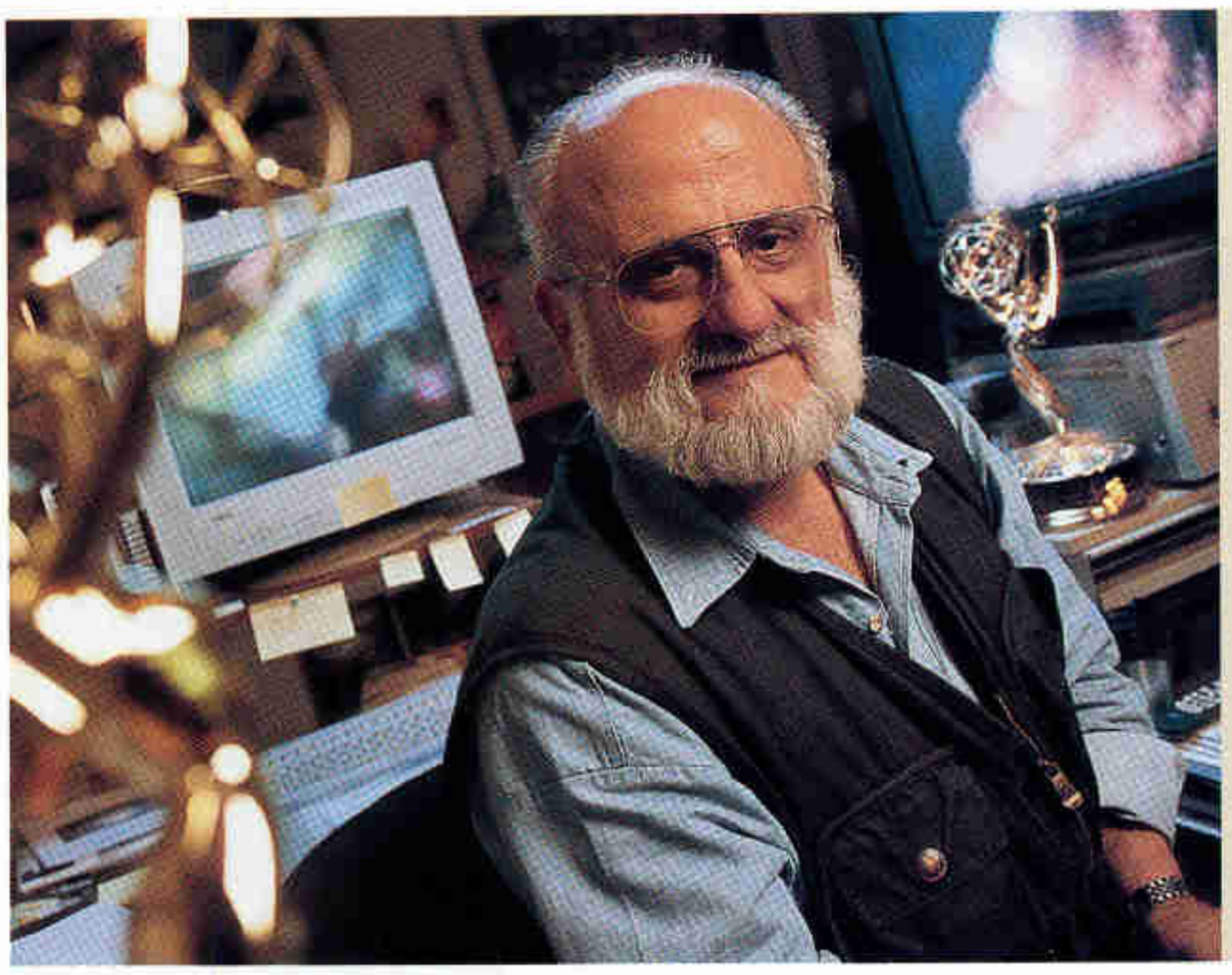

Yeorgos Wins Again

"Art is communication," says Yeorgos Lampathakis, whose own communication skills on *Asteroids: Deadly Impact* just landed him a second Emmy award. The NG Television art director started at NATIONAL GEOGRAPHIC magazine in 1970. His expertise was just what our growing television division needed three years later. He loves the challenge of film, he says. "Nobody can turn a page and reread a TV show if he doesn't understand something. We have to do it right the first time."

A Real Shaggy Dog Story

It was a dog's life, being on display. This stuffed husky from our Explorers Hall exhibit on Adm. Robert E. Peary was beloved by a generation of visiting schoolchildren—all of whom, it seems, gave a tug to his tail. He was purchased for $100 in 1963 from the American Museum of Natural History in New York City, which assured us that "this specimen certainly resembles some of the dogs of the region in which Peary worked."

Our curators soon learned that his proximity to reaching hands was a problem. By 1969 they noted he had "deteriorated beyond further repair" and requested a replacement "with fiberglass liners for ears and tail." But the new dog's price tag—$1,000—ensured that our old husky kept his job. He stayed on until the Peary display was retired in 1988—then went back to his box, like a good dog always does.

TEXT BY MAGGIE ZACKOWITZ

Forum

October's Millennium articles on population prompted some members to speak out for animals. "When will mankind learn that as a species it has no more right to populate the world than any other?" asked one. Wrote another: "Human overpopulation has driven many species to extinction. It will be small consolation when technology allows our grandchildren to learn only from their CD library about the beautiful and bizarre species that once graced this planet."

Population

The Earth is a finite place with room for a finite number of people. Better civil engineering and improved food production cannot overcome this simple truth.

LYNN LANDES
Director, Zero Waste America
Yardley, Pennsylvania

One wonders what the impact of AIDS will be on population growth, particularly in countries like Botswana and Zimbabwe, where HIV infection in adults approaches 25 percent. It seems unlikely that present fertility rates can be sustained in the current generation, let alone the next. The dream of an African renaissance as fostered by the South African political leadership may find its fulfillment in a deserted continent, marked only by the return of the wildlife.

PETER VOS
Uvongo, South Africa

Perhaps we need to reread Genesis. The first command to be fruitful and multiply is given not to us but to the creatures of the sea and every winged bird (1:21-22). What have we done to help the endangered spotted owl and migrating salmon be fruitful and multiply?

DAVID E. ORTMAN
Seattle, Washington

Human Migration

As a senior patrol agent of the United States Border Patrol who has participated in Operation Gatekeeper since 1994, I found the portions of the article dedicated to our mission interesting as well as refreshingly accurate. I do not believe that there is an agent among us who has not been touched by the economic plight of those we are charged with apprehending. A year ago I caught one tireless person three times in one day! By the third time we were on a first-name basis. Dehumanizing migrants by referring to them as "bodies" may sound cruel, but until you have arrested, identified, and turned away literally thousands of poverty-stricken individuals—with so many hopeful children among them—you have no idea how emotionally self-preserving such a simple word can be.

ROBERT L. BURGESS
Chula Vista, California

The most realistic count of internally displaced persons is not four million, as shown on the graph on page 17, but 20 to 25 million: nine to ten million in Africa, five million in Asia, five million in Europe, and two million in the Americas. Their number now exceeds that of refugees.

ROBERTA COHEN
Brookings Institution Project on Internal Displacement
Washington, D.C.

Women and Population

I come from a developing country and have five siblings; my mother, eleven. In such countries most residents do not receive pension payments sufficient for survival when they become old or disabled, if they ever receive them at all. Instead, they are forced to depend on financial help from their children. The more children you have, the better the chance that one or more of them might be gifted or lucky enough to land a job that would achieve financial security for the entire family.

DIONISIA FRIAS GREEN
Woodbridge, Virginia

The enormous amount of research in this article is deeply appreciated in helping us understand the critical problem of population growth. Of particular interest is the description of the Grameen Bank in Bangladesh. The results being obtained by lending very small sums of money to the poorest of the poor, usually women, suggest the marvelous possibilities that can result from the intelligent allocation of our foreign aid funds. My wife and I work with a nonprofit, volunteer lobbying group named RESULTS, which seeks to generate the political will to end hunger and the worst aspects of poverty. The work of the Grameen Bank demonstrates how this idealistic goal can be achieved.

BERESFORD N. CLARKE
Fort Wayne, Indiana

Feeding the Planet

While high-tech food production may meet the demands of an exploding human population, what will be the future of a planet where forests and grasslands are converted to rice fields and cattle ranches, where parks and cemeteries become chicken farms? Can we survive the loss of biodiversity and our natural surroundings in order to feed ourselves? And would we want to?

BRYAN L. STARRETT
Scottsdale, Arizona

I wish to point out an error. The fourth country that today occupies the green valleys of the Tigris and Euphrates is Syria (not Lebanon, as stated in your article), along with Iraq, Iran, and Turkey.

RAYMOND J. ARONSON
Tel Aviv, Israel

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Lewis and Clark

I really enjoyed Ron Fisher's story of the remarkable journey of Lewis and Clark. However, on page 89 he states that the Clark's nutcracker is the only bird named for William Clark. Well, this was true until a 1985 revision of the *Check-list of North American Birds*, considered the official source of North American avian taxonomy. The western grebe was reclassified into two separate species, the western grebe *(Aechmophorus occidentalis)* and the Clark's grebe *(Aechmophorus clarkii)*. Thus was the number of species named for the intrepid explorer doubled.

DANIEL S. BASTAJA
Maple Ridge, British Columbia

Aechmophorus clarkii was named not for William Clark but rather for J. H. Clark, who collected one of the first three specimens of that bird.

Particularly intriguing is the personality of Meriwether Lewis. Here is a man whose mind was gloomy enough to describe a mule deer as "weeping" and a landscape as "drairy." But with dry humor he observed that "the curiossity of our party is pretty well satisfyed" with respect to grizzlies. Throughout the expedition he proved himself a capable naturalist and thoughtful observer. Too bad the journals were not published as he had planned. They may have produced a conservationist land ethic years before the establishment of Yellowstone.

BILLY COX PLANT
Murfreesboro, Tennessee

Your readers may be interested in an item of historical record that has almost been relegated to a footnote. When Lewis and Clark and the corps returned from their exploration, they were received as heroes. Lewis and Clark had their salaries doubled and were each given 1,600 acres of Louisiana Territory by President Thomas Jefferson. The other members of the corps also had their salaries doubled and were each given 320 acres—except one, a man named York who was Clark's slave. He asked Clark for freedom as his reward, but Clark refused. York was reprimanded for being "insolent and sulky" and beaten. It is sobering to know that the dark side of human nature was present during this expedition.

THOMAS O. MADDEN, III
Elkwood, Virginia

Some ten years after the expedition Clark finally freed York and gave him a wagon and a team of six horses.

Perfume

I felt a bit depressed and without faith for the future after I read how the population is increasing and the strain that puts on natural resources. As I put the magazine down, it slipped off the bedside table and opened at Cathy Newman's perfume article. What a wonderful piece of work. She is so right when she describes perfume in her last three sentences—"An elixir to make us forget. Or remember. Or dream."

I have hope for the future, I wish my (and all other) children a happy and healthy life, and I dream that I am sleeping in the middle of a large field of jasmine in Provence.

LIESL VAN RESNBURG
Strand, South Africa

The perfume that caught my eye (or nose, as it were) was the emperor's famous scent. I do not ride over the corpses of my vanquished foes or send loyal men to their deaths (although some fellow workers could probably use a cannon to the midsection), but I would like to know where one could get such an unusual scent.

TIM SEDDON
Prince George, British Columbia

The fragrances of Cleopatra and Napoleon featured on pages 110-11 are not available commercially.

As one whose sinuses absolutely BLOW UP when I encounter someone wearing a little too much scent, I can tell you without a doubt that the world does NOT need a new perfume.

PENNY MITCHELL
Elizabeth, Colorado

On page 102 you refer to civet cats as cats. Civets are not cats but the largest and most doglike of the Viverridae, which include genets and mongooses.

ANTONY BRITTEN
Bryanston, South Africa

Millennium Moments

I was shocked as to why the time line made no mention of the 1932-33 man-made famine in Ukraine. The starvation of over 7,000,000 was a harrowing experience for the Ukrainian people, described in Robert Conquest's 1986 book, *Harvest of Sorrow.*

WASYLL GINA
New Haven, Connecticut

Earth Almanac

Regarding your item about meerkats that baby-sit the young of others—would these be referred to as suricate mothers?

BILL O'BRIEN
Los Angeles, California

Letters for Forum should be sent to National Geographic Magazine, Box 98198, Washington, D.C. 20090-8198, or by fax to 202-828-5460, or via the Internet to ngsforum@nationalgeographic.com. Include name, address, and daytime telephone. Letters may be edited for clarity and space.

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NATIONAL GEOGRAPHIC
Geographica

An Ocean Apparition: Trees From the Past

JAMES A. SUGAR

Barnacled ghosts of an ancient forest, Sitka spruce stumps (right) loom out of the Pacific Ocean at Oregon's Neskowin Beach in a bizarre manifestation of nature's whimsy. Their presence near a popular resort area made them the most prominent of more than 400 stumps that appeared along a 185-mile stretch of Oregon coastline last winter, when elevated sea levels washed away sand and exposed an old forest floor.

Carbon dating indicates that the Neskowin stumps, which measure up to six feet in diameter, are 1,700 to 2,000 years old. The trees were about 200 years old when they were felled and then buried, perhaps by an earthquake and tsunami in the Cascadia region (GEOGRAPHIC, May 1998). Ancient stumps elsewhere on the coast are about 4,000 years old, suggesting an earlier round of tectonic activity, says Roger Hart, a marine geologist at Oregon State University who has studied the phenomenon.

Hart says the stumps have appeared before during major El Niño events like the one in 1997-98, but not for long; extended exposure would have caused them to decompose. "They usually vanish from sight soon after appearing. Something unusual is going on this time," he says.

Divers Near the End of an Era

Carrying out a 1,500-year-old tradition, this woman prepares to dive for abalones, sea cucumbers, sea urchins, and octopuses at Cheju Island off Korea's southern tip. Cheju's female divers, known as *haenyo,* began honing their skills at the age of ten, learning to dive as deep as 60 feet and to hold their breath for up to two minutes. As recently as the 1930s they numbered more than 20,000. Now only about 3,000—most in their 50s and 60s—remain, as their better-educated daughters find work that is less physically demanding. "There are a lot of jobs available for young women these days," says Kyung Sook Schoenman, who has filmed and interviewed the haenyo for a decade. "Ten years from now, there may be fewer than a thousand divers."

KYUNG SOOK SCHOENMAN

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SISSE BRIMBERG (ABOVE); ROBERT I. HENKIN

A New Way to Measure the Sense of Smell

Millions of Americans suffer from hyposmia, or a reduced ability to smell (GEOGRAPHIC, September 1986). Now specialists in the field have begun to use cutting-edge technology to measure the loss and to demonstrate visually the difference between a hyposmic patient and a person with a normal sense of smell. One researcher, Dr. Robert I. Henkin of Washington, D.C., uses functional magnetic resonance imaging (fMRI) scans. He has found that scans of people who can smell normally reveal greater brain activity (above left, bottom) than do scans of hyposmic patients (top) when both are exposed to odors such as peppermint, banana oil, or fish. Henkin says he will use fMRI scans to show whether a drug he is testing helps patients whose hyposmia resulted from head injury or allergy-based nasal problems regain their sense of smell.

■ NGS RESEARCH GRANT

Unearthing a Pioneer Church

SIMON GRIFFITHS (COINS); KIM CAVANAGH

The mud-brick church once cast a formidable shadow in the bustling Jordanian port town of Aila, now called Al Aqabah. It stood 85 feet long, 52 feet wide, and 13 feet high, with glass oil lamps hanging from its ceiling and a cemetery outside. But it was no match for a fourth-century earthquake, which caused it to collapse.

In 1994 a team led by Thomas Parker of North Carolina State University began to uncover the building, which had been buried under sand. By last year the archaeologists had deciphered its layout—a central nave, two side aisles, a chancel where an altar table stood, and a rectangular apse. They also found pottery and these coins that helped them determine it was built in the late third century, the earliest building yet known designed specifically to be a church. Significantly, documents from a Christian council held in 325 mention a bishop of Aila.

"We know that early Christians met in private houses," says Parker. "Until this find, the oldest known churches, in Jerusalem and Bethlehem, were built around 325." Unlike the Aila church, those structures remained in use, their original designs modified over the centuries.

TEXT BY BORIS WEINTRAUB

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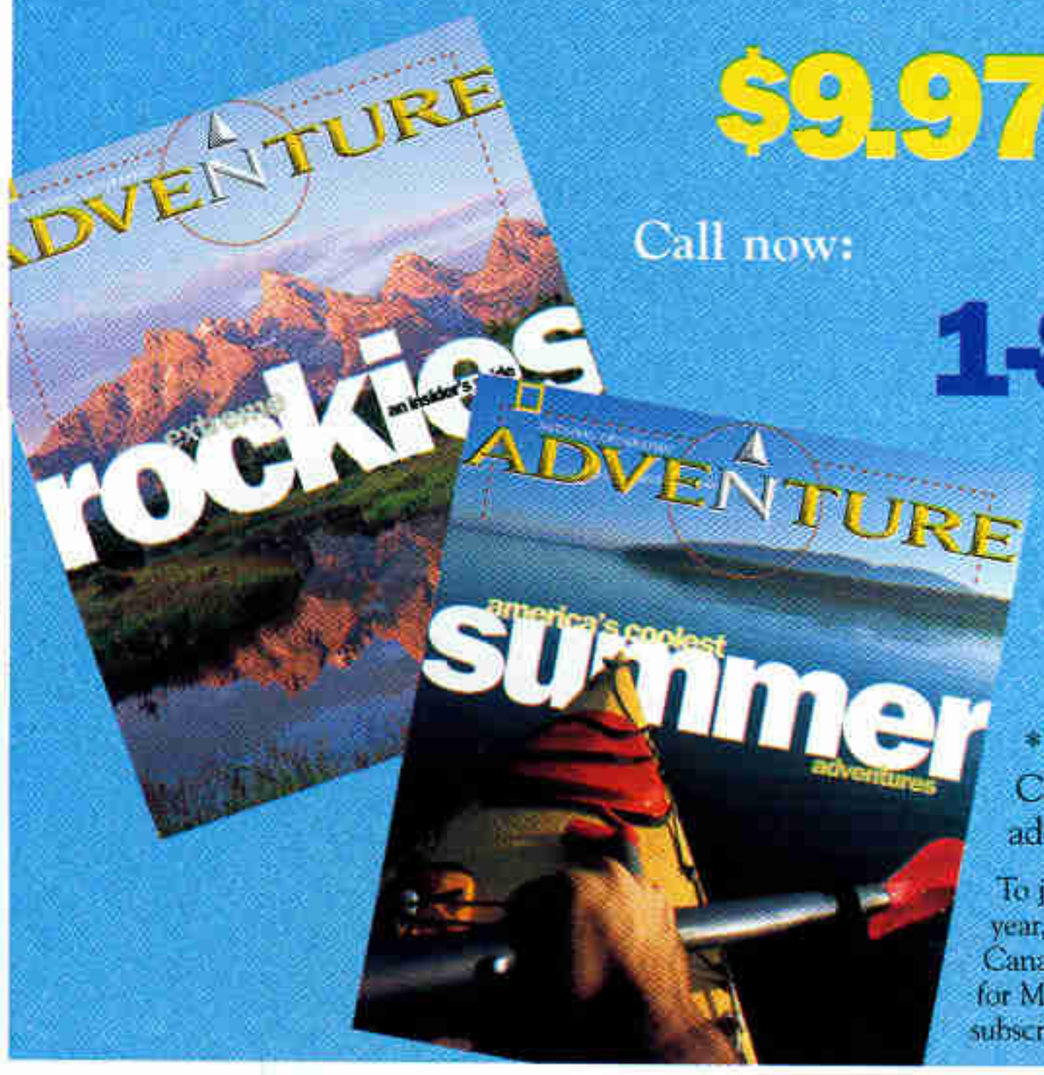

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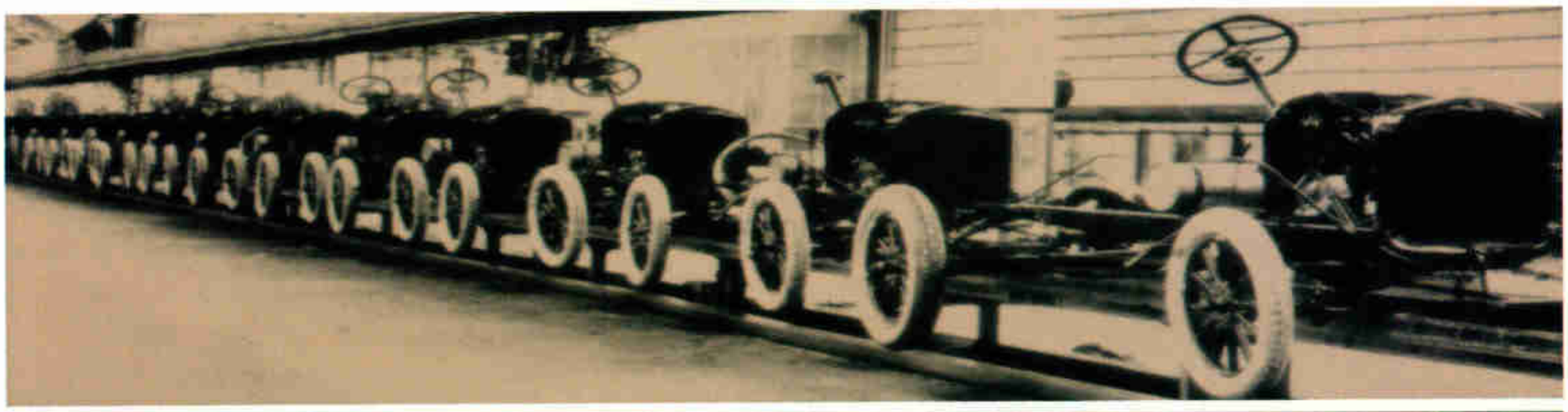

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NATIONAL GEOGRAPHIC MAGAZINE

Western Barred Bandicoot *(Perameles bougainville)* **Size:** Head and body length, 17 - 24 cm; tail, 6 - 10 cm
Weight: 172 - 286 g **Habitat:** Scrub and open steppe on Bernier and Dorre Islands, Western Australia
Surviving number: Estimated at up to 4,000 Photographed by Jiri Lochman

WILDLIFE AS CANON SEES IT

A western barred bandicoot scampers through dense scrub and thickets after nightfall, searching for food. The little marsupial adeptly unearths insects and roots with its sharp foreclaws, and with its long nose probes the sandy soil and crevices for seeds and herbs. During the day, the solitary bandicoot nestles into a shallow nest to sleep, undetected beneath a cover of gathered plant or seagrass litter. This species is no longer found on the mainland, and now exists only on two island nature reserves, where it is protected from introduced predators and habitat changes. As a global corporation committed to social and environmental concerns, we join in worldwide efforts to promote greater awareness of endangered species for the benefit of future generations.

NATIONAL GEOGRAPHIC

From the Editor

JONATHAN BLAIR

NOAH HAD IT EASY. He just held the ark's door while the animals came to him. Nowadays we have to go looking for new life-forms—and in the strangest places. Researchers on the *Johnson-Sea-Link* (right) found a new type of mussel in the Gulf of Mexico. The mussels are nourished by bacteria that in turn live on methane from undersea oil fields. Each year brings similar reports from scientists—including researchers supported by our Committee for Research and Exploration—discovering previously unknown life-forms from the seafloor to the rain forest canopy. Biodiversity, the rich variety of life on Earth, is explored in this month's magazine and map supplement. In fact, any issue from 110 years of NATIONAL GEOGRAPHIC might qualify as an ode to life's often unexpected appearances.

And what about the heavens? We now suspect that one of Jupiter's moons is a virtual ocean planet, and it appears that a second moon has liquid water too. As scientists discover life in Earth's harshest environments, they may be conducting a dress rehearsal for similar revelations in the Jovian neighborhood. The biologists who plumb the oceans, march through jungles, and dream of life beyond Earth are modern-day Noahs. And the passenger manifest on our ark is getting longer all the time.

Bill Allen

THE MILLENNIUM SERIES

BIODIVE

Taking stock of life

■ Horseshoe crabs were once ground up by the millions for fertilizer. Now their blood is used to detect contamination in drugs and medical equipment. Humans have begun to grasp the staggering variety and value of life on Earth just as we push many species toward extinction. How will we save them?

By **Joel L. Swerdlow** ASSISTANT EDITOR

RSITY

FRANS LANTING

What else will we find in what William Shakespeare

Frogs are special to Michael Zasloff. ■ From frogs this physician and biochemist has learned a few of the secrets that link these amphibians with sharks, plants, and humans—in short, with all life. ■ In 1986, while working at the National Institutes of Health, Zasloff noticed that African clawed frogs almost never got infections, even when researchers performed surgery on them and returned them to murky, bacteria-filled water. Two months after making this observation, Zasloff discovered that the frogs' skin secretes a previously unknown family of antibiotics that protect the frogs from infection. He named these antibiotics "magainins," derived from the Hebrew word for shield. ■ I meet Zasloff in Plymouth Meeting, Pennsylvania, where he founded Magainin Pharmaceuticals in 1988. I have come to ask him about his views on biodiversity, the intricate web of animals, plants, and all other living things that populate the planet. A vital element of biodiversity is not only the number of species, but the genetic diversity within species. ■ "Frog species are disappearing all over the Earth, and that concerns me," Zasloff says. He rolls up his sleeves and pulls an African clawed frog out of a holding tank. The frog is green with black and yellow speckles on its back and a silver underbelly. Holding it in the palm of his hand with its legs between his fingers, he sprinkles adrenaline powder on its back, stimulating an "I'm injured" signal in the frog's nervous system. Nothing happens. Then pinpoints of white fluid, like antibiotic cream from a home medicine cabinet, ooze from the frog's skin. Soon the white fluid covers the top of the frog's body. ■ "We're watching the arrival of a mixture of chemicals that kills virtually all known bacteria," Zasloff says. This discovery is important because bacteria, a significant cause of human illness and death, are increasingly resistant to antibiotics. ■ All frogs and toads secrete defensive fluids, many of which possess antibiotic properties. That's why Chinese folk healers have treated wounds such as sores and dog bites with toad secretions, sometimes obtained by surrounding the toads with mirrors to scare them. ■ While such methods may sound strange, a large percentage of medicines used in Western countries come from nature or from chemical formulas found in nature. Steroids, penicillin, digitalis, morphine, and aspirin are only a few examples. One of the

called "nature's infinite book of secrecy"?

most exciting discoveries in medicine is Taxol, which fights breast and ovarian cancer and is derived from the bark of the Pacific yew tree. Other promising leads come from a major source virtually untapped by both traditional and modern medicine systems—the ocean. Candidates include an anticancer drug from a deep-sea sponge and a painkiller from the venom of a tropical cone snail. ■ What else will we find in what William Shakespeare called "nature's infinite book of secrecy"? Zasloff's frog breakthrough is a random selection from this book. So is his 1992 discovery of a previously unknown molecule in the liver of the dogfish shark. Called squalamine, the natural steroid fights cancer by cutting off blood flow to tumors. ■ There's more. The chemical structure of squalamine closely resembles substances found in the bark of *Holarrhena*, a deciduous tree growing in Asia and Africa, and in *Chonemorpha macrophylla*, a climbing plant with sweet-scented flowers that grows from Java to the foothills of the Himalaya. "How can a shark's liver and tree bark have anything in common?" I ask Zasloff. ■ "Both the shark and the tree bark are working on ways to defend against organisms that attack them," he says. "Both sharks and trees have solved the same problem but from different directions. But what's most amazing is that native Africans and practitioners of Ayurvedic medicine in India use bark from *Holarrhena* to combat dysentery. *Chonemorpha* is also used in India to treat skin disorders." ■ Zasloff shows me a computer printout listing 15 other previously unknown molecules he has identified in the liver of the dogfish shark. "There's so much we don't know about the natural world," he says. "And we're destroying large parts of it before we even appreciate our ignorance." ■ Ignorance makes it easier to explain away the loss of biodiversity. Extinctions, after all, are part of nature. Billions of species have existed since multicellular life began, and 99 percent of them have disappeared. While extinctions may be a natural part of life on Earth, experts note that humans, in our search for food and living space, are accelerating the process by hundreds to thousands of times. ■ But humans also have the capacity for moral responsibility and the ability to appreciate the risks we may be taking. Destruction of biodiversity is not inevitable. As Virginia Morell and Frans Lanting show us in the pages that follow, we can savor nature's book of secrets as we learn to read it. □

The millennium series spotlights six subjects shaping our destiny. Articles in the August 1999 issue will focus on human culture. For more on the millennium visit www.nationalgeographic.com.

The Variety

■ Life comes to light when Piotr Naskrecki illuminates a sheet in the Costa Rican rain forest. The katydid

# of Life

By VIRGINIA MORELL
Photographs by FRANS LANTING

he grasps is new to science. What do we know of biodiversity? "We find new species every night."

■ A desert spadefoot frog surfaces with a wary stare at Australia's Alice Springs Desert Park. Life hides in

unexpected places: These frogs wait for rain deep in the outback's red sands—for years, if need be.

■ Crippled ark, this island in the Panama Canal was once a hilltop in a vast forest. As the planet's remaining

patches of wild land become smaller and more isolated, the number of species they can sustain shrinks.

The natural world thus stretches before

IT'S FOUR O'CLOCK in the morning in a remote Ecuadorian rain forest, and the odd thing is how much, at this wee hour of the day, the forest feels like a deserted city street. The electric hum of insect life that gives a tropical rain forest its sizzle is switched off. And that, says Terry Erwin, an entomologist from the Smithsonian Institution, is why we're awake and on a forced march to his study site. We have to get there at the insect world's equivalent of the Cinderella hour, when both the day- and night-roaming insects are at rest in the trees. Only during that sliver of time, Erwin had explained to me, could he and his team of students catch them all.

Silently we travel single file through the dark woods, our headlamps casting bright pools of light along a narrow, muddy trail. I see Erwin, a wiry, fit man in his late 50s, pause at a small stream ahead of me, then jump across. "It's higher today," he calls over his shoulder as he presses on. In the dark I can't judge how high the stream is and so simply step in, only to sink up to my knees. Brown water pours into my calf-high rubber boots, but there's no time to empty them: We have an appointment to keep. I squish along after Erwin, listening to the cries of dismay from others behind me who meet the same wet-footed fate.

A half hour later we reach a trail marked with pink surveyor's tape, and the team moves into action. Erwin and two students load two gasoline-powered foggers, which look like leaf blowers, with a biodegradable insecticide while other team members run down the trail, suspending ten white sheets just above the forest floor at random intervals. When the last sheet is open, Erwin looks at his watch: It's 4:40. "Ready?" he asks his crew. They nod yes. "Then *vamos a comenzar*—Let's begin!"

Erwin starts up one fogger and aims it at the night sky. The roar of the motor rips through the forest while an acrid blue-white cloud rises in a narrow column above the first sheet. Lazily, the deathly cloud passes through layers of spindly, broad-leaved shrubs, engulfing every leaf and twig. It swirls over the tops of the lacy fronds of palms and tree ferns and climbs up the smooth-sided trunk of a giant fig tree to the tips of its branches and the stars beyond. Within seconds insects begin to spill from their

---

VIRGINIA MORELL, a correspondent for *Science*, lives beside the biologically diverse Siskiyou Mountains in Oregon. To read more from her on how recently discovered life-forms on Earth help astronomers understand how life might form on other planets, go to *www.nationalgeographic.com/2000/biodiversity/biomes*. Photographer FRANS LANTING is a contributor to the upcoming World Wildlife Fund book *Living Planet*, which documents "savable" ecosystems.

scientists . . . like the uncharted seas of old.

FRANS LANTING WITH JOSEPH S. STANCAMPIANO, NGS

resting perches onto the sheet below. But Erwin doesn't wait to see what he's caught; he's off running down the trail to the next site, where he points the fogger again at the sky.

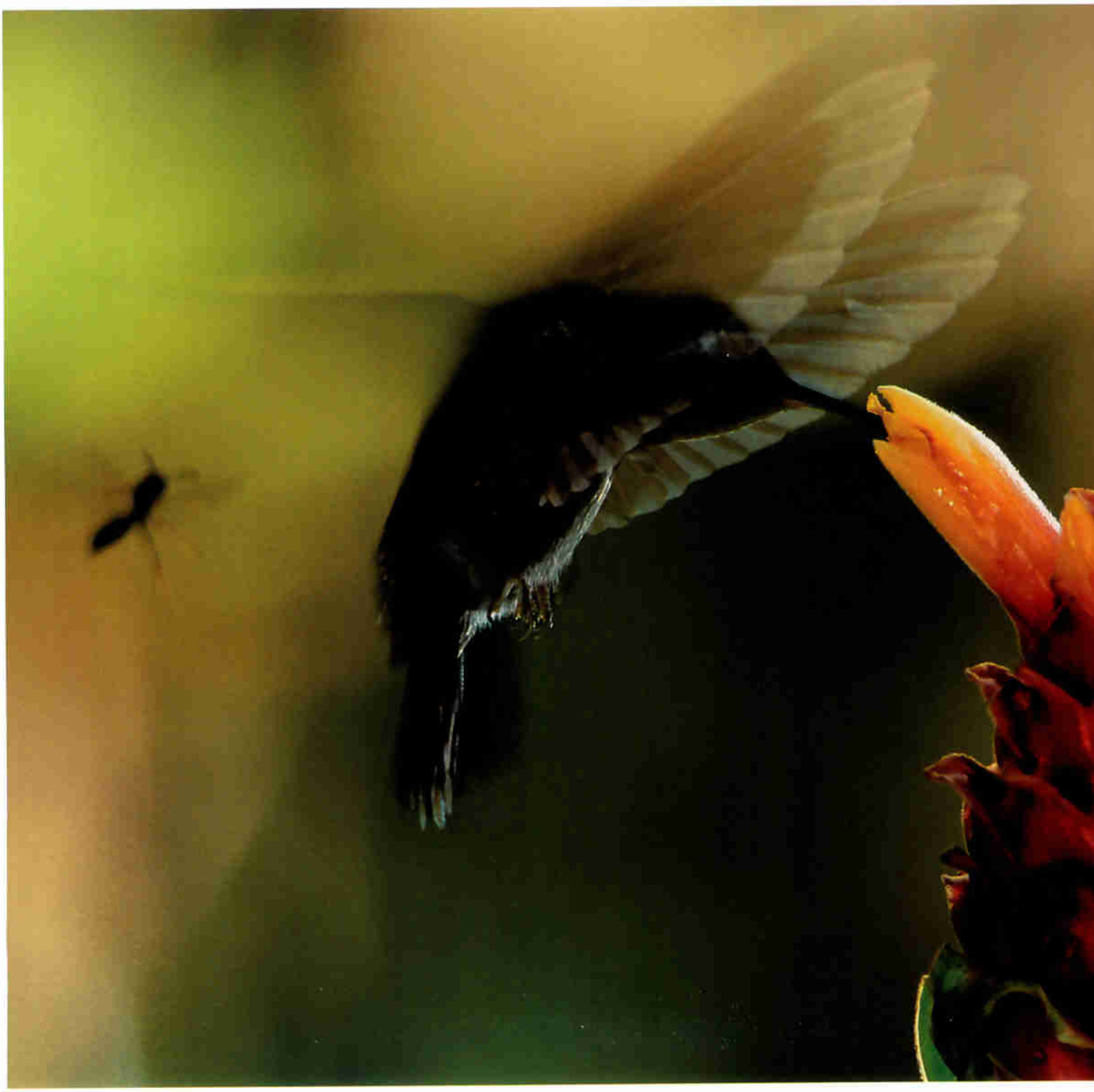
Such an inventory of the forest's insects is important, Erwin had explained earlier, as a measure of the forest's overall biodiversity—the shorthand term biologists use to describe Earth's bountiful variety of life. Based on similar counts he's made, Erwin once estimated that we share the Earth with some 30 million

"Diversity at its utmost," says biologist Terry Erwin of the humble beetle. Scientists have named 350,000 species—one-fifth of all known forms of life. "There are millions left to discover in the last biotic frontier, the rain forest canopy," he says. Erwin fogged one tree in Peru with biodegradable pesticide and counted more than 650 beetle species.

■ A scarlet banksia blooms like fireworks in Australia's southwest. Not all biodiversity hot spots are tropical.

This region's poor soils support 2,830 endemic plants—species that grow nowhere else on Earth.

A hummingbird picks up more than nectar at a flower in Costa Rica's Monteverde Cloud Forest Preserve. Pinhole-size mites live in the blossom. When the plant's last florets bloom, mites wait for a bird's bill to enter, then climb on and sprint to the bird's nostril at cheetah-like speed—12

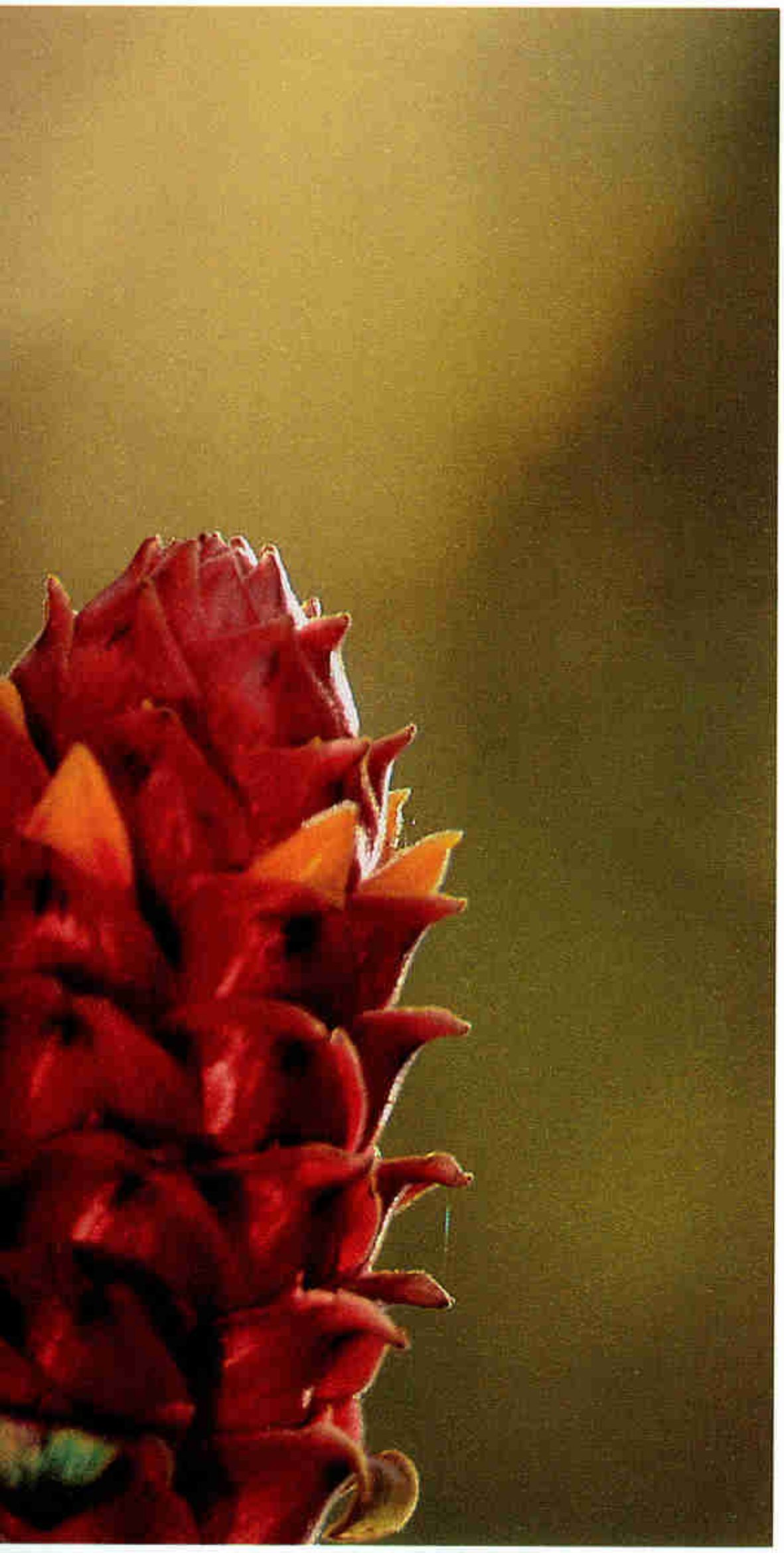


different species of animals and plants. While other biologists think that Erwin erred on the high side, he's certain that his first estimate was too low.

"I'll bet the figure is closer to 100 million," he says, shaking his head at the thought of the sheer numbers and the varied forms that DNA—the basic building block of life—has taken. Of those many species—whether 100, 30, or 10 million—biologists have described but a tiny fraction: only 1.75 million. "We don't know how many species there are, and we still can't explain how they interact, or even the relationships among the organisms in one column of forest. I've found 28 different species of fig weevils in one tree."

Nor is it just insects: Life, we now know, flourishes from the canopies of the tropical forests to the deserts of Australia to the hot volcanic cracks in the bottom of the seas. This great diversity sustains human life, maintaining the most fundamental resources—air and

body lengths per second. The stowaways cling till they smell the familiar perfume of a new host plant, then deplane. Each plant species visited by hummers shelters a different mite. Many organisms share hidden links with others; when a species dwindles, partners and parasites suffer.



water. It also gives the opportunity to make wonderful, life-changing discoveries. For instance, some of the most effective cancer treatments come from a chemical discovered in a plant from Madagascar decades ago, and a microbe harvested from Yellowstone's hot springs has provided the perfect enzyme for mass-producing DNA, leading to today's boom in genetic research. A wild species of maize promises to reinvigorate corn crops. The natural world thus stretches before scientists such as Erwin like the uncharted seas of old, and researchers puzzle over what they know and don't know like sailors stepping ashore on a new land.

ERWIN'S NEW LAND is that of the upper canopy, the limbs and leaves that rise a hundred feet and more above the tropical forest floor. He started collecting insects in this special habitat 25 years ago in a Panamanian rain forest, and what he found when his team released their columns of fog is still staggering: some 1,200 different species of beetles alone.

"That translates to 42,000 different insect species per hectare [2.5 acres]," Erwin tells me later that day at the Tiputini Biodiversity Station. "Here we're finding even higher numbers, suggesting at least 60,000 per hectare," he continues, opening one of the collecting bottles from today's catch and pouring its contents into a white enameled tray.

Piled together in a pool of alcohol lie brilliantly colored grasshoppers, leafhoppers, dragonflies, beetles of every size and hue, from species no bigger than my little fingernail that shine as if made of liquid gold to others three to four inches in length, which are black and grotesquely armed with horns and spikes. Floating beside them are mantises and ants, mites, bees, and spiders. "Now, there's biodiversity for you, and that's just from one column of forest," he says, handing me a pair of tweezers. "Go ahead—pick through it. I dare you to find any two individuals of the same species."

Gently, I use the tweezers to nudge apart this wet mass. On top lie the giant insects: praying mantises and walking sticks; a katydid, with its green wings veined and shaped like leaves that a caterpillar has munched; a helicopter damselfly with bright daubs of yellow at the end of each wing; and big black-brown horned beetles. Beneath them are tiny weevils, like bits of black obsidian with ocher yellow legs; an inch-long, yellow-green grasshopper, its red and black stripes giving it the racy, tricked-out look of a Chevy lowrider; and a fat caterpillar with

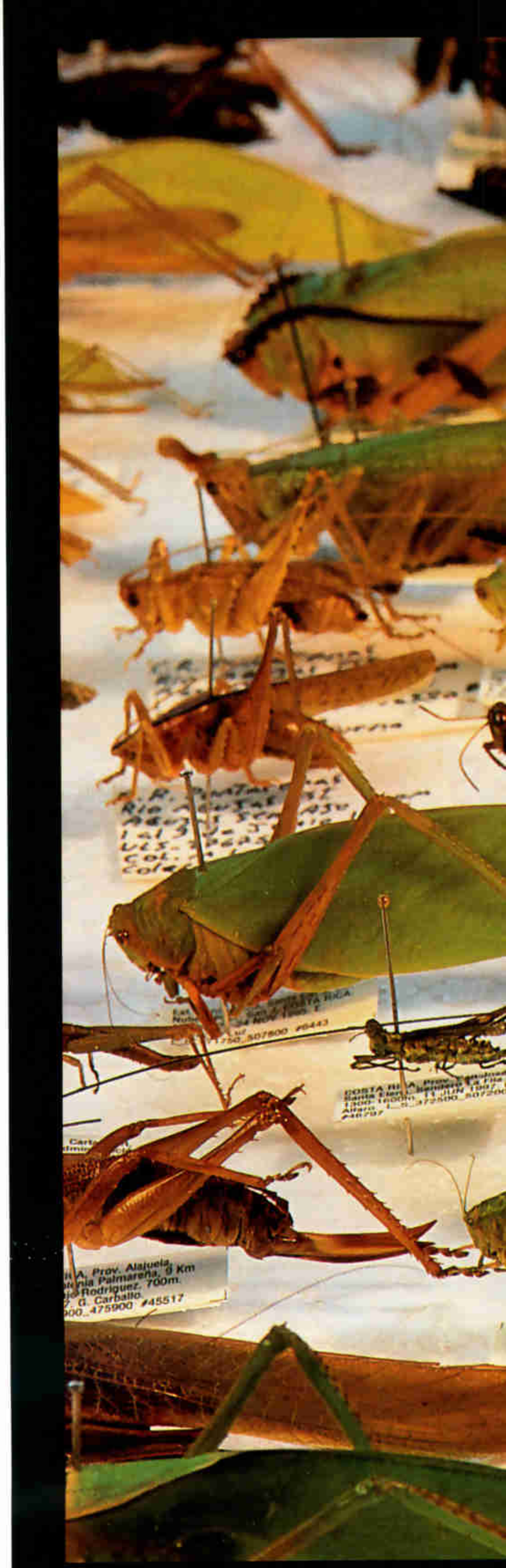
the red-and-cream mottling of a chunk of agate. I lift up what looks like a chip of fiery orange plastic—only the black, bulging eyes tell me it must be an insect.

"Oh, that's one of the E.T.'s," explains Pablo Araujo, Erwin's chief assistant. "It's a leafhopper nymph, but it is trying to look like something never seen on Earth to fool the birds."

Erwin picks out a reddish brown scarab beetle and places it under a microscope. "Look here. You can see the mites on its back, and others under its wings." Each is a different species living in a special habitat, one so small that Erwin calls it a nanohabitat. Further, each of these mites, as well as nearly all the insects from this single column of forest, are very likely new to science. "We're the first people to see most of these insects," Erwin says, "because they live in the forest's upper canopy, and we're usually limited to what we see at eyeball level."

And, of course, Erwin's insects are only part of life's variety. Here at this one site on the Equator, in about 1,500 acres, scientists have counted 3,000 species of plants, 530 species of birds, nearly 80 species of bats, and 11 species of primates. There are jaguars and other wild cats, tapir, deer, otters, capybaras, and agoutis—all bearing unknown numbers of internal and external parasites. There are uncounted numbers of reptiles, amphibians, and fish with their own parasites, plus the invertebrates and microorganisms lurking in the forest's soil. Somehow, these disparate species are all connected, says Erwin. "But we really don't understand how these connections work, or how they come about. If someone took apart this forest, we couldn't rebuild it—we wouldn't even get close."

HALF A WORLD AWAY in a lab in cold, blustery Oxford, England, Paul Rainey, a geneticist, is tackling that very issue—the rise of life's variety. "It's difficult when you're in the heart of a rain forest to sort out the origins of biodiversity," he says, setting a sealed test tube in front of me. "Or to understand what maintains it." That's why Rainey, an intense, dark-haired man in his 30s, has turned to bacteria. He uses a common bacterium, *Pseudomonas fluorescens*, which thrives in the soil as well as



■ A drawerful of Costa Rican insects hints at diversity's source: the splendid variety of ways to make a living—in this case, the art of camouflage.

SPECIMENS FROM INSTITUTO NACIONAL DE BIODIVERSIDAD, SANTO DOMINGO DE HEREDIA, COSTA RICA

Life's rich tapestry

Counting species is an imprecise science. Some 1.75 million have been officially classified. Totals are sure to change, but according to biologist Edward O. Wilson the relative numbers of known species in major taxonomic groups (represented by the icons at left) speak loudly: "Little things rule the world."

Biologists agree that human limitations distort our view of nature's true breadth. Some organisms (bacteria, nematode worms) are undercounted; some habitats (tree canopies, the deep ocean) are largely unexplored. Estimates of actual species range as high as 100 million.

How many species?

Insects and myriapods
(centipedes, millipedes)
963,000

Plants
270,000

Fungi and lichens
100,000

Protozoans and algae
80,000

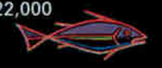
Chelicerates
(spiders, scorpions)
75,000

Mollusks
70,000

Crustaceans
40,000

Nematode worms
(hookworms,
filarial worms)
25,000

Fish
22,000



Flatworms
(flukes,
tapeworms)
20,000

Annelid worms
(earthworms,
leeches)
12,000

Reptiles and amphibians
10,500

Birds
10,000

Cnidarians
(jellyfish,
corals, anemones)
10,000

Sponges
10,000

Mammals
4,500

Bacteria and archaea
4,000

Other organisms
10,000

ART BY STÉPHAN DAIGLE

on plants, to grow a rain forest in miniature.

Four days before my arrival Rainey had placed a single bacterium in the vial along with a nourishing glycerol-based broth. Within that short period, the sole bacterium—which, as its name implies, is fluorescent, a brilliant yellow—had quickly diversified into a range of new forms in the test tube's different habitats. These vary by oxygen level, with more of the gas at the surface and less at the bottom. Some types had made a mat on the surface of the nutrient solution; others had evolved a mucus-like quality that enabled them to grow like a bathtub ring around the tube's inner rim; while others made a home on the very bottom. "If you tried to count all the different types, you'd be bamboozled," says Rainey. Yet as different as they look, they've all come about because of two factors: ecological opportunity and competition.

"They've always been thought to be essential to biodiversity, but no one had ever tested the idea before," says Rainey. At times in the distant past, for example 540 million years ago at the start of the Cambrian period, the world was almost as empty as one of Rainey's starter test tubes. But the few forms of life that did inhabit the Earth's seas exploded virtually overnight into new species that soon inhabited every nook and cranny of the globe. "That happened because there were so many unoccupied environments and intense competition between forms of life," says Rainey. On a far smaller scale Rainey's test tube offers the same opportunities to the bacterium—which it seizes instantly.

"That was what astonished me, how quickly these many forms appear." But that diversity can also be lost in an instant: Shaking the test tube destroys its mix of habitats—and the varied forms of bacteria. "It's the variety of environments—the surface of the broth, the vial's edge, and the bottom—that maintains the diversity," notes Rainey. "And that's true for the biodiversity of the natural world as well."

BOTANISTS HAVE LONG MARVELED at the variety of plants packed along the southwestern edge of the tip of Africa. Proteas, leathery-leaved shrubs with flowers the size of soup bowls, heatherlike ericas, irises, orchids, and succulents all vie for a place in the sun.

To explain how this mosaic of greenery has come about, botanists John Manning and Peter Goldblatt lead the way through low clumps of stiff, spiky-leaved plants that cover the sandstone, shale, and limestone soils of South Africa's cape region. Although much of the flora looks alike—twiggy shrubs with tiny, dark green leaves—the botanists note that almost every plant we stop to inspect is a distinct species from a different genus and family. Indeed, the plants that make up the *fynbos*, as this unique type of vegetation is collectively known, are among the most diverse in the world. Because botanists find new species here every year, that tally of diversity keeps growing.

The cape's 35,000 square miles harbor nearly 9,000 species of plants; California, four times that size, is home to only 5,500. It's those kinds of discrepancies that scientists like Manning and Goldblatt are trying to understand. Why in some parts of the world, such as the cape and the Ecuadorian rain forest, is there such an exuberance of life?

"The cape is extra rich for a temperate zone," says Goldblatt, a researcher with a sunny disposition from the Missouri Botanical Garden who spends several months each year studying the area's fynbos in an attempt to answer that question. "Usually you associate this kind of diversity with the wet tropics. Here we think it comes about because of the numerous microhabitats we have," he says, citing the variety of soils, the sudden rise in elevation from coastal plain to mountaintop, the variable rainfall, and sporadic fires. In short, the fynbos—like the Ecuadorian rain forest—is Rainey's test tube writ large.

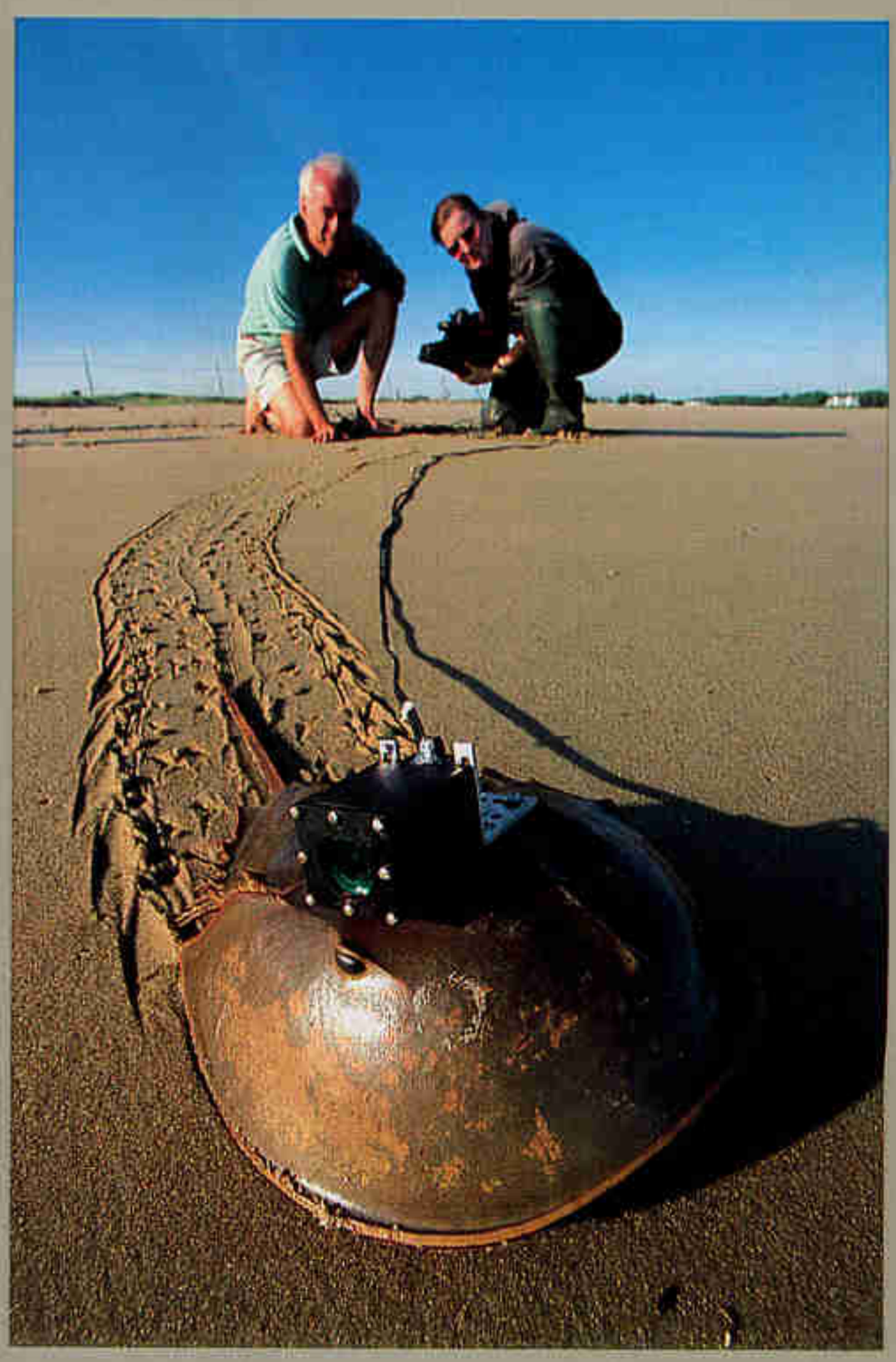
But there's another element at play: the plants' pollinators, which can act to keep species apart and to help form new ones. Consider the cape's long-tongued flies, says Manning. A dapper botanist from Cape Town's Kirstenbosch National Botanic Garden, Manning is collaborating with Goldblatt on a study of these curious insects and their tight relationships with certain flowers. In his office at the garden, Manning brings out two display boxes with dozens of long-tongued flies pinned and labeled in neat rows. They vary from about a quarter inch to an inch in length and with their wide, transparent wings look more like bees than flies. As their name suggests, these flies' proboscises are long, in some cases a good two to three inches in length. And because the flies

Horseshoe

Unlikely poster child for conservation, the horseshoe crab has changed little since an ancestor was fossilized 150 million years ago (left). Spawning crabs swarm Delaware Bay beaches in spring, fueling an egg-eating frenzy of gulls and migratory birds. Easy pickings also help a fisherman, who kills crabs for bait (right). Studies suggest that populations are dropping, leading some states to restrict harvests. Declines would be bad news, given what the crabs do for us. By decoding their visual system,

Crabs

researchers like Robert Barlow (below right, with CrabCam) have learned much about human sight. At Associates of Cape Cod, crabs are bled (bottom right) to extract a reagent used to test drugs and medical devices for contamination, then released. "This is a lesson," says ACC's Michael Dawson. "What about other species? What resources are being lost?"



With the profile of a dinosaur and the texture of a rose bush, a thorny devil in Alice Springs Desert Park looks like trouble, but this slow-moving, six-inch lizard eats only ants. When alarmed, it tucks its head between its legs and offers the lump on its neck—a false head—to predators.

cannot retract them or coil them up neatly as a butterfly does, their proboscises stretch out in front all the time like black piano wires.

"There are some long-tongued flies in India and California," says Manning, "but nowhere else do you find this kind of diversity." It shows, he adds, how diversity in one group of organisms—the flora—can promote diversity in another group, and vice versa.

"There are certain irises, geraniums, and orchids whose reproduction wholly depends on one species of long-tongued fly," explains Manning. It happens to be the fly with the longest proboscis of all, *Moegistorhynchus longirostris,* whose genus name translates appropriately to 'giant-nosed fly.' The orchids, irises, and geraniums that signal to it all bear flowers with strikingly similar colors and structures—small cream- to salmon-colored petals poised on narrow, long tubes that hold a pool of nectar at their base—even though these plants are not closely related. To make sure that the right pollen ends up on the right flower, each species deposits its pollen in a different place on the fly's body. In some species the flowers' anthers brush the underside of the fly; in others the anthers touch the fly's head or sweep the back of the fly's thorax and abdomen.

"We think the fly has stimulated the evolution of these flower types," says Manning. And since some of the flowers can be pollinated only by *M. longirostris* (no other insect has a proboscis long enough to reach the rich nectar), the fly must be considered a "keystone species," Manning adds. In other words, without this particular fly these plants would become extinct, altering their overall ecosystem in unforeseen ways. And with them, too, would go the delightful sight of a fly hovering above a blossom, searching for a drink of nectar with its impossibly long tongue.

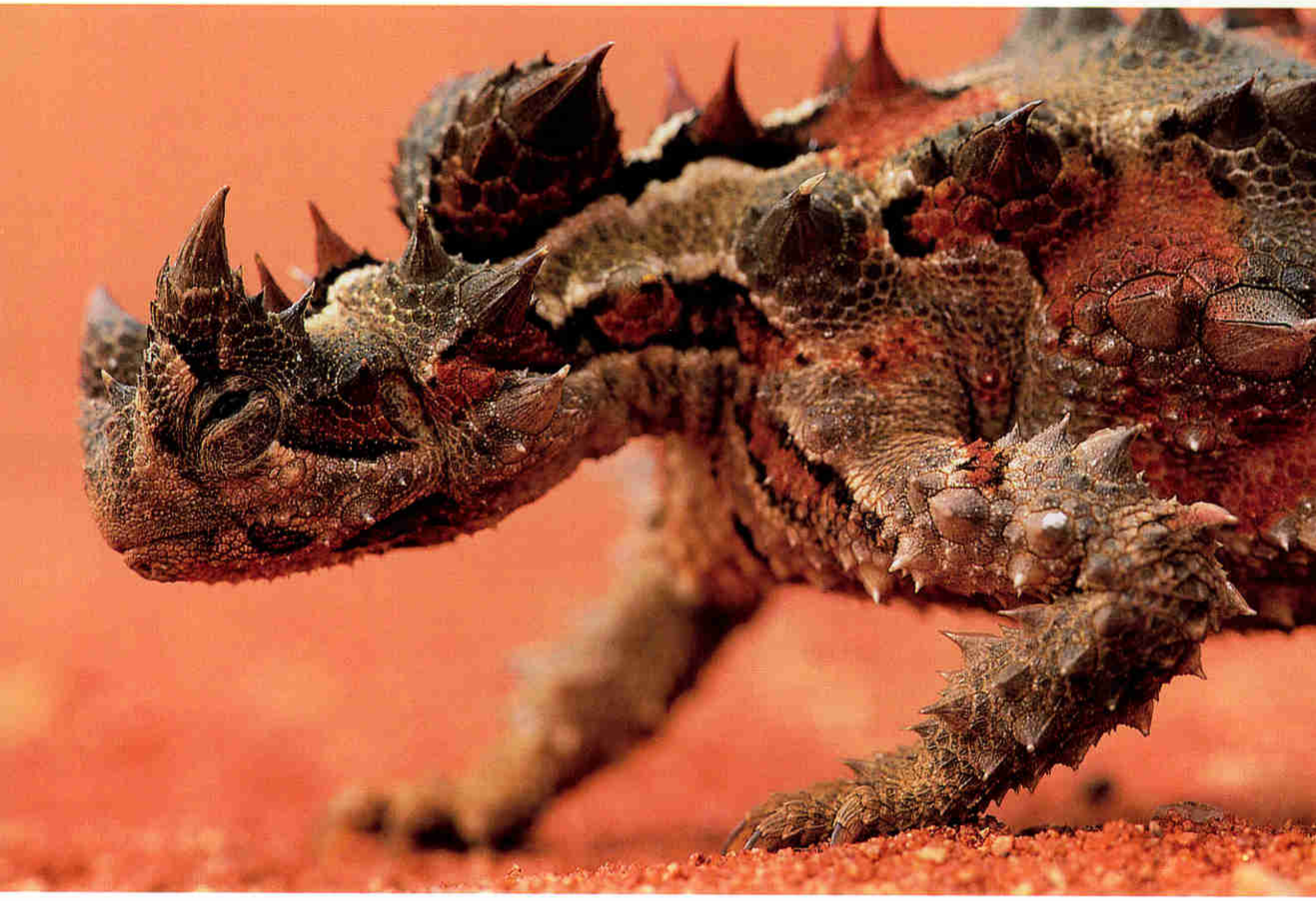
IT'S BECAUSE of that all-too-real threat of extinction that many biologists are racing to understand the world's biodiversity. Already in many parts of the globe, from southern California to the Atlantic coast of Brazil, habitats have been so altered that what is left is but a shadow of what once was. "That's true here too," says Chris Dickman, an ecologist at the University of Sydney in Australia who's studying the small marsupials, rodents, and lizards of one of his country's most remote regions: the Simpson Desert, which lies almost in the middle of this island continent.

"There used to be bettongs, bilbies, and bandicoots out here," says Dickman, listing some of the stranger medium-size marsupials. We're walking up a brick red sand dune in the bright morning sun, dodging the needle-sharp clumps of spiky spinifex to reach the traps Dickman had opened the night before. "One of the Aboriginal station hands remembers eating bilby as a kid," he adds. Although not extinct in Australia, these creatures have vanished—probably forever—from the Simpson, largely because of the introduction of foxes and cats, animals not native to this land. "So while I can unravel the present ecosystem to some extent, we'll never know how different it was here in the past. Those marsupials are the ghosts of communities past."

Yet even without them the Simpson boasts an astonishing diversity of life, particularly for such a harsh, arid land. "That's why I'm out here," says the blue-eyed Dickman, who, although an Englishman by birth, finds the desert and its specialized creatures so appealing that he ventures here as often as he can.

"We've got six species of rodents, eight small marsupials, four frogs, and 47 lizards here. Now, how can an environment that's so poor in evident resources be so good in its variety of species? If I could crack that one, I'd be a long ways toward explaining diversity anywhere." He gives a quick smile, then kneels in the sand next to an aluminum mesh fence about six inches tall. It's stretched a few feet below the ridge of the dune and runs along the sand for some yards. In the center lies the pit trap: a plastic pipe that's buried up to its rim. The small mammals and lizards that Dickman studies can't cross the fence, and if they run along next to it, they eventually fall into the pit.

Tiny channels in the devil's skin route precious rain and dew to its mouth. Isolated for 40 million years, Australia is an evolutionary factory of endemism. Seven hundred sixty-five reptile species live here, more than in any other country; 90 percent can be found only down under.



Dickman leans forward, peering into the trap. "Got one," he says, with evident satisfaction. Placing a small cotton bag over his hand for protection, he reaches down into the pit, then turns to show me his prize. "It's a mulgara," he says, holding the tiny, struggling marsupial firmly by the nape of its neck. "A carnivore." About eight inches long from pointy nose to black-tufted tail, the cinnamon-colored mulgara looks like a cross between a mouse and a fox. But it has none of a mouse's timid ways. It's a fierce predator that readily pounces on other tiny marsupials and rodents, dispatching them with a bite to the back of the neck and then devouring them from head to tail, neatly inverting the skin as it does so, like skinning a banana.

As if set on proving its ferocious reputation, this mulgara quickly latches onto Dickman's thumb as he turns it over to determine its sex; it leaves a row of sharp little tooth marks behind but draws no blood. "Well, she seems to have had her Wheat-a-Bix this morning," Dickman says. "She's just a youngster; no pouch development yet," he adds, showing me the soft pink circle on her stomach that will one day hold her young. He weighs and measures her, then carefully clips tiny triangles of skin from the edge of her ears to mark her. By marking and releasing the animals he traps and, with luck, catching them again, Dickman is discovering the specific habitats within the desert that each species prefers and how far afield they travel.

"I started this in 1990," he says, setting the mulgara free near a clump of spinifex, "and so far, it seems that the type and amount of vegetation is what affects the animals' diversity." Dickman consistently catches mulgaras along the sides and at the bottoms of the sand dunes,

Defenseless natives, lobelias and greenswords flourish in Maui's Pu`u Kukui Watershed preserve, where they're protected from introduced pigs, goats, and deer. Hawaii's plants evolved in the absence of indigenous browsing mammals and therefore bear no thorns or toxins.

never on top. Other mousy-looking marsupials, ningauis ("little wild hairy people" in Aboriginal folklore) and dunnarts, turn up in all the traps, from the bottom to the top of the dunes, as long as a clump of protective spinifex is nearby. Planigales, with a distinctively flattened head, prefer the swales between the dunes and cracks in the soil, where they squeeze along bracing themselves with their feet out to the sides like climbers in a crevasse. Similarly, Dickman finds the central netted dragon, a lizard with dark Spiderman-like markings covering its red-brown scales, more often in open areas, while the military dragon, which has gray spots on its back and black, white, and yellow stripes along its sides, lives in and under the spinifex clumps.

"You never find all 47 species of lizards living on one dune at the same time," says Dickman. "They come and go from year to year depending on the conditions—how much vegetation there is, how much rain there's been. Same with the mammals. It's what makes answering that question—how do you explain the diversity—so tricky." All the elements are so variable. "I'm looking for a pattern," Dickman adds, "something that might explain the turnover." It may be that the constant shuffling of species, some increasing with the rainfall, for example, and others disappearing, helps keep the overall variety high, he says. "But it's a puzzle. That's why I'm out here; I'm looking for a way to fit the pieces together."

"OH, YES. That's certainly one of the big questions we have about the life around us," says Edward O. Wilson, the Harvard biologist who's credited with, among other things, popularizing the term "biodiversity." We're sitting in the shade of a remnant rain forest on—of all places—the island of Barbados, where Wilson's come to collect ants, recording, as he's done for some 50 years, more details about the Earth's diversity of life. "It just shows you how little we know about these fantastic creatures we share the Earth with," says Wilson. "We don't know how many there are, or what kinds of things—new medicines or chemicals—they have to offer. It's like a library of unread books, and we haven't even finished the first chapter. And the great tragedy—more so for our grandchildren, who I think are going to be (how should I say it?) really peeved at us—is that we're losing the species around us before we can even turn the next page. Too many are dying that don't need to die."

But this tall, gangly man, with a love and enthusiasm for all living things, is an optimist at heart. Only about 50 acres remain of this island's original woods, but Wilson doesn't fret over what has been lost. Instead he takes heart in what remains. "Most of this forest was destroyed 300 years ago. But why is this remnant left; why is it protected?" he asks, leaning forward. "Partly because they can't grow sugarcane where it's too hilly, but also because some people here know it's a wonderful treasure. They're biophiles: lovers of nature. I don't think that's an exceptional trait; I think humanity is biophilic. We love the creation around us."

Wilson turns back to his ant collecting, sticking a trowel into a rotten piece of wood. Out scurry three different species of ants, and Wilson chuckles as he scoops them into collecting vials. His lifelong study of ants has given us a fresh understanding of the social animals, from bees to naked mole rats to humans, just as other researchers' analysis of the yew tree has given us new drugs for combating cancer.

High overhead a wind blows through the locust trees, rustling their pale green leaves and rippling the fronds of the macaw palms. Dappled light plays over the forest floor, and somewhere in the distance a bird fills the air with its trilling call. I walk deeper into this little patch of woods and wonder at the wealth of life around me, from Wilson's ants to the soaring palms. Like the insect-rich rain forest canopy and the Martian red desert of Australia, this fragmented forest is yet another uncharted shore of life. But even in its small space I feel the pull of the unknown, the call of mysteries to be unveiled.

■ A seedling finds a foothold on a palm leaf in Peru. The pioneer shares a tiny patch of detritus with

myriad fungi and microbes. Nature hides miraculous ecosystems in every improbable corner of the planet. □

By VIRGINIA MORELL
Photographs by FRANS LANTING

Wilderness

■ Sizing up a frog, biologist Carlos Rivera Gonzales assists in a vital survey of Peru's remote Vilcabamba

Headcount

region. The wealth of species cataloged may encourage the government to protect its fragile habitats.

"Vilcabamba has been a big question mark in

"I'M BEING BITTEN by the flies that carry leishmaniasis," says Louise Emmons, a hint of irritation in her voice. We're perched on a bench-high root of a soaring fig tree, one of two that flank a small, muddy sinkhole. Night has just fallen, and under the Peruvian forest canopy there isn't a glimmer of light. "And what does that fly's bite feel like?" I ask, trying to mimic her field biologist's air of indifference. "Not much. A pinprick. You'll know if you get it," she adds. "You'll get a sore that doesn't heal." A dark thought for a dark night, I think gloomily.

But Emmons, a small-mammal expert at the Smithsonian Institution, isn't one to dwell on such hazards. She's spotted a bat's swift flutter overhead and is already on her feet, her headlamp switched on. "We've got some more coming in," she calls to her two Peruvian colleagues, who quickly join her. The trio beam their headlamps down the length of net they've strung between the fig trees. And there, flapping as futilely as I had at the flies, are half a dozen bats. There is always the possibility—and anticipation—that at least one will be new: a species never seen by a scientist until that moment, and one perhaps that lives only in this forest and so is one of those intriguing creatures that scientists call endemics.

Hunting for endemics—whether bats, birds, reptiles, ferns, or flowering trees—is one reason for this expedition, and one reason why the team's nine zoologists and botanists shrug off everything from the calf-high mud to the flesh-tearing spiny bamboo to the flies that carry leishmaniasis. They're on a mission, a Rapid Assessment Program (RAP) organized by Conservation International, in this forest of the Vilcabamba Range in south-central Peru. In four short weeks they'll record as many different species of flora and fauna as they possibly can. By design RAP expeditions are quick-and-dirty surveys, intended to document the biological wealth of areas that researchers fear may soon be lost to development. Conservation International (CI) launched the program in 1989 with staff support from Chicago's Field Museum and, to date, has completed 21 such

inventories. "We don't make any pretense that we're going to get a complete list of everything," says Tom Schulenberg, a seemingly easygoing ornithologist from the Field Museum and the team leader. Like Emmons, he's been on many RAPs, assessing birds in special habitats from Bolivia to Madagascar, and, like her, despite his mild manner, he's determinedly passionate about his work. "We're trying for an index," he explains, "a sampling that will indicate whether the area is

the mind of every biologist who works in Peru."

—TOM SCHULENBERG, SURVEY LEADER

The only roads into this rugged area of south-central Peru are rivers such as the Urubamba. Feeding these waterways, frequent rains also support an abundance of elaborately interconnected life. Development would bring irreversible changes, threatening plants and animals before scientists even have a chance to identify them.

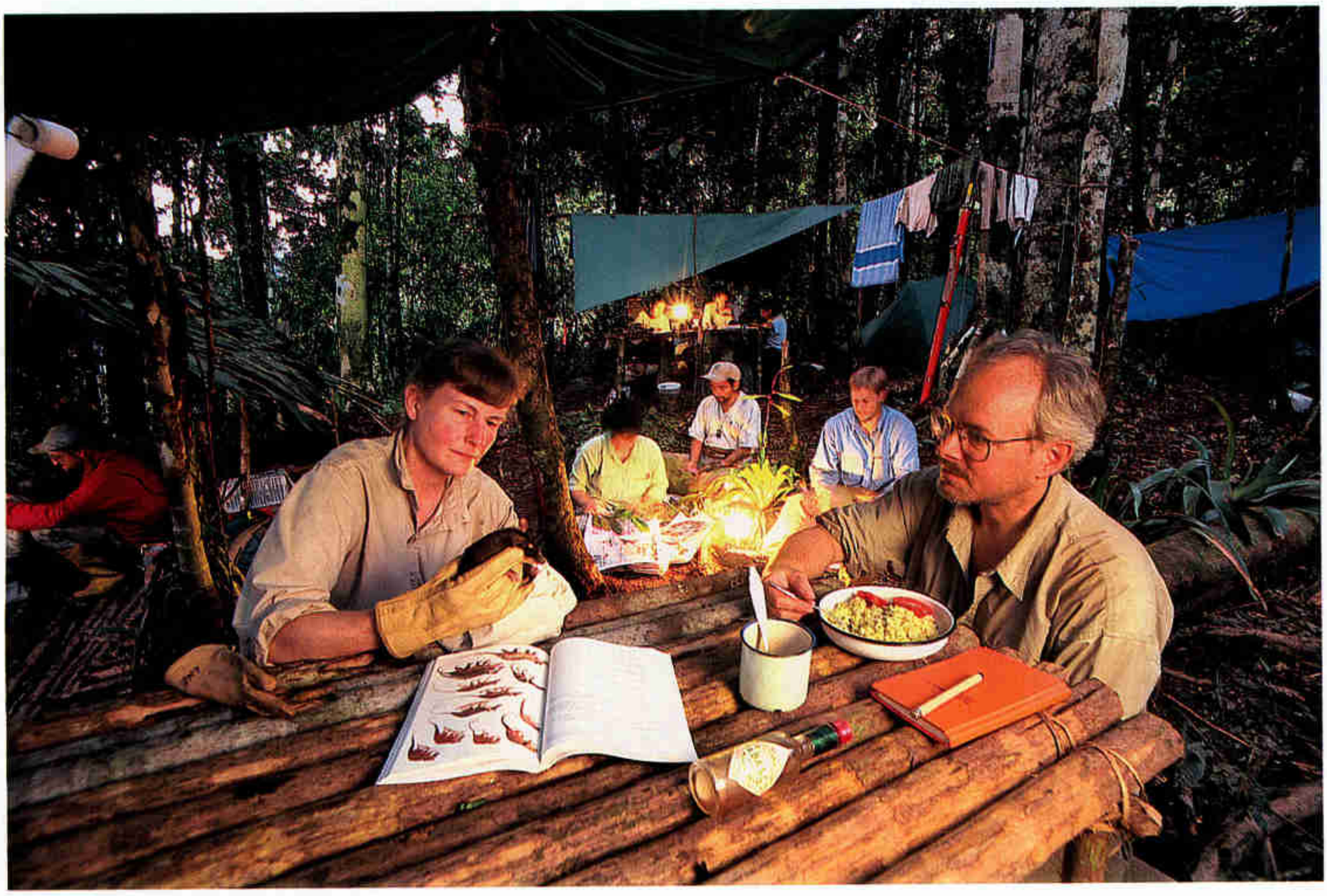
Where the Andes meet the Amazon in a narrow strip of tropical forest, a team of specialists documented specimens for a month—part of the Rapid Assessment Program of Conservation International, an environmental group based in Washington, D.C. "We were thrilled with what

as rich in threatened species as we suspect it is. Our lists can make a difference."

Once armed with that kind of data, conservationists try to work with countries to set aside these biologically rich regions. "There's a certain prestige in having your country chosen for a RAP," says Schulenberg, "and sometimes that leads to an immediate payoff." For instance, the Bolivian government created Madidi National Park five years after a RAP team's 1990 survey. "That's what we hope happens here too," says Schulenberg, noting that CI and other organizations have already drawn up proposals for Peruvian leaders to consider.

ZOOLOGISTS AND BOTANISTS have cast hungry eyes at the Vilcabamba since the 1960s. "All you have to do is look at a map to see that it's special," Schulenberg says. "You know you're going to find things here that are found nowhere else—not even in other parts of Peru." That's because the towering (over 11,000 feet) Vilcabamba mountains rise like an island from the surrounding Amazonian lowlands. The deep valleys of the Apurímac and Urubamba Rivers cut off the Vilcabamba from the other Andean ranges, isolating many of its plants and animals. Biologists call this isolation the island effect—meaning that such geographically separated populations often give rise to new species, plants and animals unable to produce offspring with their forebears. A chunk of real estate that's geographically isolated is almost guaranteed to have special, "found-nowhere-else" species. Put that landmass in the tropics, and you end up with some of the most biologically diverse flora and fauna in the world. Like the Vilcabamba's.

But it's not easy getting here, and until the RAP surveys of 1997 and 1998 only one other team of scientists had conducted an assessment of the region's species. Some 30 years ago John Terborgh, then of the University of Maryland, and John Weske, then of the University of Oklahoma, surveyed the birds on the Vilcabamba's western slopes. And although their tally of 405 species—plus 158 more found on



we found," says botanist Bruce Holst, who extends a clipper pole into a tree to get a bromeliad. Back at camp he and two Peruvian colleagues press plants while mammalogist Louise Emmons shows a brown four-eyed opossum to ornithologist Tom Schulenberg.

the valley floor—confirmed the mountains' biological wealth, scientists were unable to return largely because of the terrorist group Shining Path and cocaine traffickers. In the past few years the Peruvian government has curtailed both groups, making it possible for the RAP team to do its work.

"This is the first time that anyone's looked at the eastern slope," Schulenberg says. "And I've already seen 25 to 30 species of birds" that the first two explorers did not find on the western side. "That suggests that the bird diversity is even greater here on the eastern side, and the west was very impressive." By the end of the survey his list was up to 36.

To find his birds, Schulenberg rises before dawn, hikes down narrow trails to favorite vantage points, and sticks his tape recorder's sensitive microphone into the sky. "My specimens are their songs," he explains. "I want as complete a sample as I can get—and this is the best way to sample all the birds, including those in the upper canopy you seldom see." Already, after less than a week in the field, Schulenberg has recorded a bird he's never heard before: the fiery-throated fruiteater. "It's not new to science, but it is new to this region; it's one that Terborgh didn't find. It's also been seen at a site 270 miles to the southeast. So finding it here helps to fill in its range."

For the team's herpetologist, collecting is proceeding more slowly, although one afternoon Carlos Rivera Gonzales walks in, beaming, with a long snake whose skin is patterned and colored like the mossy lichen growing on most of the trees. Breathtakingly beautiful, it is also exceedingly poisonous, and the non-herpetologists choose to admire the prize from

■ From their sacred city of Machu Picchu the Inca may have explored the nearby Vilcabamba. They and

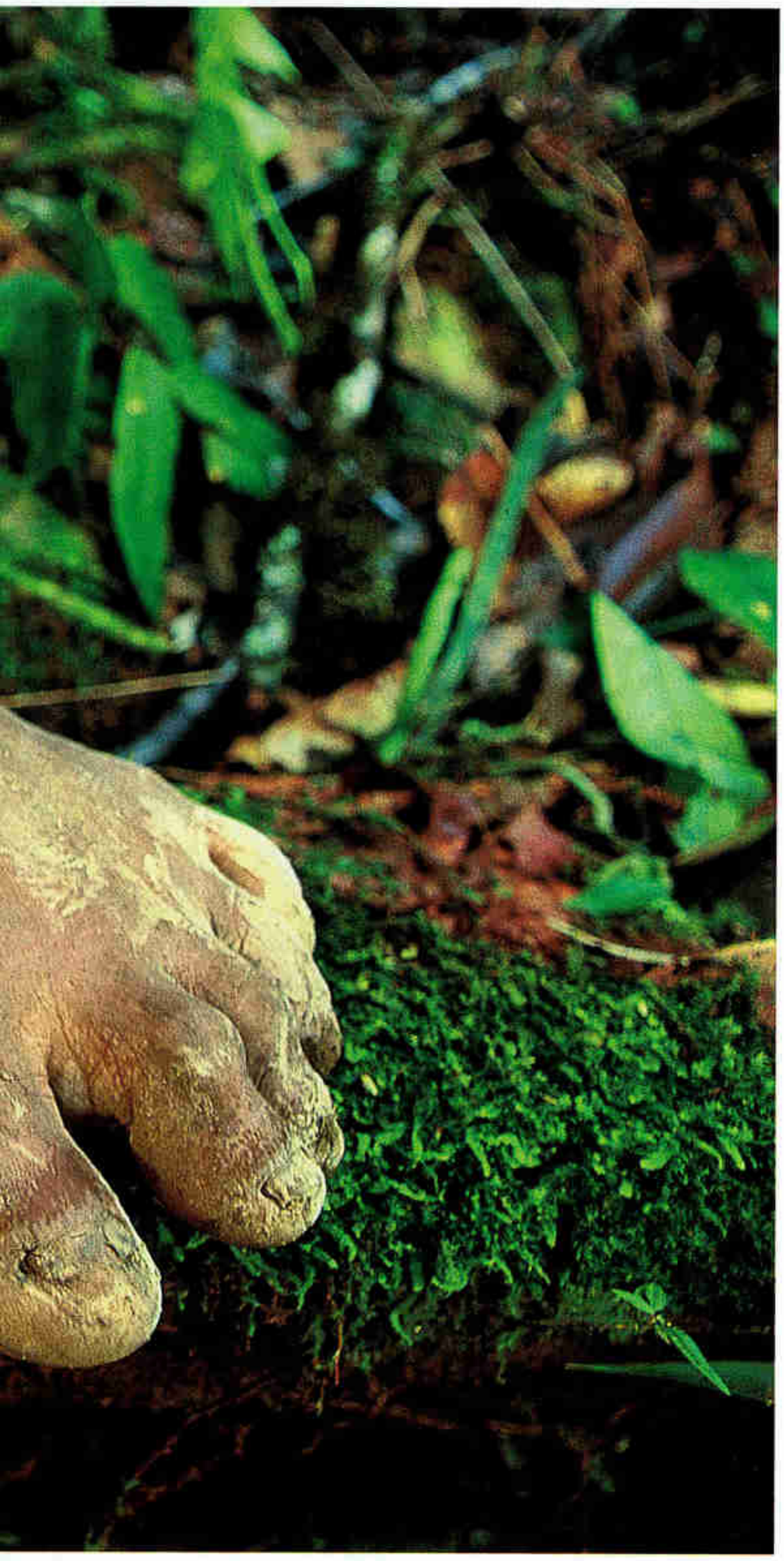
others have altered this landscape for centuries without destroying the larger balance of nature.

Feet leave a light impression in this region of the Vilcabamba—so far. The only residents, the Matsigenka and the Ashaninka, live traditionally by hunting, fishing, and planting gardens. Outsiders such as oil companies and colonists want to move in, but conservationists want the

a distance. Even if the reptile and amphibian hunt on this season's RAP finds only already known species, such as this pit viper, the survey has already added to Vilcabamba's biological luster: The previous year turned up ten new species of frogs and one new lizard.

Emmons also added to the region's bounty in 1997, finding a previously unknown mammal about the size of an opossum. "Now that's rare," she says. "Most mammals of that size were found long ago." She happened upon her prize discovery by chance. Checking her trapline one morning, she spotted a large, fluffy gray animal lying along her trail. "I think it'd just been killed by a weasel, and I was lucky enough to frighten it off." As soon as she picked up the furry creature, she knew this was one unknown to science. "I knew it was some kind of cloud forest rat; you see similar sorts of things in the high, cool forests of the Philippines. But I'd never seen one like this in the Andes before."

government to set up nature preserves. "If the people already there get a stake in managing the resources, then we hope their communities and way of life will be maintained and all the other species living in those forests will have a safe home as well," says Schulenberg.



Emmons was particularly taken with the rat's long, silky fur and the white chevrons marking its forehead. Apparently, the cloud forest rat appealed to the Inca as well; Emmons recently learned that two skulls of another species of this rat were found in clay jars at Machu Picchu in 1912 by Hiram Bingham's National Geographic–Yale University expedition. "They may have been pets," Emmons speculates. "That was a high moment for me: finding an animal alive today that the Inca once prized."

To make discoveries like this—and to get a fair measure of all the Vilcabamba's species—the scientists venture into the most remote reaches of the range. On the 1997 expedition the team helicoptered to two sites at elevations of 6,700 and nearly 11,000 feet, spending two weeks at each spot. On this RAP, the crew is working along a densely forested ridge at 3,200 to nearly 4,000 feet. "It's an elevation that's often overlooked," says Schulenberg. "But it's potentially one of the richest," since it marks the uppermost limit of the lower Amazonian forest and the lowermost limit of the Andean. "It's really a tiny little habitat," he adds. "It's like a ribbon that runs between the lowland and montane forests." And because of its narrowness, it's easily disrupted. "It's one of the first places people settle, since it's good for growing coffee." Indeed further north, around the town of Satipo, the ribbon is almost completely gone, cut into pieces by small farms.

And while the Vilcabamba is largely uninhabited, there are growing pressures—making the RAP's assessment even more urgent than usual. In nearby valleys Shell, Chevron, and Mobil are exploring for oil and natural gas; if either resource is found, a pipeline will be built through the Andes, and with that will come more roads and settlements. "Exactly the things that will fragment and destroy a fragile forest like this," says Schulenberg, aiming his microphone into the trees. It's just after dawn, the leishmaniasis flies are gone, and the sky is a silvery blue. Around us on all sides hardwood trees weighed down with spiky bundles of bromeliads and orchids muscle their way into the blue. Towering ferns and palms add a feathery softness to the woods. And then there is a burst of song, followed by another and yet another.

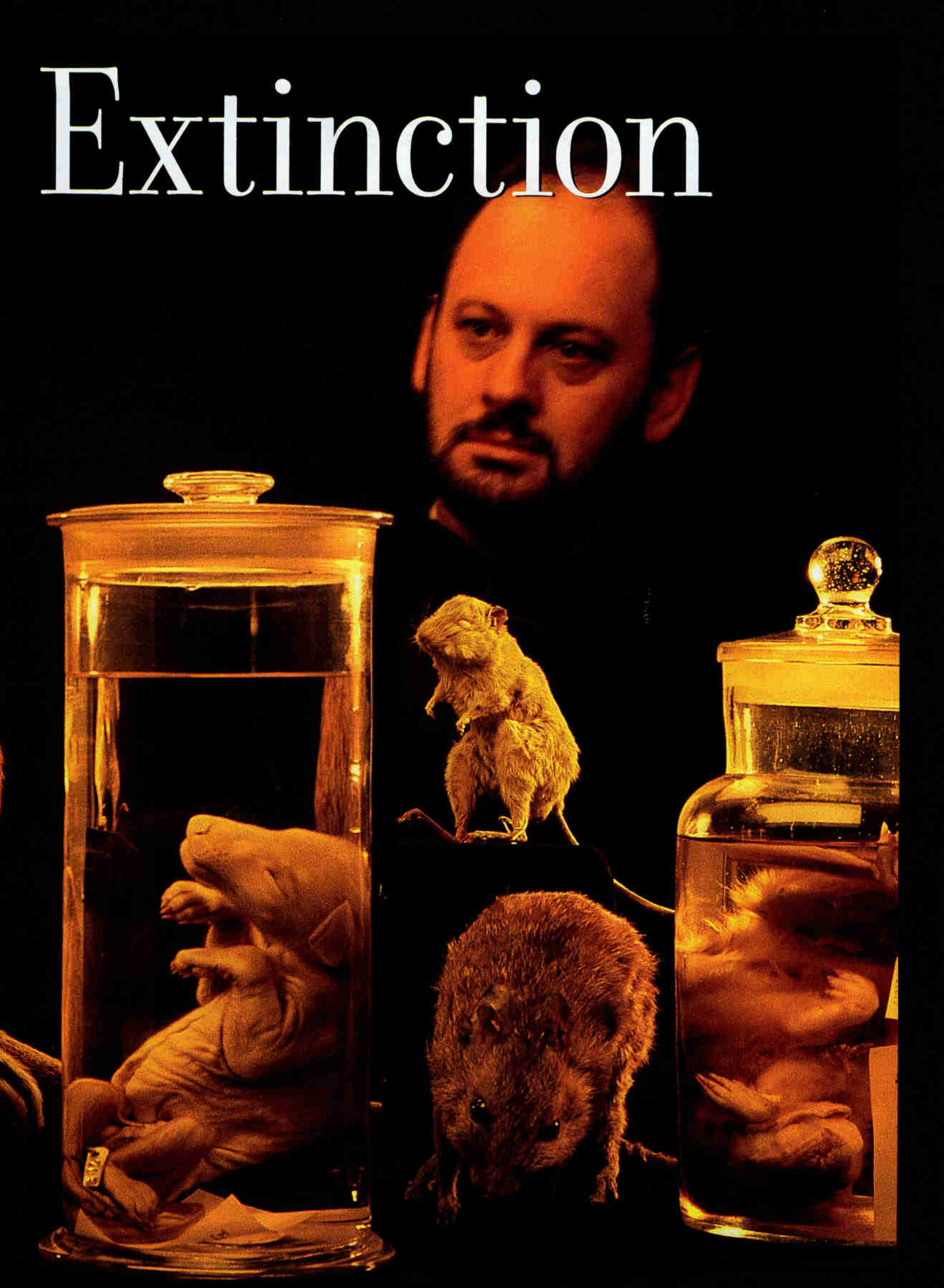
"Ahh. This is great," says Schulenberg. "Some real gems," he adds, softly listing the names of the birds, separating song into species. "And it's just what we're hoping to find: They're rare or poorly known and geographically restricted." In short the birds may be endemics—the kind of species that may spawn a park in their wake. □

The Sixth

By VIRGINIA MORELL
Photographs by FRANS LANTING

■ In the next century half of all species could be annihilated, as were these mammals seen in Tim Flannery's

Extinction



lab at the Australian Museum. Unlike the past five, this mass extinction is being fueled by humans.

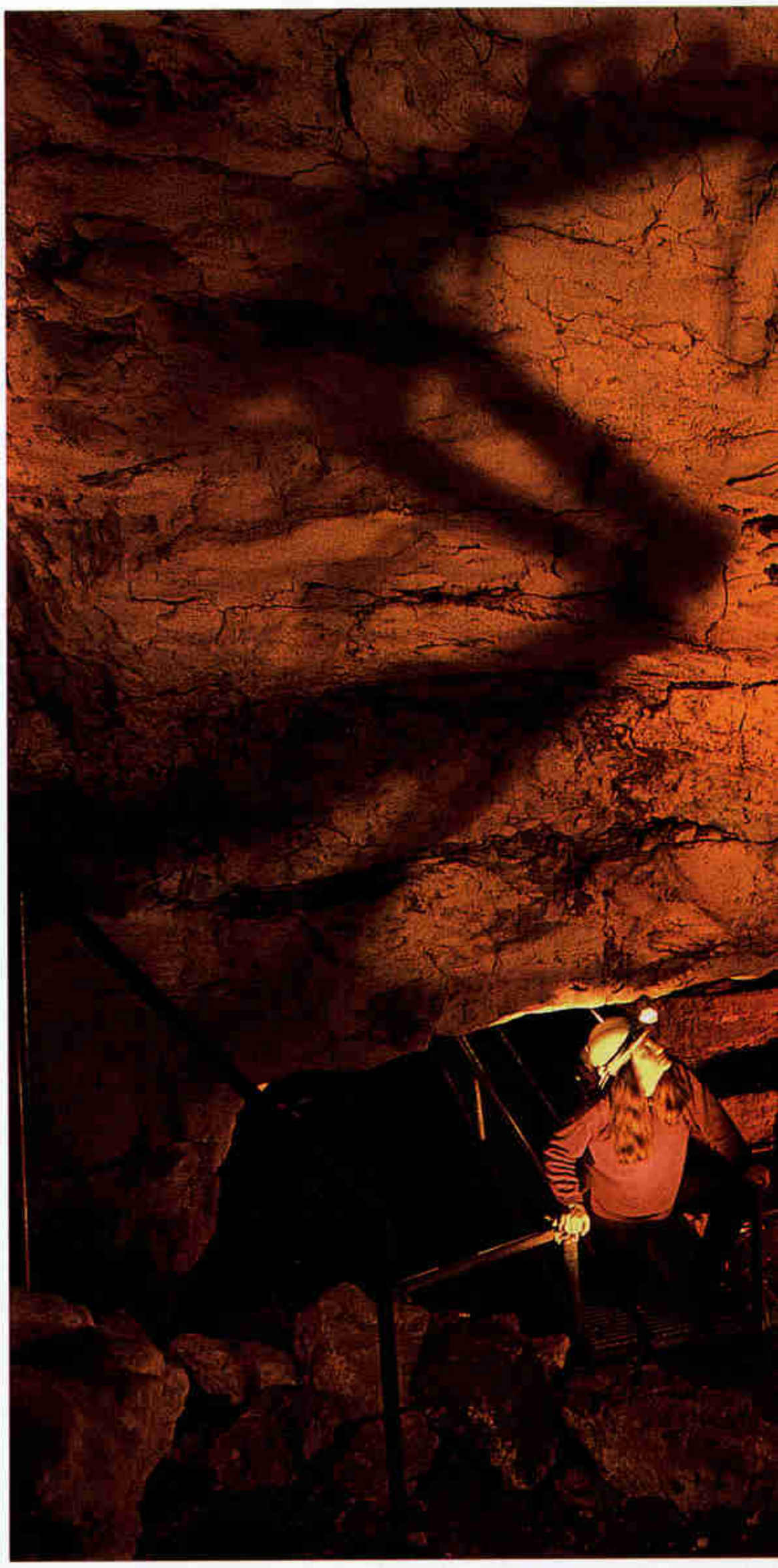
■ Working in minus 4°F cold at England's Kew Seed Bank, James Wood shelves seeds from the African mugongo tree. The bank has 1.5 percent of the world's flora on deposit, about 4,000 species; 34,000 species are at risk of extinction.

"Species that go extinct are lost forever.

THE FIRST ORANGE RAYS of the sun are just beginning to touch the saw grass prairie of Everglades National Park in Florida when our helicopter pilot lifts off from a small airport nearby. He turns low over the park, skimming above the gray-green grasses and morning mist. Here and there small stands of pencil-thin native slash pine show dark green against the pale grasslands. But it's the open marshy prairie that we seek, home to the endangered Cape Sable seaside sparrow. Heading south, the pilot searches for a particular point on a transect map, then banks and flies due west. Twenty minutes later we're on the ground. "Here's your first spot," he says over the radio to Stuart Pimm, the conservation biologist seated beside me in the back. In front another biologist, Sonny Bass, gives us the thumbs-up sign. Pimm and I, dressed in olive green flight suits and white helmets, jump into the wet marsh and run a short way from the helicopter.

For a moment this seems almost like a scene from *Apocalypse Now.* The helicopter's blades whip the air, bending the grasses in a wide swath all around and obliterating every sound except the *wap-wap-wap* of its rotors. As it peels away, ferrying Bass to the next site a kilometer away, Pimm removes his helmet and turns to me. "Welcome," he says, his voice rising above the fading roar of the helicopter, "to the front lines of saving biodiversity."

An avuncular researcher from the University of Tennessee, Pimm is not merely being theatrical. Based on his and his colleagues' calculations, some 50 percent of the world's flora and fauna could be on a path to extinction within a hundred years. And everything is affected: fish, birds, insects, plants, and mammals. By Pimm's count 11 percent of birds, or 1,100 species out of the world's nearly 10,000, are on the edge of extinction; it's doubtful that the majority of these 1,100 will live much beyond the end of the next century. The picture is not pretty for plants either. A team of respected botanists recently reported that one in eight plants is at risk of becoming extinct. "It's not just species



on islands or in rain forests or just birds or big charismatic mammals," says Pimm. "It's everything and it's everywhere. It's here in this national park. It is a worldwide epidemic of extinctions."

Such a rate of extinction has occurred only five times since complex life emerged, and each time it was caused by a catastrophic natural disaster. For instance, geologists have found evidence that a meteorite crashed into Earth 65 million years ago, leading to the demise of the

This is not like *Jurassic Park.*"

—BIOLOGIST STUART PIMM

dinosaurs. That was the most recent major extinction. Today the Earth is again in extinction's grip—but the cause has changed. The sixth extinction is not happening because of some external force. It is happening because of us, *Homo sapiens*, an "exterminator species," as one scientist has characterized humankind. The collective actions of humans—developing and paving over the landscape, clear-cutting forests, polluting rivers and streams, altering the atmosphere's protective ozone layer, and

Brought to light, an illuminated marsupial lion casts a skeletal shadow over researchers in South Australia's Naracoorte Caves, where it was unearthed. What caused the leopard-like carnivore to vanish? It's a topic of fierce debate, but some scientists point to humans, who may have hunted the island continent's megafauna to extinction.

Today the Earth is again in extinction's

populating nearly every place imaginable—are bringing an end to the lives of creatures across the Earth. "I think we must ask ourselves if this is really what we want to do to God's creation," says Pimm. "To drive it to extinction? Because extinction really is irreversible; species that go extinct are lost forever. This is not like *Jurassic Park*. We can't bring them back."

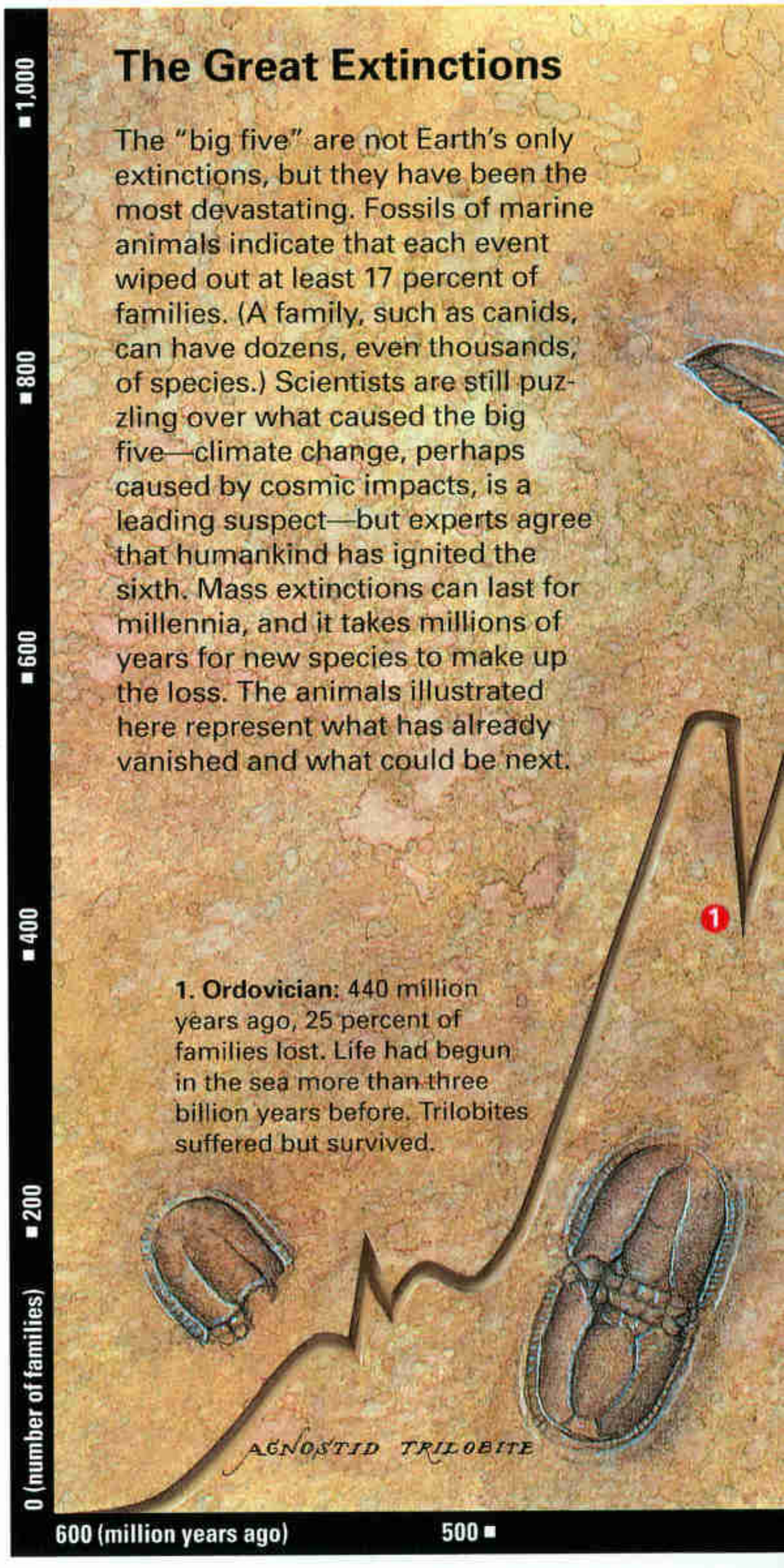
In Pimm's eyes people should be stewards of their neighboring species. That's why he's here at dawn in the Everglades, fighting to save the life of a little brown-and-white songbird with a smattering of gold feathers above its eyes.

Found only in this park, Big Cypress National Preserve, and nearby areas, the Cape Sable sparrow was once fairly common in the Everglades' hundred square miles of prairie lands, which lie adjacent to its better known "river of grass." In 1992 the sparrow's population registered a healthy 6,400 individuals. By 1995 the sparrow's numbers had taken a nosedive: Its population dropped by 60 percent to 2,600. "It was clearly on its way out," says Pimm, turning to set his helmet on the ground. "And to me that was unconscionable. In a national park of this size [the Everglades encompasses 1.5 million acres] and in the richest country in the world, species shouldn't be going extinct because of our actions. These areas, after all, were set up for their protection."

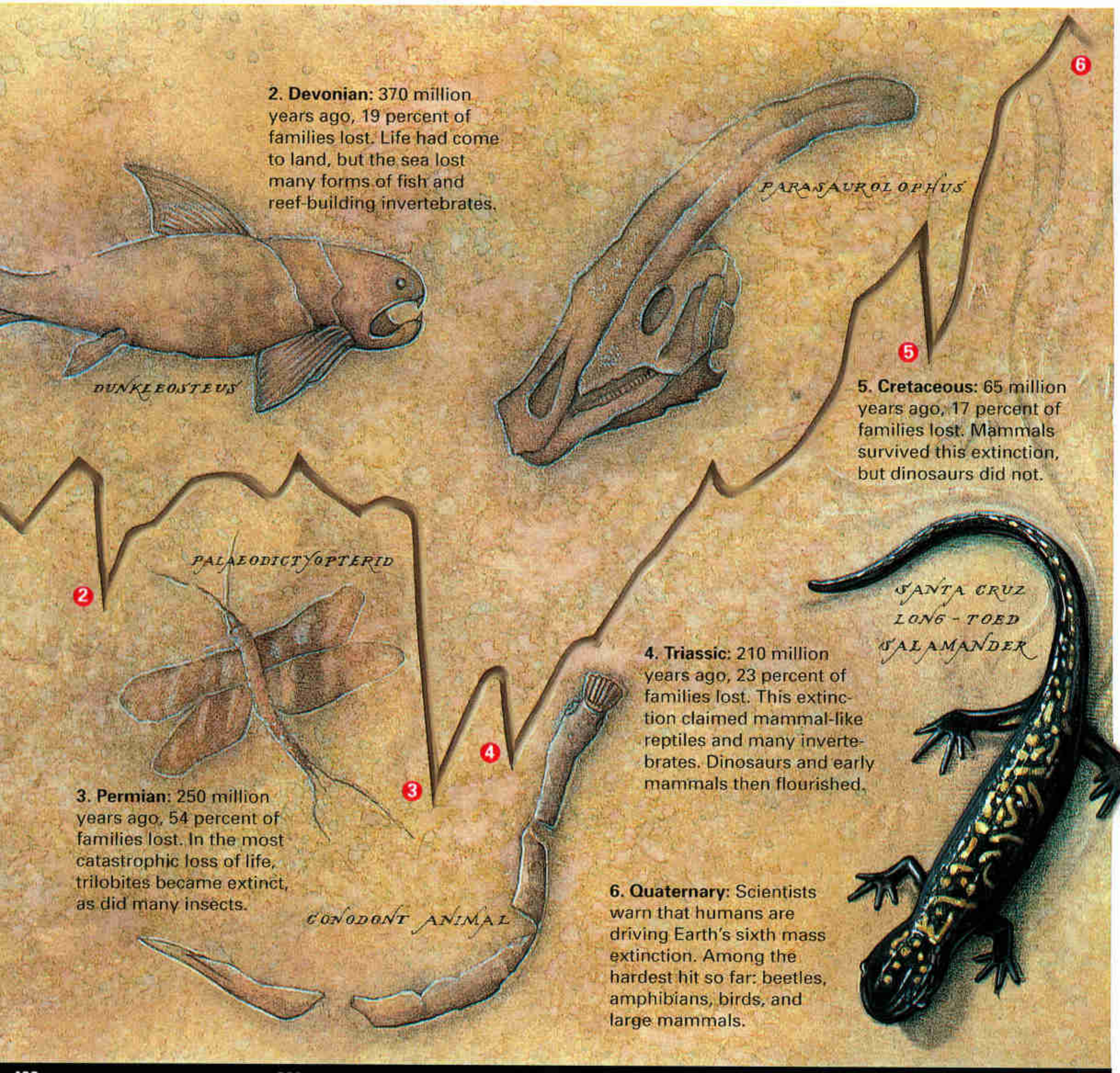
Raising his binoculars, Pimm surveys the surrounding grasses, then cups his ear to listen for the sparrow's call. "Ahhh, there's one. Do you hear it? Listen for a *chit-chit-tweeeee,*" he says, imitating the bird's short, quick notes and insect-like buzz. We stand silently, and a few moments later the call comes again, clear and brazen in the still morning air. "That's the male defending his territory; the birds have just started nesting, and so this is the best time to get a count of their population." Through our binoculars we spot this throaty male, perched at the end of a swaying grass stalk, his beak open, singing to the sky.

Throughout the three-month nesting period Pimm and Bass make these counts, flying a different line of their transect map each dawn and stopping at sites spaced precisely a kilometer (0.6 mile) apart to look and listen for the birds. The resulting data give them not only a count of the number of eligible males but also a map of where the birds prefer to build their nests. And that, in turn, has revealed what is harming them: Too much water.

"The birds start nesting in the middle of April," Pimm says. "They weave the grasses together to form a bowl about three inches off the ground."



grip—but the cause has changed.



ART BY KIRK CALDWELL; DATA FROM J. J. SEPKOSKI, UNIVERSITY OF CHICAGO

Because they nest so close to the ground, there can't be any standing water if they're to raise a brood successfully. But water throughout and around the Everglades is managed and controlled by two agencies, the South Florida Water Management District and the Army Corps of Engineers.

Water, which naturally would have flowed throughout the park, is held in reservoirs, channeled in dikes, and, above all, prevented from spilling into bordering farms and the suburbs of Greater Miami. To water managers, say Pimm and Bass, the drying western prairies of the Everglades in the spring look like an excellent place to dump excess water, which is what happened for several years beginning in 1993. While this protected some homes and roads, it has proved a disaster for the sparrow and, the biologists suspect, for other species, including many wading birds, such as egrets

The giant anteater is "an echo of a previous time, ill equipped to deal with the modern world," says ecologist Kent Redford. Grim evidence of its vulnerability lies on the border of Brazil's Emas National Park, where rushing cars kill many of the nearsighted, slow-footed animals.

and herons whose nesting patterns have also been disrupted.

"We're losing the sparrow and probably other species just because of water management decisions," says Bass on the flight back to the airport. "Admittedly, it is a big problem managing the water here, especially in stormy years. But all it takes is holding off a couple of months, as the agencies did last year, to let the birds nest and rear their young. It's a matter of making the right decision." If the Cape Sable sparrow's nesting grounds are not flooded, Pimm and Bass think their population will begin to increase.

Thin brown line. A dirt road stops soybean fields at the edge of a species-rich savanna inside Emas National Park. Farms have overrun vast swaths of the endangered ecosystem.

FOR OTHER SPECIES, though, no decision will change their fate; they are simply doomed to disappear from Earth.

In London, at the Royal Botanic Gardens at Kew, two horticulturists lead the way through a greenhouse, stopping to point out plants, from shrubs to spindly trees, that no longer exist in the wild. Kew researchers hope eventually to return some to their homelands. But for others the greenhouse is the end of the line.

"Now that poor thing, an *Encephalartos woodii,* hasn't had sex in about a hundred years," says Stefan Czeladzinski, a horticulturist-in-training, referring to one of the trees. "It's one of our living dead." The plant, about five feet tall with leathery leaves, is from Natal in South Africa. It is a dioecious species, meaning that its individuals are either male or female. In this case the plant is a male, and no females are known to exist. "Botanists have combed Natal looking for one, but they've never found it," says Czeladzinski. This survivor comes from cuttings from the last wild plant, which was moved to a botanical garden decades ago. All *E. woodii* plants alive today, including the lonely Kew specimen, are clones of that wild male; they are genetically identical and will never reproduce naturally unless a female is found.

And it's not just the *Encephalartos* that has been lost. Most of the native flora of many islands is extinct, beaten out by species that settlers introduced from Europe more than 300 years ago. "In some islands the habitats were already destroyed by the time the first botanists arrived," says Michael Maunder, a tall, dark-haired conservation biologist at Kew who

■ Sydney is home to four million Australians—and a few stuffed Tasmanian tigers. Driven off mainland Australia millennia ago, the marsupial was declared a protected species in Tasmania in 1936, the same year it became extinct.

SPECIMEN FROM AUSTRALIAN MUSEUM, SYDNEY

Far from its native Easter Island, one of the last toromiro trees (left) survives at England's Royal Botanic Gardens, where horticulturist Martin Staniforth examines it for mites. The bugs are as deadly to the tree as introduced foxes are to the Australian mala (below), now extinct in the wild.

specializes in the recovery of critically endangered plants. "We've managed to piece the flora together by reading travelers' diaries, collecting pollen from soil samples, and having bits of wood identified. But we only have a shadow of an idea of what was once there."

Because the species on islands are often endemics—meaning that they are found nowhere else in the world—their populations are typically small and consequently more prone to extinction. When a foreign plant is introduced—for example, the Chinese guava tree that blankets much of Mauritius, an island off Madagascar—it can become a weed that ends all others.

Kew Gardens and the Mauritian Wildlife Foundation have launched a project basically to weed the island of Mauritius. On the wall of his office Maunder has a large photo of an area known as the Black River Gorge, which retains remnants of Mauritius's original forest. These plots, some a mere acre in size, are caged in chain-link fences to keep out the deer and pigs, also introduced from Europe. Outside, as if biding its time, grows a thick, tangled mat of similarly introduced guava and privet.

"The plots are weeded every year," Maunder says. "We can keep these small plots of natives going, but how do we extend them? Can we ever fully restore Mauritius?" Maunder only shakes his head.

THROUGHOUT THE ISLANDS of the Indian Ocean and the South Pacific, the tale is much the same: extinctions being driven by species introduced by European explorers a few hundred years ago. But there was an even earlier round of extinctions in these and other places as humans moved out of Africa and into new lands. In Australia the arrival of the first people 50,000 to 60,000 years ago may have led to the demise of that island continent's megafauna, which included 20 species of giant kangaroos, the marsupial lion, and diprotodons—herbivorous marsupials that resembled cow-size rodents.

Out of the blue, an explosion of amphibian deformities has shocked the world. The cause could be pollution, parasites, or ultraviolet radiation. The effects could be far-reaching. Says biologist Andrew Blaustein, "If it affects frogs, it's likely to affect other forms of life, including humans."

"I've no doubt that people hunted them to extinction," says Tim Flannery, a mammalogist at the Australian Museum in Sydney, who has investigated his country's extinctions, past and present. "It's the same story in New Guinea and New Zealand. There you can still find some of the evidence, such as piles of bones from the giant moas [large, flightless birds] that the Maori killed until there were no more."

"THE SAME THING happened here," says Dolores Piperno, an archaeologist at the Smithsonian Tropical Research Institute in Panama, giving a quick smile and a sigh almost simultaneously. "Let me show you something." She walks briskly across the tile floor of her office and riffles through a row of files. From one she pulls out a large chart and unfolds it on her desk. It's a graph of plant fossils collected from sediments taken from a lake in central Panama, and it spans a period from 14,000 years ago to the present.

Fourteen thousand years ago the diversity of trees and plants was relatively modest, reflecting the tail end of the last ice age in the tropics. But by 11,000 years ago, as Panama began to warm up, the variety of flora increased dramatically. Piperno traces this burst of plant life with her forefinger as the graph makes an upward spike, but then the line takes a sudden downward plunge, as if tracking the collapse of the stock market in 1929. "That," she says, tapping the graph, "is when people began practicing slash-and-burn agriculture here, about 7,000 years ago. That's what people can do to a forest with a stone ax and fire. It shows that the idea of the noble savage—that people in the past in simpler societies lived in harmony with the natural world—isn't true. We humans have short-term goals. That's what makes saving species and conserving the environment for the long term so hard. We want results now."

But that short-term outlook can also work against people by eliminating potentially useful species. "We have not yet identified all the plants on Earth," says Sir Ghillean Prance, the director of Kew Gardens, "and we're losing them, I'm afraid, faster than we can catalog them." Because so many of our most effective medicines, from aspirin to morphine, come from plants, Prance worries that in losing the flora of the world, we're also losing the possibility of finding new drugs and chemicals.

"Every time we lose a species, we lose an option for the future," he says. "We lose a potential cure for AIDS or a virus-resistant crop. So we must somehow stop losing species, not just for the sake of our planet but for our own selfish needs and uses."

The Cape Sable sparrow, of course, is not likely to lead to a cure for cancer or to any other earthshaking discovery. Nor are most species around us. What would it matter if this little bird, or any of the 1,100 others on Pimm's list, becomes extinct? That thought crosses my mind one morning while joining his team of bird banders in the Everglades.

To trap the sparrows, the team watches the males to identify each individual's nesting territory. The banders then set up a mist net nearby and play a tape recording of another male's song, fooling the resident male into thinking a rival has arrived to court his mate. That kind of cheeky behavior elicits an immediate response from the male in this territory. He swoops in low over the grass, stops for a few seconds atop a single blade to sing his own territorial song, and then flies determinedly into the net, where he thinks his competitor is lurking.

Two banders rush forward to catch him. They weigh and measure him and gently fasten two yellow bands onto his left leg. "Would you like to let him go?" asks Dave Okines, the chief bander. He shows me how to hold the sparrow's legs between my first and second fingers, so that he sits upright on the top of my hand. For a brief moment, I keep him there, feeling his warmth, admiring the bright gold of his eyebrow feathers. Then I open my hand and he's gone in a flash, and I allow myself the thought that the sixth extinction is not inevitable. If humans are the cause, they can also be the solution.

For more on the sixth great extinction join our online forum at *www.nationalgeographic.com/ngm/9902.*

■ Safe in a wildlife sanctuary, a dazzling Australian lyrebird performs its courtship dance. Protecting species

has a price, but so does extinction: With each loss our planet becomes immeasurably poorer. □

By VIRGINIA MORELL
Photographs by FRANS LANTING

Restoring

■ Joining hands, Western and Malagasy conservationists rush to identify and protect biological

Madagascar

treasures—including the vanga (above)—on the island once called "the naturalist's Promised Land."

From space, astronauts could see

"YOU SPIRITS who live in the forest, please forgive us," says Mila the Second, the white-haired patriarch of a small village at the foot of Mount Analavelona in southwestern Madagascar, an island country that lies off the eastern coast of Africa. He is addressing a thick forest and speaking as if he expects his ancestral spirits to answer. "These outsiders have come not to make trouble but to learn from our woods, and to leave something to help us and our children."

Beside Mila stand other members of his Bara tribe. The "outsiders" are us: a team of zoologists and botanists who have come to document the animals and plants in this remnant forest. Outside the woods, on the sunny ridge where we are gathered, the land is like an open, rolling prairie: Rounded green hills edge the horizon, then drop to distant river valleys. The world feels high and exposed up here, although Mount Analavelona rises little more than 4,000 feet.

But that sun-drenched feeling vanishes as soon as you push aside the tangle of shrubs and vines to enter the forest, as we had the afternoon before. Inside, it was a twilight zone of long shadows and small dancing pools of light. Thirty-to-fifty-foot-tall trees spread their leafy limbs overhead, blocking the sky; even when I craned my neck, I could not see the sun. There were dark, mossy seeps and streams whose water looked inky black in this dimly lit world, but which ran clear and cool through my fingers. What color there was appeared suddenly and vanished as quickly: butterflies of such brilliant blues and yellows that I always caught my breath.

It had taken us two days of steady walking up a wide river valley and over the steep, windswept grasslands on the mountain's lower flanks simply to reach the forest where we stand with the Bara. Centuries ago virgin tropical forest blocked the sun on Mount Analavelona from summit to base, but as in much of Madagascar the forest here has been shrinking. Grasses introduced from mainland Africa now sweep over Analavelona's foothills, rolling toward the base of the tall trees like a green sea lapping at a sea cliff.

"We think that a drying climate, especially in the southwest, was partly responsible" for some of this loss, said Steve Goodman, the leader of this expedition and a field biologist with the World Wildlife Fund (WWF) and Chicago's Field Museum. "But people have had an enormous impact too," he continued as we hiked through knee-high grass. Indeed, along the highway south of this mountain Goodman,

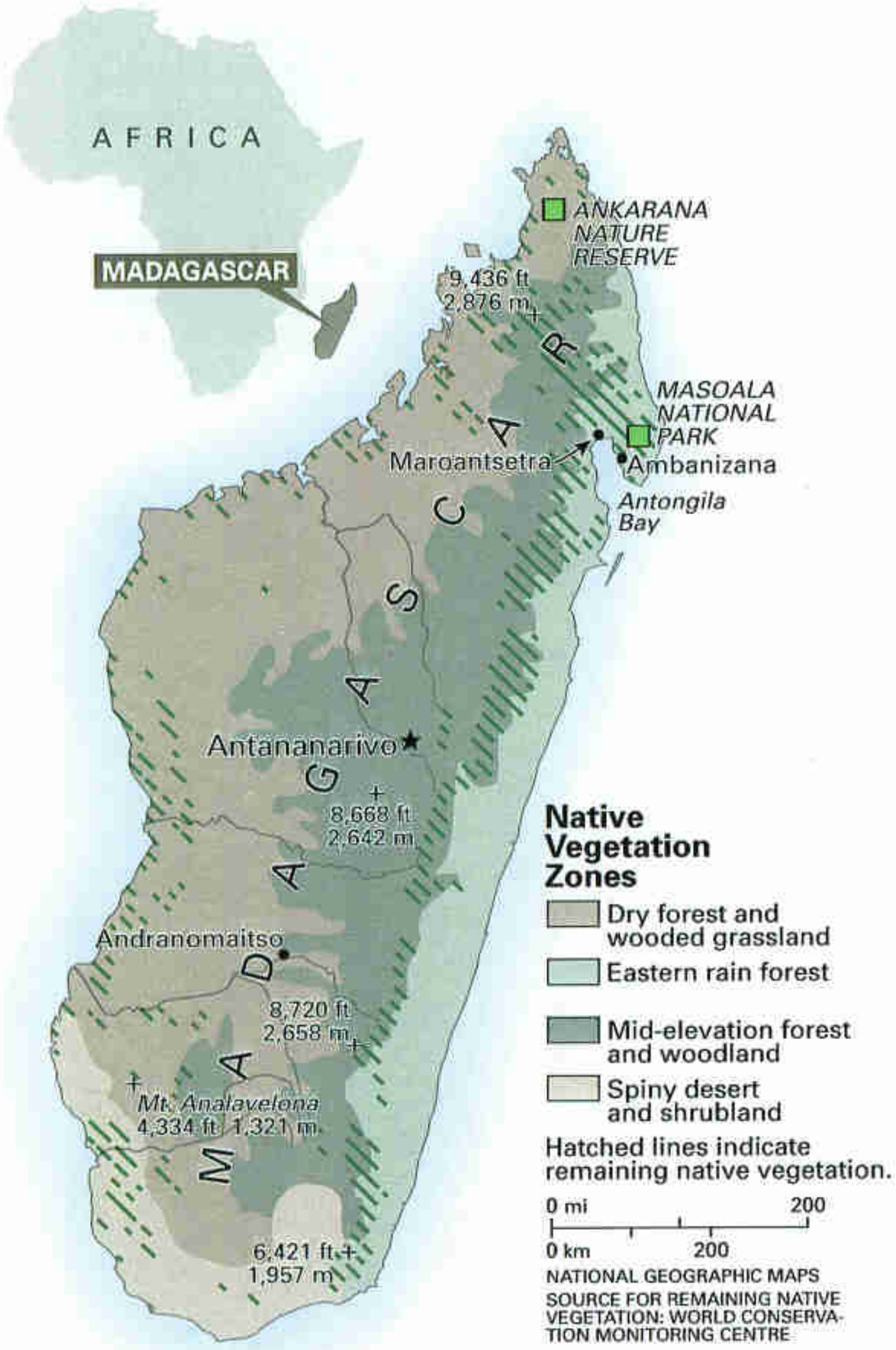
Madagascar's red earth bleeding into the sea.

who has led numerous scientific teams into Madagascar's dwindling forests over the past ten years helping document the plants and animals unique to its shores, had pointed out lengthy stretches of land that were "solid forest" in 1990 but are now fields of crops.

A decade ago that kind of destruction was all too common in this island nation. From space, astronauts could see Madagascar's red earth bleeding into the sea. Nearly all the environmental damage stemmed from poor

Get rich quick—that's the fantasy of fortune hunters who in recent years have swarmed into the Ankarana Nature Reserve in search of sapphires. Besides hunting lemurs and other endangered species to feed themselves, these miners have stripped and scoured the land, increasing soil erosion and damaging the watershed.

Evolving in splendid isolation, Madagascar's wildlife includes a multitude of species found nowhere else. For instance, of its some 300 identified reptile species, 95 percent are endemic, including *Uroplatus malahelo*—the leaf-tailed gecko (right, top). Shedding light on such biological



agricultural practices. Traditional farmers use slash-and-burn methods here, and a growing population (now about 14 million and expected to double by the year 2021) led to the clearing of more land. In the worst cases nearly a hundred tons of topsoil an acre were being lost each year. And while that flow has yet to be fully stanched, some progress has been made. Still, scientists estimate that unless these farming methods change, virtually all the island's forests will be gone within 25 years.

Alarmed by that prediction, the government of Madagascar is working hand in hand with several international conservation and aid agencies to kindle in its citizens a sense of pride and ownership in the nation's biodiversity.

That's why Goodman, whose long beard attests to his lengthy stays in Madagascar's most remote regions, now joins Mila in prayer. Only with the approval of the ancestral spirits will his expedition be allowed to continue, Goodman explains in a soft whisper. "It's a sacred forest to the Bara," he says, "which means, in theory, that no one goes there, or at least not without the ancestors' approval. And that's the best way to protect a forest in Madagascar—make it sacred."

"We're trying to help them revive their own conservation traditions," adds Koto Bernard, a Malagasy geographer with WWF. "If the ancestors say through the patriarchs that this forest is not to be cut, no one will go against them." If they do, they risk the worst Malagasy punishment of all: being banned from the family tomb at death. Collectively these principles are known as the *dina*. In the farthest reaches of Madagascar, such as this village of largely illiterate cattle herders, dina is more influential than any regulation enacted in the distant capital of Antananarivo. Now, through their ancestors and their dina, the villagers too have a stake in Goodman's expedition.

In time WWF hopes to strengthen this bond by improving the lives of the Bara, perhaps with a school or ecotourism project and a national park. Although such community-based conservation programs have their problems, many conservationists view them as essential to saving biodiversity, particularly in the poorest countries. "If you want people living near a biologically rich area to help preserve it, it's not enough to simply fence it off and throw away the key," says Jean-Paul Paddack, the program director for WWF in Madagascar. You've got to offer them better ways to make a living and "a sense that they will benefit" from preserving the biodiversity around them.

Such projects are under way across Madagascar, where several new national parks were announced in the past three years and two more are on the drawing board. Of these, the most celebrated is Masoala, on the country's northeast coast. Many conservationists regard this protected peninsula as Madagascar's prize, the last of the island's forests stretching unbroken from the mountains to the sea. And, after flying to Maroantsetra, a town across the bay from the park, I could see why. From the air much of Madagascar looks like a badly

mysteries are herpetologist Achille Raselimanana, holding the gecko, and American field biologist Steve Goodman (bottom), pondering the taxonomic niche of a recently captured rodent. In the past decade teams organized by Goodman have identified hundreds of new species.

■ Bara herders tread lightly on the land, partly because taboos prohibit their exploitation of the

forests on Mount Analavelona. Few of the island's slash-and-burn farmers are similarly restrained.

Charting their own course, villagers in Andranomaitso study a local map as they seek a way to preserve their forest and regional watershed. Grassroots involvement in such planning is critical, since the Malagasy government has difficulty enforcing environmental laws.

bloodied prizefighter: Raw wounds of barren red earth cover the summits of nearly every hill and mountain.

"It's what I hope we can prevent here," says Bruno Raterajaona, one of two Malagasy advisers from Cooperative for Assistance and Relief Everywhere (CARE), an international aid organization, who joined me on a visit to the new park. We speed in a small boat across Antongila Bay to Masoala's western border. In the distance, beyond the blue of the sea, a rugged line of mountains rises above a curve of white sand. Misty clouds hang over the highest peaks, but in spite of that cloudy cover I can see the glorious, rumpled growth of a tropical forest climbing to their summits; there are no gouged-out red gullies in view. Indeed, from the boat, it seems as if only that thin strip of sand separates the bay's waters from the rich greens of the sheltering woods.

"Of all the world's tropical islands, there are only a handful where you still see a sight like that," says Pete Lowry, a botanist with the Missouri Botanical Garden and the fourth member of our party. His reports in 1988 helped establish Masoala's botanical importance. "It's what all of eastern Madagascar looked like when the first humans arrived" about 2,000 years ago, he adds. With the fierce tropical sun beating down on us, the dense forest, punctuated here and there with the broad, fan-shaped leaves of Madagascar's traveler's-tree, looks especially inviting, and it is easy to imagine the joy of those first to reach this forested shore.

A few moments later we are standing in that shade ourselves. Just beyond the beach's broad-leaved trees, we head up a path leading first to a small village and then to the shelter of the park. "This is the village of Ambanizana," explains Raterajaona, a sturdily built man of 50. "The people here are still worried about the park, because they will be prohibited from selling its hardwoods. In fact, we're trying to show them how to use the forest's resources more wisely." To this end a large buffer zone of forest surrounds the park; villagers living around the zone can still harvest trees and farm the clearings they've cut from the land, though they are forbidden from cutting the park's timber. The government hopes that with help from advisers like Raterajaona the villagers will learn to use the buffer-zone resources in a sustainable manner—cutting only a certain number of trees and planting others for future harvests.

BUT RATERAJAONA KNOWS this will not happen overnight. He grew up in Maroantsetra and so understands local traditions and how wedded people are to these. He has also worked with government forestry projects elsewhere in his country and has seen how his countrymen have destroyed other forests. "There's not much you can do where the land is so badly eroded," he says, shaking his head. "But here, we still have a chance. It's why I came back."

He leads the way into Ambanizana, a tidy village of thatch-roofed homes built on stilts, and stops at one where several women, dressed in colorful wraps called *lambas,* have gathered on the porch. They belong to a women's group that was formed when the government established the park; with Raterajaona's assistance they're investigating ways to supplement their incomes. Raterajaona introduces me to Lourinette, the group's president. A willowy woman with a blue-patterned lamba tied gracefully under her arms, she speaks in a vowel-rich Malagasy dialect while Raterajaona translates. "We're just beginning to think about what kind of project we should do," she says. "Now that we can't go into the forest, we hope the government will help us build a dam to increase our rice production. That will help make up for our loss" of access to the forest's products.

"It will take a long time to change their ways," Raterajaona tells me, explaining that for many traditional Malagasy wealth lies in the amount of land a man has cleared, whether it is cultivated or not. "If you ask them, 'Do you know the forest is disappearing?' they'll simply say, 'Oh no, there will always be a forest here.' Yet as soon as you ask them about a particular species, for instance a palm they use for the floor of their homes, they'll nod their heads, 'Oh yes, we have to walk half a day now to find

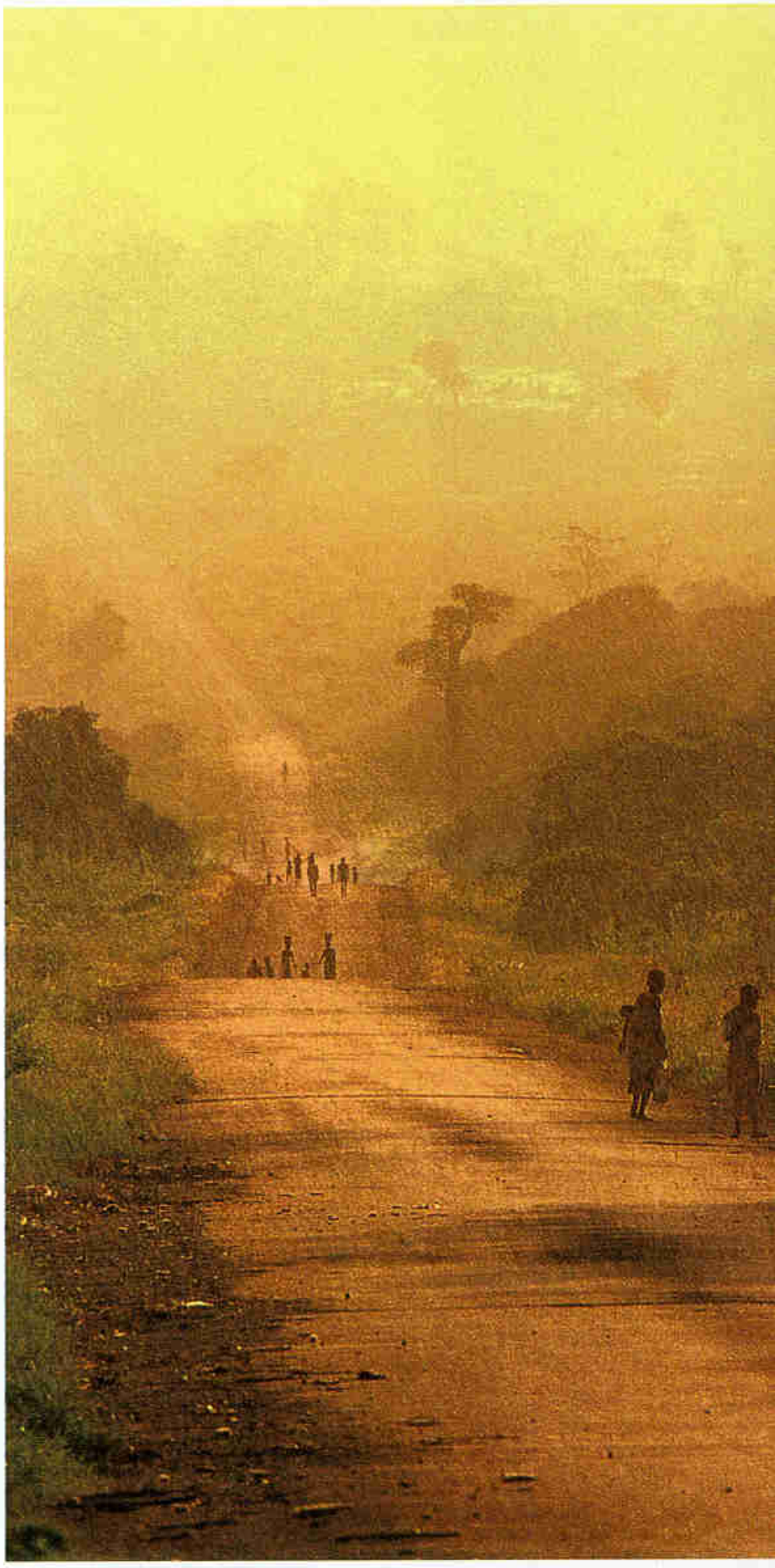

DEFRICHEMENT DANS LA REGION D'
ANDRANOMAITSO

"When I drove this road ten years ago, it was surrounded by forest," says photographer Lanting. "All that remains now is a few baobab trees." Elsewhere, though, environmentalists point to progress, like an expanding network of national parks and a growing awareness of biodiversity's

that one.' But they still haven't made the connection between their own individual actions and the final result: deforestation."

Beyond the village a path leads into the woods that Raterajaona hopes will never be cut. Laden with vines and orchids, the trees—an almost endless variety of species—tower overhead. One, a leathery-leaved *Symphonia,* is in bloom, its bunches of red-and-white-striped flowers raised to the sun like offerings of peppermint candies. In the tree's shade we spot a few feathered remains of a green pigeon. Perhaps it had fallen prey to the Madagascar serpent eagle, a raptor that until 1993 was thought to be extinct. Climbing higher, we pass ebonies, screw pines, and palms of such diversity that botanists are still sorting them out. Below us a troop of red-ruffed lemurs bark and grunt as they crash through the trees. Like the Masoala pitcher plant and the red-lemur palm, these lemurs are found only in the peninsula's dark woods. For such rare species to survive, Masoala's richly varied forest must be kept intact.

And little by little Raterajaona thinks that goal can be achieved. On the park's eastern border, where more people live, he is assisting another village to launch a small "green timber" industry. They'll harvest rare hardwoods in their buffer zone for overseas firms that insist on using only timber that is cut by environmentally sensitive methods. CARE is also helping to fund butterfly farming and ecotourism projects, again with an eye to giving locals another way to earn a living.



ALTHOUGH SMALL IN SCALE, these simple development projects seem to be making a difference. Back in Antananarivo, Raymond Rakotonindrina, then the energetic director-general of Madagascar's National Association for the Management of Protected Areas, observes that until two years ago the government's forestry department regularly received requests from villages to declassify the preserved lands in their neighborhoods. "I worked there 23 years, and every year we had stacks of these requests," he says, his hand rising toward the ceiling. "Now we're getting delegations that are *asking* for parks; they've heard about a development project somewhere, and they want a reserve and a project too."

On Mount Analavelona the cattle herders did not specifically ask for a forest reserve, but preservation is a concept they appreciate, although in a somewhat different way than Western conservationists do. For these people a dense forest is a good one, explains Goodman, because it's the best place to hide cattle from

economic benefits. Yet a dilemma persists. While enterprises such as ecotourism and butterfly farming may spare habitats, Madagascar's growing population must raise crops to survive. What strategy can satisfy both immediate human need and long-term environmental protection?

would-be rustlers. "They want to see this forest stay intact as much as we do," he says, leading the way into its depths. His team's herpetologist, Achille Raselimanana, has already plucked a leaf-tailed gecko and a dwarf chameleon from the branches of two trees, while the botanists exclaim over flowering trees they think must surely be new to science. Goodman sets out traps for small mammals along a ridge, then drops into a small valley below, where tall trees, giant ferns, and palms shoot toward the sky. He stops beside one hardwood tree and pats its fluted green trunk. "This is a sacred tree to the Malagasy," he says, looking up at its topmost branches, "and it's a good sign. It means this part of the forest has never been cut." It means, too, that the forest—this haven for spirits and cattle, for flora and fauna—is likely to be given national recognition and added as a satellite to a larger park nearby. And because of that status the soils of Mount Analavelona will not soon be bleeding into Madagascar's sea. □

In Search

■ Driving rain brings flash floods but no relief to the people of Madagascar's backcountry, where deforestation

By VIRGINIA MORELL
Photographs by FRANS LANTING

# of Solutions

has stripped away untold species. Earth's biodiversity is likewise deluged, but help is on the way.

■ Biotic gold, beetles glisten in Costa Rica's National Institute of Biodiversity. Its mission: Save natural wealth

by inventorying species, determining their commercial usefulness, and licensing sustainable harvests.

"There's one good thing about our

FROM THE POLISHED stone stoop of her home on the slopes of Mount Isarog in the Philippines, Naty Dumalagan can just make out the edge of Isarog's dense forest. A small, sturdy woman in her 50s with a ready smile, she has lived here 30 years but has never set foot in that forest, although it is home to some of the world's rarest birds and mammals. Under Isarog's spreading canopy live oddities such as the Isarog shrew-rat, a whiskered rodent that eats mainly earthworms, and beauties like the red-bellied pitta, a bird of dazzling crimsons and blues.

"I'd like to go, but I think the trails are too steep for me now," she says in Tagalog, a Filipino language, while Danilo Balete, a biologist with the Haribon Foundation, a conservation organization in Quezon City, translates. "She would like to see the forest," Balete continues, "especially now that she and her family are helping protect the trees."

Only a few years ago Dumalagan's husband and other men in the surrounding villages were logging that same forest, cutting down its prized Philippine mahogany and ebony trees and causing some species of plants and animals to disappear. Between 1961 and 1988 more than 40 percent of the bird species from Isarog's lowland forest vanished, even though the mountain is a national park.

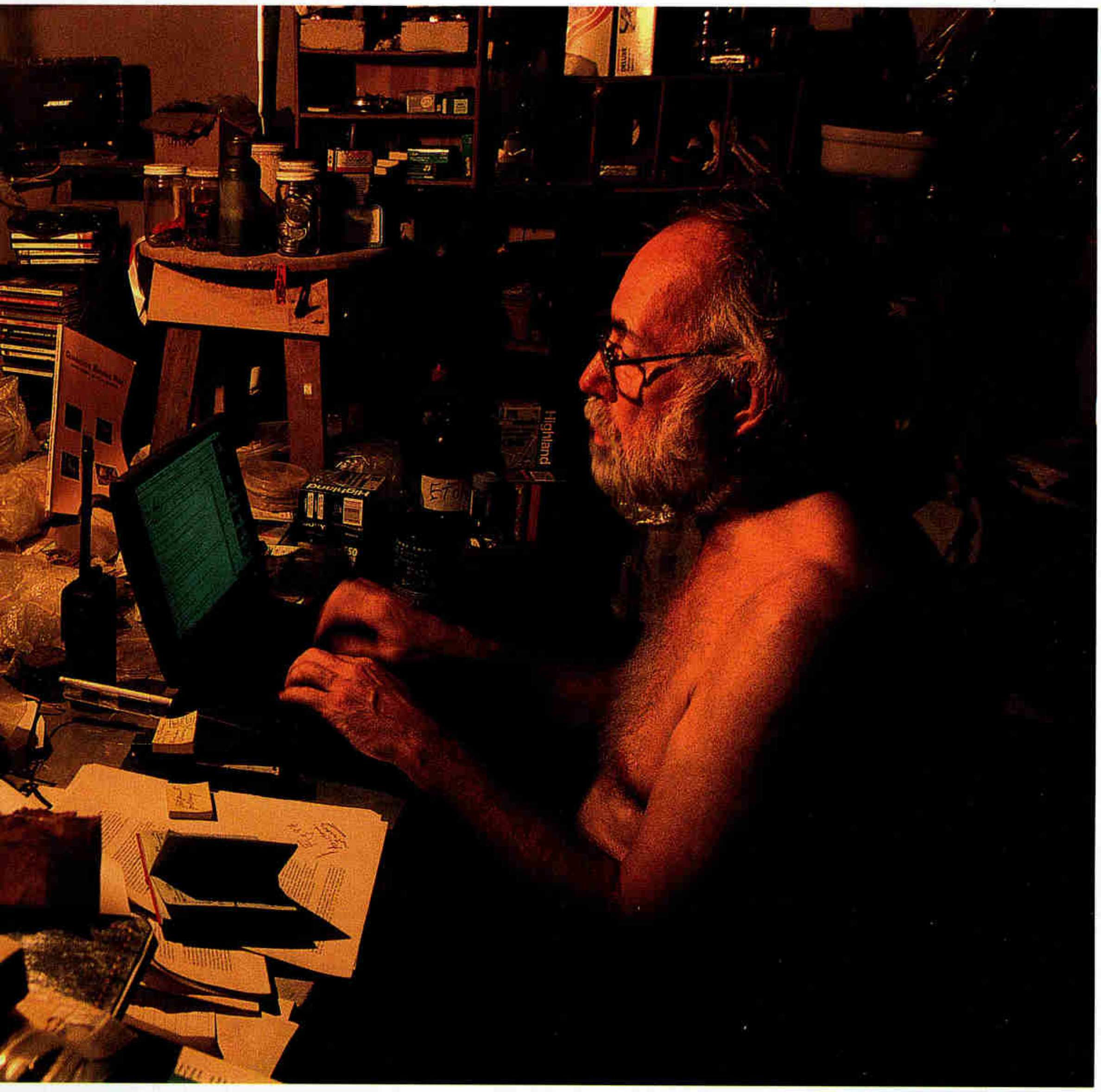
"Most parks in the Philippines are parks only on paper," says Balete, a slightly built man in his 30s, who helped survey Isarog's mammals and birds in the late 1980s—often with the whine and roar of chain saws echoing in the background. "We have to accept that parks here are different from those in the United States," he says. "People were living in and around these parks and using their resources from the beginning, so the idea that everything inside their boundaries wasn't going to be touched was simply unenforceable."

But in the past few years the logging has largely stopped. Dumalagan's husband and other villagers now work as volunteer guards, helping to stop the illegal cutting of timber. "Yes, it means less money for us," Dumalagan says, nodding her head. "But we know what will happen if we continue to cut Isarog's trees—there will be landslides, like those in Ormoc." She and Balete exchange a glance.

The last old-growth forests in the mountains above the city of Ormoc were logged out by the end of the 1980s, Balete explains. When a typhoon struck in 1991, the rushing water swept down two rivers, carrying rocks, broken trees, and masses of mud into the heart of Ormoc. As many as 7,000 people died. "It made

species: We like a challenge."

— BIOLOGIST EDWARD O. WILSON



a very big impression on people living next to other mountains, like here," says Balete. It's a lesson that they do not want to repeat.

"We think it is a lesson for the world too," he says later, as we head up a steep trail on Isarog. Although we start within the park's boundaries, we hike for more than an hour through plantations of non-native trees and bananas before we come to relatively undisturbed forest. Almost instantly the trees close in overhead, the sky disappears, and we're in a misty world of shadow

Ground zero in the fight to save Costa Rica's dry forests: Ecologist Dan Janzen's living room is surrounded by Guanacaste Conservation Area, the 323,600-acre preserve he helped create. A quilt of parks and recovering ranchland, Guanacaste is a living laboratory of restoration biology. Janzen calls it "absorbing the human footprint."

In forests worldwide, as here at Thoreau's Walden Pond, famed biologist Edward O. Wilson (right) uses simple tools to collect specimens and frame ideas. Among his notions: biophilia—an innate passion for nature that draws people to love and preserve parks like Walden (below).

and light. Thick mats of spongy mosses cover every rock, tree trunk, and branch, forming an emerald carpet for the orchids and ferns that drape the limbs overhead—a lush testament to the 35 feet of rain that can annually drench this mountain's summit. That kind of rainfall is typical for the Philippines' mountains, and in areas where dense forests remain, the water is quickly absorbed. But where the trees have been clear-cut and the earth left exposed, as has happened to more than 90 percent of the Philippines' old-growth forests, floods and landslides such as those that ravaged Ormoc are inevitable.

To help reinforce his message, Balete and the Haribon Foundation have drawn up plans for projects that give the local villagers a bigger role in deciding how to manage Isarog's forests. "How do you manage a protected area with lots of people living in and around it?" Balete asks. "It seemed to me the only way we could do this was to turn them into our partners." After a series of campaigns teaching villagers about everything from how a watershed works to how to write grant proposals, Balete himself is amazed at how well his "gamble," as he calls his initial idea, has worked. "We'll have to wait to see whether we have a lasting marriage between the villages and the mountain—and whether any of the birds we lost come back."

Increasingly conservationists are looking for such marriages, seeing in this kind of community-based stewardship the best way to save Earth's threatened biodiversity, much of which is found in the world's poorest countries. Yet community projects are not the only answer. The number of species facing extinction and the speed at which they're vanishing are so great that people are attacking the problem from all sides.

"It's the challenge now and of the next century," says Edward O. Wilson, the renowned Harvard biologist. "Right now we're pushing the species of the world through a bottleneck. We've got to make it a major moral principle to get as many of them through this as possible. And there's one good thing about our species: We like a challenge."

Putting a Price Tag on Nature

Green spaces are easily taken for granted, yet their great expanses unobtrusively support human existence. Among many other things, they furnish essential raw materials, renew soils and prevent erosion, shelter animals that pollinate crops and control agricultural pests, purify our air and water, and help regulate climate.

Because many of these ecosystem services, as scientists call them, have no traditional market value, their long-term protection is often ignored in favor of short-term profits. "Humans are now a relatively major component of life on Earth, and we can damage ecosystems quite intensively," says Robert Costanza, an ecologist at the University of Maryland. To demonstrate the economic benefits of conservation, Costanza and others are attempting to estimate the worth of ecosystem services—which runs well into tens of trillions of dollars a year worldwide. "Assigning values, even if they are imprecise, helps make it clear that losing this stuff entails a cost," explains Gretchen Daily, a conservation biologist at Stanford University.

New York City, for example, calculated that building a water treatment plant would cost between six and eight billion dollars. Instead, the city will spend 1.5 billion dollars to keep development from overwhelming the Catskill and Delaware watersheds, which have filtered its water naturally for decades.

ART BY STÉPHAN DAIGLE

■ "This forest is a living sponge," says Hank Oppenheimer, collecting plant specimens for researchers at Maui Pineapple Company's Pu`u Kukui Watershed preserve. "Without it, rain would run off into the ocean. By protecting the native plants, we protect our water supply."

Tread with care. Millions of seeds of *Miconia,* at far right, a fast-spreading alien tree that shades out natives, litter the soil around this infestation near Hilo, Hawaii. "We clean our boots before we go to uncontaminated areas," says Duane Nelson, leader of a team that roams the island like

AT THE ROYAL BOTANIC GARDENS at Kew, in London, botanists have set themselves what seems at first glance an impossible challenge: Collect and store seeds from all the flowering plants of the British Isles by the year 2000. But, in fact, says Roger Smith, director of Kew's Millennium Seed Bank, it's perfectly doable; indeed the seeds from more than 60 percent of the flora are already in hand. "In part that's because these are small islands with limited habitats and relatively few species," about 1,570, says the lanky Smith, leaning back in his chair in his office at Wakehurst Place, one of Kew's satellite gardens, 45 miles south of London. "But it shows what can be done."

Now the Kew botanists have set their sights still higher: collecting 10 percent of the world's flora by the year 2010. "I'm not saying that these plants are necessarily the ones that are most at risk of going extinct," says Smith, "but it gives us an insurance policy. We're losing habitats worldwide at a phenomenal rate—and when habitats go, the plants go. This gives us the possibility of restoring them at some future date."

No one knows, of course, when that date might be, particularly in the case of islands, where many plants are usually natives found only in that place and particularly vulnerable to extinction. That's why a key part of the Seed Bank is storage.

In a low brick building across from Smith's office two young women pull on fiber-filled suits, hats with long earflaps, mukluks, and two layers of wool gloves, equipping themselves as if heading into the Arctic. But their destination is actually only a few feet away: the Seed Bank's cold rooms, where the temperature is minus 20 degrees Celsius (-4°F). It's in these icy chambers that the seeds collected from the wild are stored. Keeping the seeds cold and dry will preserve them for at least 200 years. "That buys us some time to understand the implications of worldwide habitat loss—and the time, I hope, to restore or save them," says Smith. After all, the goal, he adds, "is not to have these seeds sitting in the cold in little foil packets. It's to see the plants thriving again in the wild."

But storing seeds is not the only way to save biodiversity. Other scientists are looking for ways to demonstrate in practical terms the economic value of native plants and animals. On a grassy peninsula that juts into Lake Victoria, Zeyaur Khan, an entomologist at the Kenya-based International Centre of Insect Physiology and Ecology, leads the way to several test plots of corn and native grasses he has planted.

"African farmers have a big problem with stem borers," explains Khan, describing how the larvae of moths burrow into cornstalks. He stops at a corn plot surrounded by a two-foot swath of tall grass. "It used to be thought that the native grasses were the cause, that they were the primary hosts of the borers. It was even suggested that by getting rid of the grasses, we'd be rid of the stem borers too."

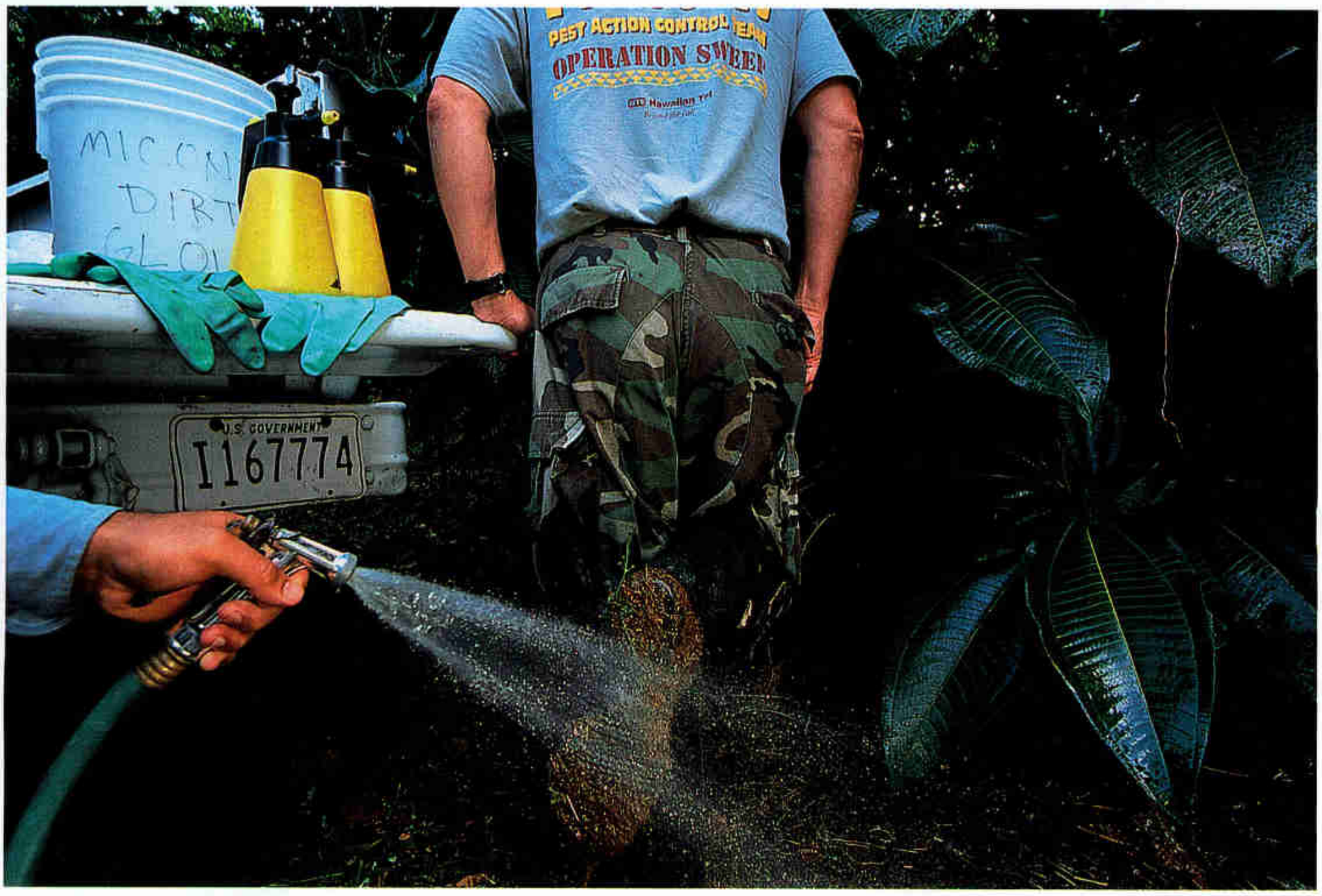
But no one had ever studied the relationship between the borers and grasses in depth, so in 1994 Khan launched a survey. Of the 600 species of grass he examined in Kenya, only 30 were hosts to stem borers. A few of these 30 were especially sought after by the moths. This led Khan to think that they could be used to control the stem-borer problem in corn.

One grass that the moths like to lay their eggs on, he found, has a clever defense: When attacked by larvae, it produces a gummy substance that traps the pests, so that only 5 to 10 percent emerge as adults.

"Look at this," Khan says, slicing open a stalk of the grass. Inside are curled several cream-colored larvae, about an inch long. "Now look at this corn," he says, cutting open a stalk growing beside the grass. Its interior is pest free, the stalk firm and healthy. The stem borers have apparently chosen the grass as a host over the corn. Another grass gives double protection. It exudes chemical signals that repel the moths and, at the same time, attract wasps that inject their eggs into stem borer larvae. When the wasps' eggs hatch, their larvae eat the pests. Drawn to a cornfield by this grass, the wasps lay their eggs in the larvae infesting corn.

By planting such grasses side by side with his crop, Khan has cut borer damage by almost

epidemiologists, killing invaders and warning locals. *Miconia* arrived 40 years ago as a backyard ornamental. Now up to 20,000 acres are overrun with what's being called green cancer. Perhaps leaf spot fungus, a disease from *Miconia*'s home in the tropical Americas, will check its advance.



70 percent. "It's a simple way to improve our crop yields," he says, "and very clearly demonstrates why we need to save biodiversity."

In Costa Rica's Guanacaste Conservation Area, Dan Janzen and his wife, Winnie Hallwachs, both ecologists, take a broader approach to the problem. "It's simple: Buy every scrap of trashed land anybody wants to sell and add it to the conservation area," says Janzen, a robust man who's so intent on saving the tropical dry forest in the country's far northwest that the mundane tasks of life never seem to get done. Wearing an unbuttoned shirt, he stomps through the woods in hiking boots only half-laced; his trifocals are spotted, his shoulder-length white hair finger combed. But his words and energy are messianic: Costa Rica's reputation as an ecologically enlightened country has some roots in his beliefs. "Yes, you want to save this forest because you might find a new drug or new pest control or attract tourists, but none of these are *the* reason for wanting to keep this a wildland. For me, there's only one objective: that this biodiversity survive."

Janzen leads the way through a young forest of thin, spindly trees, now naked during the dry season, their brown leaves scuttling under our feet. He stops when it turns abruptly cool and looks up. The trees here have huge girths, and their leafy branches cast a cool, welcoming shade. "These trees aren't bigger or greener because it's wetter here," Janzen says. "It's because they're old-growth original forest—evergreen mahoganies and chicle trees that once grew everywhere here." The spindly trees we hiked through are juveniles of what 500 years from now will once again be a semi-evergreen closed canopy.

"At one time, dry forests like this made up more than half the tropics' forest," Janzen says. "But less than 2 percent of it remains. Why? Because it's where people want to live and farm and ranch. From San José [Costa Rica's capital] to the Pacific—all that land was dry forest." When Janzen arrived in 1963, the Guanacaste lowlands were thriving ranches, and the

Promise takes root in Costa Rica, where children's cards (right) and contributions support the 55,000-acre Children's Eternal Rainforest, run by the Monteverde Conservation League. In the adjacent Monteverde Cloud Forest Preserve, students observe what they're helping to save.

remaining forests were being actively logged. By the mid-1980s, when Guanacaste Conservation Area germinated as a small national park, the forests had vanished, and the ranches were being abandoned as uneconomical.

"I thought those lands could be restored simply by leaving them alone," says Janzen, explaining that the ranchers burned their land every year. "A lot of scientists said you'll never get anything to grow in those grassy pastures. But the ranchers told me, 'Of course the forest will come back. Why do you think we burn our pastures every year?' "

Through grants and donations and help from Costa Ricans, Janzen and Hallwachs raised 28 million dollars to purchase Guanacaste lands, establish a 120-member staff, and set up a 12-million-dollar management endowment. The conservation area now covers 323,600 acres, from 12 miles out into the Pacific to the Atlantic foothills of volcanic peaks 40 miles inland.

"You have to buy land people don't want," he says. "Forget prime bottomland—someone's always going to want to farm it. But after you buy the trashed land and restore it, it becomes more acceptable to include better lands in the 'wildland garden,' especially when it's owned and managed by the region's residents."

Back in the Philippines on Mount Isarog, Balete sees a similar chance for biodiversity to survive. "I'm betting that these villagers will change their ways permanently, that they won't destroy this forest," he says, standing on jet-black rocks beside a small, sparkling stream. He pauses for a moment, a broad smile lighting his face.

"Hear that bird?" he asks, pointing downstream. The call comes again, light and musical, a tumbling waterfall of bright notes. "That's the Luzon white-browed shama; to me, it's the sound of these woods." We stand silently under the mossy, orchid-laden trees in this forest that this one man has fought so hard for. And that, I think, is how our biodiversity will be saved: one on one, a patch at a time.

Discuss "In Search of Solutions" at *www.nationalgeographic.com/2000/biodiversity/forum.*

Howler monkey

Dear Sir or Madam, April 17, 1997
I would like information
about Saving the rainforest.
We would like to raise money
to help. We have raised twenty
dollars So far.

Sincerely,
ms. Julie's class

Dear M.C league,
I was wonde'ing if I
could be your partnere?
I like how you are saving
the rain forests. I want to
your parte because I
to help
our boolit
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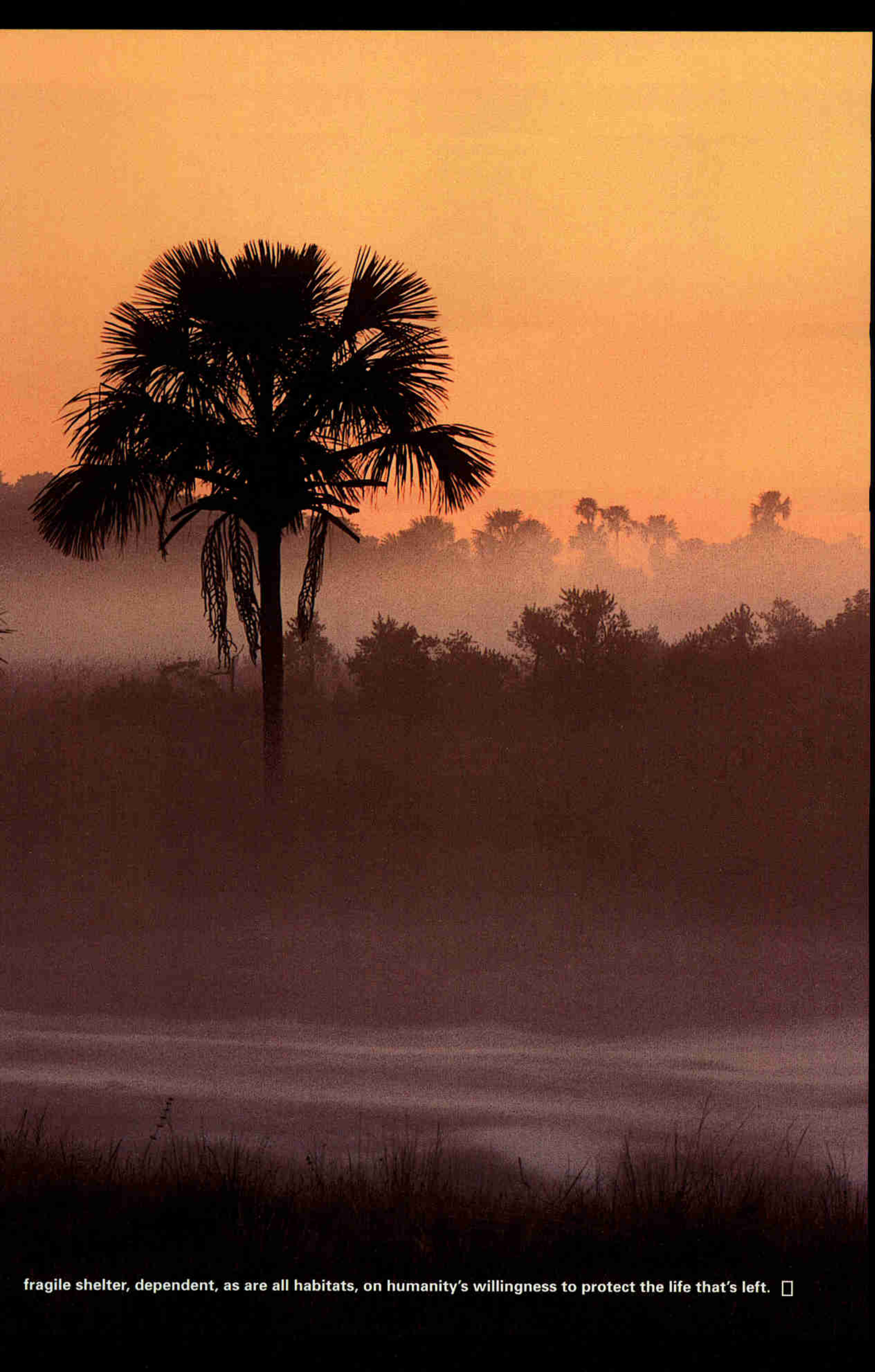
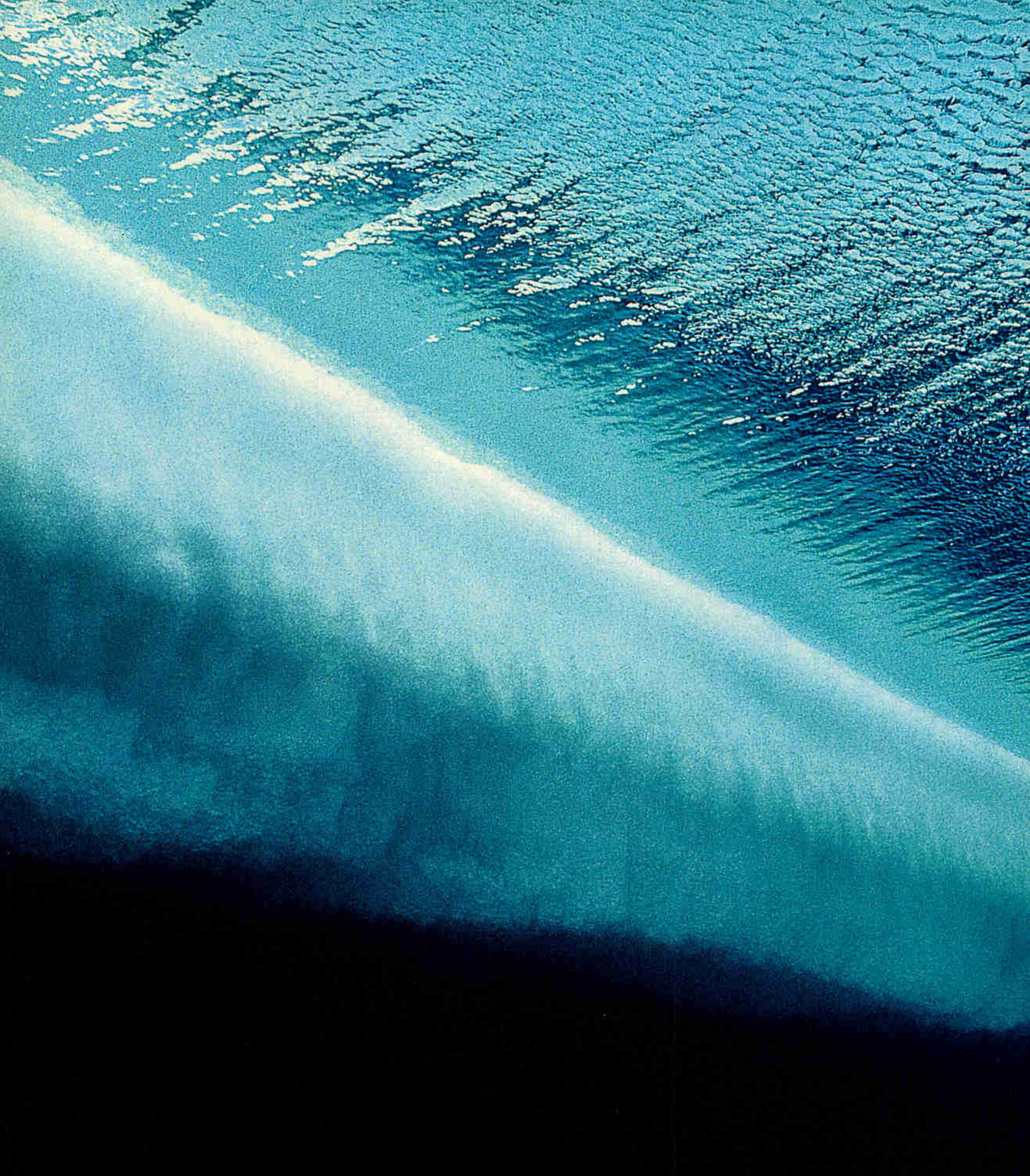
■ Surrounded by roads and fields, invaded by poachers and farmers' fires, Brazil's Emas National Park is a



fragile shelter, dependent, as are all habitats, on humanity's willingness to protect the life that's left. □



UNDERANT

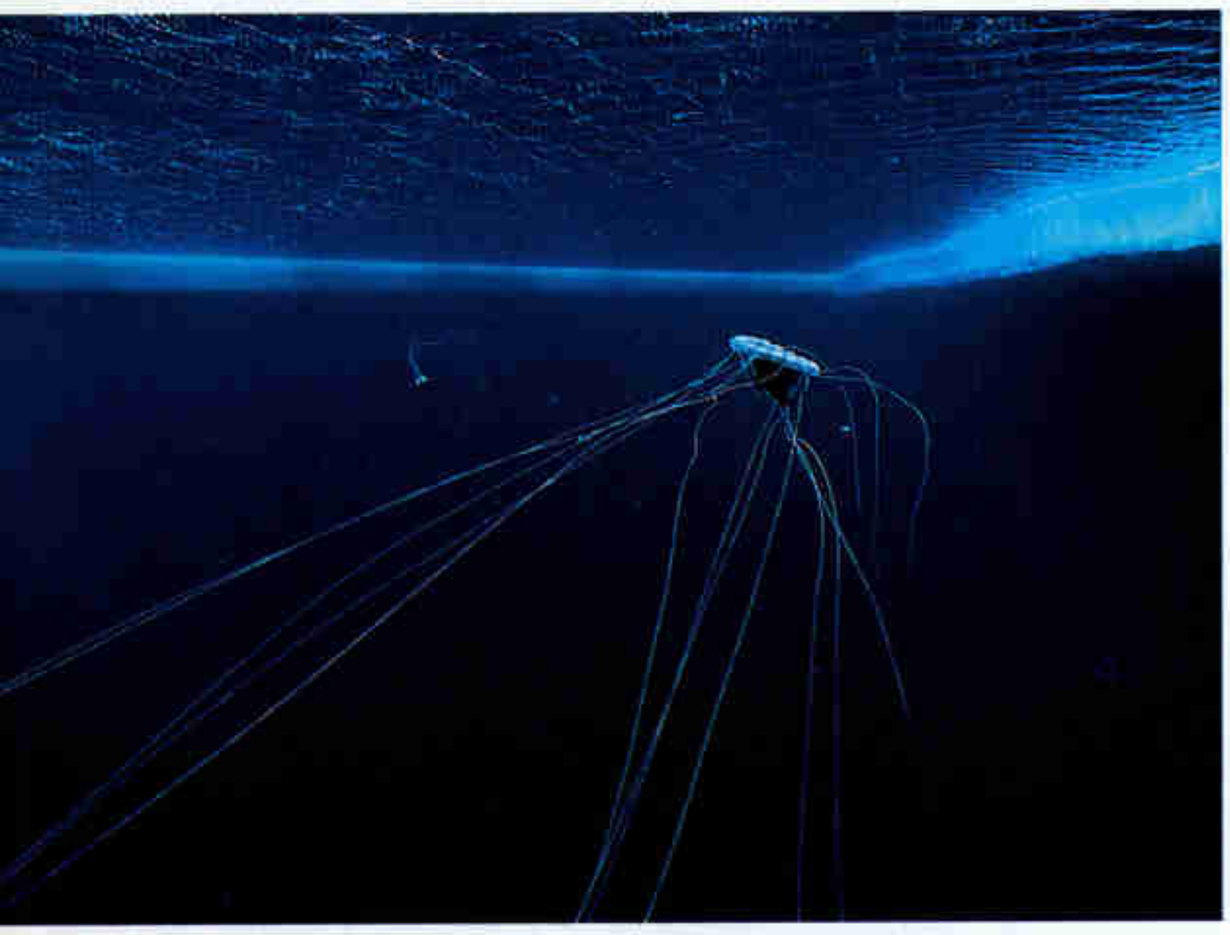
ARCTIC ICE

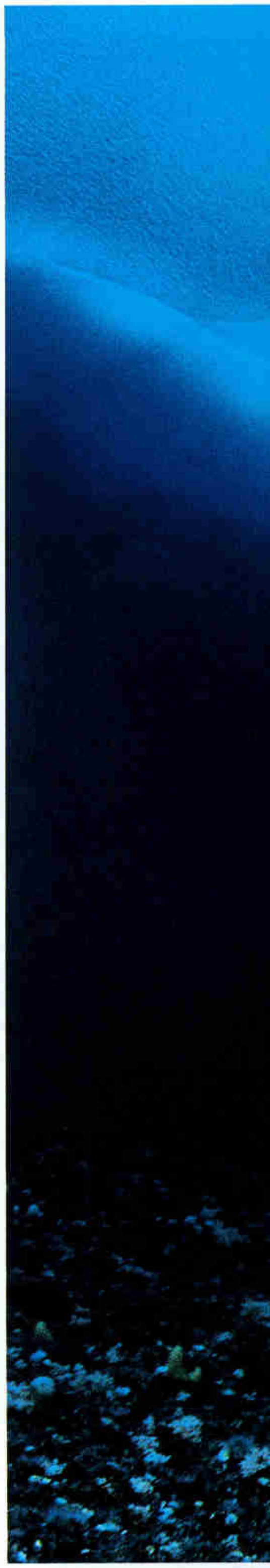
Article and photographs by NORBERT WU

With hurricane-force winds and cold that can kill in minutes, Antarctica's surface hosts little year-round life. But beneath its frozen seas lies one of Earth's most stable and vibrant ecosystems—and one of its most enchanting realms.

"It was like being suspended in space,

There's something special about peering beneath the bottom of the world. When Antarctica's summer diving season begins in September, the sun has been largely absent for six months, and the water, virtually free of phytoplankton, has become as clear as any in the world. Visibility is measured not in feet but in football fields. "There was no visual awareness of there being water," says my diving colleague Peter Brueggeman. "It was like being suspended in space, as if we were birds flying around in a big room." It felt as cold as outer space too. With its freezing point lowered by salt, the seawater is as cold as it can get—28.8 degrees F—an equipment-breaking, head-numbing reminder that this is a merciless realm. Yet even an encounter with Antarctica's treachery—when my leg cramped on a dive and the current almost swept me away—couldn't keep me from falling in love with the place. Of the hundreds of spots I've dived, this one, with its invisible water and crystalline ceiling, stands apart. Only here can you orbit an electric-blue iceberg (right) while being serenaded by the eerie trills of Weddell seals. Only here will you see huge invertebrates—sponges the size of bears or jellyfish with 30-foot tentacles (above). Indeed, these seas are full of surprises. Until recently scientists thought that Antarctica's waters, like the Arctic's, had a relatively low diversity of life; it now appears that Antarctic biodiversity is richer than they had imagined. But you'd never guess it from the surface, and it's this contrast that marine ecologist M. Dale Stokes says struck him most about our dives: "There's this large, active, colorful community under the ice, and then you come up through a hole into a raging blizzard."

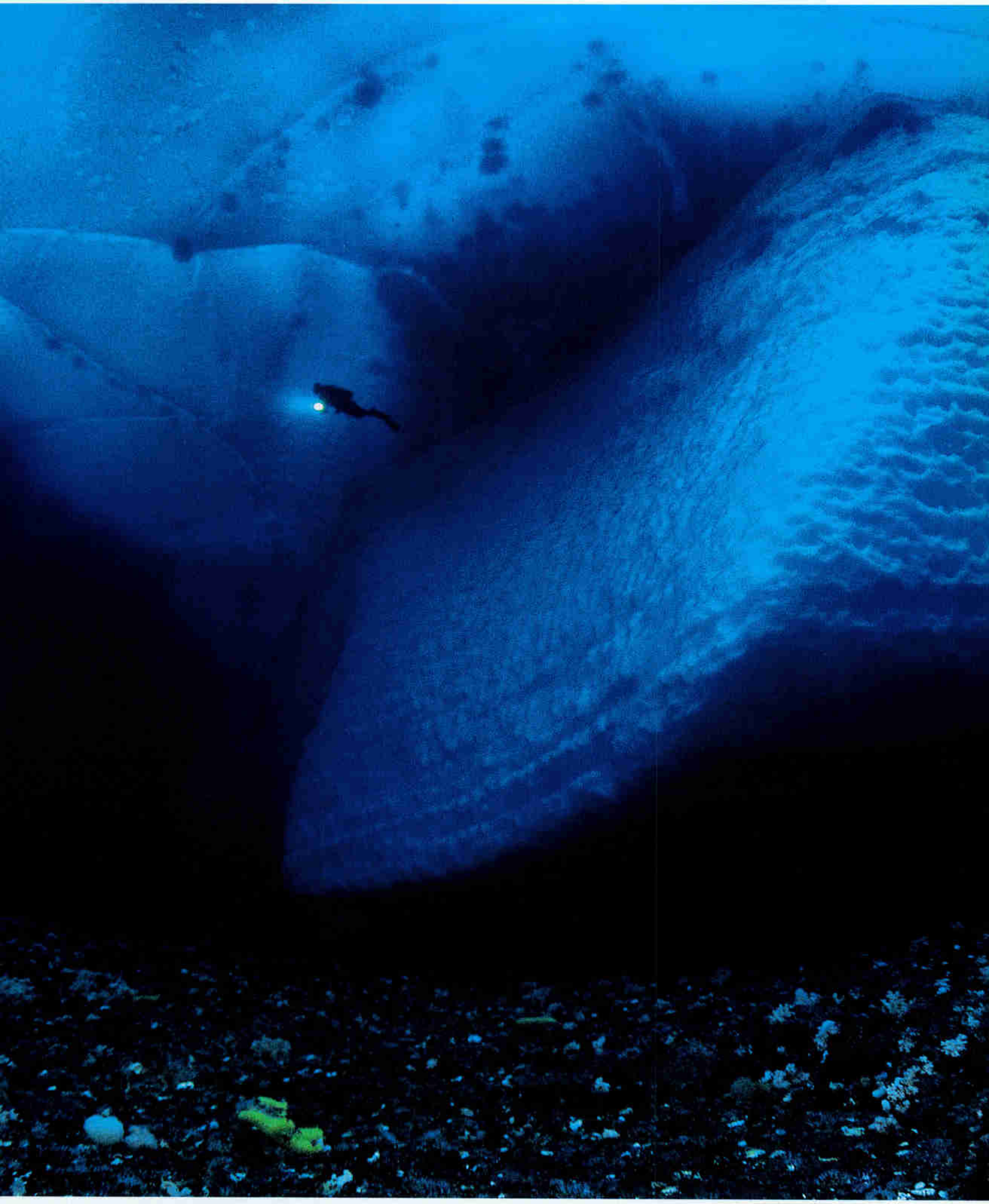




Photographer and filmmaker Norbert Wu specializes in ocean exploration.

as if we were birds flying around in a big room."

— PETER BRUEGGEMAN



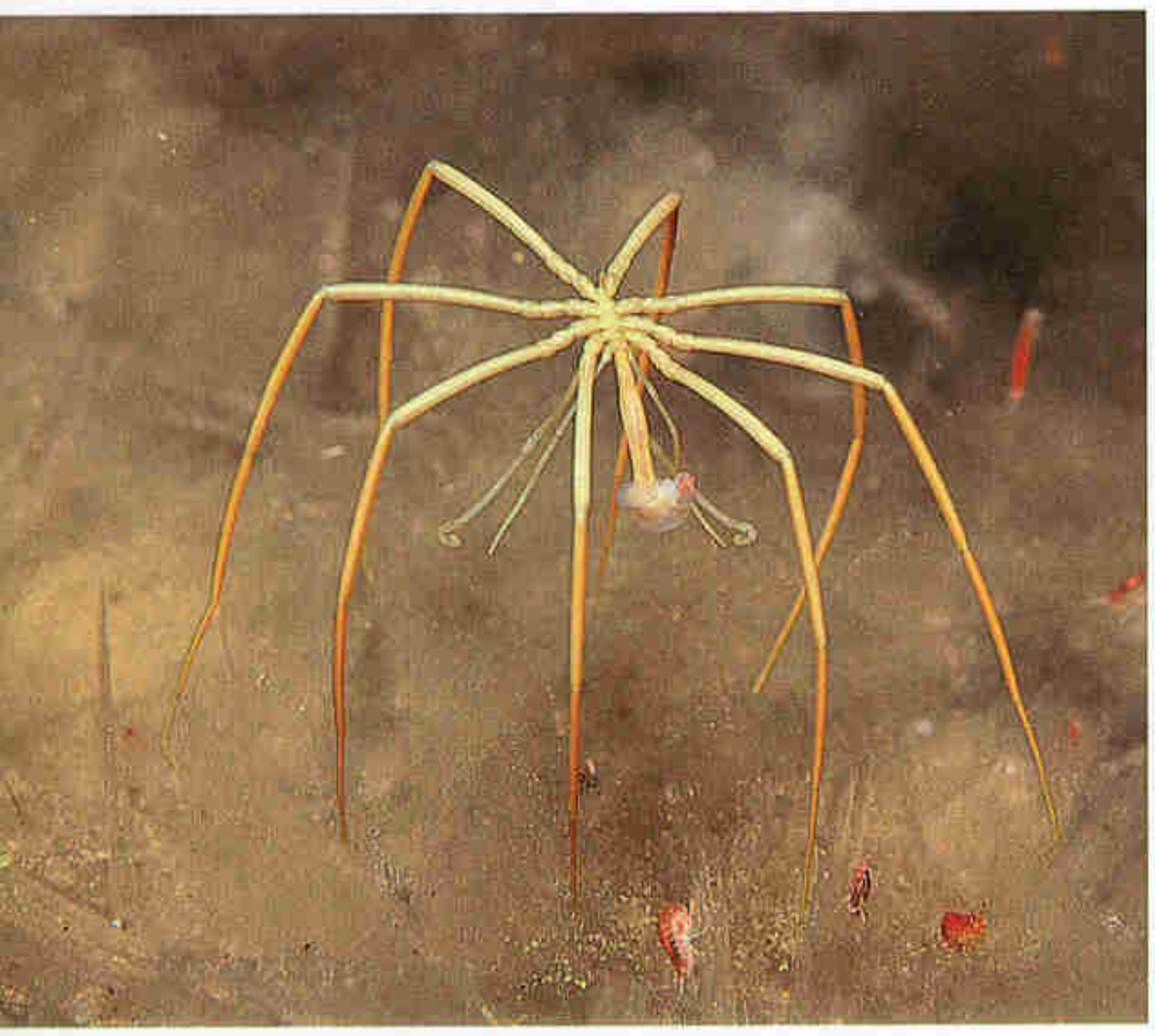
Weddell seals stake their claim as the world's southernmost mammals by keeping year-round

airholes in the ice. Safe from open-sea predators, this mother and pup show no fear of divers.

Sea stars gather beneath seal holes to feed on feces and other debris. In the barren shallows

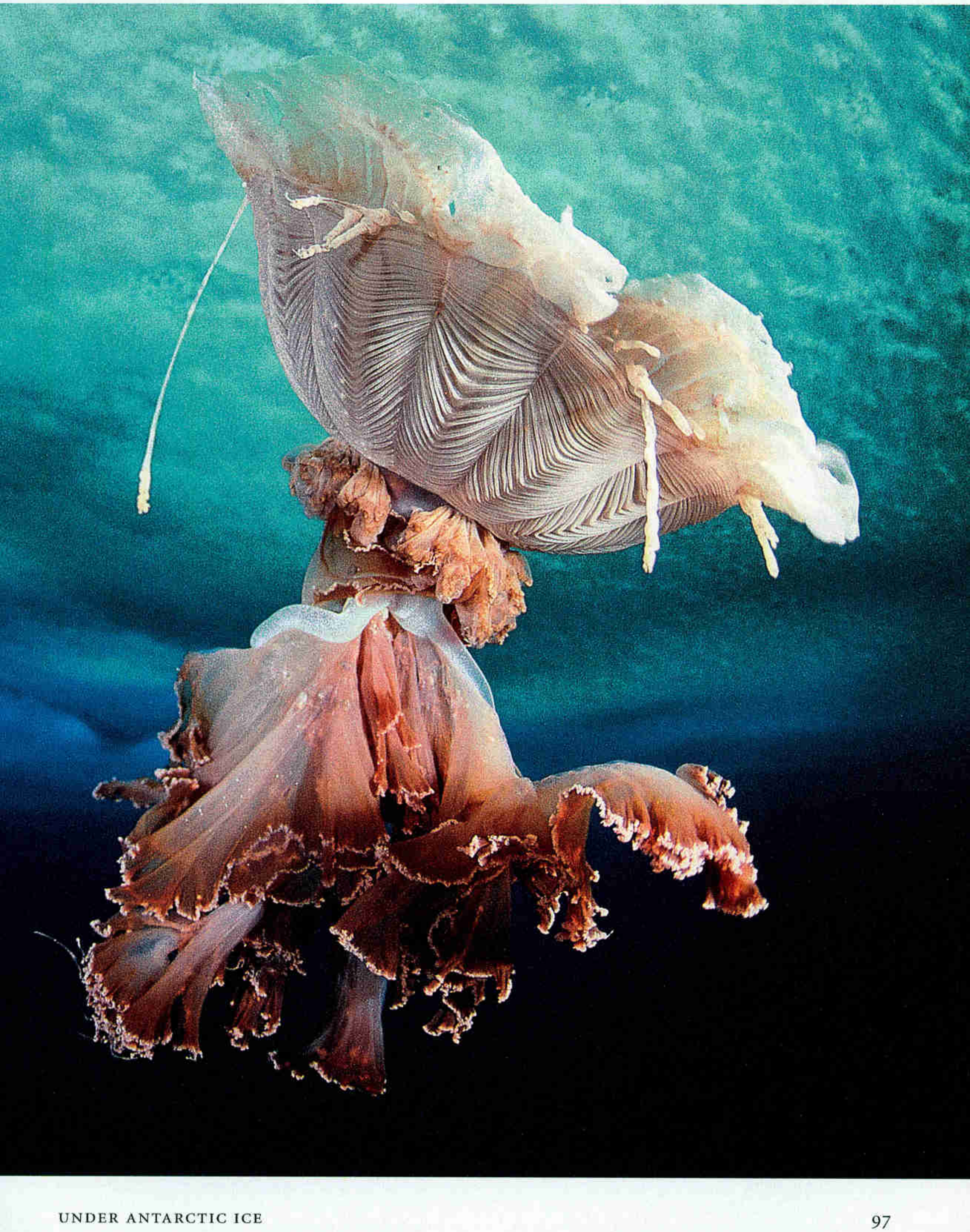
where ice crystals form on anything that doesn't move, animals can't afford to be picky.

Because it's hard to study life under ice, many Antarctic



With a flamenco flourish, a jellyfish the size of a barrel attracts the camera of oceanographer Stokes. "It was huge—just this big pulsating living thing," he says, "not a helpless little drifter like you think of most jellyfish." With slow metabolisms and relatively few predators, many Antarctic invertebrates grow exceptionally large and live years longer than their cousins in warmer water. The pycnogonid, or sea spider, pictured above is the size of a human hand; most of the 600 pycnogonid species worldwide are smaller than a fingernail. The sea stars on the preceding pages may live as long as 20 years.

creatures are as novel to science as they are to the eye.



Emperor penguins weave contrails of bubbles through a sapphire sea. They need not be so

agile above the ice; all the action—hunting and being hunted—lies beneath it. □

FOREST ELEPHANTS

Cloaked in foliage and mystery, Africa's forest elephant has eluded science for decades. Yet at the remote Dzanga Bai clearing in the Central African Republic, a jungle-tough biologist is revealing this animal one breath-taking glimpse at a time.

Photographs by
MICHAEL FAY and
MICHAEL NICHOLS
NATIONAL GEOGRAPHIC PHOTOGRAPHER

MICHAEL NICHOLS

Protecting the family

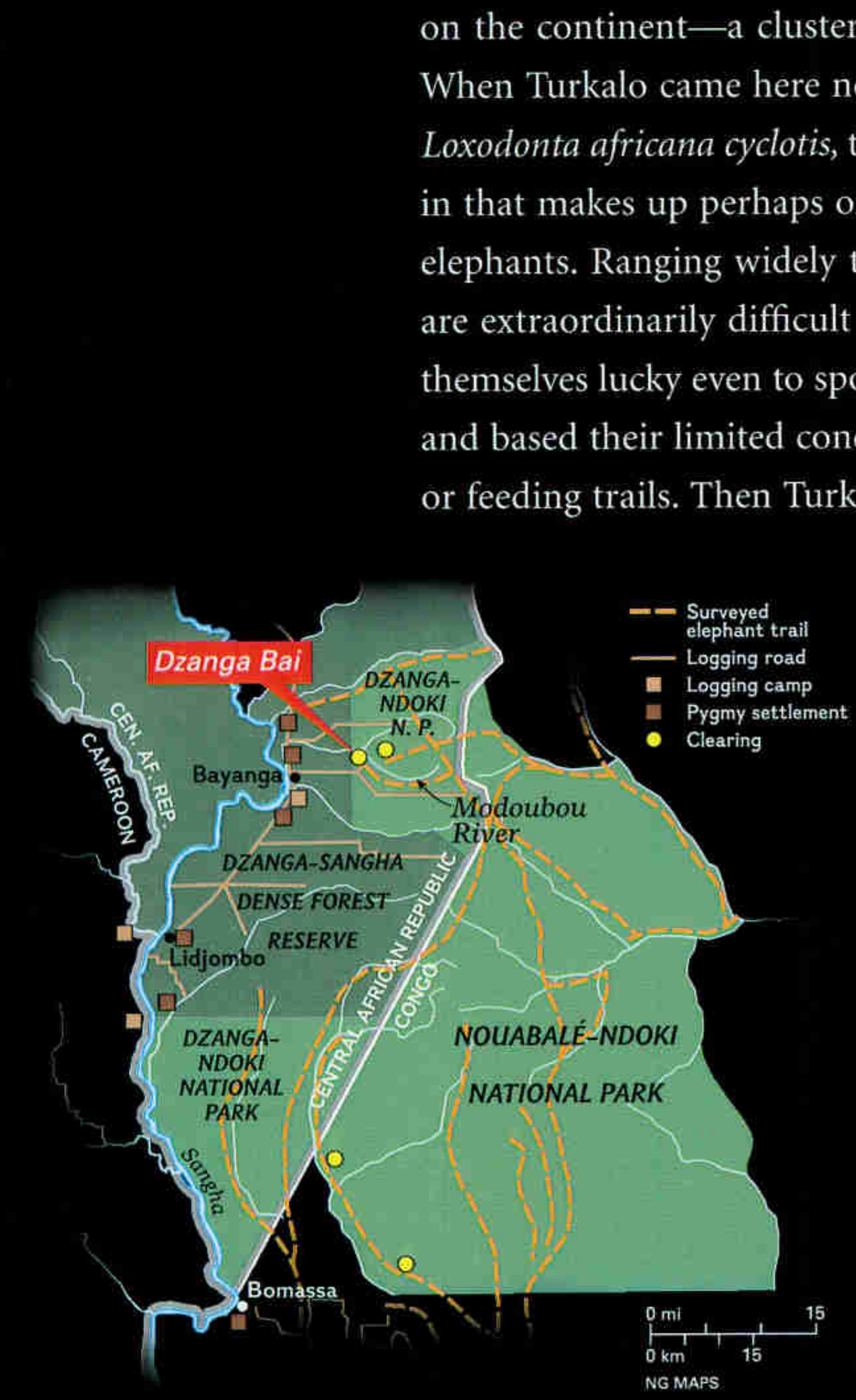
Ears out and trumpeting a warning, the matriarch Ladybeard makes a false charge at photographer Michael "Nick" Nichols to protect a younger female, Anemone, at left, and her calf. Though females often guard younger elephants, this kind of charge is "extremely rare" at Dzanga Bai, says biologist Andrea

MICHAEL NICHOLS

Turkalo. She speculates that when the animals are in the clearing, they don't consider humans a threat.

Elsewhere forest elephants are afraid of people. Outside the boundaries of the national park that surrounds Dzanga Bai, the animals are illegally hunted. The killing is expected to draw closer and closer to the clearing as the search for old-growth timber intensifies. Loggers will inevitably cut more roads through the bush. Poachers are sure to follow.

"It was once said that in Africa human communities were like islands surrounded by elephants," recalls Andrea Turkalo, of the Wildlife Conservation Society. "These days it's exactly the opposite." She would know: Her pioneering study of forest elephants is conducted at Dzanga Bai, a remote, 30-acre clearing within one of the largest such islands on the continent—a cluster of rain forest preserves in central Africa. When Turkalo came here nearly a decade ago, little was known about *Loxodonta africana cyclotis,* the savanna elephant's elusive smaller cousin that makes up perhaps one-third of the 600,000 remaining African elephants. Ranging widely through dense vegetation, forest elephants are extraordinarily difficult to study. For years researchers considered themselves lucky even to spot a forest elephant, much less observe one, and based their limited conclusions on indirect evidence such as dung or feeding trails. Then Turkalo set up camp at Dzanga Bai in Dzanga-Ndoki National Park, where elephants congregate to drink and dig minerals from the soil. Today, working from a platform in the trees, Turkalo meticulously observes every elephant that visits, noting physical characteristics to establish individual identities, then builds on this data to study life histories, family structure, and patterns of group behavior. Equipped with insect repellent and a spotting scope, Turkalo spends most afternoons on her platform, "unraveling the intricacies of the forest elephants' lives."



Bachelor life

Quenching their thirst, three middle-aged males gather at the Modoubou River during the rainy season, using a network of foot-worn trails that are probably centuries old. Solitary travelers in the forest, bachelors socialize at such clearings, relying more on their sense of smell than on eyesight to identify old friends or foes.

MICHAEL NICHOLS (OPPOSITE)

The lady in charge

Just like their mom, Tuesday, two youngsters plastered in mud use their trunks to probe for salt as an adolescent male, at right, submissively waits his turn.

Like their relatives in the savannas of East and southern Africa, "forest elephants have highly organized social lives," says Turkalo, citing her study of

MICHAEL FAY

some 300 elephant families at Dzanga Bai. What she's found is a classic matriarchy, with all groups led by mature females like Tuesday. Tuesday's immediate family of two offspring is typical of forest elephants, which travel in smaller groups than savanna elephants—possibly because they face fewer predators. While lions prey on juveniles in the savanna, Dzanga's largest carnivore, the leopard, is no match for a young elephant—especially with mother nearby.

Bonding over the mineral-rich mud in the hole at their feet, an older female (left) places her trunk into a juvenile's mouth. Elephants dig relentlessly with their tusks and trunks in the muck at Dzanga Bai, mining the substrata for salt and other minerals to supplement their diet of leaves, bark, grasses, and fruit. Elephants work overtime to excavate these holes, says Turkalo. "It's their main activity in the clearing. *Sometimes* they dig so deep that all you can see is the back of the elephant working the hole." As one might expect, there's also much jockeying for position. "I've watched males low in the hierarchy stand patiently for hours, waiting for a larger elephant to finish—only to be driven off time after time."

With notoriously bad eyesight, forest elephants tend to follow their trunks, using the appendage as a blind person might use fingertips on a stranger's face—to identify, visualize, gather clues, communicate. From infancy, elephants entwine their trunks in play (below), establishing bonds of kinship while storing vital information—from smells and textures to the muscular strength of their playmates. Later these games become more aggressive, especially among males, which grapple and joust with each other in order to establish dominance.

Mining for salt

BOTH BY MICHAEL FAY

Miracles in the mist

Picture window on the elephant world, Dzanga Bai is "absolutely ethereal" in the morning, says Turkalo, who likes to start work early and watch the animals materialize in the mist—they spend all night in the open. On one such morning a few years ago, she counted 180 elephants. "This is one great place for elephants,

MICHAEL NICHOLS

especially the young," she says. "Most of the time they just look happy." Trampled by generations of tonnage afoot, the clearing is constantly growing. Elephants will often pull down tree branches around the perimeter by tugging on a vine, or will strip bark off a tree until it dies and falls—opening the forest to sunlight and new, more edible vegetation that is quickly eaten to the nub.

Michael Fay, a Wildlife Conservation Society ecologist, was featured in "Ndoki" (July 1995).

Sharing the wealth

Elephants aren't the only ones lured to Dzanga by the salt at the clearing. All animals in the neighborhood—buffalo, wild hogs, bongo, otters, civets, sitatungas, even insects—crave a taste of salinity in the salt-poor rain forest environment. Each dry season thousands of African snout butterflies invade the clearing (right), dropping in on the locals to get salt from their skins. Most elephants take it in stride, says Turkalo, going about their business in what amounts to a blizzard of wings.

So far Turkalo has identified some 2,500 elephants at Dzanga Bai—including 50-year-old Emma and her offspring (below)—and

chronicled their lives and behavior. Yet with poachers slaughtering elephants for their tusks—and no guarantee that the international ban on the sale of ivory will continue—she can't help looking over her shoulder. "Dzanga is like a miracle," she says. "But without protection, all this could perish in a very short time." □

TEXT BY DON BELT
ASSISTANT EDITOR

BOTH BY MICHAEL FAY

Article and photographs by DARLYNE A. MURAWSKI

DIA

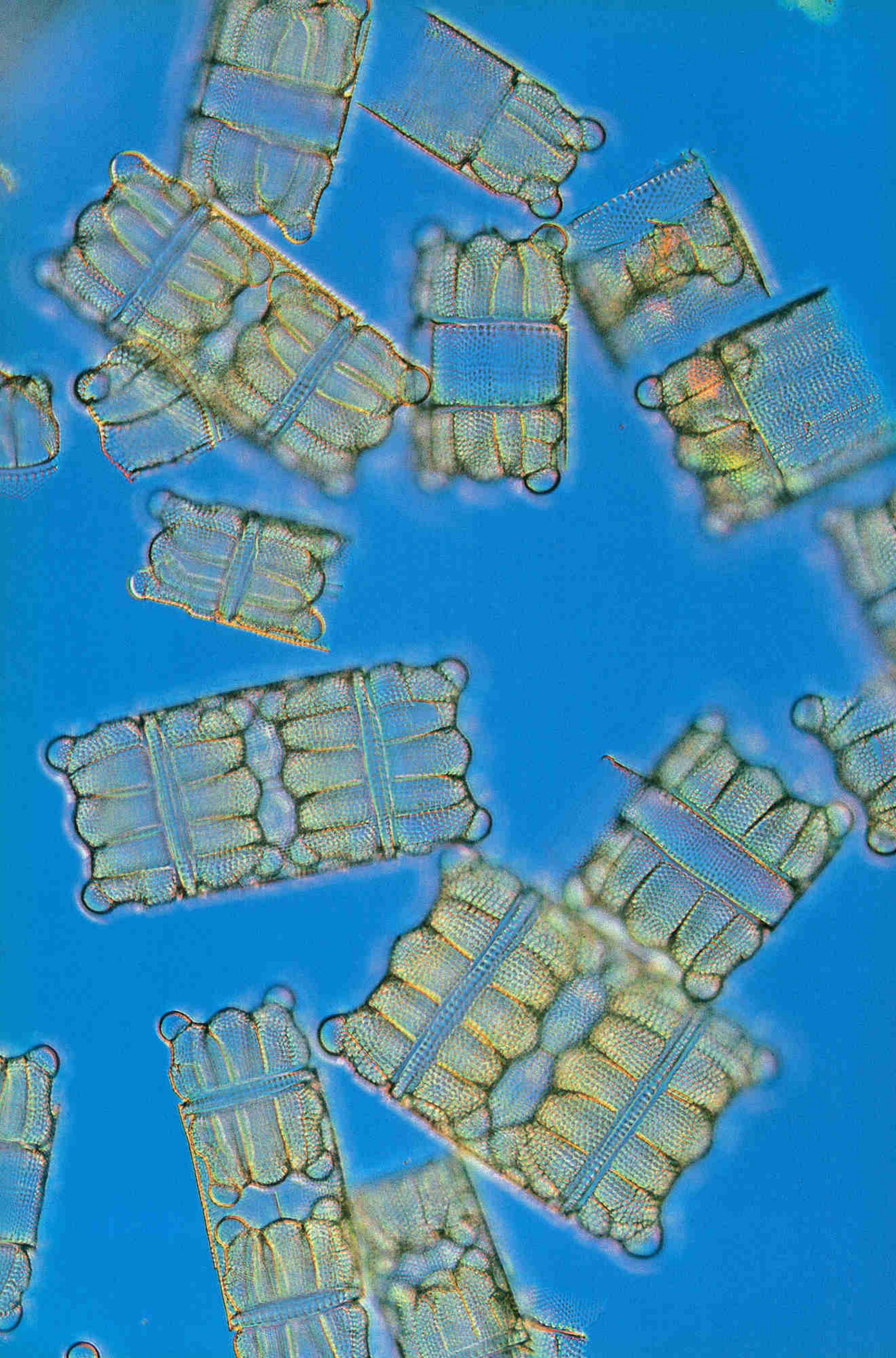
Plants With a Touch of Glass

Single-celled algae, tens of thousands of diatom species, including delicate *Pleurosigma*,

TOMS

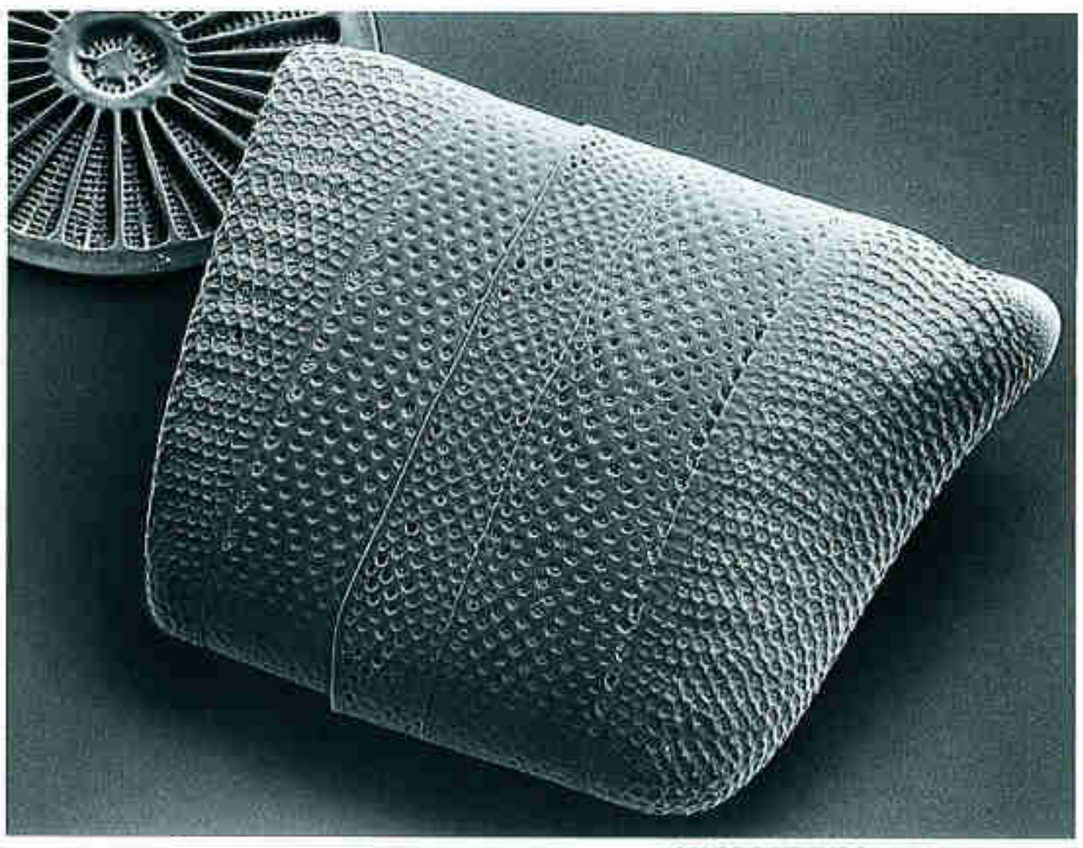
inhabit fresh water or ocean. All build glass shells of fantastic form and practical use.

PLEUROSIGMA ANGULATUM (MARINE DIATOM), MAGNIFIED 4,400 TIMES

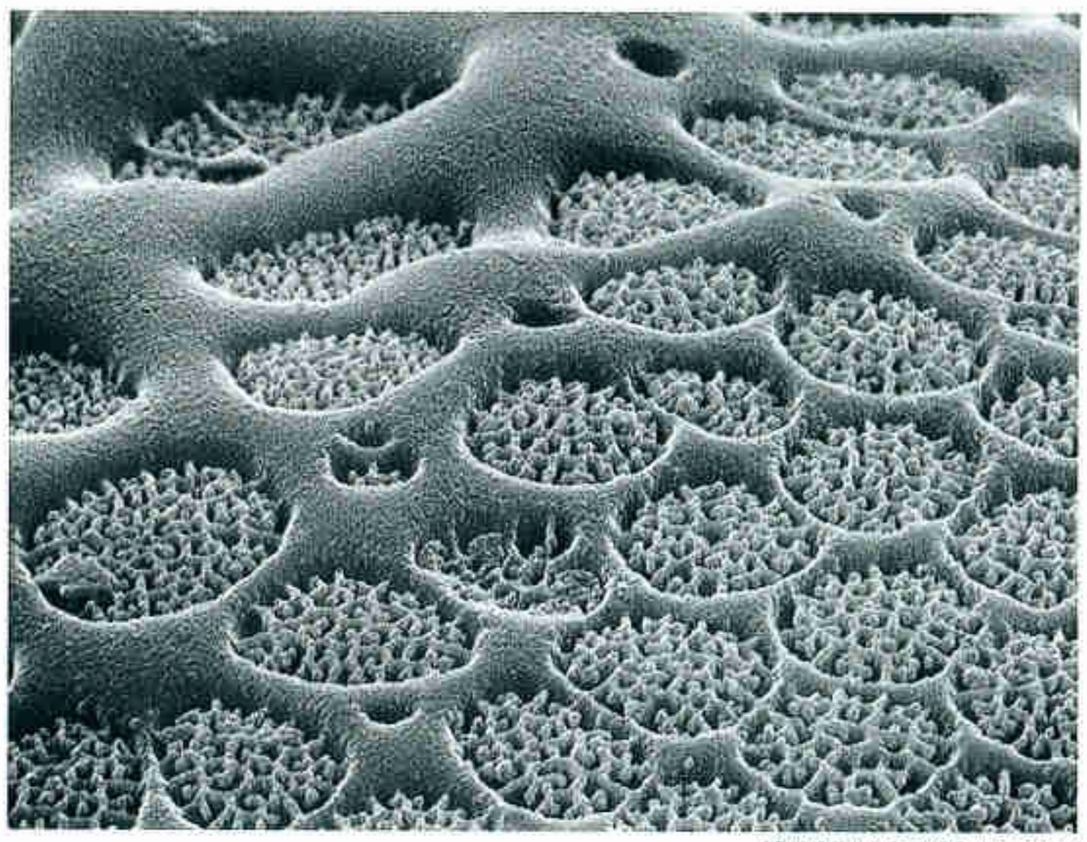


There's no disputing Charles Darwin on this point: "Few objects are more beautiful than the minute siliceous cases of the diatomaceae: were these created that they might be examined and admired under the higher powers of the microscope?" So Darwin wrote in 1872, sounding as much the Victorian connoisseur as the peerless field scientist. The symmetry and grace of diatoms are now even more evident when seen under the extreme magnification of a scanning electron microscope (right) or in the polarized light of Nomarski interference microscopy, as in the colored images here.

And the living algae that once inhabited these silica shells? About 70,000 species, both fossil and recent, have been described, and that may be only the half of it. As small as they are diverse (some 25 million would fit in a teaspoon), diatoms are both abundant and essential. They make up about a quarter of plant life by weight and produce at least a quarter of the oxygen we breathe. In life they provide high-quality nutrition to animals as small as protozoans and as large as baleen whales. In death they rain down on ocean floors, where their oil-rich plasma is eventually buried and transformed into petroleum. Their skeletons are mined for use as filters and abrasives.



ISTHMIA NERVOSA (MARINE), 185 X



ISTHMIA NERVOSA, 5,535 X

Diatoms enable biologists to pinpoint sources of water pollution and monitor the health of ecosystems. They help geologists reconstruct the history of ancient climates. As for me? I stand with Darwin.

DARLYNE A. MURAWSKI photographed "Parasites" in the October 1997 issue of NATIONAL GEOGRAPHIC and "Body Beasts" in the December 1998 issue.

Only glassy yellow rafts remain of diatoms that reproduced by simple cell division (left). Diatoms also reproduce sexually. The myriad openings in their silica shells (above) are usually arranged in elaborate patterns unique to individual species.

BIDDULPHIA PULCHELLA (MARINE), 1,400 X (LEFT)

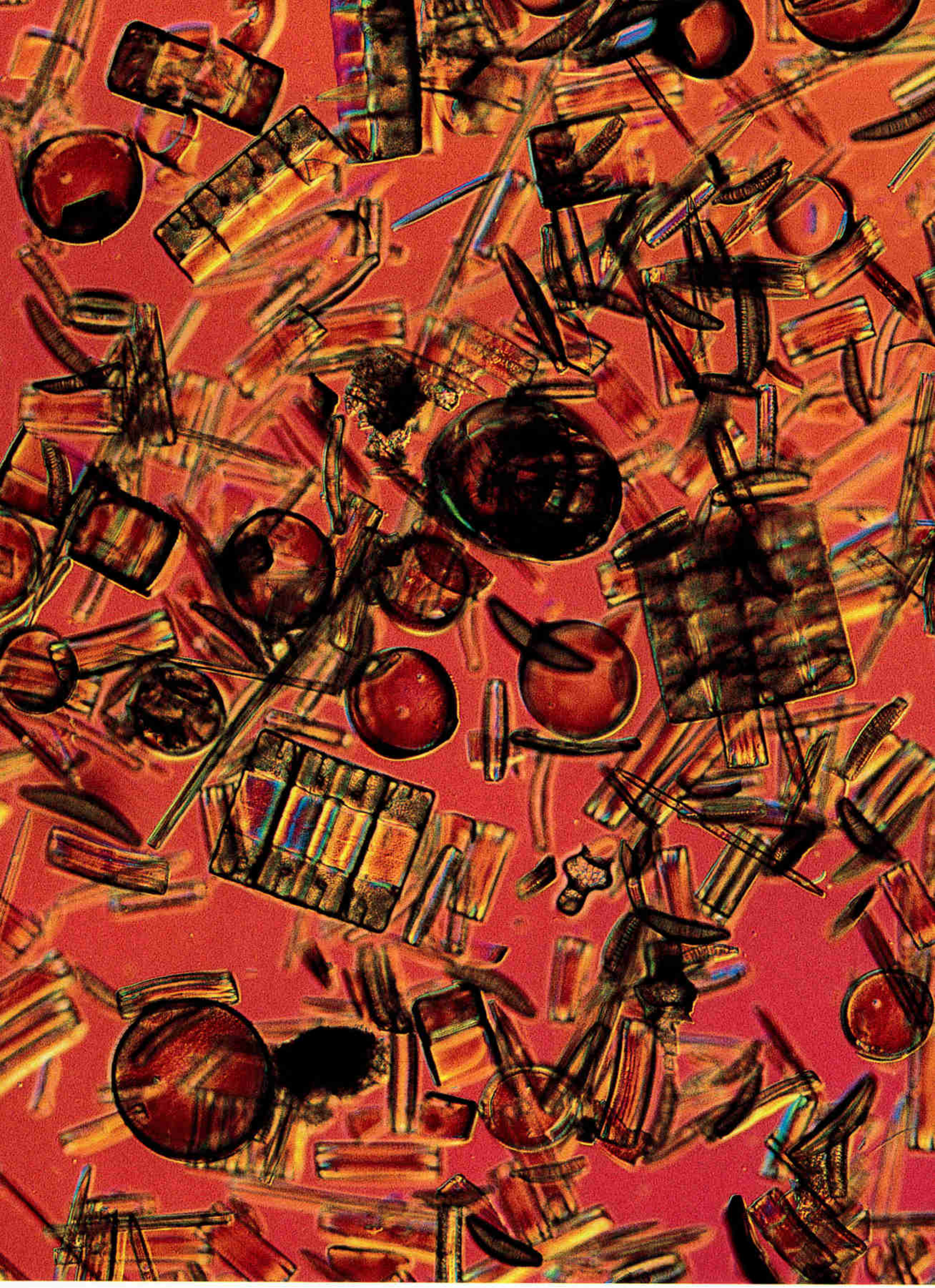
RHABDONEMA SP., 1,000 X (TOP); *TRICERATIUM* SP., 900 X

Kaleidoscopic variations in diatoms have fascinated professional biologists and intrigued hobbyists, who during the Victorian era arranged the shells in artistic ensembles on microscope slides. Marine

CAMPYLODISCUS NORICUS, 2,000 X (TOP); *HIMANTIDIUM PECTINALE*, 1,000 X

diatoms (facing page), though usually poorer in silica than freshwater varieties (above), appear in shapes just as fantastic: breakfast cereal and flying coffee tables, compared with gliding smiles and ghostly ladders.

Optical magic of prisms and polarized light transforms a collection of freshwater diatoms into a bauble factory. Biologist Edward Theriot points out that diatoms have been used as tracers in military intelligence,



to connect criminals to crime scenes, to locate the sites of drownings, and in archaeology to find the sources of clay in ancient pots. Almost all diatoms are benign, and that's good. Because they're everywhere. □

ANTS AND

In Borneo forests a pitcher plant and *Colobopsis* ants have struck a deal. The plant gives the

Article and photographs by MARK W. MOFFETT

PLANTS

A Profitable Partnership

ants room and board. In return the ants help their host digest insects—a new discovery.

During millions of years of evolution, ants have developed intriguing relationships with many different kinds of plants. Most of these associations are loose ones—the ants find dwelling places on the plants, while bringing neither harm nor benefit to them. Often the ants live in hollow dead stems or small pockets of soil that accumulate on branches. Thus ants inhabit trees over our heads and herbs at our feet, carving out living chambers and foraging for food. As many as 72 different species of ants have been found living on one tree in Peru's Amazon Basin alone.

However, in some relationships between ants and plants both sides give and get. The plants in such mutualistic partnerships are called ant-plants. Many of them are beautiful examples of coevolution, having adapted together with their ant partners to thrive in nutrient-poor areas.

In ant-plant relationships ants provide nutrients, protection, and housekeeping to plants. Plants provide food and shelter to ants. Some ants in these types of relationships serve their hosts as devoted sentinels, repelling or killing unwelcome intruders such as beetles and caterpillars. Others fertilize their hosts with waste from the food they drag home to eat. In return, many plants have evolved special structures to house and feed ant colonies, including leaves with hollow cavities and seeds with edible coatings or attachments. Frequently plants and ants become so dependent on one another that they cannot live apart.

Ecologist Mark W. Moffett is a frequent contributor to the magazine.

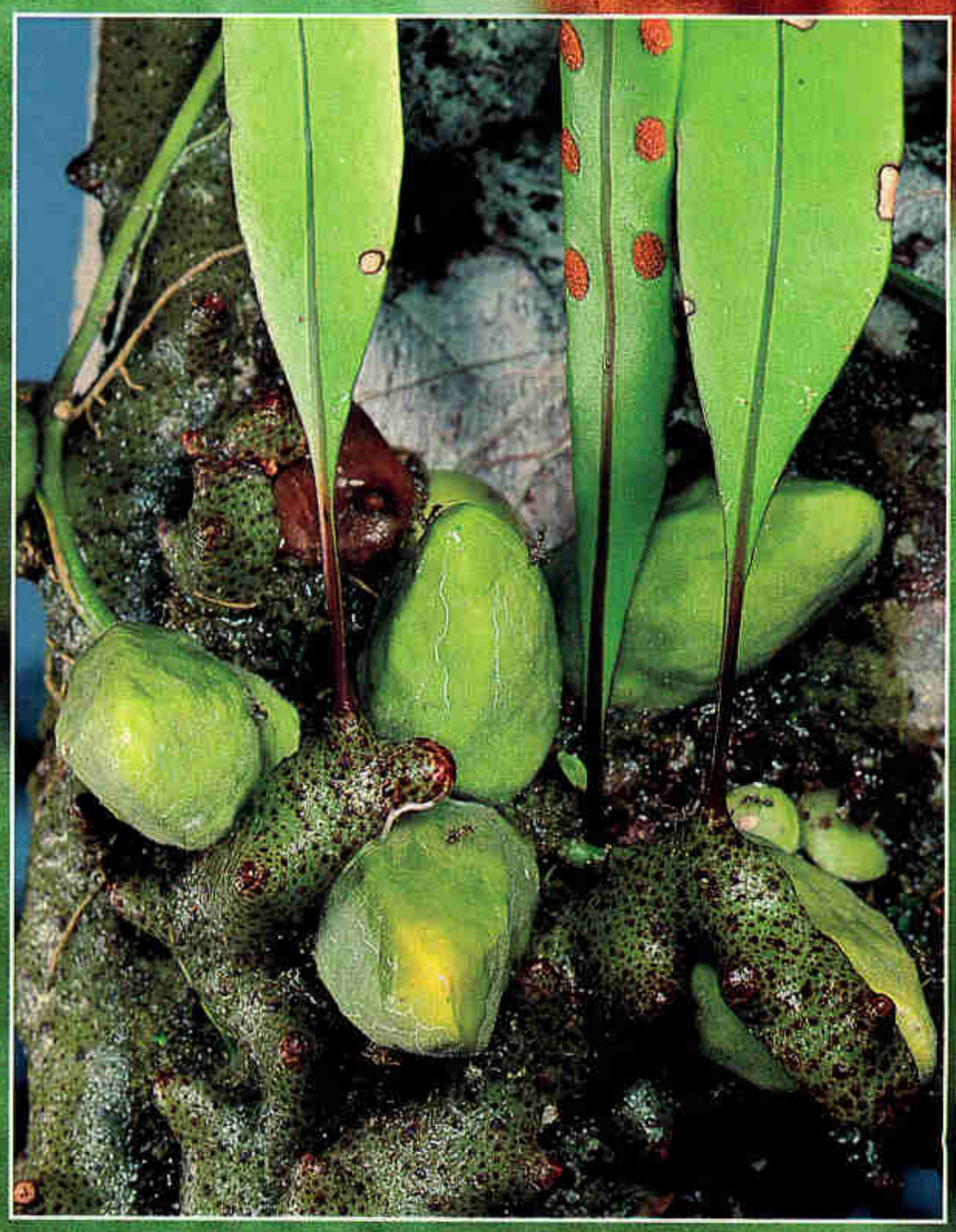
Deadly beauty, the pitcher plant (above) traps insects in its fluid-filled cup, where they drown. But *Colobopsis* ants that live in the tendril (cutaway, right) are unharmed. Charles Clarke and Roger Kitching of Australia's Griffith University began to understand why when they discovered the world's only known ant swimmers (following pages).

AQUATIC ANTS

Venturing out from their tiny homes in the pitcher plant *Nepenthes bicalcarata, Colobopsis* ants dive into the plant's digestive juices and paddle about, patrolling the liquid trap. They collect large prey like a cricket (above). Several workers were needed to haul this heavy meal up the pitcher's wall to the rim for a communal feast (right). Such apparent thievery benefits the plant. When large prey pile up in the pitcher and start to decompose, the juices turn foul—plant indigestion. *Colobopsis* ants keep this from happening by removing large insects. How do the ants manage to climb the slick walls and escape? As yet, no one knows.

ROOM AND BOARD

On infertile sandstone hills in Borneo, *Philidris* ants act like mobile root systems, bringing nourishment to their host plants, according to ecologist Dan Janzen (pages 76-7). A fern feeds its ant colony with edible masses of oily orange spores. The ants live in the fern's speckled stems (inset), where they drag nutrient-rich debris to create a sort of compost for the plant. Among the stems grows *Dischidia,* another plant that prospers in partnership with *Philidris.*



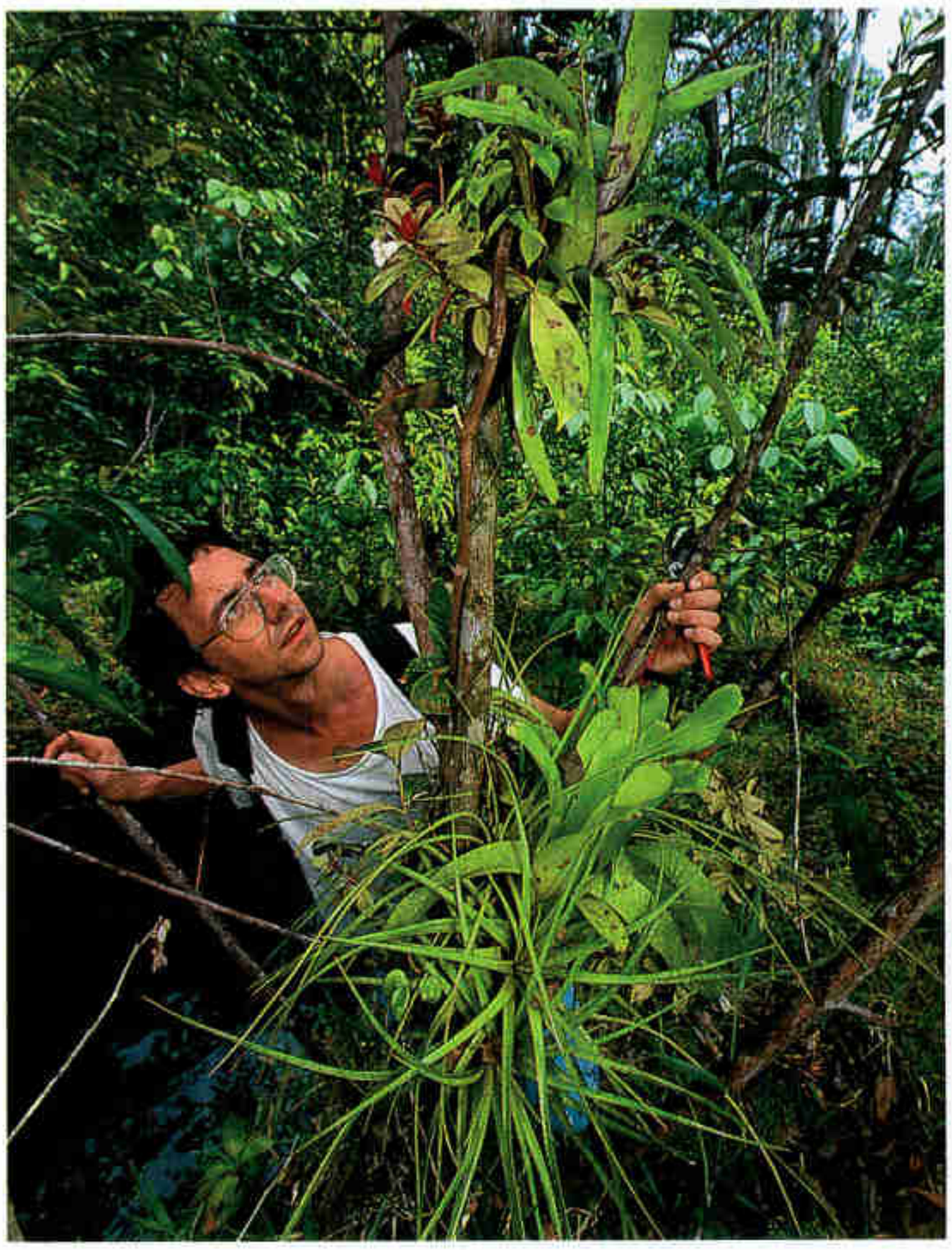
ANT CONDOS

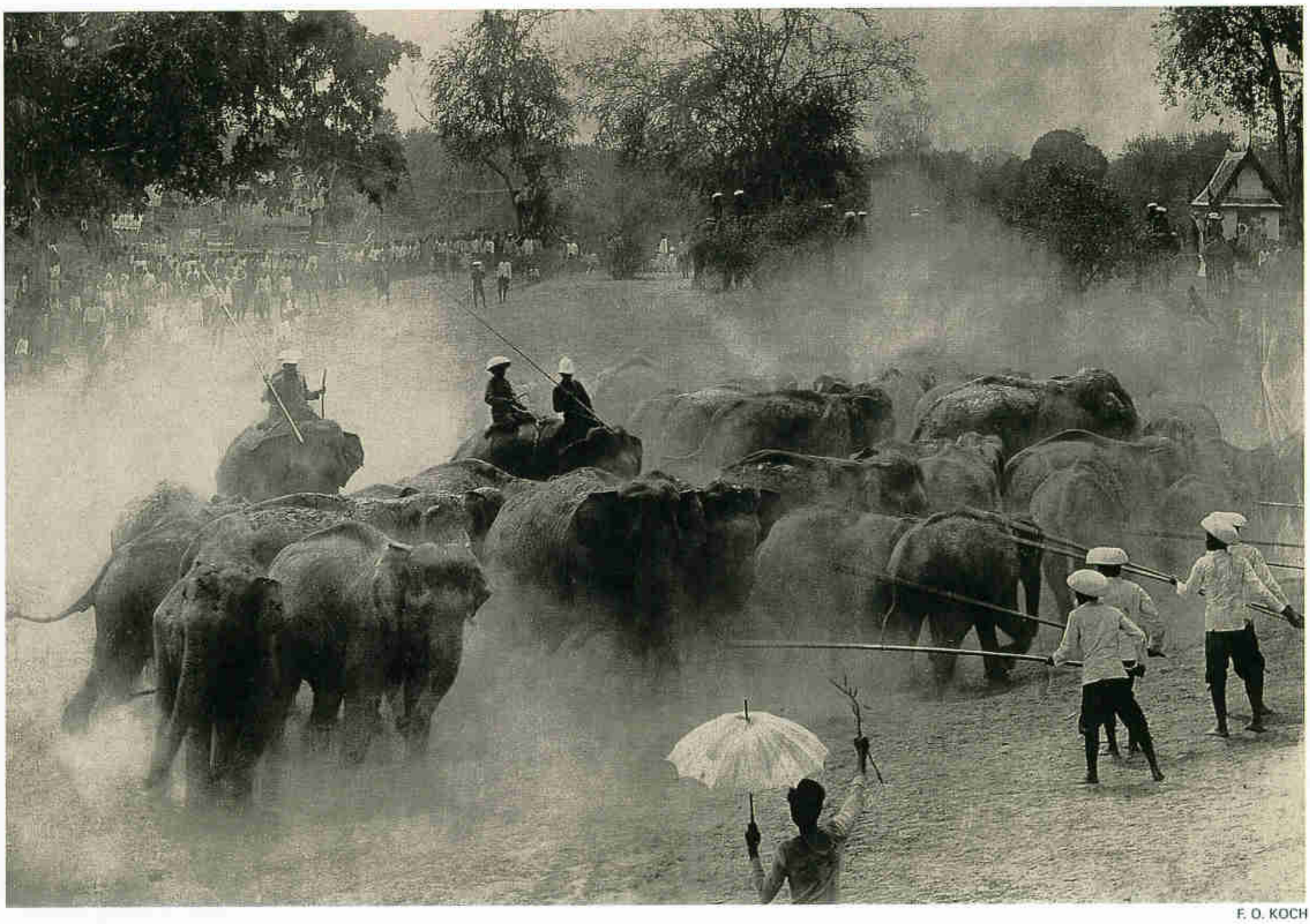
Slicing open a *Dischidia* leaf, I find a thriving *Philidris* nursery between the plant's slender white roots (cutaway, left). Because of their unique location within leaves, the roots can draw nourishment from insect parts that *Philidris* ants collect and bring back to their home. Another plant, grayish-brown *Hydnophytum,* which grows plastered to tree trunks (below), also provides *Philidris* a place to live in return for such "fertilizer." In French Guiana, scientists are studying whether *Tillandsia bulbosa* (right) relies on nutrients from the ants it shelters.

PLANTING AND PROTECTING

Ants defending their plants can be ferocious. In Singapore an army of ants together with the plant's spines guards a rattan palm (facing page). Even more aggressive are the South American ants *Pachycondyla goeldii,* which readily attack passersby to protect the plants that keep the ants' fragile nests and gardens from dissolving like cardboard in the rain.

Diligent planters as well as loyal defenders, ants also sow plant seeds in gardens dispersed throughout the canopy. Researcher Bruno Corbara (right) studies a pair of ant gardens in French Guiana. One *P. goeldii* ant (above) carries an anthurium seed back to its nest, where it will eat the sticky string attached and then plant the seed. Later the seed will sprout—and thus the ant garden grows. □





F. O. KOCH

■ FROM THE GEOGRAPHIC ARCHIVES

Herd on the Street

Few elephants missed the point in Ayutthaya, Siam, after the ancient Thai city rumbled to life for a royal elephant hunt in 1903. Hundreds of wild pachyderms were rounded up from surrounding jungles and driven into a teak-log corral. When animals suitable for work had been culled from the herd, the rest were released from the pen then goaded into charging an umbrella-waving youth, who would at the last moment dart to safety—most of the time. This photograph appeared in "The Warfare of the Jungle Folk" in February 1928, and a series of pictures from the same event ran in December 1906 under the title "The Greatest Hunt in the World."

NATIONAL GEOGRAPHIC

*On*Screen

MARK EMERY

■ EXPLORER

Bearing Tales of Journeys and Homecomings

Ben Kilham, one of the few people in New England licensed to raise orphaned black bears, plays with Squirt, a $2^1/_2$-year-old cub (right). EXPLORER's film *Mother Bear Man* follows Ben in the woods of New Hampshire as he practices his parenting skills on Squirt and her siblings, Curly and Boy, whose mother fled when a logging tractor overran their winter den.

The cubs let Kilham in on a few bear secrets, like their instinctive behavior of sniffing "mom's" breath to see what's good to eat.

For bear cubs on the Alaska Peninsula such subtle olfactory hints are just one part of the learning process. They watch their elders fish and feast on the summer run of sockeye salmon, a massive migration that nourishes the area's ecosystem. EXPLORER's *Seasons of the Salmon* traces the surge of millions of sockeye upstream, desperate to reach their place of birth and spawn before they die. Their scarlet color (above) is an indication of their readiness to spawn but also may make the fish easier game for brown bears and their cubs. The nutrients provided by the salmon will help the bears survive the coming winter.

JEROME ROBINSON

■ PROGRAM GUIDE

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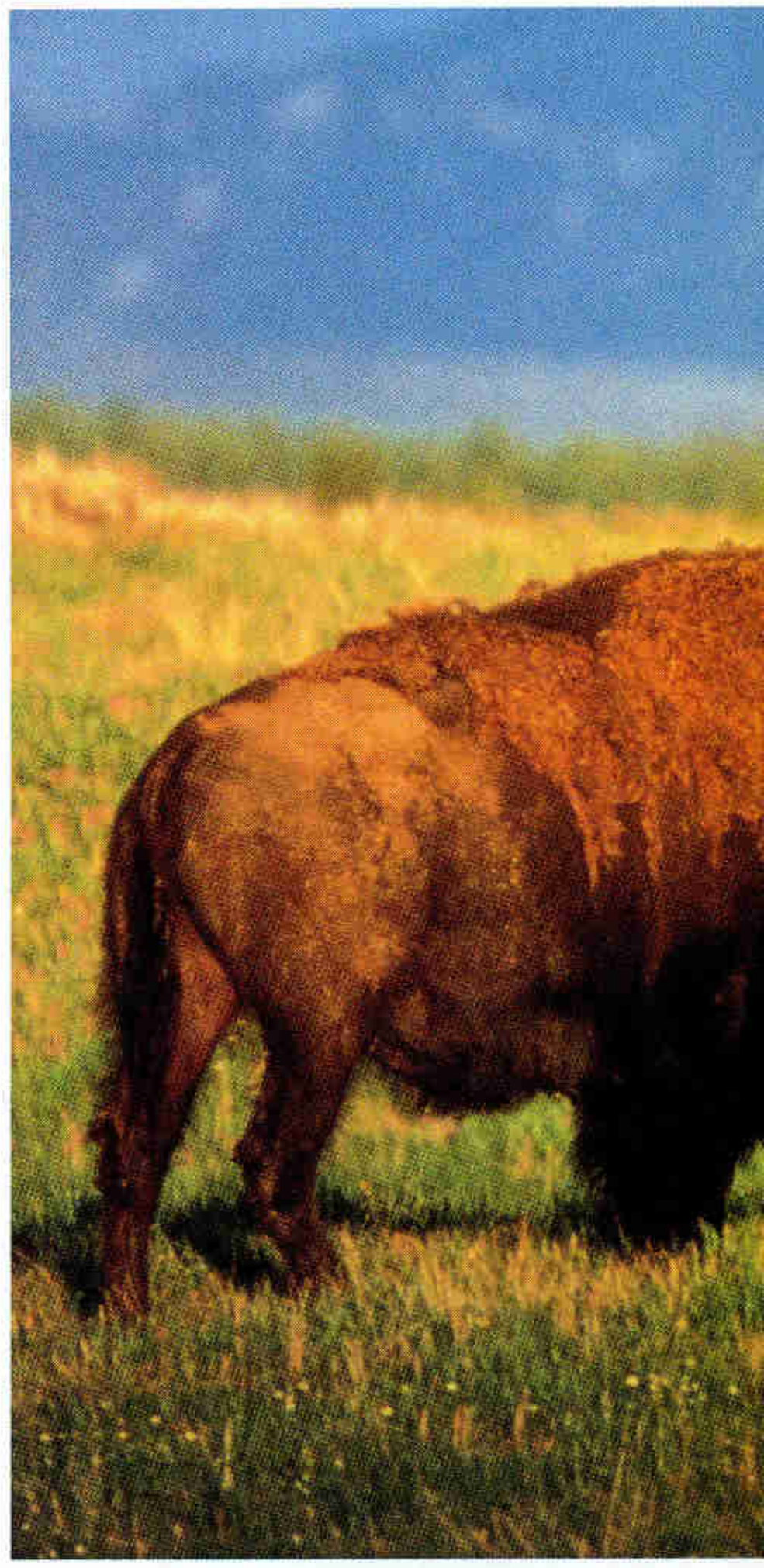

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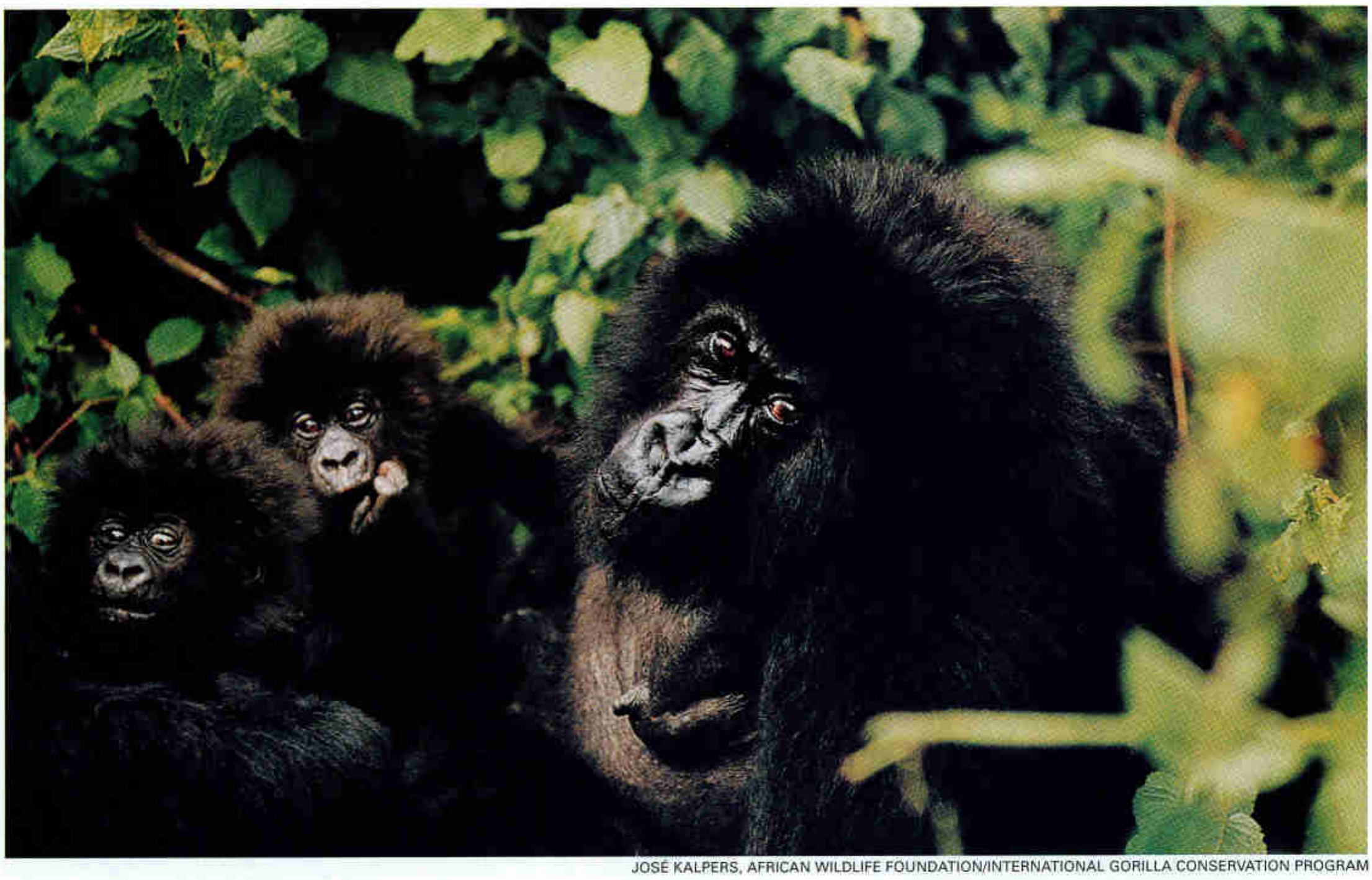
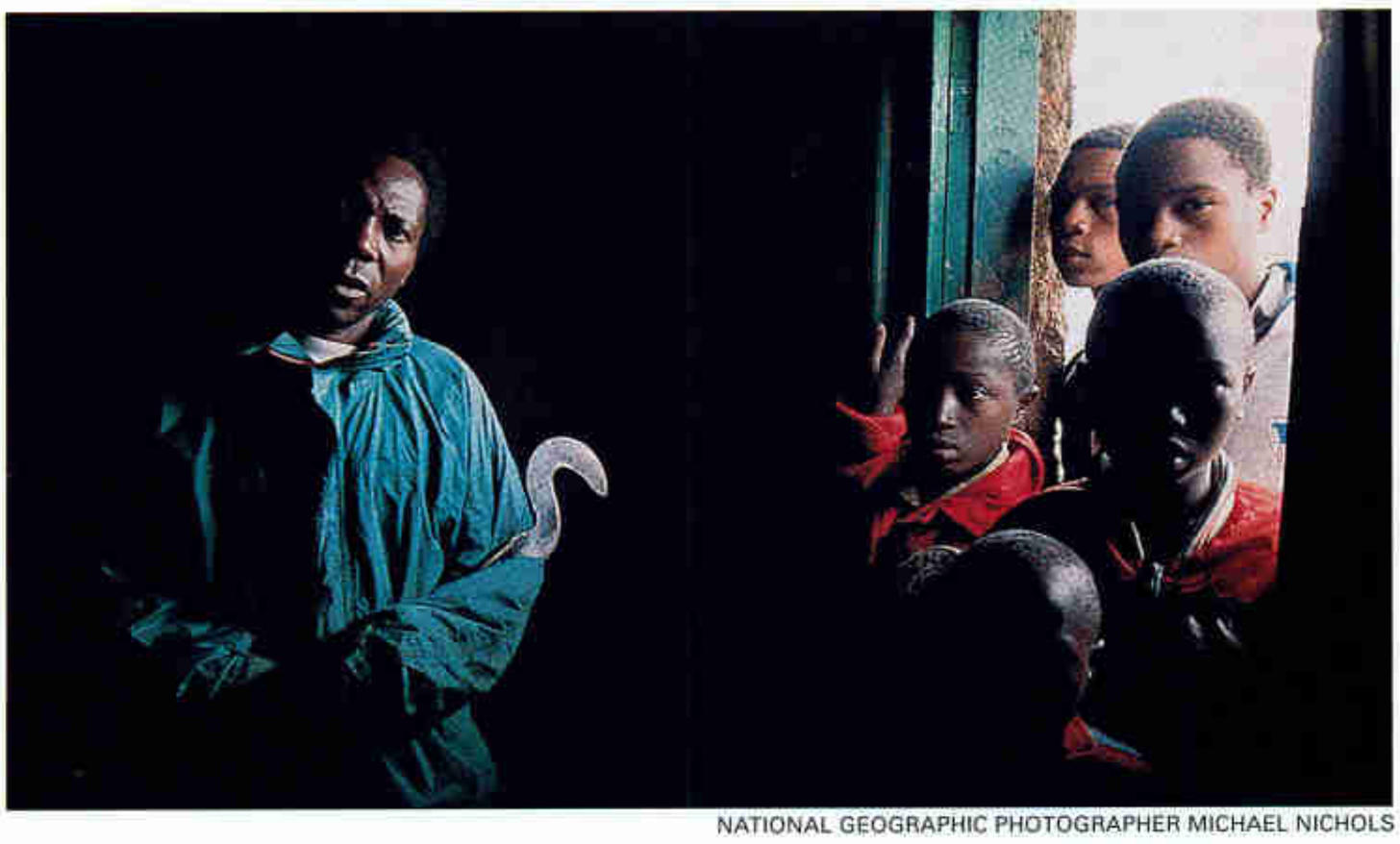


JOSÉ KALPERS, AFRICAN WILDLIFE FOUNDATION/INTERNATIONAL GORILLA CONSERVATION PROGRAM

Still a War Zone for Gorillas



NATIONAL GEOGRAPHIC PHOTOGRAPHER MICHAEL NICHOLS

For mountain gorillas there's good news and bad news. Some 300 remain in the war-torn Virunga region of Rwanda, the Democratic Republic of the Congo (formerly Zaire), and Uganda. At least 20 babies have been born in the past two years in Rwanda's Volcanoes National Park and the Congo's Virunga National Park, including the two youngsters above.

But conflict has disrupted park patrols that monitor the gorillas, and rebels and poachers have killed at least six since 1997. Poachers have set illegal snares for antelope, and several gorillas have been injured. Tragically, gorilla caregivers have been killed, including tracker Fidele Nshogoza (above right, at left) featured with his family in the October 1995 GEOGRAPHIC. Dian Fossey, founder of Karisoke Research Center, hired him in 1978. "He was a man of the forest," says photographer Michael "Nick" Nichols. "Once a gorilla bit him—he said it was his own fault." The murderers were probably *interahamwe*, Hutu terrorists who loot villages for food, clothing, and money. Their presence forced Karisoke to close for a year until last September, when a Rwanda Army commander allowed trackers access to the gorillas.

Finally: L.A. to Return Water to Owens Lake

The worst airborne pollution in the U.S. comes from dust storms in central California's Owens Lake. The lake bed has been bone dry since the 1920s, when Los Angeles diverted the Owens River into an aqueduct to supply about half of Los Angeles's water. After nearly 20 years of wrangling, city officials agreed last summer to reduce the dust by covering 22.5 square miles of the lake bed with water, gravel, and vegetation by 2006. Estimated cost: 120 million dollars.

GORDON WILTSIE

BERND WÜRSIG

■ NGS RESEARCH GRANT

Long Look at Dusky Dolphins

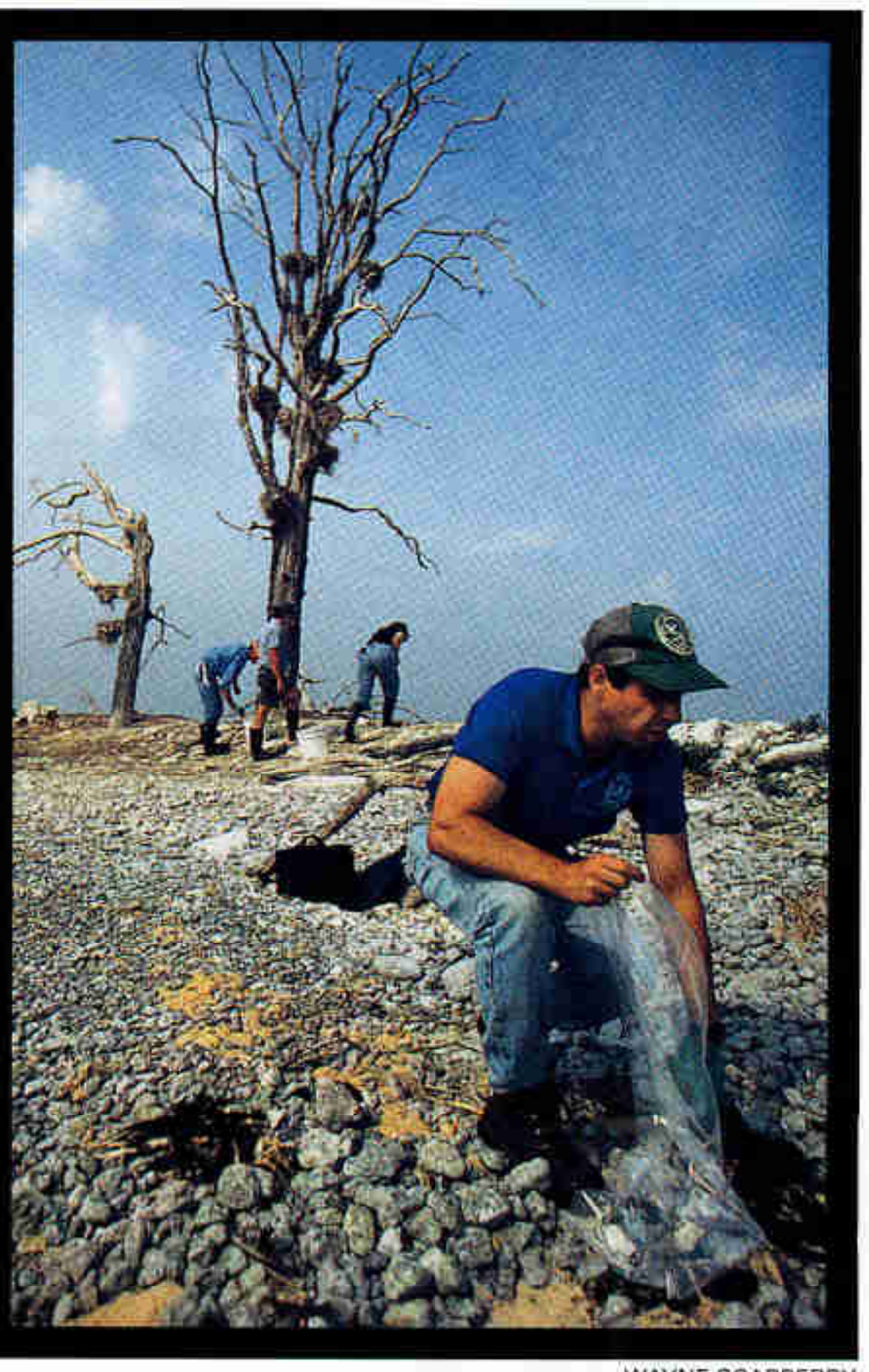
Airborne courtship: A male dusky chases a female off New Zealand. Since 1973 NGS grants have aided Bernd Würsig of Texas A&M in his dolphin studies. A new threat for the dolphins, which once became tangled in fishing nets by the hundreds each year, may come from pleasure boaters seeking a close encounter with them.

Cormorant Slaughter in Lake Ontario Provokes Outrage—and a Reward

A chill emerged from Lake Ontario's waters last July. New York State Department of Environmental Conservation researchers found nearly a thousand double-crested cormorants killed by shotgun blasts on Little Galloo Island, about five miles from the New York shoreline. "It was pretty gruesome and disgusting," says the department's Jim Farquhar (right).

With 5,800 nests, the island serves as a rookery for cormorants, not endangered but protected by state and federal law. Fishermen and members of surrounding communities had complained that the birds were hurting their livelihood by reducing populations of smallmouth bass and other sport fish. To test the charges, conservation officials are conducting a yearlong study. At least one fisherman was subpoenaed by a grand jury. Rewards as high as $50,000 for leads on the identity of the perpetrators have so far produced no arrests.

TEXT BY JOHN L. ELIOT



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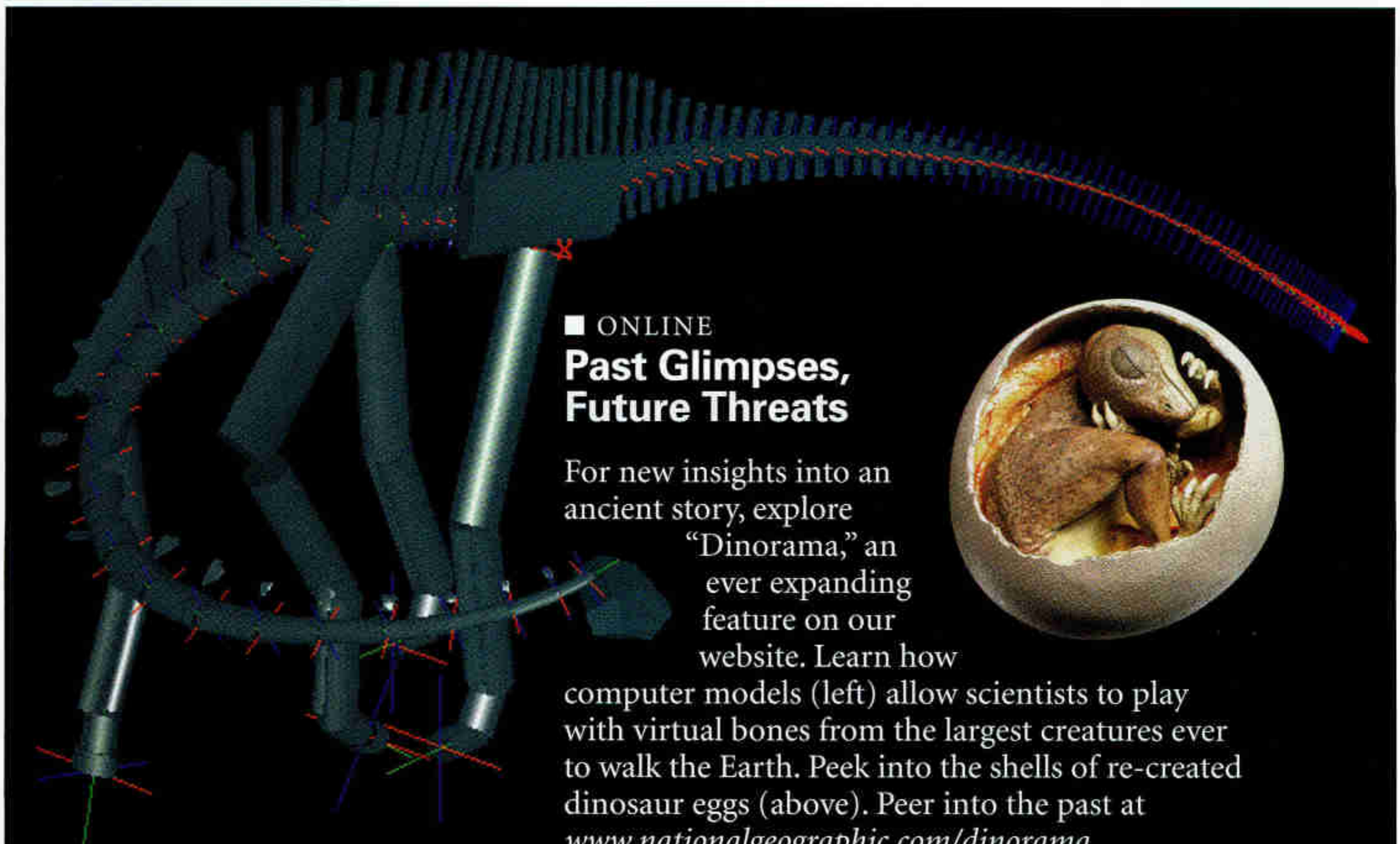

■ ONLINE

Past Glimpses, Future Threats

For new insights into an ancient story, explore "Dinorama," an ever expanding feature on our website. Learn how computer models (left) allow scientists to play with virtual bones from the largest creatures ever to walk the Earth. Peek into the shells of re-created dinosaur eggs (above). Peer into the past at *www.nationalgeographic.com/dinorama.*

■ What can lobsters teach us about the possibility of life in space? Virginia Morell, who writes on biodiversity in this issue, reports from the coast of Maine at . . . */2000/biodiversity/biomes.*

■ Half the planet's species could face extinction within a century. Discuss this grave problem online at . . . */ngm/9902.*

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CARSTEN PETER (ABOVE); DINOSAUR EGG MODEL BY BRIAN COOLEY; COMPUTER GRAPHIC BY KENT A. STEVENS

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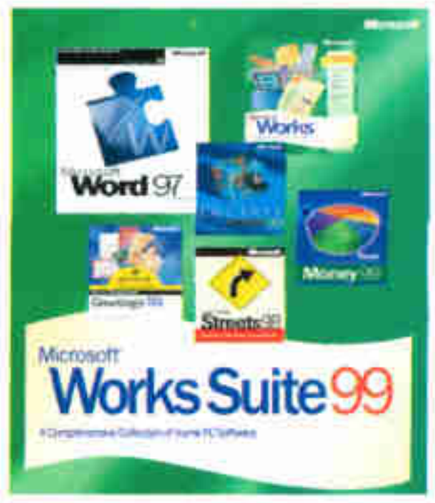
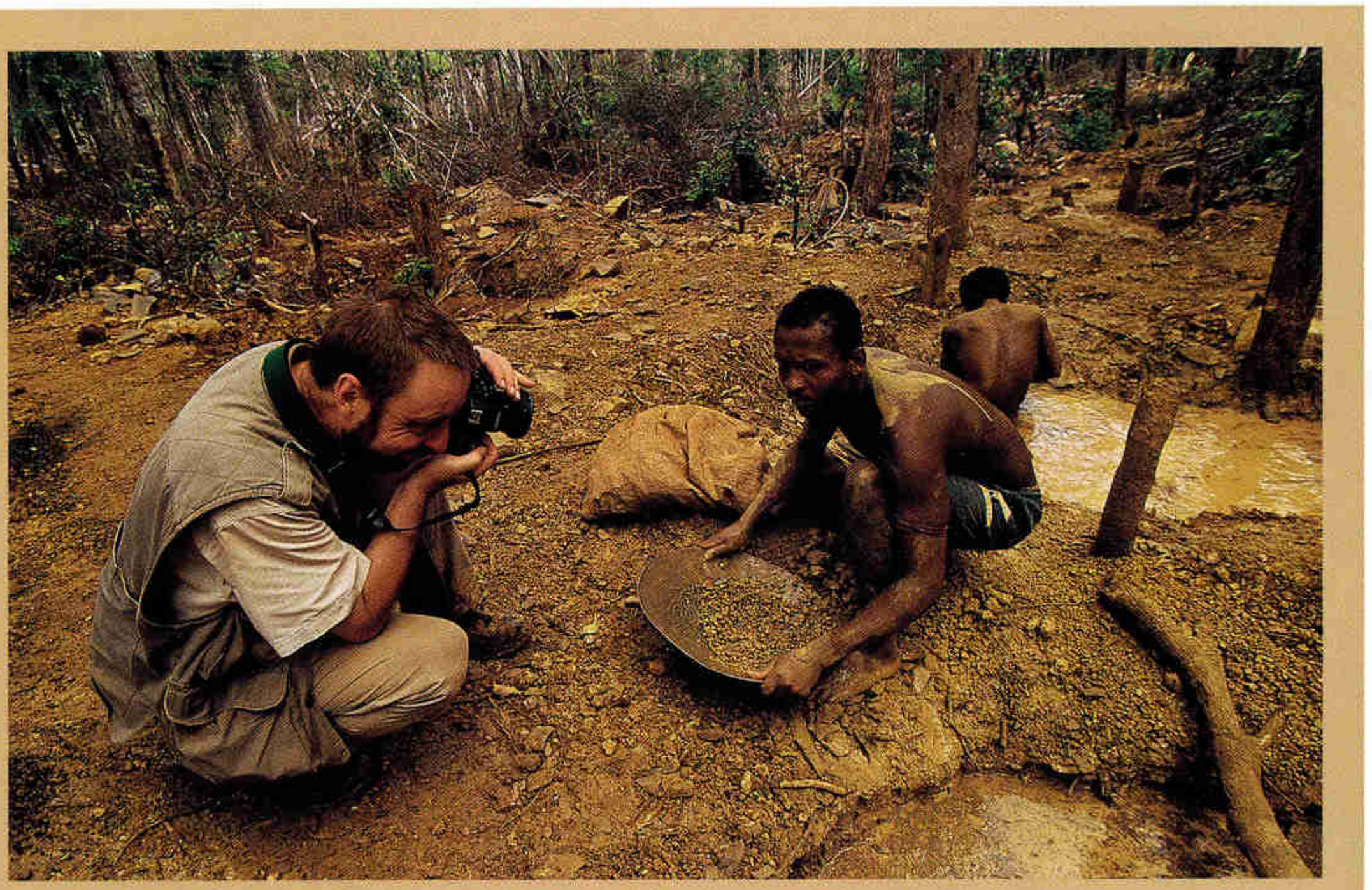


NATIONAL GEOGRAPHIC

On Assignment



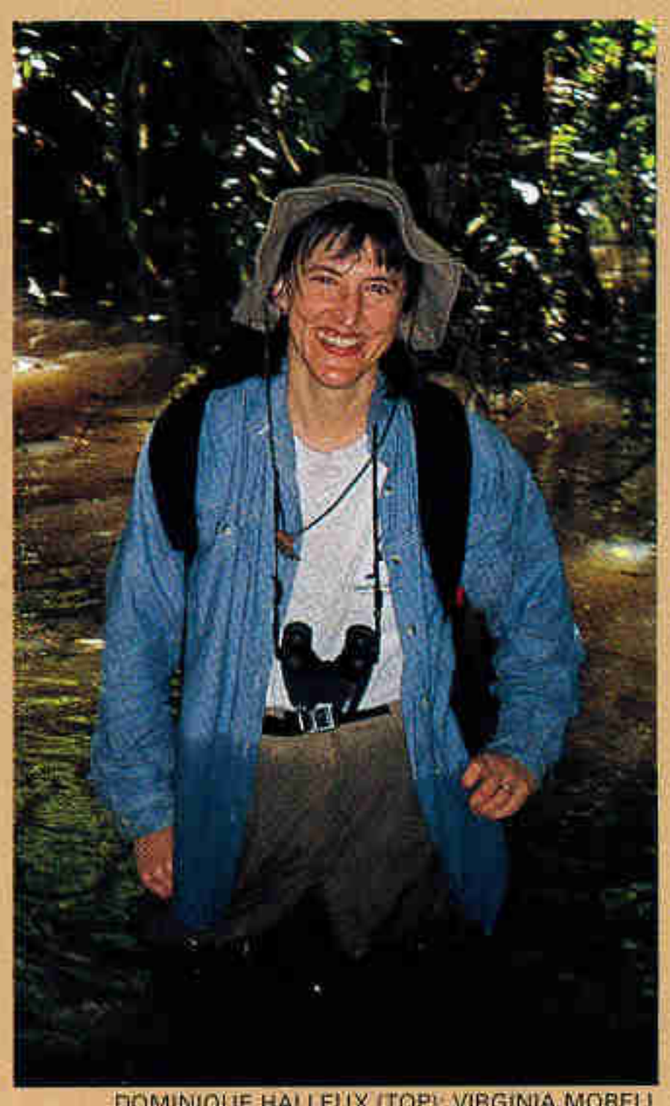
■ BIODIVERSITY

Life—on the Road

Though reporting on the diversity of life for this issue, writer Virginia Morell and photographer Frans Lanting could just as easily have filed stories on the diversity of airports.

"I was in England, Kenya, South Africa, Costa Rica, Peru, the Philippines . . .," says Virginia. "I think it was 13 countries in all. I just tell people I went from Maine to Madagascar." The most remarkable place Virginia visited, she says, was Ecuador's Tiputini Biodiversity Station. There she waded into Río Tiputini (right) while following a troop of golden mantled tamarins. "Nobody had hunted in that part of the forest in 20 years, so the animals weren't afraid. They must have considered us some strange new kind of primate."

"How many countries did I visit for this story?" muses Frans Lanting, shooting sapphire miners in Madagascar (above). "I have no idea! I traveled nonstop for eight months. Once I went straight from a mountaintop in Hawaii—a place so fragile that stepping in the wrong spot could wipe out an entire plant species—to a plane that flew me across the Pacific, then across the U.S., to Massachusetts to photograph E. O. Wilson at Walden Pond."



DOMINIQUE HALLEUX (TOP); VIRGINIA MORELL

So, after all their travels, what do these two contributors think the future holds for biodiversity? "We're a self-centered species," says Virginia. Frans is more optimistic. "A photographer has the tools to document what's happening, to make people aware. I'm still idealistic enough to believe I can make a difference."

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