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The Restoration of a Hotspot Begins

by Chris Bright and Ashley Mattoon

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Mata Atlântica: Endangered Biome

The Restoration of

Brazil's Atlantic Forest is one of the richest biomes on Earth, and one of the most intensively developed. To save it, conservation will have to go on the offensive, and "re-develop" much of the landscape as forest.

by Chris Bright and Ashley Mattoon

To stand in the small, dark reception building at the trailhead, examining its mournful stuffed-animal dioramas—this does not prepare you for the hushed, vegetable exuberance of the forest. Outside, the puma and coati mundi, the birds and assorted snakes all remained invisible to us. But we saw the giant trees enrobed in liana vines, the flowing queues of leaf-cutter ants bearing snippets of green, and the big, white butterflies hovering in the still air, or descending amidst shafts of light, like animated confetti.

We were in a fragment of the Mata Atlântica, the Atlantic Forest of eastern Brazil. And for many years, it was the forest itself—not just the pumas—that had somehow remained invisible. This is a realm that was nearly destroyed before it was even discovered—in the sense of being recognized as a place distinct from other places. And yet it is a huge realm. In its original extent, it stretched along the coast from around South America's "snout," all the way to Brazil's southernmost state of Rio Grande do Sul, and into neighboring regions of Argentina and Paraguay (see map, page 10). All told, the Atlantic Forest region accounts for 13 percent of Brazil's area, which makes it the third largest biome in the country, after the much more famous Amazon forest and the Cerrado, the savannah-woodland formation that lies inland from the Atlantic Forest.

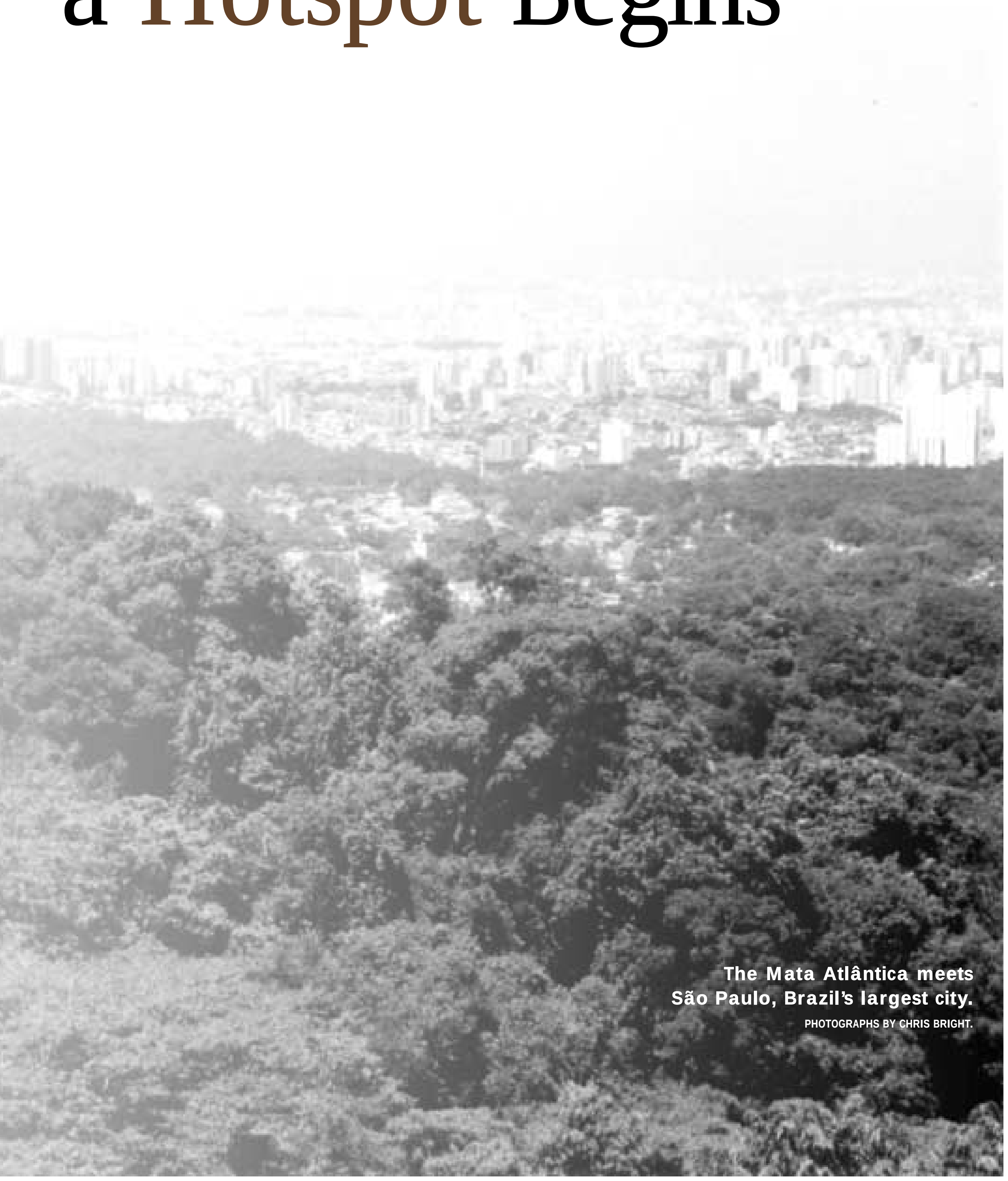
But the vastness of this biome is not so much geographical as biological. The forest includes some 20,000 vascular plant species, of which nearly a third are endemic—that is, they occur naturally nowhere else. ("Vascular" means that the plant has tubes inside it for moving liquids; nearly all plants are vascular, except for some fairly simple groups like the mosses.) Botanists have found as many as 476 tree species in a single hectare of Atlantic Forest; some areas of the biome probably have the highest tree diversity per unit area in the world.

The forest's animal life is just as rich. Nearly two-thirds of its mammals are found nowhere else, including a variety of endangered primates. Among these are the muriquis (the two species in the genus *Brachyteles*), which are the New World's largest monkeys, and the diminutive lion tamarins (the four *Leontopithecus* species). The black–faced lion tamarin (*L. caissara*) was only discovered in 1990 and is believed to number fewer than 260 individuals. The biome is also a bird watcher's paradise: one area contains 52 endemic bird species. Much less is known about the other types of animals, but it's clear that, in terms of the number of endemics per unit area, the Atlantic Forest is one of the richest places on Earth. It is also one of the most threatened. Nearly three-quarters of all species officially recognized as endangered in Brazil live in the Atlantic Forest. To enter this forest is to encounter a world poised on the brink of extinction.

So it's not surprising that the Atlantic Forest is considered one of the hottest of the world's "biodiversity hotspots." The hotspots are areas that have been identified as global conservation priorities because they are unusually rich in biodiversity and highly threatened. (For a comprehensive survey of the hotspots, see *Hotspots: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions*, by Russell A. Mittermeier and others—an important resource for this article.) Less than 1.5 percent of the planet's land area falls inside the hotspots, yet they are the *exclusive* home of 35 percent of all terrestrial vertebrates and 44 percent of all vascular plants. (The hotspot analysis has not yet been extended to aquatic ecosystems.) Of the 25 hotspots, 15 are tropical forests. The Atlantic Forest is usually ranked fourth or fifth on the hotspot list. (See the table on page 11 for an overview of the forest's diversity.)

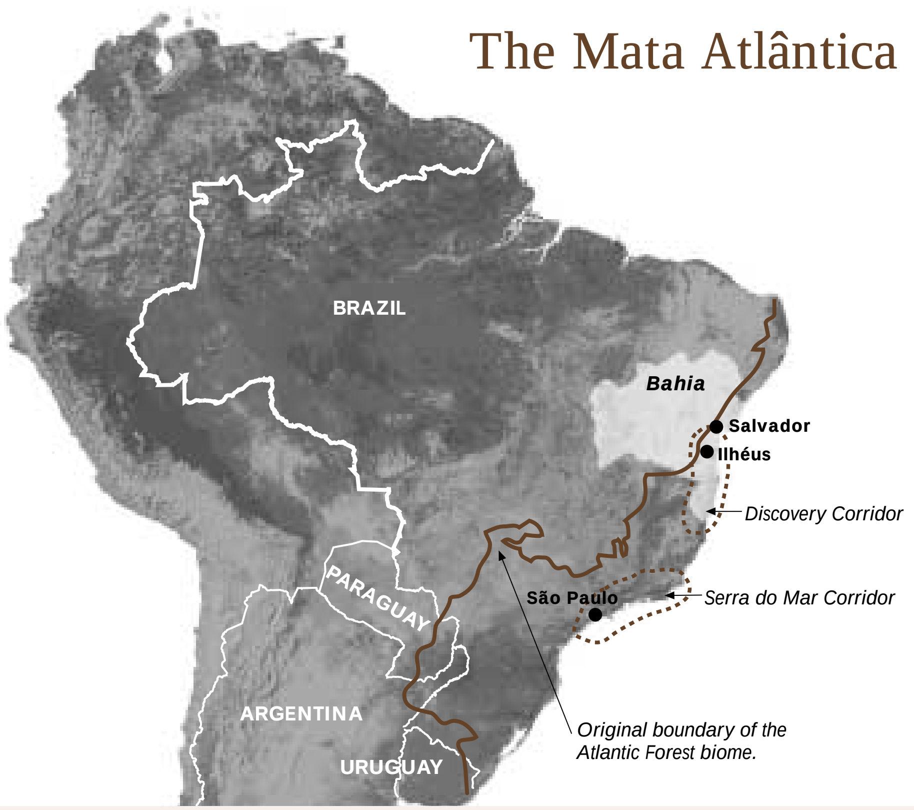
In general, the hotspots are highly populated; it's estimated that more than 1.1 billion people live

a Hotspot Begins



The Mata Atlântica meets São Paulo, Brazil's largest city.
PHOTOGRAPHS BY CHRIS BRIGHT.

The Mata Atlântica



Geographic Scale (in square kilometers):

Total area of the Atlantic Forest biome:	1,300,000
Total forest area remaining within the biome:	92,000 to 99,000
Approximate land area of the continental United States:	9,600,000

(Compare U.S. and Atlantic Forest biodiversity: see table on page 11.)

The corridor and biome outlines are only approximate. Sources are listed in the table at right.

within them. But even in this respect, the Atlantic Forest exceeds the norm. It's not just populated—to a considerable degree, it's urban, or at least suburban. That forest with the butterflies lies within Brazil's largest city, São Paulo. It contains São Paulo's old reservoir, still equipped with its antique steam-engine pumps, now preserved as a museum. Although it's no longer in use, the reservoir is powerful evidence of the forest's importance to the cities of the Brazilian coast. Even in its battered state, the Atlantic Forest is still critical for protecting the watersheds and soil that sustain roughly three-quarters of Brazil's population.

A 500-year war on the forest

On April 22, 1500, when the Portuguese explorer Pedro Alvares Cabral dropped anchor at Pôrto Seguro, on the coast of what is now the state of Bahia, he encountered a wet, luxuriant forest that cloaked the low mountains rising from the coastal plain and followed the meandering rivers back into the interior, sometimes for hundreds of kilometers, before giving way to cerrado. In Cabral's day, the forest is thought to have covered 1.3 million square kilometers, but hardly as a uniform carpet. Mangrove thickets lined river estuaries; evergreen rainforest covered most of the coastal plain. Inland and upslope, the forests became semi-deciduous in response to a "dry season" (the part of the year when it doesn't rain nearly every day). Here and there, more distinctive communities appeared, like the patches of fully deciduous forest at higher altitudes, or the coniferous araucaria "Brazilian pine" communities in the southeast.

The ecological fine points would not, presumably, have interested the colonists. But there was one species of tree that quickly caught their attention. The brazilwood tree (*Caesalpinia echinata*) became a major commodity during the second half of the 16th century; its beautiful, dense, red wood was in great demand for lumber and as a source of dye for the European textile industry. Eventually, the tree would lend the country its name: "Brazil" is from "brassa," a reference to a brazier of coals glowing red, like the color of the wood. But by the early 17th century, the tree itself had nearly been forced into extinction from uncontrolled logging. (It is now widely cultivated in special reserves.)

Over the next two centuries, much of the forest was lost to sugar cane plantations and cattle. Forest was often burned both to make way for pasture and to displace the native people. By the early 19th century, coffee plantations were swallowing up forest in the south, and the region's cities were demanding ever greater quantities of charcoal and fuelwood. A century later, mountains of charcoal were disappearing into the blast furnaces of the newly established steel industry. The state of Minas Gerais (in about the middle of the biome), lost half its forest to the furnaces in just 20 years, from 1920 to 1940. The cut-over ground was not replanted with native trees, but with monocultures of eucalyptus, fast-growing trees native to Australia. And all along the coast, many forests that

Species Diversity in the Atlantic Forest: An Overview of Selected Taxa

	Total number of species	Number of species that are endemic*	Percentage of species that are endemic	*By way of comparison...* Percentage of endemics for all hotspots combined	Total number of species native to the continental U.S.
Mammals	261	160	61	29	402
Birds	620	73	12	28	653
Reptiles	200	60	30	38	277
Amphibians	280	253	90	54	231
Vascular Plants	20,000	6,000	30	44	14,783

**Endemic* means occurring nowhere else.

For geographic scale, see map at left.

SOURCES: Russell A. Mittermeier et al., *Hotspots: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions* (Cemex / Conservation International: 2000); Center for Applied Biodiversity Science at Conservation International and Instituto de Estudos Sócio-Ambientais do Sul da Bahia, *Designing Sustainable Landscapes: The Brazilian Atlantic Forest* (Washington, D.C.: CI, 2000); and Bruce A. Stein et al., eds., *Precious Heritage: The Status of Biodiversity in the United States* (New York: Oxford University Press for the Nature Conservancy and the Association for Biodiversity Information, 2000).

had escaped the furnaces and farms succumbed to urban development and pollution. Today, half a millennium after Cabral came ashore, the forest's total extent is estimated at roughly 92,000 to 99,000 square kilometers, including the portions in Paraguay (perhaps 10,000 square kilometers) and Argentina (a mere 3,600 square kilometers). Less than 8 percent of the forest's original cover remains.

And yet, until very recently, few Brazilians were really aware that the ocean of trees Cabral faced was something that *could* be lost, because the biome itself had not yet come into view as a tangible, coherent entity. Roberto Klabin, the paper company magnate who is co-founder and president of the Brazilian nonprofit SOS Mata Atlântica, described this perceptual problem for a Reuters reporter in 1999: "there was this thick vegetation that everybody had to drive through on the way to the beach, but nobody really knew what it was or paid any attention to it." Some Brazilian environmentalists say the country also has a kind of cultural hostility to the forests. Mario Mantovani, SOS's director of institutional relations, explained to us that Brazilians tend to see forest as an obstacle—as something that is in the way of whatever it is they are trying to do, whether that's building a factory or getting to the beach.

It's difficult to get excited about protecting something you don't like—something that has had to be chopped away as a preliminary to virtually everything that you regard as progress. Such attitudes help to explain why, historically, Brazil has shown little political interest in forest conservation. IBAMA, the Brazilian environmental protection agency, is widely regarded as inefficient, underfunded, and corrupt. And while logging in the Atlantic Forest is now illegal, it is still common on both public and private land. Brazil's timber industry is notorious for its own corruption. On a national basis, estimates of the portion of timber cut illegally run as high as 80 percent.

But the existence of organizations like SOS is evidence of a very different set of attitudes—of a new forest ethic that is becoming a major political force. In the 1970s, the uncertain fate of the brilliant, little lion tamarins began to attract serious scientific attention. The tamarins had charisma; soon they also had scientific management committees and an international public constituency. By the mid-1980s, when SOS was founded, the first comprehensive studies of the biome were being conducted. Today, Brazil has some 700 environmental NGOs, of which 30 have annual budgets exceeding $300,000. Mantovani estimates that about 150 NGOs are active in the Atlantic Forest region. In terms of membership, the largest of these is his own, which now includes some 50,000 members.

Every day, a little bit

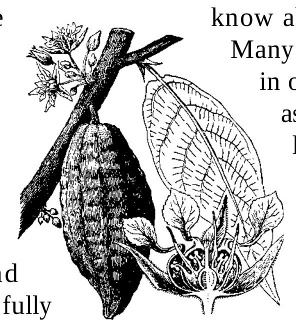
In 1993, pulpmaking operations clearcut thousands of hectares of native forest in Bahia and the neighboring state of Espirito Santo to make way for eucalyptus plantations. In 1999, Fernando Gomes, the mayor of the small Bahian city of Itabuna, illegally logged 50 hectares of lion tamarin habitat. Both of these incursions outraged environmentalists, but the differences between them are revealing. The nature of deforestation is changing. Although loggers still sometimes level large tracts of forest, especially in the southern reaches of the biome, most of the damage is now inflicted on the scale of Gomes's activities.

In a sense, the deforestation is becoming less "corporate" and more "populist"—more and more the aggregate effect of thousands of actions taken by individual people. Among the middle class, forest loss might take the form of a home in a new vacation development or a timber sale on the family farm.

Among the poor, of course, its character is more compulsory: it is collecting firewood or finding fresh soil for subsistence agriculture. This is the new pattern of destruction, low-level and chronic. “Every day,” says Klabin, “a little bit.”

The deforestation is difficult to measure, especially since so much of it is now occurring in little patches. But over most of the biome, there appears to have been a recent and substantial decline in the rate at which original cover is being lost. Klabin says that around Rio de Janeiro, for example, 144,000 hectares were lost during the first half of the 1990s, but only about 3,500 hectares during the second half. And as the logging has eased, the conservation has picked up. A little more than one-third of the remaining Brazilian Atlantic Forest is now officially protected, in a patchwork of some 170 parks, reserves, and field stations.

Unfortunately, however, the trend to less chopping and more parks will not, by itself, save the biome. That’s partly because official protection of a Brazilian forest doesn’t necessarily mean much on the ground. The region’s parks are often badly managed—or not managed at all. They’re the subject of unresolved landclaims. They suffer the incursions of timber barons, developers, subsistence farmers, and hunters. And to begin with, they’re not fully representative of the biome.



The parks are also far too small. (Although some Atlantic Forest parks cover thousands of hectares, most are under 500 hectares.) It’s this problem of scale that is the real killer. Even if all the park boundaries were enforced, and even if the destruction of all the other forests stopped immediately, it’s still likely that up to half the biome’s species would eventually disappear, because their surviving populations are probably no longer large enough to be genetically viable over the long term.

This predicament results largely from a kind of ecological cancer called fragmentation. It begins with a simple, mathematical process: as a block of forest is carved up into progressively smaller pieces, an increasing proportion of the remaining forest will be near an edge, and the edge environment is different from that of the forest interior. The edge of a tropical moist forest tends to be hotter, drier, and windier than the forest is farther in. When a new edge is created, it usually exposes “deep forest” plants and animals to an environment less suitable to them. Gradually, they will tend to yield to other species, better adapted to edge habitats. The resulting edge communities are generally much less diverse than the old-growth communities of the interior.

Fragmentation is one of the biggest problems in forest conservation, for two reasons. First, recent research is demonstrating that in tropical moist forests, those artificial edges have a very long reach. A fairly distinctive edge environment generally extends some 100 to 300 meters into the forest. In these zones, the edge effect is pervasive and is likely molding the entire community. But more subtle effects can be detected much farther in—often as far as 1 kilometer from the edge itself—so even a block of forest 2 kilometers thick could show some degree of edge effect throughout. (A typical long-distance effect might be higher seedling mortality in deep forest plants.) In areas once heavily forested, fragmentation reverses the ecological norm: what was a relatively minor component of the biome—the edge—becomes a major component. What was the major component—the interior—becomes a minor one.

Then there’s the second reason that fragmentation is so destructive: artificial edges are generally unstable. If you’re familiar with temperate zone forests, you may know about a “healthy” form of edge instability. Many temperate forests will regenerate naturally, in one form or another, after they are cut—just as they will after some natural disturbance, like a fire or a blowdown in a big storm. If there is no further disturbance, the forest edges, in effect, move outward. This can happen in tropical forests too, where conditions on the open ground don’t differ too greatly from those within the forest—that is, where the edge effects aren’t too great. In the Atlantic Forest biome, where conditions permit, you can see strong pioneer growth on cut-over ground—the beginnings of a forest—in 15 or 20 years.

But many cut-over areas are too hot or dry to permit natural regeneration. In such places, the edge vegetation is not likely to “seal” the interior either, as happens under natural conditions, where the transition is not so abrupt. So the edges begin to move *inward*. The deep forest community dies back and the edge broadens. This kind of corrosion is often exacerbated by what happens on the cleared side of the edge. Herbicide pollution from eucalyptus or sugar cane plantations may poison adjoining forest. The burning of fields, a standard preliminary to replanting, scorches forest edge and offers an opening to non-native, “fire-adapted” shrubs and grasses. Such vegetation spreads by fire and usually burns readily. Afterwards, it resprouts or sheds its seeds, to take advantage of the open ground and the nutrients released by the fire. Even the native pioneer trees—the natural denizens of the edge—may not survive this onslaught. And so gradually the forest yields to an impoverished, waste-lot flora dominated by a few, very tough species that thrive on disturbance. The edges eat the interior.

An eroding fragment is in a kind of silent turmoil. The big trees near the edge are vulnerable to drying and wind, so more and more of them are likely to fall.

The canopy becomes increasingly entangled in lianas, the woody vines that are a standard element of so much tropical forest. Lianas thrive on disturbance, and they can overwhelm big trees well into a fragment's interior. When a tree comes down, liana tangles form in the tree-fall gap, choking out saplings. Gradually, the high forest may give way to tangled low forest. A study in the southern part of the biome examined this problem in four fragments that had been isolated for more than a century; this type of low forest accounted for about a quarter of forest area on average. (In undisturbed old growth forest, such conditions are limited mainly to treefall gaps, which account for about 1 percent of forest area.) Such fragments are shrinking not only inwards, but downwards. They are losing not only species diversity but structural complexity.

Of course, the damage is not limited to the flora. From a burnt-over cane field, a forest fragment may look like an island of wilderness, but to the animals within it, it is a prison. Many animals cannot cross even relatively narrow gaps between one patch of forest and the next. Most Atlantic Forest birds, for example, will not cross more than a couple hundred meters of open space. The tendency to vegetational atrophy will likely reduce food and habitat for "deep forest" animals, forcing their populations, already isolated, into decline. Many mammals and birds face additional pressure from hunting and collection for the pet trade. In general, these activities are illegal in Brazil (although subsistence hunting is permitted). But little is done to prevent them and they are pervasive within the Atlantic Forest biome. Collection of wild animals is thought to be the third largest illegal industry in the country, after the illicit trade in guns and drugs.

The faunal decline will put even more pressure on the flora, since most tropical trees rely on animals, rather than wind, for pollination and seed dispersal. A recent study in the northern part of the biome, for example, found that more than 70 percent of the tree species depend on vertebrates (usually birds and mammals) to disperse their seed. Broad seed dispersal is essential to the survival of these species, because they won't usually reproduce by "in-breeding." (In general, that is, these trees are not self-pollinating, nor does pollination from closely related individuals usually produce viable seed.) So vegetational decline leads to faunal decline, which leads to yet more vegetational decline: whether the scale is decades or centuries, an unmanaged fragment will tend to be drawn into an intensifying vortex of extinction.

Macro connectivity

Conservation, in a narrow, traditional sense, is not likely to prevail against extensive fragmentation—not in the Atlantic Forest and not anywhere else. And that is why the discipline is undergoing a quiet revolution. In a variety of landscapes all over the world, conservationists are finding that the key to long-term preservation involves not just protecting natural areas but enlarging them. The preservation of the wild, in other words, frequently requires the *restoration* of the wild.

Replanting cut-over ground is (thankfully) not a new idea. In some regions, large-scale tree planting has been practiced for centuries as an economic operation, to maintain a timber supply. But replanting as an *ecological* enterprise—as a way of recreating, as far as possible, a disappearing ecosystem—this is an idea of much more recent vintage. In 1934, Aldo Leopold, the American naturalist who wrote *A Sand County Almanac*, proposed that the University of Wisconsin Arboretum reconstruct a sample of the original North American midwestern prairie, by then largely a memory. The eventual result was the Arboretum's "library" of small-scale prairie reconstructions. In the mid-1970s, restoration arrived at a level of major ecological significance when the ecologist Robert Betz and the horticulturist Ray Schulenberg launched the first large-scale prairie restoration, at Batavia, Illinois, outside Chicago. A decade later, the forest ecologist Daniel Janzen saw the promise of restoration for countering tropical deforestation. Saddled with the defense of his disintegrating field study site, the forests of Costa Rica's Guanacaste Province, Janzen had the ecological and tactical genius to realize that the only hope was to go on the offensive—and not incrementally but in a big way. He and his colleagues have since restored some 1,200 square kilometers (120,000 hectares) of high-diversity forest. (Costa Rica lies within the Mesoamerican hotspot.) Today, in eastern Brazil, restoration is being scaled up again, to include an entire biome.

At its best, restoration addresses the landscape as a whole. It's geophysical, as it relates to soil and water; it's biological in its concern for flora and fauna; it's political in its recognition of the need to recruit local support for the restoration process. And it is opening up possibilities for conservation that go far beyond the old dichotomy of parks versus development. In the Atlantic Forest, you can see this happening in three dimensions.

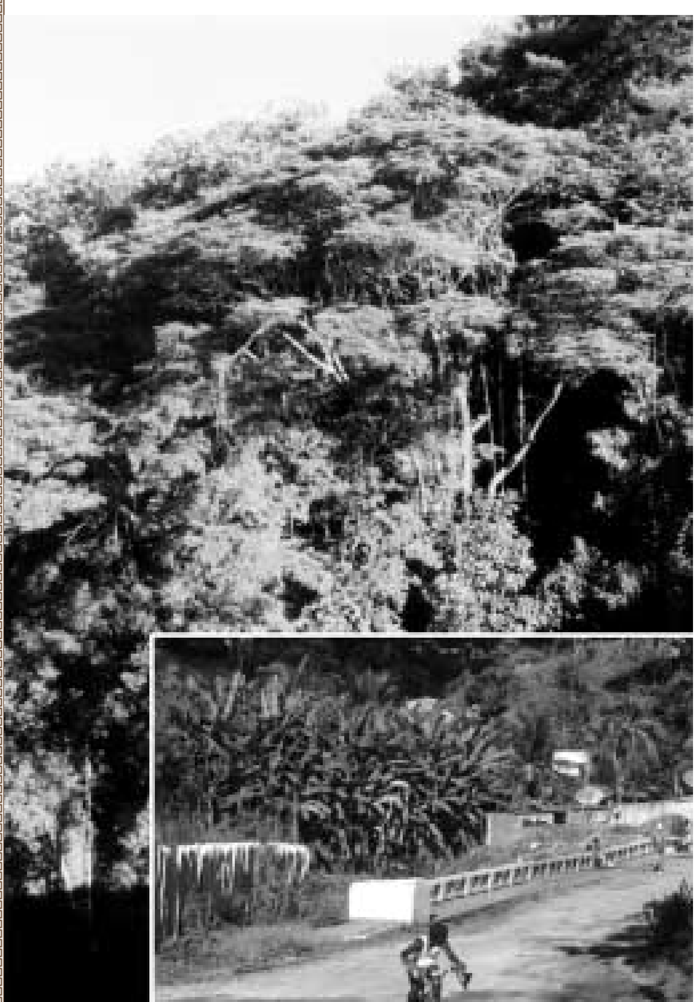
1: "Hands-on" ecological proficiency. Restoration is a kind of applied ecology, but the degree of application varies depending on the state of the land. In the Atlantic Forest, the possibilities run through the entire spectrum. At its least intensive, restoration simply informs the management of forest fragments. It may involve the control of liana infestations, for example, or "enrichment planting"—that is, increasing the seedling bank of plants native to a fragment.

$300,000

There is an old reservoir on the outskirts of the city of Ilhéus, on the Bahian coast (see map, page 10). It's a small artificial lake backed up behind a dam that was built in 1920, to create a central water supply for the city. At the time, the drainage was forested, and the city maintained the forest in its pristine state, because logging would have silted up the reservoir.

For 50 years, the city drank from the lake. But Ilhéus was growing and in the early 1970s, the old reservoir was abandoned for a larger water supply. The forest was left undeveloped—and unprotected—in a landscape that, by this time, had few other large tracts of old growth. Today, Ilhéus and its environs are home to 250,000 people, and an estimated 55,000 of them inhabit the favelas that surround the reservoir forest, now known as the Mata Esperança da Costa Atlântica.

Officially, the Mata Esperança has been a park since 1990, but it's only a "paper park." There are no rangers to keep the local people from felling trees or hunting within it. And so the forest is disintegrating. From its original extent of 730 hectares (2.8 square miles), the forest has thus far been reduced to 437 hectares.



There is far more at risk here than just a patch of suburban "green space." A botanical survey conducted by the Brazilian federal cocoa research center (CEPLAC), the local university (Universidade Estadual de Santa Cruz or UESC), and the New York Botanical Garden found 310 tree species in a single hectare of the fragment. To put that in a temperate forest context, a recent survey of an old growth remnant near Washington, D.C. found just 14 tree species in an area ten times as large. The flora of the Mata Esperança is not well understood, but some species are apparently rare.

Among the fauna, 289 bird species have been identified in or around the fragment; 11 of these are officially endangered. The mammals include the crab-eating fox (*Cerdocyon thous*), an armadillo, and the forest rabbit (*Sylvilagus brasiliensis*), which is endangered in Brazil. The tayra (*Eira barbara*), a predator of the weasel family, haunts the forest, as does the rare and peculiar thin-spined "porcupine" (*Chaetomys subspinosus*), which is sort of a cross between a true porcupine and a group of rather uncharismatic rodents known as spiny rats. Among the reptiles is Brazil's only officially endangered snake, *Lachesis muta rhombeata*. It's a subspecies of the bushmaster, a potentially deadly viper that can grow to 2 meters.

A consortium of local organizations, including CEPLAC, UESC, and the municipality of Ilhéus itself, requested federal aid for preserving the fragment, but the Brazilian government will not fund proposals for areas smaller than 1,000 hectares. So the money will have to come from somewhere else. The scientists at CEPLAC and UESC figure that about $300,000 is needed over the course of three years. After that initial investment, they hope to make the park self-sustaining on the basis of visitors' fees. (Ecotourism is a feasible option because Ilhéus is already a tourist destination and has comfortable hotels.)

The initial infusion of cash is needed for a range of projects, including the restoration of degraded areas, additional scientific study, and an "orphanage" for stray animals. But perhaps the most important part of the plan involves fencing the park completely and enlisting some favela residents as rangers. The idea is to educate the local people about their natural heritage, to pay some of them, and to make it plain to everyone that disruption of the forest will no longer be tolerated.

The homework has all been done. The scientists have assembled a thick proposal, complete with a detailed budget. There's even an English-language abstract. It's all there, ready to go. Except for the money. Now what?

— Chris Bright

The latter activity is a good example of the ecological finesse that restoration requires: it's generally considered good practice to use only local seed stocks, when possible, to preserve the genetic characteristics of local plant populations.

At its most intensive, restoration brings the forests back onto ground from which they have vanished. The basic idea is to jump-start and manage a natural process called *succession*, the series of changes that a plant community goes through as it progresses from open ground to some reasonably stable climax state. In tropical moist forests, one way of analyzing succession is by grouping the tree species that specialize in the various successive states. The first trees to move out onto open ground are called primary species or pioneers; they are followed by early secondary species, then by late secondary species, and finally by the "deep forest" climax species. (In temperate forests, succession doesn't break down into species groups so easily; many climax species, for example, will also pioneer open ground quite happily.)

Recent research shows how critical an understanding of succession can be. Paulo Kageyama, a forestry professor at the University of São Paulo at Piracicaba, a small city about 150 kilometers northwest of São Paulo, has developed a kind of planting grid that regulates the density of each of the four tree groups just mentioned. With this simple but ingenious procedure, Kageyama has found that he can reduce the cost of open-ground restoration from $4,000 per hectare per year, to $1,500, because there are fewer dead trees to replace and less pesticide is needed. (Leaf-cutter ants often swarm over the seedlings and take them apart. But a healthy proportion of tough, fast-growing primary species—about 10 percent—greatly reduces the vulnerability of the entire planting.) Kageyama's system also truncates succession, by allowing climax species to be included in the initial planting. And it reduces the number of years required to achieve stability (when pesticide and tree replacements are no longer necessary) from about seven years to only three. Kageyama and his colleagues have used the system to restore several large areas around hydroelectric dams, and they are collaborating with Greenpeace on another large restoration project.

But a great deal of basic research is still needed to extend such efforts. In order to generate a supply of seedlings, for example, some of Kageyama's colleagues are studying the germination requirements of the biome's prodigious flora. By a very rough estimate, close to a third of the species they're working with cannot yet be reliably germinated in the laboratory.

2: Social engagement. The biggest challenges in restoration do not generally come from working with trees—they come from working with people. Deforestation is a kind of dysfunction between the land and the people who live on it; restoration must repair that relationship. In part, that means reforming the standard categories of land use. Conventional agriculture, for example, produces immense, pesticide-laced monocultures that isolate nearby natural areas and tend to exacerbate degradation within them. Organic, polycultural systems, on the other hand, can achieve a high degree of integration with natural areas and allow for a better functioning of the landscape as a whole.

But it's also important to recruit residents directly into the restoration effort, so that they have a stake in the outcome. In the Atlantic Forest biome, one of the simplest ways to do this is to contract with local farmers to grow tree seedlings. In Bahia, we visited a farmer who had joined a seedling program set up by a local NGO, the Instituto de Estudos Sócio-Ambientais do Sul da Bahia (IESB). Gilberto de Lima was sprouting both ornamental plants and tree seedlings, in black plastic "grow bags" lined up in neat rows, under a small shelter consisting of poles topped by shade cloth. He collected his seeds when doing trail maintenance in a nearby forest fragment. IESB provided some training and helped him sell his plants. He made up to $1.00 per plant. At the time we visited, there seemed to be about 2,500 seedlings in his shelter. Despite the modest size of such operations, IESB reports that the seedling program has tripled the average family income of its participants.

In some deforested landscapes, this type of social forestry could become an important part of the local economic fabric. In São Paulo state, the Instituto de Pesquisas Ecológicas (IPE) and its U.S. partner, the Wildlife Trust, have been working with about 80 families to plant a forest corridor connecting the 35,000-hectare Morro do Diabo State Park to a 400-hectare tract of forest outside the park. The tract is habitat for the critically endangered black lion tamarin, and for other vulnerable species, such as ocelets, tapir, and puma. The plantings themselves are not natural forest; they're "agroforest," that is, they're composed of trees and shrubs that can provide fruit, fodder, firewood, and so forth. The agroforests should ease the exploitation of the natural fragments, reduce edge effects, and allow forest animals to move between the park and the fragment. The families are former landless people who have only recently settled in the area. They design and plant their own agroforests, with seedlings supplied by community nurseries, and with advice from project staff. To participate, families must agree to maintain 10 to 15 percent of their land in forest. The corridor will emerge as the aggregate effect of many individual decisions—it's "populist restoration." It's also a kind of community investment in the landscape.

Restoration may even help create new economic instruments for conservation. In the coastal region of

Guaraqueçaba, near the city of Curitiba, the U.S.-based Nature Conservancy is working with the Sociedade de Pesquisa em Vida Selvagem e Educacao Ambiental (SPVS) to restore 16,800 hectares of forest. SPVS had wanted to restore this area for several years, but could not afford to purchase the land. (Ownership was considered necessary because the goal, essentially, is to create a large park of restored natural forest.) So in a deal brokered by the Nature Conservancy, General Motors and American Electric Power contributed $15.4 million to the project, in exchange for the right to claim credit for the carbon that the restored forest will eventually sequester. If the climate treaty negotiations produce a carbon-trading system, those credits might actually acquire a tangible value. At present, however, their worth is presumably limited to public relations. A carbon-trading system might be an incentive to restoration, but it also entails serious risks. It could just as easily encourage ecologically destructive tree plantations, which obviously also sequester carbon, and the idea has already been used in the climate negotiations as a way of avoiding the basic need to reduce the emissions themselves. (See "Bogging Down in the Sinks," November/December 1998.) The article beginning on page 17 advocates another economic instrument: cocoa, the major tree crop in the northern part of the Atlantic Forest.

3: Landscape vision. All three of the projects just mentioned are local in the best sense of the term: they have been crafted to fit both the natural and the social character of their sites. But to resurrect the Atlantic Forest, another level of effort will be required, one that is informed with a vision of the biome as a whole. Essentially, the key is to do what is being done around Morro do Diabo, but on a much larger scale. The best forest fragments will need to find each other across a highly developed landscape. Restoring the biome will be a labor in macro connectivity.

This is the principle that underlies the large-scale forest corridor project launched by the government of Brazil in 1996. Seven corridors are planned, five in Amazonia and two in the Atlantic Forest: the Serra do Mar Corridor and the Discovery Corridor (see the map on page 10). The project is funded primarily from the G7 Pilot Program to Conserve Brazilian Rain Forests, administered by the World Bank, and it has numerous partners, both inside Brazil and abroad.

The term "corridor" may be slightly misleading, since the goal of the project is not to create narrow bands of forest. Instead, the corridors are regions where the planting will aim to create as many links between the fragments as possible, and to insulate them with buffer zones of restored vegetation. Some areas will be restored to natural forest, others to agroforest. Where large areas of undisturbed but as yet unprotected forest exist, new reserves may be created. The result should be a landscape matrix still containing plenty of human activity, but in which most of the native plant and animal populations have adequate living space.

The effort of bringing a corridor into existence is enormously complex, but this complexity creates opportunities not available solely through broad regulatory approaches. The Discovery Corridor, for example, is the scene of an innovative mapping effort conducted by Conservation International, a U.S.-based NGO that is a major participant in the corridor project, together with IESB, CI's local partner. The mapping is designed to pinpoint areas that have high ecological value but relatively low value for conventional uses (that is, they're poor sites for development or farming). Planners can use the tool to decide exactly where to purchase land, to get the most out of their expenditures. But outright purchases probably won't be the rule; instead, it should often be possible to work out compensation mechanisms for current landowners, who pledge in turn to keep portions of their property forested. Of course, the key to making the whole system work is serious enforcement of conservation measures, on both public and private land. Given the state of current enforcement, that may be the most difficult task of all.

If the system does work, the two Atlantic Forest corridors would protect a substantial portion of the best of the biome's remaining fragments. Overall, the seven corridors planned for the country would cover 15 to 20 percent of the two biomes concerned and could preserve more than three-quarters of Brazil's rainforest diversity. And of course, the approaches developed for building the corridors could be extended to the lands beyond them. If they work properly, as both economic and ecological instruments, such an extension should be, if not inevitable, at least probable.

That is why these tattered fragments hold such promise. "The Atlantic Forest," says Gustavo Fonseca, director of CI's Center for Applied Biodiversity Science, "will be the first success story for any biodiversity hotspot." If it comes, that success may mark the reversal of 500 years of landscape dysfunction. It may in effect inaugurate a new social contract with the land. And it may one day seem as dramatic a step as that which Pedro Alvares Cabral took when he first set foot on these shores.

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