In essence, practical, "low-order" forest restorations can and must become government regulatory policy, though the "ecologically complete" projects will probably depend on philanthropy or programs such as Earthkeeping in the foreseeable future.

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The Neotropics

A broad look at prospects for restoration in Central and South America raises some basic questions about methods, about goals, and about the restorationist's role in evolution.

By Daniel H. Janzen

The New World mainland tropics can never be fully restored to an "unaltered by humans" state. The first wave of professional hunters passed through the New World tropics about 10,000 years ago. They extinguished most of the herbivorous megafauna (the tapir was the largest survivor), and a diverse array of predators and scavengers subsequently starved to death. This first anthropogenic megaperturbation irreversibly altered the species composition, vegetation structure, and suite of evolutionary forces in virtually all neotropical habitats.

Subsequently, during the past 5,000 years, neotropical hunting, agrarian and urban humans have reduced all habitats to ecological islands. These islands are invariably altered in size, configuration and biodiversity in a way that is for all practical purposes irreversible.

Clearly restoration of neotropical habitats cannot be a return to a pre-human landscape. On the one hand, it is not biologically possible and it is therefore dishonest to seek funding and social support for that purpose. On the other hand, it is not socially practical; the pursuit of such a goal leads to an isolationism and disregard for society that will eventually cause rejection of the project by society.

What can be sought, however, is a biologically literate and stable society that seeks to have wildland patches of various sizes, configurations and biological properties coexisting with other kinds of land use. In such a circumstance, the act of "restoration" is in fact not "restoration" in the literal sense of replicating what once was, but rather the implementation of a micromanagement regime that allows an array of species to live out their lives and interactions as best they can within a new set of environmental boundaries. These boundaries are imposed by a long list of factors ranging from rice fields to regional climate change to introduced species to ecotourists to migration barriers to island biogeographic factors, and so forth.

Thus the neotropical countryside a century hence will not be altogether natural. But it could be a mosaic of many kinds of traditional agrohabitats with islands of wildlands ranging from those so large and unmolested that they nearly mimic pre-European conditions, to those that are hardly more than a municipal park with a few percent of the species that were present when the Spaniards arrived

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Characteristic of highly altered environments throughout the neo-tropics, a tropical dry forest re-emerges in an abandoned old field of African grasses in Rincon de la Vieja near Guanacaste National Park, Costa Rica.

Photo by Tom McClintock

and that have almost no interactions resembling those of the past. Each of these extremes, and all the grades between, have a highly significant place in a biologically literate society that demands the maximum return from its real estate, so to speak. And each of these extremes, and all the grades between, find themselves repeatedly on the restorationist's menu throughout the neotropics.

Those who use wildlands—whether restored or original—vary enormously in what they expect from them, and the result is not necessarily a prescription for restoration. So the first step in analyzing human use is to determine which humans. While the Minister of Energy may want to reforest an area to protect the watershed of a hydro-electric dam, one can note that many different kinds of vegetation—from carefully manicured dairy pastures to timber plantations to raw wilderness—may protect a watershed. The Minister of Education may want a patch of wildland near every grade school and high school to serve as a living laboratory and library for biological literacy. However, an awful lot of lessons can be illustrated with a restored patch containing only a small fraction of the species to be found in a relatively intact tropical forest. The Minister of Agriculture may want big blocks of wildlands in which to search for wild genes and exotic chemicals; here at least the maximum number of species and interactions is terribly important. It is so important that the Minister may even argue for converting the wildland to a Noah's ark into which are stuffed not only the species that are "naturally" there, but also all the exotics that might eventually be of interest. A greenhouse is a greenhouse, even if it is called a national park in some other language. The Minister of Finance may want roads, inns, campsites, restaurants and other user-friendly structures scattered throughout the wildland area. Anything that keeps the ecotourist one day longer boosts the national treasury. And restoration here may even involve the day-to-day rotation of tourists among areas with known vegetative regeneration rates or the restoration of impact-resistant areas where the administration can "park" tourists with little sophistication about tropical ecosystems.

In short, tropical restoration biology begins with an analysis of what kind of human use is expected in an area. This must somehow be balanced with a consideration of the various ecological possibilities a site offers and the prospects for realizing them. Let's not get stuck in the mud-hole of trying to restore the quetzal population on a mountainside where society will not allow the habitat to be designed in such a manner as to allow the quetzals to move up and down the mountain to follow the fruiting cycles of their food plants. And let's not hear anyone say that a patch of wildland is too small to be worth saving because it's too small to support jaguars and tapirs. Such a wildland may be a quite comfortable home to 10,000 species of insects and 500 species of plants—and just great for the local school system.

So what hope is there for restoration biology in the Neotropics? Huge hope. And this is quite simply because biological literacy has begun to take root throughout the Neotropics. In February 1992 Mexico inaugurated a national biodiversity institution and consolidated yet one more large area of conserved wildlands. Guatemala has an exploding conservation system. It seems that almost everyone wants to save Belize. El Salvador is embarking

on a gigantic plan to put wildland vegetation back where it can be useful on its Pacific coast. Nicaragua is seething with discussion about how much rainforest should be conserved and how much should be put into sustained-yield logging. Costa Rica has a growing National Biodiversity Institute (INBio) and a new National System of Conservation Areas. Similar stories continue to unfold to the south.

The last two decades of conservation, building on another half-century of sporadic conservation attempts here and there in the neotropics, have alerted many in neotropical societies to the value of the natural areas that are the raw materials of restoration biology, even as other portions of society have steadily ground them up and eaten them. Now that wild biodiversity—genes, individuals, species, habitats, ecosystems—are all beginning to find a place in the structure of a biologically literate and biologically opportunistic society, we find the social circumstances for restoration biology to be highly favorable. It is not surprising that this occurs in the tropics. Restoring a piece of Wisconsin prairie is unlikely to affect anything but the intellectual and emotional health of some Wisconsin residents. Restoring an equivalent piece of wildland El Salvadorean dry forest could very easily be the beginning of rational watershed management in a seasonal desert—as well as make considerable offerings in biodiversity education, biodiversity prospecting and recreation.

Now that we are fortunate enough to have diverse sectors of neotropical society clamoring for direct restoration and for reversal of the degradation process in a variety of wildlands, what are the technical challenges and what are the pertinent biological concepts?

Sources of species

What should be the origin of inocula? In the most favorable situation, the species are already present as population fragments, and simply stopping whatever is stressing the system allows populations to expand, fight it out, and create whatever wildland comes to occupy the site naturally. This process is characteristic of almost all major reconstruction projects in the neotropics—especially the biosphere reserves and the portions of large national parks that once were occupied by colonists. Society is only just beginning to think about real, wholesale restoration in landscapes where the original biodiversity has been virtually eliminated—areas such as the cotton fields on the Pacific coast of El Salvador, for example, or the islands of the Caribbean (see accompanying story by Gary Ray). Where species are truly missing from the site, or where for some reason species originally foreign to the site are desired, then the restorationist faces some tricky questions. If the goal is to recreate tropical dry forest, for example, then there is the question of whether to work hard to get dry forest genotypes from remote dry forest relics, or to accept genotypes from nearby rainforest areas. The tapir has been gone from El Salvador for so long that the people there believe that there never were tapirs in El Salvador. Should El Salvador's restored tapir population come from nearby Honduran-Nicaraguan rainforest or from more distant Costa Rican dry forest?

In any case, since the goal of a truly non-anthropogenic habitat is unattainable, the restorationist must become a realist at balancing biological and economic costs and benefits. "Fidelity of inocula source" is a very central question in this discussion, yet, ironically, the law of diminishing returns looms large here. In general the better the condition of a site, the more "natural" it is, the more effort the restorationist will want to invest in "purity"—in getting rare local stock for reintroductions, and in excluding exotics. It is the same in building restoration. Enormous care might be put into restoring a slightly damaged 13th Century cathedral to its Medieval condition. However, if the cathedral has been reduced to rubble, and most of the bricks were long ago removed for paving stones, the ensuing discussion among the architects and others planning its restoration will be quite different. They might even wind up with electric lights and a loudspeaker system built into the pulpit.

Waifs and Strays

Another problem is deciding what species really belong in the system you are planning to restore. If one inventories any piece of habitat in a large area of tropical habitat (say, 50,000 hectares or more), it is very likely that 1-20 percent of the species in a given higher taxon are represented only by waifs. These are individuals that are living, seem to be healthy, but do not maintain a viable population. That is to say, if the other habitats in the wildland are stripped away (say, by conversion to rice fields), these species disappear from the remaining wildland—not because the site is too small or lacks the right kind of mutualists, but because these species were only there in the first place as incoming waifs.

So the tropical restorationist who attempts to put back into a site all the species that were known previously from that site, may actually be attempting to maintain species that in fact were there only incidentally, played no important role in the community and had no future there. On the other hand, it may well be that the only way to identify these species is simply to try to restore the whole list. Tropical islands may offer an extreme case of this general problem, since many of their species may be present only as colonists persisting until the next local extinction event. Here, restoration may depend on the simultaneous restoration of the source area for the colonists.

Migrants

Many tropical habitats have large numbers of migrants in their inventories—insects, birds and mammals. They spend part of the year there, and part of the year elsewhere. Within-tropics migration is commonplace on a scale ranging from a few meters to hundreds of kilometers—to say nothing of those that arrive from extra-tropical regions.

When present, these migrants may play a major role as food for other organisms, mutualists (pollinators, seed dispersers, etc.), carnivores (parasitoids, predators), detritus producers, herbivores, etc. The restorationist who tries to put back these species without putting back (or conserving) their *other* habitats—in Ontario, say—has simply guaranteed failure. The point is that just as a national park planner cannot afford to think of each park as a thing unto itself, neither can the tropical restorationist think of his or her project as a lunar capsule—at least without accepting the likelihood that the biota of the resulting system will be missing some species.

Fire

Natural fires are extremely rare in most neotropical habitats. Anthropogenic ones are very common, and have been for up to 10,000 years. It is probably best to view fire as simply another organism, and apply the same rules to it as to other exotics. (I should note that even the "natural fire" is generally not natural, since such fires are far more likely to start and to spread in a highly altered environment. It is true that a lightning fire can occur in Costa Rica in the middle of the rainy season, but it rarely spreads unless the lightning hits a tree standing in a pasture that has not been burned for several years and thus is standing in a pile of anthropogenic fuel.)

It is fair to say that free-running anthropogenic fires are the number one challenge for the restorationist in the dry tropics, which is easily half or more of the neotropics. Good fire-control programs are expensive in human resources, administrative energy and dollars. There is some respite, however, if the wildland is allowed to develop a closed canopy similar to that of old-growth forests of the area. In this state the vegetation becomes either unburnable or will support only slow-moving, easily extinguished fires.

Genetic engineering

Untillable land is the greatest friend that the neotropical conservationist has ever had. It is also a good friend of the restorationist because it provides refuges for remnant populations of plants and animals, and also because it sets some visible limits to the exploitation of the landscape. Let me put this another way. If there were a high-yield corn plant for tropical lowland lateritic soils, there would be no lowland rainforest for us to argue about today. There is not one tropical national park on fertile delta soils anywhere in the world.

Genetic engineering (so-called biotechnology) may offer both the challenge and the solution with the restorationist (and conservationist) being the go-between. The bad side of the coin is that the genetic engineering of specialty plants and animals, transnational and transcontinental introductions, and massive infusion of new "semi-domesticates" from tropical wildlands, will render virtually every square meter of the tropics "productive" in the agropastoral sense. The result could be the elimination of the last relict wildlands in some areas as lands now regarded as useless come to be viewed as a fertile ground for novel forms of intensive agricultural management.

The good side of the coin is that the restored and conserved tropical wildlands are in fact *in situ* zoos and botanical gardens which will provide the genes, varieties and species that will be essential for the new agriculture. This gives them a new kind of value, and provides a new argument for their conservation.

Part and parcel of intensive agroscape micromanagement for diverse and carefully engineered animal and plant products is a thorough removal of the things that either compete or molest the "productive" organism in which so much has been invested. Throughout the tropics today, various kinds of intensive agriculture are polishing off landscapes that had been protected for centuries by nothing more than economic limitations and administrative inefficiency. Such areas still provide habitat for hundreds of thousands of species, and priceless reserves of local biodiversity. The brushy cattle pasture, the wooded rocky slope, the failed banana plantation, the abandoned hillsides on which charcoal was processed—all these "habitats" are a godsend for the restorationist—and the first to disappear when real first-world development takes hold.

Habitat Sharpening

In a large tropical area, despite the neat lines drawn on maps to demarcate them, most habitats blur from one into another. When does dry forest stop and rain forest begin? When is it cloud forest and when is it intermediate-elevation moist forest? Such distinctions are hard to make in an undisturbed landscape, and are ultimately arbitrary. However, if a block of tropical vegetation is restored, its boundaries with the more conventional agroscape are likely to be very sharp. All that is within will be called one thing. All that was outside is gone. The result is a tendency to regard all wildlands as "natural" and to overlook the subtler variations among them. The same thing occurs when a block of intact vegetation is protected from destruction in an area undergoing development. But the problem is likely to be even greater with areas undergoing restoration because the differences among wildland habitats appear to be less, and actually are less during the earlier stages in the restoration process. It may take millennia for species and ecological processes to sort themselves out to where once again the north side of the slope is really as different from the south side of the slope as was originally the case. In the meantime biological important variations may be overlooked and whole suites of species may be lost.

Noah's Ark?

Should restoration projects serve as refugia for species from other areas? This question brings us back to the more basic question of the goal of the restoration project. For

many projects, the presence of certain introduced species—whether from 10 km or 1,000 km away, or from across an ocean barrier—may be irrelevant or even beneficial. In such cases it may be quite appropriate to regard the restored area as an *ex-situ* conservation site—at least for appropriate species.

But this raises more questions. Does a restorationist have the right to introduce a species (for whatever reason) that may in turn merrily leave the restoration area and become widely established as a pest? I don't care how endangered, a species of African mongoose should not be introduced into a conserved wildland in Central America.

If a habitat is being restored, it lacks many species of carnivores, parasites, herbivores, and so forth that are present in an "intact" wildland. When species are returned from other areas, it may be necessary simultaneously to return some of their primary interactants. In other words, the Spaniards' Pleistocene gift to the neotropics—the horse—is best added back to a restored neotropical wildland only if accompanied by artificial predators such as hunters, or a program of castration.

Evolution and insularity

The vast majority of tropical mainland species have ranges that extend over many degrees of latitude. These species clearly evolved in some limited area and then spread, and so in the strictest sense are exotics throughout much of their present-day range.

The result is a situation of great interest to the restorationist. So long as these new species existed only in the small, genetically isolated areas where they first appeared, they evolved rapidly under the selective pressures peculiar to that area. Once widely dispersed, however, they have evolved more slowly, so that for the most part their morphology, physiology, behavior, and so forth are just as they were at the time of dispersal.

Now consider the implications of this for the restorationist. During the past 5,000 years, we have taken these large distributions and reduced them to constellations of small patches. In doing so we are maximizing insularity and recreating at least one of the conditions for rapid evolutionary change. This in turn will increase biodiversity among the surviving lineages, and it will increase it even more if we generate a massive change in climate that heats up or dries out or drowns the island patches.

At this point, the restorationist suddenly appears offering a new technology that might reverse the whole process. The question is how to use it. On the one hand the restorationist might be called in to re-establish wildlands that are 10-1,000 km distant to serve as Noah's arks for species that are being extirpated by major changes in local climate. On the other hand, he or she may well be called up to restore habitat bridges or "corridors" between habitat islands. This, however, raises the question of whether to keep species isolated in their habitat islands (and thus promote evolutionary change) or to try to keep them from differentiating by linking habitats. To deal with this question, of course, the restorationist will also need detailed understanding of how various species actually use such corridors, especially when corridor habitat differs from that of the islands it links together.

We do not live by bread alone

For a biologically literate tropical society, a conserved wildland is a potential national theater, public library, civic center and university. Obviously, the citizens of such a society will want to have some conserved wildlands close at hand. Tropical areas with high human density are characteristically severely degraded. We usually don't have the luxury of decreeing a large pristine national park on the margin of an urban area with 1-5 million people or an area of intense agriculture. Restoration is the only option, and takes on the form of actually constructing an object—the wildland whose biodiversity is conserved for a variety of users from the first day.

Ecotourism—the process by which society examines the wildland—is a kind of ranching. It is memories, knowledge, stimulation, and inspiration that are marketed. And as in other kinds of ranching, the administration needs to monitor impact, improve pastures, maintain fences, call the vet, watch the market, pay taxes, put different kinds of livestock in different parts of the ranch, make capital investments, and train the cowboys. And the best fertilizer is the footsteps of the administration. In contrast to the very passive kind of ranching, a kind of absentee landlordism that may be appropriate for very large blocks of natural habitat with no need for restoration, the tropical restoration project that is to be used by ecotourists—and virtually all will be—will be very much like a well-run ranch. The up side of this is that most ecotourists can read and are not dependent on the ranch for a two-year stay. The down side is that the ecotourist knows the place only as a snapshot in time.

Playing God?

In the species-poor habitats outside of the tropics that so many of us grew up in, it may seem reasonable to descend into discussions of where to put what species in a restoration effort, almost as though one were growing a garden. For example, we are likely to find someone arguing that a restoration project cannot begin until we know the community structure of the site before the degradation occurred.

In the neotropics this is nonsense. Where one site originally has hundreds of species of plants and vertebrates, and tens of thousands of species of invertebrates, restoration quite frankly consists of just two steps. First, you stop the processes causing the degradation—or at least those that are within your power to stop. Second, you anguish over whether you want to add back any or all of the species that you have reason to believe were once there, but that are now missing. Having anguished, you probably

do a few introductions, knowing full well that some of the species are not going to persist, and that some of the species you left out—or didn't know about—will arrive on their own accord.

And then you just leave the damned thing alone.

But of course all the users are not going to leave it alone, so micromanagement of the users becomes a major action. The gains from users must be balanced against the damage they cause. And in the meantime, there are going to be endless questions. Shall we go to war against the tilapia and the trout in the rivers in the neotropical national park, or simply accept that their introduction five or 50 years ago was a callous trashing of native aquatic habitats for the pleasure of the fish hunters? Shall we scream perturbation when the ecotourists cause the peccaries and agoutis to modify their foraging ranges, or shall we recognize that their foraging ranges were irretrievably altered when the last gomphotheres and glyptodonts were speared out of the habitat. Shall we complain about altering the altered? Yes and no, depending on . . . .

The point is that decisions are going to have to be made. We should have recognized this long ago: all neotropical wildland habitats are already managed. The differences are that some are managed well, while most are managed poorly. So if we are going to play God, then let's figure out what kind of greenhouses we want and get on with site-specific, society-specific quality management and restoration.

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