Parks: How Big Is Big Enough?

A major ecological experiment in the Amazon rain forest addresses the crucial size question of national parks

The annual felling of some 11 million hectares of Amazon rain forest exemplifies the massive and pervasive environmental destruction that is occurring on a global scale in the bow wave of unrelenting development. It is therefore fitting that, on any geographical and temporal scale, the Amazon forest is also the site of the world's most ambitious environmental experiment, which is designed to determine how best to protect the dwindling habitat resources that remain.

The project area, which is located in northern Brazil and covers some 600 square kilometers, is now designated as a permanently protected entity, as announced in June by the country's environment secretary. "This means that our reserves will remain isolated and protected for at least 30 years, and maybe longer" comments Thomas Lovejoy, the project's co-director and World Wildlife Fund scientist. Herbert Schubart, of Brazil's National Institute for Amazon Research, is the study's second co-director. Data collected throughout that period will answer some questions on the optimum size of habitat reserves and will also have a bearing on theoretical debates that have been rumbling among academic ecologists for almost a decade.

Currently the study area contains seven isolated reserves: three measuring 1 hectare, 3 of 10 hectares, and 1 of 100 hectares. Ultimately there will be as many as 40 reserves, including some of 1000 hectares and one covering at least 10,000 hectares.

During the lifetime of this joint Brazilian–U.S. enterprise biologists from around the world will monitor the loss of plant and animal species—the ecosystem decay—throughout the 1 to 10,000 hectare range of reserves. "The small reserves will give us a quick and simple picture of what we might expect," explains Lovejoy, "whereas the larger ones should provide more sophisticated insights over a longer period. We expect the 10,000-hectare unit to be representative of unbroken forest, except perhaps for some very wide ranging species, such as the harpy eagle and the jaguar."

Ecologists can already predict that the smaller units will suffer more than the bigger ones: a generally positive relationship between habitat area and number of species contained has been known for more than a century. And fragmented habitats are known to lose species once they are isolated, but the rate of loss and the processes involved in the decay are unknown. In very general terms, the Amazon project is meant to go beyond simple quantitative measures of numbers of species at risk, and instead yield some information on the minimum size of reserve that is required to preserve the principal characteristics of the ecosystem, to maintain the biological integrity.

Many academic ecologists are deeply involved in conservation efforts worldwide, at least part of their role being to apply ecological theory to optimum design of reserves. Faced with the pace of economic development and habitat destruction, some of them wonder whether Lovejoy, Schubart, and their colleagues are doing the environmental equivalent of fiddling while Rome burns. "It is the rest of us who are fiddling," says Frances James, an ecologist at Florida State University. "They are down there collecting data. This is the only experiment in the tropics that has a major bearing on this conservation issue." It is a matter of hard practical reality, however, that 30 years down the line the planning of many, perhaps most, national parks around the world will already be a matter of history.

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Because fragmentation of once continuous habitats is a major environmental consequence of economic development, the question of the size of a potential reserve becomes important in considering the composition of the ecosystem that will remain. It is obvious, for instance, that a reserve can contain only those species whose area requirements are equal to or less than the total available. Species whose needs are greater will, in all probability, become locally, and perhaps globally, extinct.

In addition, the fact that any such reserve is in effect an "island" amidst an uninhabitable "sea" will also affect the long-term dynamics of the ecosystem. Species will be lost through time, through stochastic and other processes. And as immigration of species from elsewhere is likely to be small, the island inevitably becomes ecologically impoverished as time passes.

"Although one can make some reasonable generalizations about ecosystem decay—such as species at low population density will be at risk following habitat fragmentation and isolation, as will top carnivores and others with large foraging ranges," says Lovejoy, "one cannot predict what might happen to the ecosystem as a whole." A knowledge of the processes involved, which will be derived from observation of repeated patterns of ecosystem decay, will give an insight into the dynamics of the ecological community and might allow selective intervention in the management of habitats that are below the minimum size.

A fair number of studies have addressed the problem of ecosystem decay following isolation, but none has been prospective. The great strength of the "minimum critical size of ecosystems project," as the Brazilian–U.S. venture is called, is that it is the first time the effects of fragmentation and isolation will have been closely observed throughout the decay process. "It is beautifully designed," comments Jared Diamond, an ecologist at the University of California, Los Angeles. "It is unique in human history."

Lovejoy conceived the idea for the project at a time—1976—when ecologists were arguing over the application of island biogeography theory to the design of ecological refuges. The theory, which was developed in the late 1960's and was prominent in ecological thinking through the 1970's, addresses the equilibrium state of communities of particular sizes. It gives predictions of the number of species a particular type of habitat of a particular size might contain, given a balance between loss through local extinction and gain through immigration.

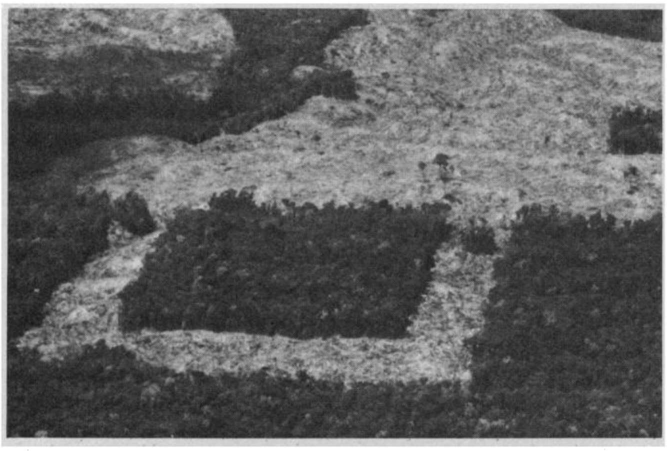
The arguments of the time came to focus on whether a large reserve would contain more species than several smaller ones of equal total area. Some contended that the theory could answer the point, whereas others countered that, in the real world, it was unhelpful.

"The trap with island biogeography theory," says Lovejoy, "is its simplicity. It treats all species as being equal. Our aim is to get away from a simple quantitative assessment and address the ecosystem as a whole, as a functioning unit. Our goal is to try to determine what minimum critical size of reserve can protect the characteristic species composition of the habitat."

Each different habitat type has a roughly typical species composition, which has to do with diversity. For instance, 10 hectares of Amazonian forest will support some 300 species of trees, whereas diversity in a temperate forest is about one tenth that figure. "Each habitat type has a characteristic species/area curve, and, roughly speaking, the 'minimum critical size' is that which will protect the habitat's species/area curve, or something close to it."

Forest Isolate

This 10-hectare reserve, isolated last summer, will eventually lose its neighboring forest completely. It is one of a planned 40 reserves in which the ecosystem decay curves will be determined over a period of 30 years.



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To establish the minimum critical size for the rain forest habitat—for any habitat—two separate but related questions must be answered. First, are species lost in some sort of predictable order? And second, will forest fragments of similar size end up with similar final species compositions. The natural world is so very complicated that ecologists still cannot agree on whether there is "order" to ecological communities, whether they are structured units or random assemblages, which is why these two questions remain to be answered. As James notes, "the value of the Amazon project is that it will give an example of exactly what happens in a particular case." The outcome will be of both theoretical and practical import.

With two of the forest reserves being just 4 years old and the remainder less than one, there are no answers yet to these large questions. It is clear, though, that the loss of bird species proceeded more rapidly in the 1-hectare unit than in the 10-hectare reserve, which in general is what was expected. Eventually the project will yield a series of decay curves for each species group within each reserve size range. There should be enough duplicates within each size range to at least approach the question of randomness in species loss. And it should be possible to extrapolate through these four orders of magnitude (1 through 10,000 hectares) to a prediction of a minimum critical size.

During these first years of reserve isolation the focus of most folks' minds was, not unnaturally, the size question. It therefore came as something of a surprise when events forced attention to be turned to the phenomenon known as the edge effect.

The tropical rain forest forms for itself a highly insulated ecosystem—dark, cool, moist, often in the face of hot, dry winds. When a patch of forest is exposed to the elements, therefore, dramatic microclimate changes ensue which have had a much more dramatic impact than anyone had anticipated. In addition to encroachment by light-loving herbaceous plants, shrubs, and trees into the previous moist gloom, tree falls and drying out of leaf litter alters the edge habitat considerably. With these changes come concomitant shifts in animal populations. The penetration of this altered habitat has been surprisingly deep, with only a core of the 100-hectare reserve maintaining its characteristic butterfly community, for example.

"We have begun to devote a lot of attention to the edge effect," says Lovejoy, "and we've mounted a series of systematic studies on soil moisture, leaf fall, leaf litter, soil nutrients, as well as on air temperature and humidity." Once the magnitude of the edge effect has been established it can be discounted when calculations are made on the desired size of a reserve. "On the other hand, there will be plenty of small pieces of woodland under conservation around the world, and the edge effect would be dominant in these cases. We have to know about it."

This summer some 50 researchers have been going to and from the project site, continuing the monitoring of plant, animal, and insect populations in the planned and already isolated reserves. Already it is clear from the 4-year-old units that species with low populations—whether of birds or rodents—are particularly vulnerable to local extinction, which is no great surprise. The most numerous small rodent, *Proechimys*, also disappeared, which was a surprise. "We simply can't explain it at the moment." Fruit-eating saki monkeys could not find enough resource trees in their 10-hectare reserve and became extinct there. By contrast, a band of red howler monkeys, which live on leaves, are apparently sustaining themselves.

In a display of the connectedness of things, several species of ant-following birds, which prey on the fleeing victims of army ant colonies on the march, found 10 hectares too small a territory in which to survive: apparently there were insufficient active ant colonies to support them. And three species of frog have vanished from one reserve they previously occupied. The reason? They were dependent on standing water, which was provided by the wallow of the peccaries in the area. Along with other large mammals, the peccaries moved on when the reserve was isolated—the wallow dried up, and so did the frogs.

Each different habitat type is distinguished by the composition and diversity of the species it contains, and each can be expected to be susceptible in different ways and extents to the effects of fragmentation and isolation. Because of the great complexity of the Amazon rain forest habitat—its great species diversity and insulation, for instance—it is particularly vulnerable to ecosystem decay. Data from the Amazon project therefore cannot be expected to be completely transferable to other habitats. "Ideally, there should be a minimum size of ecosystem project in every habitat type throughout the world," notes Lovejoy. "In the absence of that we expect to be able to derive principles and patterns that can be applied elsewhere."

Diamond already sees one result that is directly relevant to conservation efforts in other parts of the world. "Government officials are always asking us, 'How big should our park be?' and 'How many species will we lose if it is only half that size?' and so on. Biologists have always sensed that large parks are necessary, but we haven't been able to back it up with strong evidence. The Amazon project is now providing that evidence. That is very important."—**Roger Lewin**