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Research Focus

When bigger is better: the need for Amazonian mega-reserves

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The rate of forest destruction has accelerated sharply in Brazilian Amazonia, but there are also vital conservation opportunities with the ongoing designation of important new protected areas. In a timely paper, Carlos Peres argues that an extensive network of mega-reserves, operationally defined as those exceeding 1 million ha in area, is needed to ensure the long-term persistence of Amazonian species and ecological processes. Although such protected areas might seem excessively large to some, disparate lines of evidence suggest that mega-reserves are vital for the future of Amazonian biodiversity.

Introduction

During the past 15 years, rates of forest loss, degradation and fragmentation have accelerated sharply in the Amazon (Figure 1), the largest and most biologically diverse of all tropical wildernesses. These losses are being driven by a combination of factors, including rapidly increasing cattle ranching and soybean farming, a proliferation of industrial logging, forest-colonization projects, and an unprecedented expansion of new highways, roads and other transportation infrastructure [1,2].

Yet, this is also a time of unparalleled opportunity for conservation in the Amazon. Brazil, via various federal and state initiatives, is currently designating many new protected areas and sustainable-use forests within the Amazon (Box 1). These conservation units vary in the kinds of resource use that is legally permitted [3]; for example, intensive uses, including industrial logging, are permitted in some reserves, such as National Forests and Environmental Protection Areas, whereas others, such as National Parks, nominally allow only limited uses that include tourism and scientific research. Other conservation units, such as Extractive Reserves, permit intermediate activities, such as hunting, rubber tapping, and traditional swidden farming.

A related challenge is that, in reality, enforcement of environmental laws in the Amazonian frontier is patchy and inconsistent at best. Illegal logging is rampant, laws that regulate deforestation on private properties are rarely enforced, illicit forest invasions are common, and numerous reserves are being threatened by illegal deforestation, predatory loggers and gold-miners [4]. Such pressures will only increase as highways and other transportation infrastructure infiltrate throughout the basin [2], bringing conservation units and the expanding Amazonian population into ever-closer contact.

The need for mega-reserves

Into this mix of environmental promise and peril comes a new paper by Carlos Peres [5], part of a special section in the journal *Conservation Biology* about the Brazilian environment. Peres argues, based on several lines of evidence, that Amazonian reserves need to be large (>1 million ha) and embedded within a relatively benign matrix of sustainable-use forests to preserve their most vulnerable species and large-scale ecological processes. They should also be stratified across major vegetation types and key centers of endemism (Box 1). Finally, wherever possible, he and many others [6] assert, individual conservation units should be linked together into large-scale regional corridor systems.

At first glance, Peres' proposal might seem excessive to some policy makers, but the evidence for mega-reserves is compelling. One of the most important justifications is that our biogeographical knowledge of the Amazon is appallingly incomplete, even for relatively well-studied groups such as birds and mammals. As a result, apparent centers of endemism and diversity are skewed toward accessible areas and certain forest types [7], distorting efforts to identify high-priority areas for conservation. Even at the few relatively well-studied sites, species inventories are usually deficient. For example, a five-year plant inventory at Ducke Forest Reserve (a center of research for decades) more than doubled the number of recorded plant species [8]. Field surveys often reveal scores of new plant and animal species, and taxonomic revisions for many groups are out of date. Since 1990, for instance, at least 14 new primate species have been discovered (or are currently being described) in Brazilian Amazonia [9]. Rare or locally endemic species are especially likely to be missed by patchy, incomplete surveys. According to a recent biogeographical model, this could include an astonishing 30 000–100 000 undiscovered species of seed plants in Amazonia*. In the face of such daunting uncertainty, an expansive network of large, functionally interconnected reserves is an effective way to capture much of the biodiversity of the region.

A second key justification for mega-reserves is to preserve populations of rare predators, such as jaguars,

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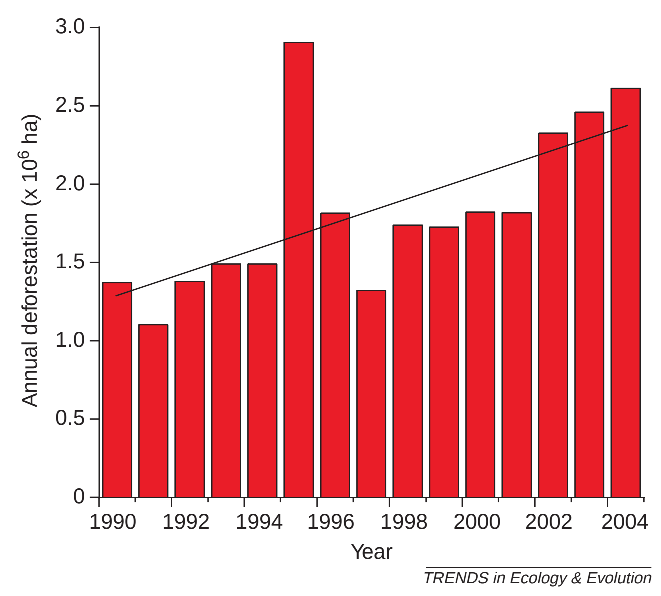

Figure 1. Annual rates of deforestation in Brazilian Amazonia since 1990. The regression line shows the overall trend. Data from the Brazilian Institute for Space Research (http://www.inpe.br/english/index.htm).

Box 1. Current and planned protected areas in the Brazilian Amazon.

Strategies for locating reserves in Amazonia have changed over time. During the 1970s, the initial emphasis was on protecting putative Pleistocene forest refugia, major vegetation formations, suggested phytogeographical regions, and areas with little economic potential [3]. Today, reserve locations are influenced by three concepts that arose during the mid-late 1990s. One of these is the Amazon Regional Protected Area (ARPA) initiative, which is focusing on establishing reserves within 23 Amazonian ecoregions, identified by WWF, that encompass major river drainages and vegetation types [24]. Another is a series of expert workshops initiated by the Brazilian Ministry for the Environment, which identified 385 priority areas for conservation in Amazonia [25]. The third is the biodiversity corridor concept, which proposes to link conservation units of various types into three to five large, separate chains, to help maintain forest connectivity [6]. Several of the proposed corridors span major rainfall gradients and might, if adequately secured and protected, limit the impacts of future climate change, by enabling species to shift their ranges in response to changing conditions [21].

Although <5% of the Brazilian Amazon is currently included in strict-protection reserves such as National Parks [3], this figure will increase in coming years. Via the ARPA initiative, the Brazilian Federal Government has committed to establish a total of 10% of forests in the region (50 million ha) in strict-protected areas [3]. ARPA is also promoting new 'sustainable-use' reserves that allow various types of extractive activity, from rubber tapping to industrial logging, and in which biodiversity conservation is a secondary priority. Although many new reserves have been designated since the inception of ARPA in 2002, most are still 'paper parks' that as yet have little staffing or infrastructure.

In addition, some forward-looking states in the Brazilian Amazon, especially Amapá and Amazonas, are currently establishing new conservation units, mostly smaller sustainable-use reserves. The Brazilian Amazon also contains several hundred indigenous lands and territories that are controlled by Amerindian tribes. Although not considered conservation units, these lands encompass a fifth of the Brazilian Amazon and often have an important role in protecting forests from predatory logging and land development [22]. To provide territories for additional Amerindian groups, the network of indigenous lands is likely to increase [3].

Figure 2. Predators such as giant river otters *Pteronura brasiliensis* are sensitive to hunting and require vast territories for survival. Reproduced with permission from Finding Species (http://www.findingspecies.org).

pumas, bush dogs and harpy eagles [10]. Despite spanning 2.1-million ha, for example, the Pacaya-Samira Reserve in Peru contains only 20 known packs of giant river otters (Figure 2) [5]. Densities of predators and many other Amazonian species are evidently limited by low secondary productivity caused by the heavily weathered, nutrient-poor soils of the basin [11] and by strong density-dependent processes such as pervasive disease and parasitism [12]. Populations of top predators frequently collapse in isolated reserves that are too small or that suffer intense hunting from humans along their periphery [13]. In the long term, viable communities of top predators are likely to be vital for maintaining the stability of tropical food webs and ecosystem functioning [14].

Aside from apex predators, many other Amazonian species also require large areas for survival. Numerous terrestrial vertebrates, such as certain peccaries, primates, bats, guans, parrots, cotingas and fruitcrows, undertake extensive seasonal movements to exploit staggered pulses of fruit and other resources in different habitats [5]. Amazonian trees are typically rare and obligately outbreeding and, thus, are likely to have large genetic-neighborhood sizes [15]. The Amazon is home to 3000 freshwater fish species, many of which migrate seasonally from productive feeding areas to spawning grounds in stream headwaters, which are rarely protected [5]. For such species, reserves must be large enough to contain the full complement of different habitats that is needed for long-term survival.

According to Peres, a final reason for mega-reserves is that they are easier and cheaper to protect than are smaller reserves [5]. Because of limited enforcement, even nominally fully protected reserves in Amazonia often suffer from poaching, wildfires, predatory logging and illegal gold mining [4]. The smaller the reserve, the more difficult it is to protect from the direct and indirect impacts of human encroachment. For example, Peres [5] estimates that, on a per-hectare basis, the staffing and operational cost for the tiny Saium-Castanheira Reserve (110 ha) is 18 000 times higher than that for the vast Tumucumaque Mountains National Park (3.9 million ha).

Further reasons for big reserves

There are additional reasons, beyond those suggested by Peres, to advocate mega-reserves in Amazonia. For example, large reserves are likely to be more resilient than are small reserves to deforestation-induced changes in atmospheric circulation that provoke increased rainfall over cleared areas and reduced rainfall over adjoining forests [16]. Mega-reserves are also likely to provide a better buffer during ecological crunches, such as periodic El Niño droughts, which can have large effects on plant phenology, fruit production and animal survival [17]. More generally, large reserves should be less susceptible to desiccation caused by deforestation, which reduces plant evapotranspiration [18], and by the moisture-trapping effects of smoke plumes from biomass burning [19].

One of the most compelling justifications for mega-reserves is that destructive surface fires, frequently lit by ranchers and farmers, can operate as a large-scale edge effect, penetrating up to several kilometers into forests during drought years [20]. Simulation models suggest that even large (>100 000 ha) reserves can be vulnerable to such fires [20]. These considerations highlight the importance not only of maximizing reserve size, but also for maintaining fire-free buffer zones around reserves and limiting roads inside reserves, which can facilitate forest invasions and fires.

Finally, mega-reserves should be far better than small reserves at withstanding future climatic and atmospheric changes [21]. Large reserves will span a greater range of elevations, latitudes, climates and habitats, affording greater flexibility for their constituent species to adjust their realized niches and distributions in response to changing environmental conditions. Linking mega-reserves together to form large regional 'corridors' should be an especially effective strategy to buffer the impacts of future climate change (Box 1).

Is there a downside to mega-reserves? The most probable objections will be economic, given the lost opportunity costs that can arise if forest exploitation is prohibited over sizeable areas. Such costs are greatest for human settlements within or near new reserves, and for this reason the Brazilian federal and state Governments might look more favorably on multiple-use than on strict-protection areas. To increase political support for new protected areas, efforts to integrate local communities into reserve management and sustainable activities, such as ecotourism and nontimber harvests, will be vital [3,22].

Conclusions

Many Amazonian species require large areas for survival. Area-demanding species might be common in Amazonia because of its inherent vastness, its nutrient-starved soils that limit abundances of many species, and the fact that the forests of the basin, contrary to earlier assertions, could well have persisted throughout the Pleistocene in a largely intact condition [23], reducing the impacts of past extinction filters. Compounding these features is the self-sustaining nature of the Amazon hydrological system [18], whereby moisture recycled from forests is crucial for maintaining local cloud cover and rainfall, particularly because the forests themselves are so vast and moisture-giving oceans so far away. The net result is an ecosystem that has evolved to be big, and needs to stay big, to retain its essential characteristics.

For regions that have already been severely reduced and degraded, such as the Philippines, Madagascar and the Atlantic forests of Brazil, smaller reserves are often the only options for preserving the remaining vestiges of ecosystems. Only a few tropical areas, particularly Amazonia and the greater Congo Basin, still offer realistic prospects for establishing new mega-reserves. Even in these regions, the windows of opportunity are swiftly closing. For the rapidly disappearing Amazon, the best conservation strategy is to move fast – and think big.

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