ISSN 1679-0073

Natureza & Conservação

Revista Brasileira de Conservação da Natureza

The Brazilian Journal of Nature Conservation

Abril, 2006 - vol. 4 - nº1 - April, 2006 - vol. 4 - n.1

FUNDAÇÃO O BOTICÁRIO DE PROTEÇÃO À NATUREZA

More reasons for megareserves in Amazonia[1]

William F. Laurance, PhD[2]
- Smithsonian Tropical Research Institute
Biological Dynamics of Forest Fragments Project, National Institute for Amazonian Research (INPA),

ABSTRACT

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. A recent paper by Carlos Peres suggests that an extensive network of megareserves, operationally defined as those exceeding one million hectares in area, is needed to ensure the long-term persistence of Amazonian species and ecological processes. Here I summarize Peres' arguments and provide a number of additional reasons why megareserves are likely to be vital for the future of Amazonian biodiversity.

Key words: Amazon; conservation; deforestation; fires; logging.

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: 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, among others (Fearnside, 2001; Laurance et al., 2001a; Kaimowitz et al., 2004; Asner et al., 2005).

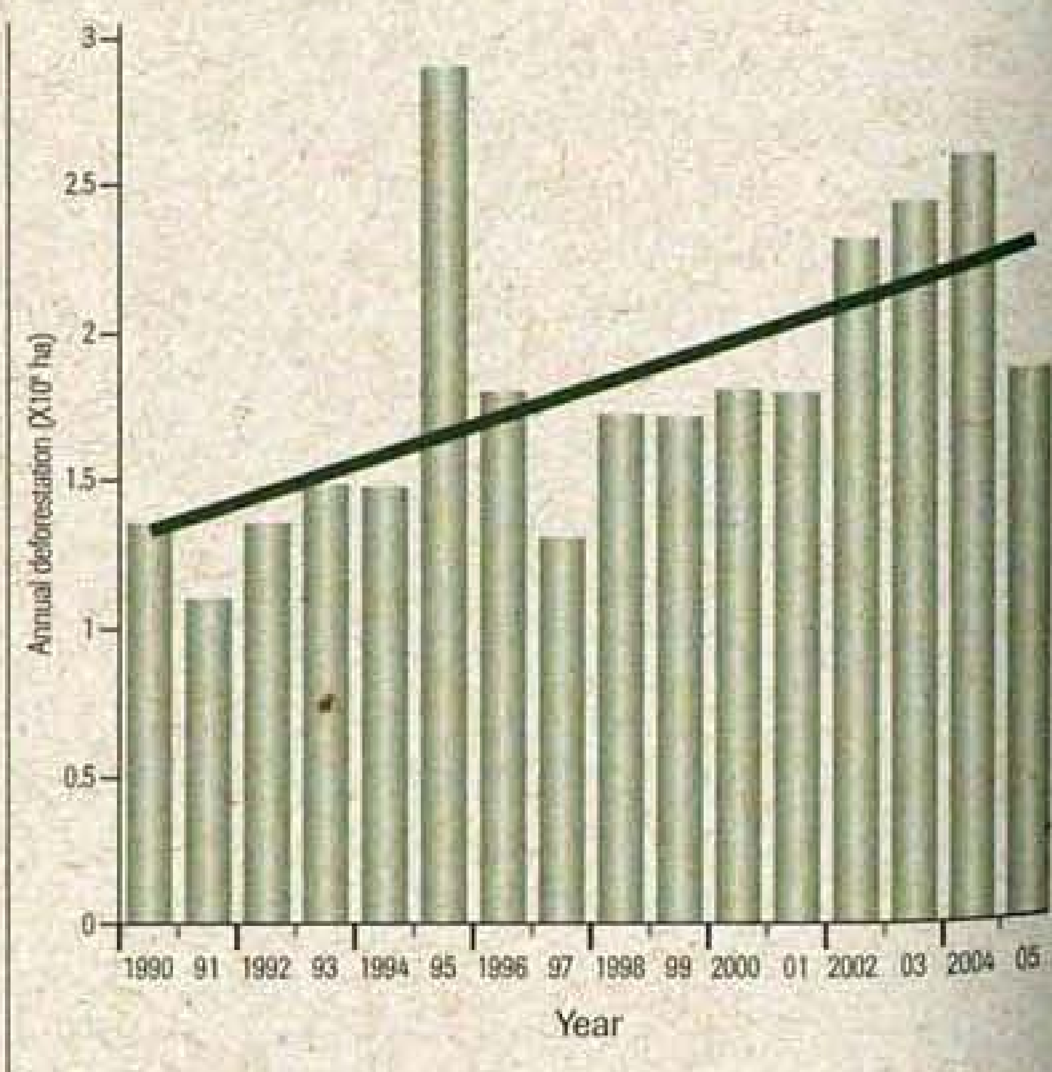

FIGURE 1. Annual rates of deforestation in Brazilian Amazonia since 1990, based on data from INPE (2005). The regression line shows the overall trend.

---

[1] Sent originally in English

[2] laurancew@tivoli.si.edu

Yet at the same time, this is a moment 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 uses that are legally permitted (Rylands & Brandon, 2005). 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. Yet other conservation units, such as Extractive Reserves, permit intermediate activities such as hunting, rubber tapping, and traditional swidden farming.

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

Although <5% of the Brazilian Amazon is currently in strict-protection reserves such as National Parks (Rylands & Brandon, 2005), this figure will rise in coming years. Via the Amazon Regional Protected Area (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 (Rylands & Brandon, 2005). ARPA is also promoting new 'sustainable-use' reserves that allow various types of extractive activities, from rubber tapping to industrial logging, and in which biodiversity conservation is a secondary priority. Although many new reserves have been designated since ARPA's inception in 2002, most are still 'paper parks' that as yet have little staffing or infrastructure.

In addition to ARPA, some forward-looking states in the Brazilian Amazon, especially Amapá and Amazonas, are currently establishing many 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 (Schwartzman & Zimmerman, 2005). To provide territories for additional Amerindian groups, the network of indigenous lands is likely to increase in the future (Rylands & Brandon, 2005).

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 (Rylands & Brandon, 2005). Today, however, reserve locations are being influenced by three concepts that arose during the mid-late 1990s. One of these is ARPA, which is focusing on establishing reserves within 23 Amazonian ecoregions, identified by WWF, that encompass major river drainages and vegetation types (Ferreira et al., 2001). Another is a series of expert workshops initiated by Brazil's Ministry for the Environment, which identified 385 priority areas for conservation in Amazonia (MMA, 2002). The third is the biodiversity corridor concept, which proposes to link conservation units of various types into several large, separate chains, to help maintain forest connectivity (Ayres et al., 1997). 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 (Noss, 2001).

A related challenge is that, in reality, enforcement of environmental laws in the Amazonian frontier is patchy and inconsistent at best. Illegal logging is widespread, laws that regulate deforestation on private properties are rarely enforced, illicit forest invasions are common, and numerous reserves are being threatened by predatory loggers and goldminers, and by illegal deforestation (Fearnside, 1990; Laurance et al., 2001b; Asner et al., 2005). Such pressures will only increase in the future as highways and other transportation infrastructure ramify throughout the basin (Laurance et al., 2001a), bringing conservation units and the expanding Amazonian population into ever-closer contact.

THE NEED FOR MEGARESERVES

Into this mix of environmental promise and peril comes a recent paper by Carlos Peres, published both in Natureza e Conservação (Peres, 2005a) and Conservation Biology (Peres, 2005b). Peres' key argument, which builds on earlier studies—especially that of Ayres et al. (1997)—is that Amazonian reserves need to be both 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 assert (e.g., Ayres et al., 1997), 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 megareserves is compelling. One of the most important justifications is that biogeographical knowledge for the Amazon is appallingly incomplete, even for relatively well-studied groups like birds and mammals (Patton et al., 1997; Oren, 2001). As a result, apparent centers of endemism and diversity are skewed toward accessible areas and certain forest types (Nelson et al., 1990), 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 (Nelson & Oliveira, 2001). 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 (Rylands et al., 2001; van Roosmalen et al., 2003). 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 to 100,000 undiscovered species of seed plants in Amazonia (Hopkins, 2005). 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 megareserves is to preserve populations of rare predators, such as jaguars, pumas, bush dogs, and harpy eagles (**FIGURE 2**) (Thiollay, 1989; Lambeck, 1997). Despite spanning 2.1 million ha, for example, the Pacaya-Samira Reserve in Peru contains only 20 known packs of giant river otters (Peres, 2005b). 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 (Gentry & Emmons, 1987; Laurance, 2001) and by strong density-dependent processes such as predation and disease (Terborgh & Nuñez, 2006). Populations of top predators frequently collapse in isolated reserves that are too small or that suffer intense hunting from humans along their periphery (Woodroffe & Ginsbert, 1998; Cullen et al., 2000; Peres, 2001). In the long term, viable communities of top predators are likely to be vital for

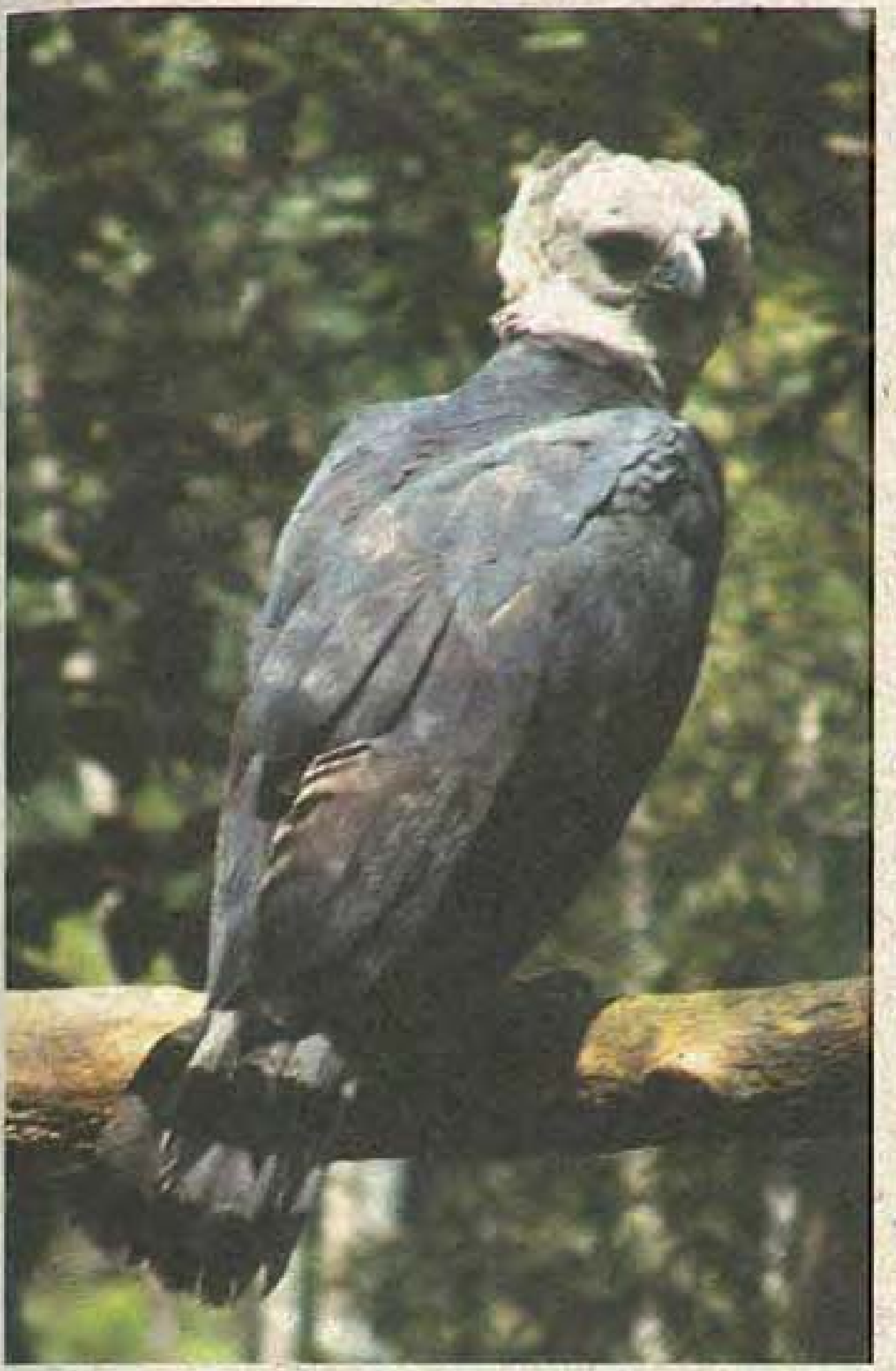

FIGURE 2. Large predators such as harpy eagles (*Harpia harpyja*) are sensitive to hunting and require vast territories for survival. Photo by William F. Laurance.

maintaining the stability of tropical food-webs and ecosystem functioning (Rao et al., 2001; Terborgh et al., 2001).

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 (Peres, 2005b; see also Powell & Bjork, 1995). Amazonian trees are typically rare and obligatory outbreeding, and thus are likely to have large genetic-neighborhood sizes (Losos & Leigh, 2005). The Amazon is home to 3,000 freshwater fish species, many of which migrate seasonally from productive feeding areas to spawning grounds in stream headwaters, which are rarely protected (Peres, 2005b). For such species, reserves must be large enough to contain the full complement of different habitats needed for long-term survival.

According to Peres (2005b), a final reason for megareserves is that they are easier and cheaper to protect than are smaller reserves. Because of limited enforcement, even nominally fully protected reserves in Amazonia often suffer from poaching, wildfires, predatory logging, and illegal gold mining (Laurance et al., 2001b; Asner et al., 2005). The smaller the reserve, the more difficult it is to protect from the direct and indirect impacts of human encroachment. For example, Peres (2005b) estimates that, on a per-hectare basis, the staffing and operational cost for tiny Saium-Castanheira Reserve (110 ha) is 18 000 times higher than that for the vast Tumucumaque Mountains National Park (3.9 million ha).

MORE REASONS FOR BIG RESERVES

Peres makes a compelling case for a comprehensive network of very large reserves in Amazonia. However, there are additional reasons, beyond those suggested by Peres, to advocate Amazonian megareserves.

First, megareserves are likely to be more resilient than are small reserves to deforestation-induced changes in local atmospheric circulation. Such changes may provoke increased rainfall over cleared areas and reduced rainfall over adjoining forests (Silva Dias & Regnier, 1996; Badya Roy & Avissar, 2000; Chagnon & Bras, 2005). This phenomenon occurs because pastures and other clearings have higher albedo (heat reflectance from solar radiation) and less evaporative cooling than do forests. As a result, the air over the clearing is warmed, creating a zone of low atmospheric pressure that draws in moist air from adjoining forests (**FIGURE 3**). As the warm, moist air rises and cools, it condenses into rain clouds that dump their rainfall over the clearing—with dry air then recycling from the clouds back over the forests. The vegetation breeze is essentially a large-scale edge effect; satellite observations in Rondônia, Brazil, suggest that the desiccating effects of major clearings can extend up to 20 km into adjoining forests (Silva Dias et al., 2002).

Second, on a regional scale, megareserves should generally be less susceptible to desiccation caused both by large-scale deforestation, which reduces plant evapotranspiration (Walker et al., 1995), and by the moisture-trapping effects of smoke plumes from biomass burning (Rosenfeld, 1999). Major centers of biomass burning, such as those in southern and eastern Amazonia, create vast rain shadows that can extend for hundreds to thousands of kilometers downwind of the fires (Freitas et al., 2000). As a result, large expanses of the Amazon (ca. 1.2-2.6 million km2) exhibit significantly elevated levels of atmospheric aerosols from biomass fires in the dry season (Procopio et al. 2004). In addition to creating rain shadows, aerosols from biomass burning affect the thermodynamic stability of the atmosphere, by absorbing and scattering incoming solar radiation and increasing cloud formation, but the consequences of such changes for forests are poorly understood (Martins et al., 1998; Andreae, 2001). Although even large reserves may be influenced by such phenomena, the climates of small reserves are likely to be more seriously altered by intensive deforestation and burning in the surrounding landscape.

Third, megareserves will be far less vulnerable to destructive surface fires that can penetrate deep into forests. These fires are frequently lit by ranchers and farmers, and can penetrate as far as several kilometers into forests (**FIGURE 4**) during drought years (Cochrane & Laurance, 2002; Alencar et al., 2004; Laurance, 2004). Such fires kill many trees and most vines and forbs, and by increasing dead fuels and thinning the canopy

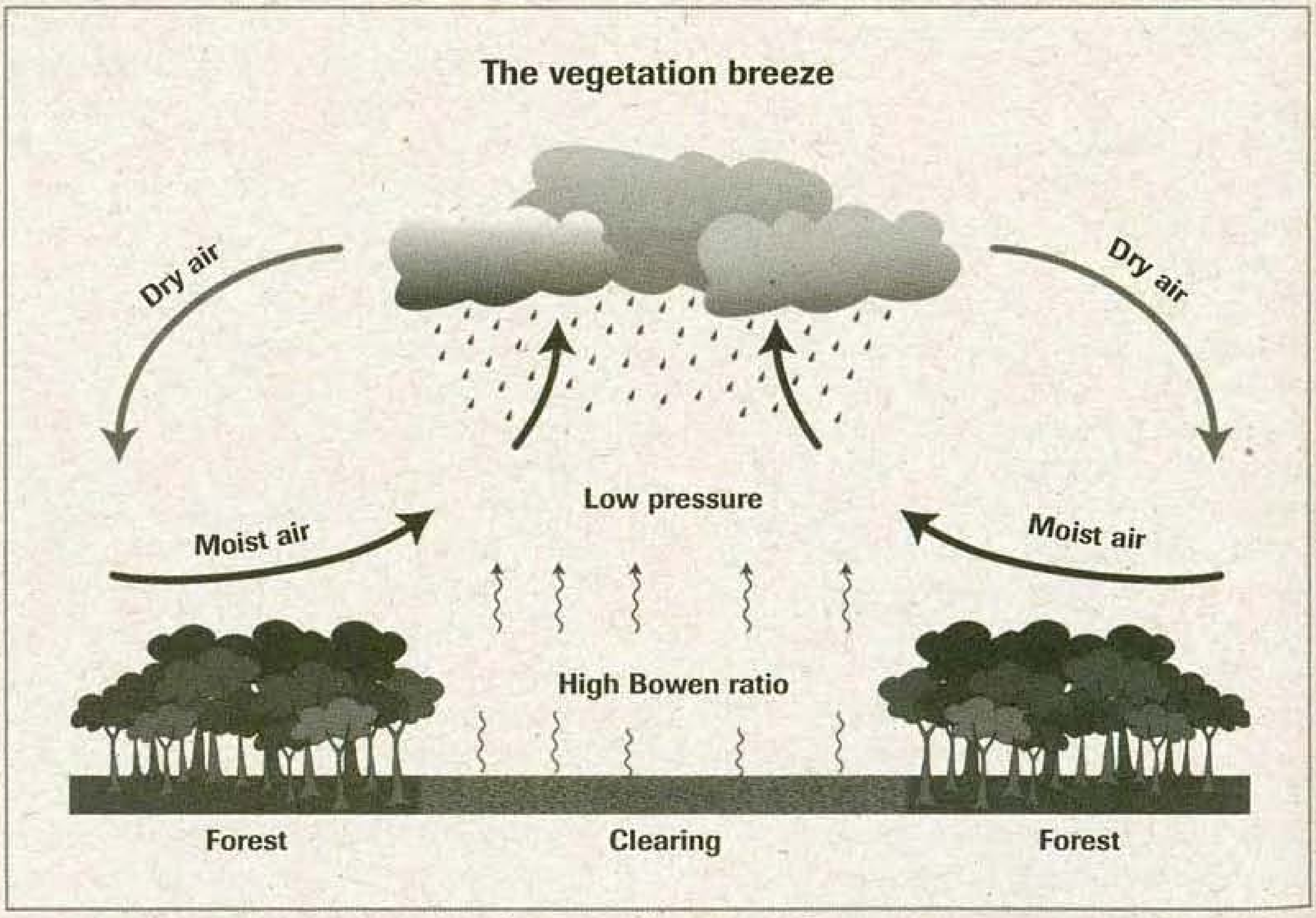

FIGURE 3. Illustration of the 'vegetation breeze,' whereby moist air is drawn into clearings from nearby forests and then recycled back to forests as dry air (from Laurance, 2006).

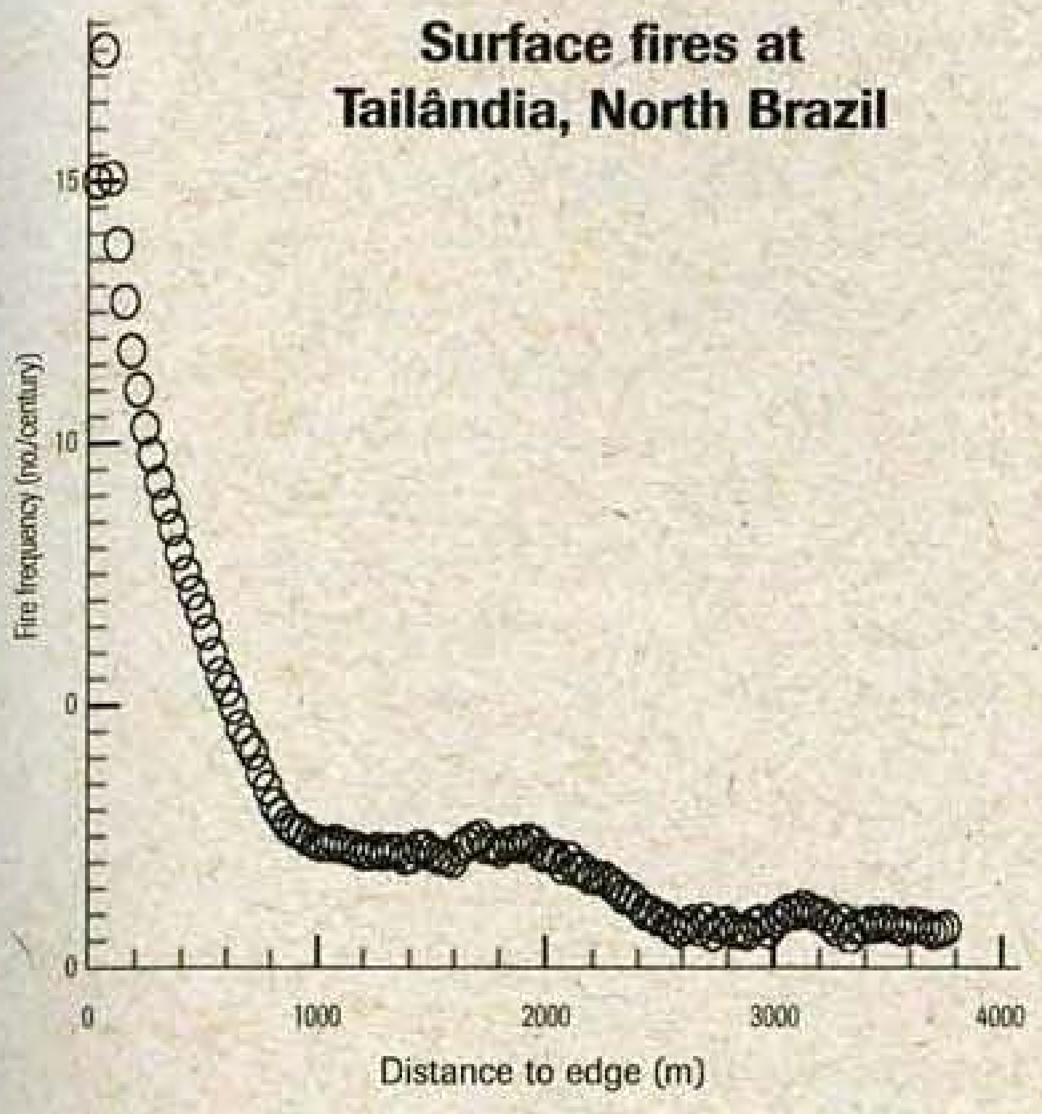

FIGURE 4. Increased incidence of surface fires as a function of distance from forest edge, averaged across several hundred forest fragments in a human-dominated landscape in eastern Amazonia (from Laurance, 2004).

render burned forests even more vulnerable to subsequent fires (Cochrane et al., 1999; Barlow et al., 2004). Simulation models suggest that even quite large (>100,000 ha) reserves can be vulnerable to recurring surface fires (Cochrane & Laurance, 2002), which can cause reserves to "implode" over time (Gascon et al., 2000). 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 (S. G. Laurance, 2006).

Fourth, megareserves likely provide a better buffer against ecological crunches, such as strong droughts that can arise because of El Niño events or high Atlantic sea-surface temperatures. These events can have large impacts on plant phenology, fruit production, and animal and plant survival in tropical forests (Condit et al., 1995; Wright et al., 1999; Laurance et al., 2001c; Nepstad et al., 2002). In concert with the random demographic and genetic events that can plague small, isolated populations, ecological crunches can sharply increase the likelihood of local extinctions of species in small reserves (Leigh, 1981). Amazonian droughts may become more frequent in the future as a result of increasing deforestation and global warming, and could have especially serious effects on the vast expanses of forest in the basin that already experience strong dry seasons (Nepstad et al., 1999; Laurance & Williamson, 2001).

Finally, megareserves should be far more effective than small reserves as refugia from future climatic and atmospheric changes (Noss, 2001; Laurance & Peres, 2006). Several global-circulation models predict that future global warming will result in both higher surface temperatures and substantial reductions in Amazonian precipitation (e.g. Costa & Foley, 2000; Cox et al., 2000; Zhang et al., 2001). Large reserves typically span a greater range of elevations, latitudes, climates, and habitats than do small reserves, affording greater flexibility for their constituent species to adjust their realized niches and distributions in response to changing environmental conditions. Linking megareserves together to form large regional 'corridors' should be an especially effective strategy to help buffer the impacts of future climate change (Box 1).

Is there a downside to megareserves? The most likely objections will be economic, given the lost opportunity costs that can arise if forest exploitation is prohibited over sizeable areas (Whitten & Balmford, 2006). 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 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 (Schwartzman et al., 2000; Rylands & Brandon, 2005; Schwartzman & Zimmerman, 2005).

CONCLUSIONS

Many Amazonian species require large areas for survival. Area-demanding species may be common in Amazonia because of its inherent vastness, its nutrient-starved soils that limit the abundances of many species, and the fact that the forests of the basin, contrary to earlier assertions, may well have persisted throughout the Pleistocene in a largely intact condition (Mayle et al., 2004; Colinveaux, 2005), reducing the impacts of past extinction filters. Compounding these features is the self-sustaining nature of the Amazon hydrological system (Salati & Vose, 1984; Walker et al., 1995), whereby moisture recycled from forests is crucial for maintaining local cloud cover and rainfall, especially 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 megareserves. 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.

ACKNOWLEDGEMENTS

This is a substantially expanded and updated version of an article originally published in Trends in Ecology and Evolution, vol. 20, "When bigger is better: the need for Amazonian megareserves", pp. 645-648, by W. F. Laurance, copyright (2005) Elsevier Press. I thank Carlos Peres, Mark Cochrane, Robert Ewers, Susan Laurance, and three anonymous referees for comments on drafts of the article.

REFERENCES

Alencar, A. A.; Solórzano, L.; Nepstad, D. C. 2004. Modeling forest understory fires in an eastern Amazonian landscape. *Ecological Applications* 14: S139-S149.

Andreae, M. 2001. The dark side of aerosols. *Nature* 409: 671-672.

Asner, G. P., et al. 2005. Selective logging in the Brazilian Amazon. *Science* 310: 480-482.

Ayres, J. M.; da Fonseca, G. A. B.; Rylands, A. B.; Quieroz, H. L.; Pinto, I. P.; Cavalcanti, R. 1997. *Abordagens inovadoras para conservação da biodiversidade no Brasil: os corredores das florestas neotropicais*. Ministério do Meio Ambiente, Brasília.

Baidya Roy, S.; Avissar, R. 2000. Scales of response of the convective boundary layer to land-surface heterogeneity. *Geophysical Research Letters* 27: 533–536.

Barlow, J.; Peres, C. A.; Lagan, B. O.; Haugaasen, T. 2003. Large tree mortality and the decline of forest biomass following Amazonian wildfires. *Ecology Letters* 6: 6-8.

Chagnon, F. J. F.; Bras, R. L. 2005. Contemporary climate change in the Amazon. *Geophysical Research Letters* 32: doi:10.1029/2005GL022722.

Cochrane, M. A.; Laurance, W. F. 2002. Fire as a large-scale edge effect in Amazonian forests. *Journal of Tropical Ecology* 18: 311-325.

Cochrane, M. A.; Alencar, A.; Schulze, M. D.; Souza, C.; Nepstad, D.; Lefebvre, P.; Davidson, E. 1999. Positive feedbacks in the fire dynamics of closed canopy tropical forests. *Science* 284: 1832-1835.

Colinvaux, P. 2005. The Pleistocene vector of Neotropical diversity. In: Bermingham, E.; Dick, C.; Moritz, C. (eds.). *Tropical rain forests: past, present, and future*, Pp. 78-106, University of Chicago Press, Chicago.

Condit, R.; Hubbell, S. P.; Foster, R. B. 1995. Mortality rates of 205 neotropical tree and shrub species and the impact of a severe drought. *Ecological Monographs* 65: 419-439.

Costa, M.; Foley, J. 2000. Combined effects of deforestation and doubled atmospheric CO2 concentrations on the climate of Amazonia. *Journal of Climate* 13: 18-34.

Cox, P. M.; Betts, R. A.; Jones, C. D.; Spall, S. A.; Totterdell, I. J. 2000. Acceleration of global warming due to carbon cycle feedbacks in a coupled climate model. *Nature* 408: 184–187.

Cullen, L.; Bodmer, R. E.; Padua, C. V. 2000. Effects of hunting in habitat fragments of the Atlantic forests, Brazil. *Biological Conservation* 95: 49-56.

Fearnside, P. M. 1990. Environmental destruction in the Amazon. In: Goodman, D.; Hall, A. (eds.). *The future of Amazonia: destruction or sustainable development?* Pp. 179-225, MacMillan, London, U.K.

Fearnside, P. M. 2001. Soybean cultivation as a threat to the environment in Brazil. *Environmental Conservation* 28: 23-38

Ferreira, L.V. et al. 2001. Identificação de áreas prioritárias para a conservação da biodiversidade por meio da representatividade das unidades de conservação e tipos de vegetação nas ecorregiões da Amazônia brasileira. In: Verissimo, A.; Moreira, A.; Sawyer, D.; dos Santos, I.; Pinto, L. P.; Capobianco, J. P. (eds.). *Biodiversidade na Amazônia brasileira: avaliação e ações prioritárias para conservação, uso sustentável e repartição de benefícios*, Pp. 211-245, Editora Estação Liberdade, São Paulo.

Freitas, S. R.; Silva Dias, M. A. F.; Silva Dias, P. L. 2000. Modeling the convective transport of trace gases by deep and moist convection. *Hydrid Methods in Engineering* 3: 317-330.

Gascon, C.; Williamson, G. B.; Fonseca, G. A. B. 2000. Receding edges and vanishing reserves. *Science* 288: 1356-1358.

Gentry, A. H.; Emmons, L.H. 1987. Geographic variation in fertility and composition of the understory of neotropical forests. *Biotropica* 19: 216-227.

Hopkins, M. C. G. 2005. Amazonian plant biodiversity. Oral Presentation, *Annual Meeting of the Association for Tropical Biology and Conservation*, Uberlândia, Brazil.

INPE. 2005. *Monitoramento da floresta amazônica brasileira por satélite*: Projeto Prodes. Instituto Nacional de Pesquisas Espaciais, São José dos Campos, Brasil.

Kaimowitz, D.; Mertens, B; Wunder, S.; Pacheco, P. 2004. *Hamburger connection fuels Amazon destruction*. Technical Report, Center for International Forest Research, Bogor, Indonesia.

Lambeck, R. J. 1997. Focal species: a multispecies umbrella for nature conservation. *Conservation Biology* 11: 849-856.

Laurance, S. G. 2006. Rainforest roads and the future of forest-dependent wildlife: a case study of understory birds. In: Laurance, W. F.; Peres, C. A. (eds). *Emerging threats to tropical forests*. University of Chicago Press, Chicago.

Laurance, W. F. 2001. The hyper-diverse flora of the central Amazon: an overview. In: Bierregaard, R. O.; Gascon, C.; Lovejoy, T. E.; Mesquita, R. (eds.). *Lessons from Amazonia: ecology and conservation of a fragmented forest*, Pp. 47-53, Yale University Press, New Haven, Connecticut, USA.

Laurance, W. F. 2004. Forest-climate interactions in fragmented tropical landscapes. *Philosophical Transactions of the Royal Society* B 359: 345-352.

Laurance, W. F. 2006. Fragments and fire: alarming synergisms among forest disturbance, local climate change, and burning in the Amazon. In: Laurance, W. F.; Peres, C. A. (eds). *Emerging threats to tropical forests*. University of Chicago Press, Chicago.

Laurance, W. F.; Albernaz, A. K. M.; da Costa, C. 2001b. Is deforestation accelerating in the Brazilian Amazon? *Environmental Conservation* 28: 305-311.

Laurance, W. F.; Cochrane, M. A.; Bergen, S.; Fearnside, P. M.; Delamonica, P.; Barber, C.; D'Angelo, S.; Fernandes, T. 2001a. The future of the Brazilian Amazon. *Science* 291: 438-439.

Laurance, W. F.; Peres, C. A. (eds.). 2006. *Emerging threats to tropical forests*. University of Chicago Press, Chicago.

Laurance, W. F.; Williamson, G. B.; Delamonica, P.; Olivera, A. A.; Gascon, C.; Lovejoy, T. E.; Pohl, L. 2001c. Effects of a strong drought on Amazonian forest fragments and edges. *Journal of Tropical Ecology* 17: 771-785.

Laurance, W. F.; Williamson, G. B. 2001. Positive feedbacks among forest fragmentation, drought, and climate change in the Amazon. *Conservation Biology* 15: 1529-1535.

Leigh, E. G. 1981. The average lifetime of a population in a varying environment. *Journal of Theoretical Biology* 90: 213-239.

Losos, E.; Leigh, E. G. (eds.). 2004. *Tropical forest diversity and dynamics*: findings from a large-scale plot network. University of Chicago Press, Chicago.

Martins, J. V.; Artaxo, P.; Liousse, C.; Reid, J.; Hobbs, P.; Kaufman, Y. 1998. Effects of black carbon content, particle size and mixing on light absorption by aerosol particles from biomass burning in Brazil. *Journal of Geophysical Research-Atmospheres* 103: 32041-32050.

Mayle, F. E.; Beerling, D. J.; Gosling, W. D.; Bush, M. B. 2004. Responses of Amazonian ecosystems to climatic and atmospheric carbon dioxide changes since The Last Glacial Maximum. *Philosophical Transactions of the Royal Society of London* B 359: 499-514.

MMA. 2002. *Biodiversidade brasileira*: avaliação e identificação de áreas e ações prioritárias para conservação, utilização sustentável e repartição de benefícios da biodiversidade brasileira. Ministério do Meio Ambiente, Brasília.

Nelson, B. W.; de Oliveira, A. A. 2001. Área botânica. In: Verissimo, A.; Moreira, A.; Sawyer, D.; dos Santos, I.; Pinto, L. P.; Capobianco, J. P. (eds.). *Biodiversidade na Amazônia brasileira*: avaliação e ações prioritárias para conservação, uso sustentável e repartição de benefícios, Pp. 132-176, Editora Estação Liberdade, São Paulo.

Nelson, B. W.; Ferreira, C. A. C.; da Silva, M. F.; Kawasaki, M. L. 1990. Endemism centres, refugia and botanical collection intensity in Brazilian Amazonia. *Nature* 345: 714-716.

Nepstad, D. C., et al. 1999. Large-scale impoverishment of Amazonian forests by logging and fire. *Nature* 398: 505-508.

Nepstad, D. C., et al. 2002. The effects of partial throughfall exclusion on canopy processes, aboveground production, and biogeochemistry of an Amazon forest. *Journal of Geophysical Research-Atmospheres* 107 (D20): 8085.

Noss, R. F. 2001. Beyond Kyoto: forest management in a time of rapid climate change. *Conservation Biology* 15: 578-590.

Oren, D. C. 2001. Biogeografia e conservação de aves na região amazônica. In: Verissimo, A.; Moreira, A.; Sawyer, D.; dos Santos, I.; Pinto, L. P.; Capobianco, J. P. (eds.). *Biodiversidade na Amazônia brasileira*: avaliação e ações prioritárias para conservação, uso sustentável e repartição de benefícios, Pp. 97-109, Editora Estação Liberdade, São Paulo.

Patton, J. L.; da Silva, M. N.; Lara, M. C., Mustrangi, M. A. 1997. Diversity, differentiation, and the historical biogeography of nonvolant mammals of the neotropical forests. In: Laurance, W. F.; Bierregaard, R. O. (eds.). *Tropical forest remnants: ecology, management, and conservation of fragmented communities*, Pp. 455-465. University of Chicago Press, Chicago.

Peres, C. A. 2001. Synergistic effects of subsistence hunting and habitat fragmentation on Amazonian forest vertebrates. *Conservation Biology* 15: 1490-1505.

Peres, C. A. 2005a. Porque precisamos megarreservas na Amazônia. *Natureza & Conservação* 3: 8-16.

Peres, C. A. 2005b. Why we need megareserves in Amazonia. *Conservation Biology* 19: 728-733.

Powell, G. V. N.; Bjork, R. 1995. Implications of intratropical migration on reserve design: a case study using Pharomachrus mocinno. *Conservation Biology* 9: 354-362.

Procopio, A. S.; Artaxo, P.; Kaufman, Y.; Remer, L.; Schafer, J.; Holben, B. 2004. Multiyear analysis of Amazonian biomass burning smoke radiative forcing of climate. *Geophysical Research Letters* 31: L03108 (DOI:10.1029/2003GL018646).

Rao, M.; Terborgh, J.; Nuñez, P. 2001. Increased herbivory in forest isolates: implications for plant community structure and composition. *Conservation Biology* 15: 624-633.

Rosenfeld, D. 1999. TRMM observed first direct evidence of smoke from forest fires inhibiting rainfall. *Geophysical Research Letters* 26: 3105-3108.

Rylands, A. B.; Brandon, K. 2005. Brazilian protected areas. *Conservation Biology* 19: 612-618.

Rylands, A. B.; Mittermeier, R A.; Konstant, W. R. 2001. Species and subspecies of primates described since 1990. *Neotropical Primates* 9: 75-78.

Salati, E.; Vose, P. B. 1984. Amazon basin: a system in equilibrium. *Science* 225: 129-138.

Schwartzman, S.; Moreira, A.; Nepstad, D. C. 2000. Rethinking tropical forest conservation: perils in parks. *Conservation Biology* 14: 1351-1357.

Schwartzman, S.; Zimmerman, B. 2005. Conservation alliances with indigenous peoples of the Amazon. *Conservation Biology* 19: 721-727.

Silva Dias, P. L.; Regnier, P. 1996. Simulation of mesoscale circulations in a deforested area of Rondônia in the dry season. In: Gash, J.; Nobre, C.; Roberts, J.; Victoria, R. (eds.). *Amazonian deforestation and climate*, Pp. 531–547. John Wiley, San Francisco, USA.

Silva Dias, M. A. F.; Williams, E.; Pereira, L.; Pereira Filho, A.; Matsuo, P. 2002. A case study of convective organization into precipitating lines in the Southwest Amazon during the WETAMC and TRMM-LBA. *Journal of Geophysical Research-Atmospheres* 107: 8078. (DOI 10.1029/2001JD000375).

Terborgh, J.; Nuñez, G. 2006. Disperser-free forests await an unhappy fate. In: Laurance, W. F.; Peres, C. A. (eds). *Emerging threats to tropical forests*. University of Chicago Press, Chicago.

Terborgh, J., et al. (2001) Ecological meltdown in predator-free forest fragments. *Science* 294: 1923-1926.

Thiollay, J. M. 1989. Area requirements for the conservation of rain forest raptors and game birds in French Guiana. *Conservation Biology* 3: 128-137.

van Roosmalen, M. G. M.; van Roosmalen, T.; Mittermeier, R. 2003. A taxonomic review of the titi monkeys, genus Callicebus Thomas, 1903, with the description of two new species, *Callicenus bernhardi and Callicebus stephennashi,* from Brazilian Amazonia. *Neotropical Primates* 10: 1-52.

Walker, G. K.; Sud, Y. C.; Atlas, R. 1995. Impact of ongoing Amazonian deforestation on local precipitation: a GCM simulation study. *Bulletin of the American Meteorological Society* 76: 346-361.

Whitten, T.; Balmford, A. 2006. Who should pay for tropical forest conservation, and how should the costs be met? In: Laurance, W. F.; Peres, C. A. (eds). *Emerging threats to tropical forests*. University of Chicago Press, Chicago.

Woodroffe, R.; Ginsberg, J. R. 1998. Edge effects and the extinction of populations inside protected areas. *Science* 280: 2126-2128.

Wright, S. J.; Carrasco, C.; Calderón, O.; Paton, S. 1999. The El Niño Southern Oscillation, variable fruit production, and famine in a tropical forest. *Ecology* 80: 1632-1642.

Zhang, H.; Henderson-Sellers, A.; McGuffie, K. 2001. The compounding effects of tropical deforestation and greenhouse warming on climate. *Climate Change* 49: 309–338.