(Lamont, Lemaitre et al. 1991, Turner 1996, Turner, Romme et al. 1997, Mittermeier, Myers et al. 1998, Waide, Willig et al. 1999, Cincotta, Wisnewski et al. 2000, Bruner, Gullison et al. 2001, Daily, Ehrlich et al. 2001, Fearnside 2001, Schwilk and Ackerly 2001, Tapias, Gil et al. 2001, Blaustein and Kiesecker 2002, Brooks, Mittermeier et al. 2002, Olson and Dinerstein 2002, Dirzo and Raven 2003, Fahrig 2003, Rodrigues, Akcakaya et al. 2004, Tapias, Climent et al. 2004, DeFries, Hansen et al. 2005, Fearnside 2005, Klink and Machado 2005, Lamb, Erskine et al. 2005, Naughton-Treves, Holland et al. 2005, Rudel, Coomes et al. 2005, Malcolm, Liu et al. 2006, Michalet, Brooker et al. 2006, Miles, Newton et al. 2006, Wright and Muller-Landau 2006, Barlow, Gardner et al. 2007, Jetz, Wilcove et al. 2007, Mittelbach, Schemske et al. 2007, Wunder 2007, Andam, Ferraro et al. 2008, Koh and Wilcove 2008, Lips, Diffendorfer et al. 2008, Malhi, Roberts et al. 2008, Wake and Vredenburg 2008, Chazdon, Peres et al. 2009, Gardner, Barlow et al. 2009, Joppa and Pfaff 2009, Cardoso, Erwin et al. 2011, Keeley, Pausas et al. 2011, He, Pausas et al. 2012, Laurance, Useche et al. 2012, Parchman, Gompert et al. 2012, Mouillot, Bellwood et al. 2013, Laurance, Sayer et al. 2014, Newbold, Hudson et al. 2015)

Andam, K. S., et al. (2008). "Measuring the effectiveness of protected area networks in reducing deforestation." Proceedings of the National Academy of Sciences of the United States of America **105**(42): 16089-16094.

Global efforts to reduce tropical deforestation rely heavily on the establishment of protected areas. Measuring the effectiveness of these areas is difficult because the amount of deforestation that would have occurred in the absence of legal protection cannot be directly observed. Conventional methods of evaluating the effectiveness of protected areas can be biased because protection is not randomly assigned and because protection can induce deforestation spillovers (displacement) to neighboring forests. We demonstrate that estimates of effectiveness can be substantially improved by controlling for biases along dimensions that are observable, measuring spatial spillovers, and testing the sensitivity of estimates to potential hidden biases. We apply matching methods to evaluate the impact on deforestation of Costa Rica's renowned protected-area system between 1960 and 1997. We find that protection reduced deforestation: approximately 10% of the protected forests would have been deforested had they not been protected. Conventional approaches to evaluating conservation impact, which fail to control for observable covariates correlated with both protection and deforestation, substantially overestimate avoided deforestation (by over 65%, based on our estimates). We also find that deforestation spillovers from protected to unprotected forests are negligible. Our conclusions are robust to potential hidden bias, as well as to changes in modeling assumptions. Our results show that, with appropriate empirical methods, conservation scientists and policy makers can better understand the relationships between human and natural systems and can use this to guide their attempts to protect critical ecosystem services.

Barlow, J., et al. (2007). "Quantifying the biodiversity value of tropical primary, secondary, and plantation forests." Proceedings of the National Academy of Sciences of the United States of America **104**(47): 18555-18560.

Biodiversity loss from deforestation may be partly offset by the expansion of secondary forests and plantation forestry in the tropics. However, our current knowledge of the value of these habitats for biodiversity conservation is limited to very few taxa, and many studies are severely confounded by methodological shortcomings. We examined the conservation value of tropical primary, secondary, and plantation forests for 15 taxonomic groups using a robust and replicated sample design that minimized edge effects. Different taxa varied markedly in their response to patterns of land use in terms of species richness and the percentage of species restricted to primary forest (varying from 5% to 57%), yet almost all between-forest comparisons showed marked differences in community structure and composition. Cross-taxon congruence in response patterns was very weak when evaluated using abundance or species richness data, but much stronger when using metrics based upon community similarity. Our results show that, whereas the biodiversity indicator group concept may hold some validity for several taxa that are frequently sampled (such as birds and fruit-feeding butterflies), it fails for those exhibiting highly idiosyncratic responses to tropical land-use change (including highly vagile species groups such as bats and orchid bees), highlighting the problems associated with quantifying the biodiversity value of anthropogenic habitats. Finally, although we show that areas of native regeneration and exotic tree plantations can provide complementary conservation services, we also provide clear empirical evidence demonstrating the irreplaceable value of primary forests.

Blaustein, A. R. and J. M. Kiesecker (2002). "Complexity in conservation: lessons from the global decline of amphibian populations." Ecology Letters **5**(4): 597-608.

As part of an overall "biodiversity crisis" many amphibian populations are in decline throughout the world. Numerous causes have been invoked to explain these declines. These include habitat destruction, climate change, increasing levels of ultraviolet radiation, environmental contamination, disease, and the introduction of non-native species. In this paper, we argue that amphibian population declines are caused by different abiotic and biotic factors acting together in a context-dependent fashion. Moreover, different species and different populations of the same species may react in different ways to the same environmental insult. Thus, the causes of amphibian population declines will vary spatially and temporally. Although some generalizations (e.g. those concerning environmental stress and disease outbreaks) can be made about amphibian population declines, we suggest that these generalizations take into account the context-dependent dynamics of ecological systems.

Brooks, T. M., et al. (2002). "Habitat loss and extinction in the hotspots of biodiversity." Conservation Biology **16**(4): 909-923.

Nearly half the world's vascular plant species and one-third of terrestrial vertebrates are endemic to 25 "hotspots" of biodiversity, each of which has at least 1500 endemic plant species. None of these hotspots have more than one-third of their pristine habitat remaining. Historically, they covered 12% of the land's surface, but today their intact habitat covers only 1.4% of the land. As a result of this habitat loss, we expect many of the hotspot endemics to have either become extinct or-because much of the habitat loss is recent-to be threatened with extinction. We used World Conservation Union [IUCN] Red Lists to test this expectation. Overall, between one-half and two-thirds of all threatened plants and 57% of all threatened terrestrial vertebrates are hotspot endemics. For birds and mammals, in general, predictions of extinction in the hotspots based on habitat loss match numbers of species independently judged extinct or threatened. In two classes of hotspots the match is not as close. On oceanic islands, habitat loss underestimates extinction because introduced species have driven extinctions beyond those caused by habitat loss on these islands. In large hotspots, conversely, habitat loss overestimates extinction, suggesting scale dependence (this effect is also apparent for plants). For reptiles, amphibians, and plants, many fewer hotspot endemics are considered threatened or extinct than we would expect based on habitat loss. This mismatch is small in temperate hotspots, however, suggesting that many threatened endemic species in the poorly known tropical hotspots have yet to be included on the IUCN Red Lists. We then asked in which hotspots the consequences of further habitat loss (either absolute or given current rates of deforestation) would be most serious. Our results suggest that the Eastern Arc and Coastal Forests of Tanzania-Kenya, Philippines, and Polynesia-Micronesia can least afford to lose more habitat and that, if current deforestation rates continue, the Caribbean, Tropical Andes, Philippines, Mesoamerica, Sundaland, Indo-Burma, Madagascar, and Choco-Darien-Western Ecuador will lose the most species in the near future. Without urgent conservation intervention, we face mass extinctions in the hotspots.

Bruner, A. G., et al. (2001). "Effectiveness of parks in protecting tropical biodiversity." Science **291**(5501): 125-128.

We assessed the impacts of anthropogenic threats on 93 protected areas in 22 tropical countries to test the hypothesis that parks are an effective means to protect tropical biodiversity. We found that the majority of parks are successful at stopping land clearing, and to a Lesser degree effective at mitigating logging, hunting, fire, and grazing. Park effectiveness correlates with basic management activities such as enforcement, boundary demarcation, and direct compensation to Local communities, suggesting that even modest increases in funding would directly increase the ability of parks to protect tropical biodiversity.

Cardoso, P., et al. (2011). "The seven impediments in invertebrate conservation and how to overcome them." Biological Conservation **144**(11): 2647-2655.

Despite their high diversity and importance for humankind, invertebrates are often neglected in biodiversity conservation policies. We identify seven impediments to their effective protection: (1) invertebrates and their ecological services are mostly unknown to the general public (the public dilemma); (2) policy-makers and stakeholders are mostly unaware of invertebrate conservation problems (the political dilemma); (3) basic science on invertebrates is scarce and underfunded (the scientific dilemma); (4) most species are undescribed (the Linnean shortfall); (5) the distribution of described species is mostly unknown (the Wallacean shortfall); (6) the abundance of species and their changes in space and time are unknown (the Prestonian shortfall); (7) species ways of life and sensitivities to habitat change are largely unknown (the Hutchinsonian shortfall). Numerous recent developments in taxonomy, inventorying, monitoring, data compilation, statistical analysis and science communication facilitate overcoming these impediments in both policy and practice. We suggest as possible solutions for the public dilemma: better public information and marketing. For the political dilemma: red-listing, legal priority listing and inclusion in environmental impact assessment studies. For the scientific dilemma: parataxonomy, citizen science programs and biodiversity informatics. For the Linnean shortfall: biodiversity surrogacy, increased support for taxonomy and advances in taxonomic publications. For the Wallacean shortfall: funding of inventories, compilation of data in public repositories and species distribution modeling. For the Prestonian shortfall: standardized protocols for inventorying and monitoring, widespread use of analogous protocols and increased support for natural history collections. For the Hutchinsonian shortfall: identifying good indicator taxa and studying extinction rates by indirect evidence. (C) 2011 Elsevier Ltd. All rights reserved.

Chazdon, R. L., et al. (2009). "The Potential for Species Conservation in Tropical Secondary Forests." Conservation Biology **23**(6): 1406-1417.

In the wake of widespread loss of old-growth forests throughout the tropics, secondary forests will likely play a growing role in the conservation of forest biodiversity. We considered a complex hierarchy of factors that interact in space and time to determine the conservation potential of tropical secondary forests. Beyond the characteristics of local forest patches, spatial and temporal landscape dynamics influence the establishment, species composition, and persistence of secondary forests. Prospects for conservation of old-growth species in secondary forests are maximized in regions where the ratio of secondary to old-growth forest area is relatively low, older secondary forests have persisted, anthropogenic disturbance after abandonment is relatively low, seed-dispersing fauna are present, and old-growth forests are close to abandoned sites. The conservation value of a secondary forest is expected to increase over time, as species arriving from remaining old-growth forest patches accumulate. Many studies are poorly replicated, which limits robust assessments of the number and abundance of old-growth species present in secondary forests. Older secondary forests are not often studied and few long-term studies are conducted in secondary forests. Available data indicate that both old-growth and second-growth forests are important to the persistence of forest species in tropical, human-modified landscapes.

Cincotta, R. P., et al. (2000). "Human population in the biodiversity hotspots." Nature **404**(6781): 990-992.

Biologists have identified 25 areas, called biodiversity hotspots, that are especially rich in endemic species and particularly threatened by human activities. The human population dynamics of these areas, however, are not well quantified. Here we report estimates of key demographic variables for each hotspot, and for three extensive tropical forest areas(1) that are less immediately threatened. We estimate that in 1995 more than 1.1 billion people, nearly 20% of world population, were living within the hotspots, an area covering about 12% of Earth's terrestrial surface. We estimate that the population growth rate in the hotspots (1995-2000) is 1.8% yr(-1), substantially higher than the population growth rate of the world as a whole (1.3% yr(-1)) and above that of the developing countries (1.6% yr(-1)). These results suggest that substantial human-induced environmental changes are likely to continue in the hotspots and that demographic change remains an important factor in global biodiversity conservation. The results also underline the potential conservation significance of the continuing worldwide declines in human fertility and of policies and programs that influence human migration.

Daily, G. C., et al. (2001). "Countryside biogeography: Use of human-dominated habitats by the avifauna of southern Costa Rica." Ecological Applications **11**(1): 1-13.

Understanding the multifaceted relationship between biodiversity and landuse intensity is key to conservation policy. To begin to characterize this relationship in a tropical region, we investigated the bird fauna in an agricultural landscape in southern Costa Rica. Landsat Thematic Mapper (TM) data show that about 27% of the land remains forested in the 15 km radius study region encompassing our sites. The rest was cleared about 40 yr ago for relatively small-scale coffee and cattle production, intermixed with other crops. Our goals were to: (1) compare the composition of the avifauna found in forest-fragment and open habitats of the countryside; (2) assess the faunal change that has occurred since deforestation: and (3) provide a baseline for future comparisons. We surveyed the avifauna of eight forest fragments (0.3-25 ha) and 13 open-habitat sites (1.0 ha each) in the agricultural landscape. The pre-deforestation avifauna was approximated by the long-term bird list for the largest forest fragment (Las Cruces, LC; 227 ha) in the study region. We assumed conservatively that a species recorded in LC but not detected elsewhere occurred only in LC. Of the 272 locally extant bird species considered in this study, 149 (55%) occurred in forest habitats only. There was a significant positive correlation between forest fragment size and species richness for these forest birds. Of the remaining 123 species, 60 (22% of the total) occurred both in forest and open habitats. Sixty-three species (23%) occurred in open habitats only; the three nonnative species (1%) are in this group. Based on comparisons with larger forest tracts outside of the study region, it appeared that between 4 and 28 species (1-9% of the possible original totals) have gone locally extinct since deforestation began. The avifauna of open habitats was similar throughout the study region and did not vary with proximity to extensive forest. A substantial proportion of the native bird fauna occurs in a densely (human) populated, agricultural landscape almost a half-century after extensive clearance. There are, however, cautionary messages: (1) the common occurrence of forest birds in human-dominated countryside (including both forest-fragment and open habitats) does not necessarily imply that these species maintain sustainable populations there; (2) about half of the species have little prospect of surviving outside of the forest; and (3) ongoing intensification of land use may greatly reduce avian diversity in countryside habitats. Nonetheless, countryside habitats may buy time for the conservation of some species; at best, they may even sustain a moderate fraction of the native biota.

DeFries, R., et al. (2005). "Increasing isolation of protected areas in tropical forests over the past twenty years." Ecological Applications **15**(1): 19-26.

Protected areas are one of the cornerstones for conserving the world's remaining biodiversity, most of which occurs in tropical forests. We use multiple sources of satellite data to estimate the extent of forest habitat and loss over the last 20 years within and surrounding 198 of the most highly protected areas (IUCN status 1 and 2) located throughout the world's tropical forests. In the early 1980s, surrounding habitat in the 50-km unprotected or less highly protected "buffers" enhanced the protected areas' effective size and their capacity to conserve richness of forest-obligate,species above the hypothetical case of complete isolation. However, in nearly 70% of the surrounding buffers, the area of forest habitat declined during the last 20 years, while 25% experienced declines within their administrative boundaries. The loss of habitat occurred in all tropical regions, but protected areas in South and Southeast Asia were most severely affected because of relatively low surrounding forest habitat in the early 1980s and high subsequent loss, particularly in dry tropical forests. The future ability of protected areas to maintain current species richness depends on integrating reserve management within the land use dynamics of their larger regional, settings.

Dirzo, R. and P. H. Raven (2003). "Global state of biodiversity and loss." Annual Review of Environment and Resources **28**: 137-167.

Biodiversity, a central component of Earth's life support systems, is directly relevant to human societies. We examine the dimensions and nature of the Earth's terrestrial biodiversity and review the scientific facts concerning the rate of loss of biodiversity and the drivers of this loss. The estimate for the total number of species of eukaryotic organisms possible lies in the 5-15 million range, with a best guess of similar to7 million. Species diversity is unevenly distributed; the highest concentrations are in tropical ecosystems. Endemisms are concentrated in a few hotspots, which are in turn seriously threatened by habitat destruction-the most prominent driver of biodiversity loss. For the past 300 years, recorded extinctions for a few groups of organisms reveal rates of extinction at least several hundred times the rate expected on the basis of the geological record. The loss of biodiversity is the only truly irreversible global environmental change the Earth faces today.

Fahrig, L. (2003). "Effects of habitat fragmentation on biodiversity." Annual Review of Ecology Evolution and Systematics **34**: 487-515.

The literature on effects of habitat fragmentation on biodiversity is huge. It is also very diverse, with different authors measuring fragmentation in different ways and, as a consequence, drawing different conclusions regarding both the magnitude and direction of its effects. Habitat fragmentation is usually defined as a landscape-scale process involving both habitat loss and the breaking apart of habitat. Results of empirical studies of habitat fragmentation are often difficult to interpret because (a) many researchers measure fragmentation at the patch scale, not the landscape scale and (b) most researchers measure fragmentation in ways that do not distinguish between habitat loss and habitat fragmentation per se, i.e., the breaking apart of habitat after controlling for habitat loss. Empirical studies to date suggest that habitat loss has large, consistently negative effects on biodiversity. Habitat fragmentation per se has much weaker effects on biodiversity that are at least as likely to be positive as negative. Therefore, to correctly interpret the influence of habitat fragmentation on biodiversity, the effects of these two components of fragmentation must be measured independently. More studies of the independent effects of habitat loss and fragmentation per se are needed to determine the factors that lead to positive versus negative effects of fragmentation per se. I suggest that the term "fragmentation" should be reserved for the breaking apart of habitat, independent of habitat loss.

Fearnside, P. M. (2001). "Soybean cultivation as a threat to the environment in Brazil." Environmental Conservation **28**(1): 23-38.

Soybeans represent a recent and powerful threat to tropical biodiversity in Brazil. Developing effective strategies to contain and minimize the environmental impact of soybean cultivation requires understanding of both the forces that drive the soybean advance and the many ways that soybeans and their associated infrastructure catalyse destructive processes. The present paper presents an up-to-date review of the advance of soybeans in Brazil, its environmental and social costs and implications for development policy. Soybeans are driven by global market forces, making them different from many of the land-use changes that have dominated the scene in Brazil so far, particularly in Amazonia. Soybeans are much more damaging than other crops because they justify massive transportation infrastructure projects that unleash a chain of events leading to destruction of natural habitats over wide areas in addition to what is directly cultivated for soybeans. The capacity of global markets to absorb additional production represents the most likely limit to the spread of soybeans, although Brazil may someday come to see the need for discouraging rather than subsidizing this crop because many of its effects are unfavourable to national interests, including severe concentration of land tenure and income, expulsion of population to, Amazonian frontier, and gold-mining, as well as urban areas, and the opportunity cost of substantial drains on government resources. The multiple impacts of soybean expansion on biodiversity and other development considerations have several implications for policy: (1) protected areas need to be created in advance of soybean frontiers, (2) elimination of the many subsidies that speed soybean expansion beyond what would occur otherwise from market forces is to be encouraged, (3) studies to assess the costs of social and environmental impacts associated with soybean expansion are urgently required, and (4) the environmental-impact regulatory system requires strengthening, including mechanisms for commitments not to implant specific infrastructure projects that are judged to have excessive impacts.

Fearnside, P. M. (2005). "Deforestation in Brazilian Amazonia: History, rates, and consequences." Conservation Biology **19**(3): 680-688.

Brazil's Amazon forest remained largely intact until the "modern" era of deforestation began with the inauguration of the Transamazon Highway in 1970. Amazonian deforestation rates have trended upward since 1991, with clearing proceeding at a variable but rapid pace. Although Amazonian forests are cut for various reasons, cattle ranching predominates. The large and medium-sized ranches account for about 70% of clearing activity. Profit from beef cattle is only one of the income sources that make deforestation profitable. Forest degradation results from logging, ground fires (facilitated by logging), and the effects of fragmentation and edge formation. Degradation contributes to forest loss. The impacts of deforestation include loss of biodiversity, reduced water cycling (and rainfall), and contributions to global warming. Strategies to slow deforestation include repression through licensing procedures, monitoring, and fines. The severity of penalties for deforestation needs to be sufficient to deter illegal clearing but not so great as to be unenforceable. Policy reform is also needed to address root causes of deforestation, including the role of clearing in establishing land claims.

Gardner, T. A., et al. (2009). "Prospects for tropical forest biodiversity in a human-modified world." Ecology Letters **12**(6): 561-582.

The future of tropical forest biodiversity depends more than ever on the effective management of human-modified landscapes, presenting a daunting challenge to conservation practitioners and land use managers. We provide a critical synthesis of the scientific insights that guide our understanding of patterns and processes underpinning forest biodiversity in the human-modified tropics, and present a conceptual framework that integrates a broad range of social and ecological factors that define and contextualize the possible future of tropical forest species. A growing body of research demonstrates that spatial and temporal patterns of biodiversity are the dynamic product of interacting historical and contemporary human and ecological processes. These processes vary radically in their relative importance within and among regions, and have effects that may take years to become fully manifest. Interpreting biodiversity research findings is frequently made difficult by constrained study designs, low congruence in species responses to disturbance, shifting baselines and an over-dependence on comparative inferences from a small number of well studied localities. Spatial and temporal heterogeneity in the potential prospects for biodiversity conservation can be explained by regional differences in biotic vulnerability and anthropogenic legacies, an ever-tighter coupling of human-ecological systems and the influence of global environmental change. These differences provide both challenges and opportunities for biodiversity conservation. Building upon our synthesis we outline a simple adaptive-landscape planning framework that can help guide a new research agenda to enhance biodiversity conservation prospects in the human-modified tropics.

He, T. H., et al. (2012). "Fire-adapted traits of Pinus arose in the fiery Cretaceous." New Phytologist **194**(3): 751-759.

The mapping of functional traits onto chronograms is an emerging approach for the identification of how agents of natural selection have shaped the evolution of organisms. Recent research has reported fire-dependent traits appearing among flowering plants from 60 million yr ago (Ma). Although there are many records of fossil charcoal in the Cretaceous (65145 Ma), evidence of fire-dependent traits evolving in that period is lacking. We link the evolutionary trajectories for five fire-adapted traits in Pinaceae with paleoatmospheric conditions over the last 250 million yr to determine the time at which fire originated as a selective force in trait evolution among seed plants. Fire-protective thick bark originated in Pinus c. 126 Ma in association with low-intensity surface fires. More intense crown fires emerged c. 89 Ma coincident with thicker bark and branch shedding, or serotiny with branch retention as an alternative strategy. These innovations appeared at the same time as the Earths paleoatmosphere experienced elevated oxygen levels that led to high burn probabilities during the mid-Cretaceous. The fiery environments of the Cretaceous strongly influenced trait evolution in Pinus. Our evidence for a strong correlation between the evolution of fire-response strategies and changes in fire regime 90125 Ma greatly backdates the key role that fire has played in the evolution of seed plants.

Jetz, W., et al. (2007). "Projected impacts of climate and land-use change on the global diversity of birds." Plos Biology **5**(6): 1211-1219.

Over the past few decades, land-use and climate change have led to substantial range contractions and species extinctions. Even more dramatic changes to global land cover are projected for this century. We used the Millennium Ecosystem Assessment scenarios to evaluate the exposure of all 8,750 land bird species to projected land-cover changes due to climate and land-use change. For this first baseline assessment, we assumed stationary geographic ranges that may overestimate actual losses in geographic range. Even under environmentally benign scenarios, at least 400 species are projected to suffer > 50% range reductions by the year 2050 (over 900 by the year 2100). Although expected climate change effects at high latitudes are significant, species most at risk are predominantly narrow-ranged and endemic to the tropics, where projected range contractions are driven by anthropogenic land conversions. Most of these species are currently not recognized as imperiled. The causes, magnitude and geographic patterns of potential range loss vary across socioeconomic scenarios, but all scenarios (even the most environmentally benign ones) result in large declines of many species. Whereas climate change will severely affect biodiversity, in the near future, land-use change in tropical countries may lead to yet greater species loss. A vastly expanded reserve network in the tropics, coupled with more ambitious goals to reduce climate change, will be needed to minimize global extinctions.

Joppa, L. N. and A. Pfaff (2009). "High and Far: Biases in the Location of Protected Areas." Plos One **4**(12).

Background: About an eighth of the earth's land surface is in protected areas (hereafter "PAs''), most created during the 20(th) century. Natural landscapes are critical for species persistence and PAs can play a major role in conservation and in climate policy. Such contributions may be harder than expected to implement if new PAs are constrained to the same kinds of locations that PAs currently occupy. Methodology/Principal Findings: Quantitatively extending the perception that PAs occupy "rock and ice'', we show that across 147 nations PA networks are biased towards places that are unlikely to face land conversion pressures even in the absence of protection. We test each country's PA network for bias in elevation, slope, distances to roads and cities, and suitability for agriculture. Further, within each country's set of PAs, we also ask if the level of protection is biased in these ways. We find that the significant majority of national PA networks are biased to higher elevations, steeper slopes and greater distances to roads and cities. Also, within a country, PAs with higher protection status are more biased than are the PAs with lower protection statuses. Conclusions/Significance: In sum, PAs are biased towards where they can least prevent land conversion (even if they offer perfect protection). These globally comprehensive results extend findings from nation-level analyses. They imply that siting rules such as the Convention on Biological Diversity's 2010 Target [to protect 10% of all ecoregions] might raise PA impacts if applied at the country level. In light of the potential for global carbon-based payments for avoided deforestation or REDD, these results suggest that attention to threat could improve outcomes from the creation and management of PAs.

Keeley, J. E., et al. (2011). "Fire as an evolutionary pressure shaping plant traits." Trends in Plant Science **16**(8): 406-411.

Traits, such as resprouting, serotiny and germination by heat and smoke, are adaptive in fire-prone environments. However, plants are not adapted to fire per se but to fire regimes. Species can be threatened when humans alter the regime, often by increasing or decreasing fire frequency. Fire-adaptive traits are potentially the result of different evolutionary pathways. Distinguishing between traits that are adaptations originating in response to fire or exaptations originating in response to other factors might not always be possible. However, fire has been a factor throughout the history of land-plant evolution and is not strictly a Neogene phenomenon. Mesozoic fossils show evidence of fire-adaptive traits and, in some lineages, these might have persisted to the present as fire adaptations.

Klink, C. A. and R. B. Machado (2005). "Conservation of the Brazilian Cerrado." Conservation Biology **19**(3): 707-713.

The Cerrado is one of the world's biodiversity hotspots. In the last,35 years, more than 50% of its approximately 2 million king has been transformed into pasture and agricultural lands planted in cash crops. The Cerrado has the richest flora among the world's savannas (> 7000 species) and high levels of endemism. Species richness of birds, fishes, reptiles, amphibians, and insects is equally high, whereas mammal diversity is relatively low. Deforestation rates have been higher in the Cerrado than in the Amazon rainforest, and conservation efforts have been modest. only 2.2% of its area is under legal protection. Numerous animal and plant species are threatened with extinction, and an estimated 20% of threatened and endemic species do not occur in protected areas. Soil erosion, the degradation of the diverse Cerrado vegetation formations, and the spread of exotic grasses are widespread and major threats. The use of fire for clearing land and to encourage new growth for pasture has also caused damage, even though the Cerrado is afire-adapted ecosystem. Ecosystem experiments and modeling show that change in land cover is altering the hydrology and affecting carbon stocks and fluxes. Cerrado agriculture is lucrative, and agricultural expansion is expected to continue, requiring improvements in and extension of the transportation infrastructure, which will affect not only the Cerrado but also the Amazon forest. Large-scale landscape modification and threats to numerous species have led to renewed interest from various sectors in promoting the conservation of the Cerrado, particularly through strengthening and enlarging the system of protected areas and improving farming practices and thus the livelihoods of local communities.

Koh, L. P. and D. S. Wilcove (2008). "Is oil palm agriculture really destroying tropical biodiversity?" Conservation Letters **1**(2): 60-64.

Oil palm is one of the world's most rapidly expanding equatorial crops. The two largest oil palm-producing countries-Indonesia and Malaysia-are located in Southeast Asia, a region with numerous endemic, forest-dwelling species. Oil palm producers have asserted that forests are not being cleared to grow oil palm. Our analysis of land-cover data compiled by the United Nations Food and Agriculture Organization suggests that during the period 1990-2005, 55%-59% of oil palm expansion in Malaysia, and at least 56% of that in Indonesia occurred at the expense of forests. Using data on bird and butterfly diversity in Malaysia's forests and croplands, we argue that conversion of either primary or secondary (logged) forests to oil palm may result in significant biodiversity losses, whereas conversion of pre-existing cropland (rubber) to oil palm results in fewer losses. To safeguard the biodiversity in oil palm-producing countries, more fine-scale and spatially explicit data on land-use change need to be collected and analyzed to determine the extent and nature of any further conversion of forests to oil palm; secondary forests should be protected against conversion to oil palm; and any future expansion of oil palm agriculture should be restricted to pre-existing cropland or degraded habitats.

Lamb, D., et al. (2005). "Restoration of degraded tropical forest landscapes." Science **310**(5754): 1628-1632.

The current scale of deforestation in tropical regions and the large areas of degraded lands now present underscore the urgent need,for interventions to restore biodiversity, ecological functioning, and the supply of goods and ecological services previously used by poor rural communities. Traditional timber plantations have supplied some goods but have made only minor contributions to fulfilling most of these other objectives. New approaches to reforestation are now emerging, with potential for both overcoming forest degradation and addressing rural poverty.

Lamont, B. B., et al. (1991). "CANOPY SEED STORAGE IN WOODY-PLANTS." Botanical Review **57**(4): 277-317.

The retention of seeds in the plant canopy for one to 30 years or more is termed serotiny. It is well represented floristically and physiognomically in fire-prone, nutrient-poor and seasonally-dry sclerophyll vegetation in Australia, and to a lesser extent, South Africa followed by North America. While the seed-storing structures vary greatly, all will release their propagules following exposure to the heat of a fire (pyriscence). This phenomenon can be contrasted with seed release at maturity (non-storage) and soil storage of seeds. Although the evolutionary requirements for serotiny are clear, its adaptive advantages over other seed storage syndromes are largely the subject of conjecture in the absence of comparative experiments. Nine hypotheses were assessed here. Canopy storage maximises the quantity of seeds available for the next post-fire generation (unlike non-storage). Synchronized post-fire release satiates post-dispersal granivores (unlike non-storage and soil storage) and ensures arrival on a seed bed conducive to seedling recruitment (unlike non-storage). Canopy stored seeds are better insulated from the heat of a fire than non-stored, and probably soil-stored, seeds. Fluctuating annual seed crops, the opportunity for post-fire wind-dispersal, the possible advantages of dense stands of adults, short lifespan of the dispersed seeds and their optimal location in the soil for germination have only a limited role in explaining the advantages of serotiny. It is concluded that canopy seed storage is favoured in regions where seed production is restricted and inter-fire establishment and maturation are unlikely. In addition, these regions have a reliable seasonal rainfall and are subjected to intense fires at intervals occurring within the reproductive lifespan of the species.

Laurance, W. F., et al. (2014). "Agricultural expansion and its impacts on tropical nature." Trends in Ecology & Evolution **29**(2): 107-116.

The human population is projected to reach 11 billion this century, with the greatest increases in tropical developing nations. This growth, in concert with rising per-capita consumption, will require large increases in food and biofuel production. How will these megatrends affect tropical terrestrial and aquatic ecosystems and biodiversity? We foresee (i) major expansion and intensification of tropical agriculture, especially in Sub-Saharan Africa and South America; (ii) continuing rapid loss and alteration of tropical old-growth forests, woodlands, and semi-arid environments; (iii) a pivotal role for new roadways in determining the spatial extent of agriculture; and (iv) intensified conflicts between food production and nature conservation. Key priorities are to improve technologies and policies that promote more ecologically efficient food production while optimizing the allocation of lands to conservation and agriculture.

Laurance, W. F., et al. (2012). "Averting biodiversity collapse in tropical forest protected areas." Nature **489**(7415): 290-+.

The rapid disruption of tropical forests probably imperils global biodiversity more than any other contemporary phenomenon(1-3). With deforestation advancing quickly, protected areas are increasingly becoming final refuges for threatened species and natural ecosystem processes. However, many protected areas in the tropics are themselves vulnerable to human encroachment and other environmental stresses(4-9). As pressures mount, it is vital to know whether existing reserves can sustain their biodiversity. A critical constraint in addressing this question has been that data describing a broad array of biodiversity groups have been unavailable for a sufficiently large and representative sample of reserves. Here we present a uniquely comprehensive data set on changes over the past 20 to 30 years in 31 functional groups of species and 21 potential drivers of environmental change, for 60 protected areas stratified across the world's major tropical regions. Our analysis reveals great variation in reserve 'health': about half of all reserves have been effective or performed passably, but the rest are experiencing an erosion of biodiversity that is often alarmingly widespread taxonomically and functionally. Habitat disruption, hunting and forest-product exploitation were the strongest predictors of declining reserve health. Crucially, environmental changes immediately outside reserves seemed nearly as important as those inside in determining their ecological fate, with changes inside reserves strongly mirroring those occurring around them. These findings suggest that tropical protected areas are often intimately linked ecologically to their surrounding habitats, and that a failure to stem broad-scale loss and degradation of such habitats could sharply increase the likelihood of serious biodiversity declines.

Lips, K. R., et al. (2008). "Riding the wave: Reconciling the roles of disease and climate change in amphibian declines." Plos Biology **6**(3): 441-454.

We review the evidence for the role of climate change in triggering disease outbreaks of chytridiomycosis, an emerging infectious disease of amphibians. Both climatic anomalies and disease-related extirpations are recent phenomena, and effects of both are especially noticeable at high elevations in tropical areas, making it difficult to determine whether they are operating separately or synergistically. We compiled reports of amphibian declines from Lower Central America and Andean South America to create maps and statistical models to test our hypothesis of spatiotemporal spread of the pathogen Batrachochytrium dendrobatidis (Bd), and to update the elevational patterns of decline in frogs belonging to the genus Atelopus. We evaluated claims of climate change influencing the spread of Bd by including error into estimates of the relationship between air temperature and last year observed. Available data support the hypothesis of multiple introductions of this invasive pathogen into South America and subsequent spread along the primary Andean cordilleras. Additional analyses found no evidence to support the hypothesis that climate change has been driving outbreaks of amphibian chytridiomycosis, as has been posited in the climate-linked epidemic hypothesis. Future studies should increase retrospective surveys of museum specimens from throughout the Andes and should study the landscape genetics of Bd to map fine-scale patterns of geographic spread to identify transmission routes and processes.

Malcolm, J. R., et al. (2006). "Global warming and extinctions of endemic species from biodiversity hotspots." Conservation Biology **20**(2): 538-548.

Global warming is a key threat to biodiversity, but few researchers have assessed the magnitude of this threat at the global scale. We used major vegetation types (biomes) as proxies for natural habitats and, based on projected future biome distributions under doubled-CO2 climates, calculated changes in habitat areas and associated extinctions of endemic plant and vertebrate species in biodiversity hotspots. Because of numerous uncertainties in this approach, we undertook a sensitivity analysis of multiple factors that included (1) two global vegetation models, (2) different numbers of biome classes in our biome classification schemes, (3) different assumptions about whether species distributions were biome specific or not, and (4) different migration capabilities. Extinctions were calculated using both species-area and endemic-area relationships. In addition, average required migration rates were calculated for each hotspot assuming a doubled-CO2 climate in 100 years. Projected percent extinctions ranged from < 1 to 43% of the endemic biota (average 11.6%), with biome specificity having the greatest influence on the estimates, followed by the global vegetation model and then by migration and biome classification assumptions. Bootstrap comparisons indicated that effects on hotpots as a group were not significantly different from effects on random same-biome collections of grid cells with respect to biome change or migration rates; in some scenarios, however, hotspots exhibited relatively high biome change and low migration rates. Especially vulnerable hotspots were the Cape Floristic Region, Caribbean, Indo-Burma, Mediterranean Basin, Southwest Australia, and Tropical Andes, where plant extinctions per hotspot sometimes exceeded 2000 species. Under the assumption that projected habitat changes were attained in 100 years, estimated global-warming-induced rates of species extinctions in tropical hotspots in some cases exceeded those due to deforestation, supporting suggestions that global warming is one of the most serious threats to the planet's biodiversity.

Malhi, Y., et al. (2008). "Climate change, deforestation, and the fate of the Amazon." Science **319**(5860): 169-172.

The forest biome of Amazonia is one of Earth's greatest biological treasures and a major component of the Earth system. This century, it faces the dual threats of deforestation and stress from climate change. Here, we summarize some of the latest findings and thinking on these threats, explore the consequences for the forest ecosystem and its human residents, and outline options for the future of Amazonia. We also discuss the implications of new proposals to finance preservation of Amazonian forests.

Michalet, R., et al. (2006). "Do biotic interactions shape both sides of the humped-back model of species richness in plant communities?" Ecology Letters **9**(7): 767-773.

A humped-back relationship between species richness and community biomass has frequently been observed in plant communities, at both local and regional scales, although often improperly called a productivity-diversity relationship. Explanations for this relationship have emphasized the role of competitive exclusion, probably because at the time when the relationship was first examined, competition was considered to be the significant biotic filter structuring plant communities. However, over the last 15 years there has been a renewed interest in facilitation and this research has shown a clear link between the role of facilitation in structuring communities and both community biomass and the severity of the environment. Although facilitation may enlarge the realized niche of species and increase community richness in stressful environments, there has only been one previous attempt to revisit the humped-back model of species richness and to include facilitative processes. However, to date, no model has explored whether biotic interactions can potentially shape both sides of the humped-back model for species richness commonly detected in plant communities. Here, we propose a revision of Grime's original model that incorporates a new understanding of the role of facilitative interactions in plant communities. In this revised model, facilitation promotes diversity at medium to high environmental severity levels, by expanding the realized niche of stress-intolerant competitive species into harsh physical conditions. However, when environmental conditions become extremely severe the positive effects of the benefactors wane (as supported by recent research on facilitative interactions in extremely severe environments) and diversity is reduced. Conversely, with decreasing stress along the biomass gradient, facilitation decreases because stress-intolerant species become able to exist away from the canopy of the stress-tolerant species (as proposed by facilitation theory). At the same time competition increases for stress-tolerant species, reducing diversity in the most benign conditions (as proposed by models of competition theory). In this way our inclusion of facilitation into the classic model of plant species diversity and community biomass generates a more powerful and richer predictive framework for understanding the role of plant interactions in changing diversity. We then use our revised model to explain both the observed discrepancies between natural patterns of species richness and community biomass and the results of experimental studies of the impact of biodiversity on the productivity of herbaceous communities. It is clear that explicit consideration of concurrent changes in stress-tolerant and competitive species enhances our capacity to explain and interpret patterns in plant community diversity with respect to environmental severity.

Miles, L., et al. (2006). "A global overview of the conservation status of tropical dry forests." Journal of Biogeography **33**(3): 491-505.

Aim: To analyse the conservation status of tropical dry forests at the global scale, by combining a newly developed global distribution map with spatial data describing different threats, and to identify the relative exposure of different forest areas to such threats. Location: Global assessment. Methods: We present a new global distribution map of tropical dry forest derived from the recently developed MODIS Vegetation Continuous Fields (VCF) product, which depicts percentage tree cover at a resolution of 500 m, combined with previously defined maps of biomes. This distribution map was overlaid with spatial data to estimate the exposure of tropical dry forests to a number of different threats: climate change, habitat fragmentation, fire, human population density and conversion to cropland. The extent of tropical dry forest currently protected was estimated by overlaying the forest map with a global data set of the distribution of protected areas. Results: It is estimated that 1,048,700 km(2) of tropical dry forest remains, distributed throughout the three tropical regions. More than half of the forest area (54.2%) is located within South America, the remaining area being almost equally divided between North and Central America, Africa and Eurasia, with a relatively small proportion (3.8%) occurring within Australasia and Southeast Asia. Overall, c. 97% of the remaining area of tropical dry forest is at risk from one or more of the threats considered, with highest percentages recorded for Eurasia. The relative exposure to different threats differed between regions: while climate change is relatively significant in the Americas, habitat fragmentation and fire affect a higher proportion of African forests, whereas agricultural conversion and human population density are most influential in Eurasia. Evidence suggests that c. 300,000 km(2) of tropical dry forest now coincide with some form of protected area, with 71.8% of this total being located within South America. Main conclusions: Virtually all of the tropical dry forests that remain are currently exposed to a variety of different threats, largely resulting from human activity. Taking their high biodiversity value into consideration, this indicates that tropical dry forests should be accorded high conservation priority. The results presented here could be used to identify which forest areas should be accorded highest priority for conservation action. In particular, the expansion of the global protected area network, particularly in Mesoamerica, should be given urgent consideration.

Mittelbach, G. G., et al. (2007). "Evolution and the latitudinal diversity gradient: speciation, extinction and biogeography." Ecology Letters **10**(4): 315-331.

A latitudinal gradient in biodiversity has existed since before the time of the dinosaurs, yet how and why this gradient arose remains unresolved. Here we review two major hypotheses for the origin of the latitudinal diversity gradient. The time and area hypothesis holds that tropical climates are older and historically larger, allowing more opportunity for diversification. This hypothesis is supported by observations that temperate taxa are often younger than, and nested within, tropical taxa, and that diversity is positively correlated with the age and area of geographical regions. The diversification rate hypothesis holds that tropical regions diversify faster due to higher rates of speciation (caused by increased opportunities for the evolution of reproductive isolation, or faster molecular evolution, or the increased importance of biotic interactions), or due to lower extinction rates. There is phylogenetic evidence for higher rates of diversification in tropical clades, and palaeontological data demonstrate higher rates of origination for tropical taxa, but mixed evidence for latitudinal differences in extinction rates. Studies of latitudinal variation in incipient speciation also suggest faster speciation in the tropics. Distinguishing the roles of history, speciation and extinction in the origin of the latitudinal gradient represents a major challenge to future research.

Mittermeier, R. A., et al. (1998). "Biodiversity hotspots and major tropical wilderness areas: Approaches to setting conservation priorities." Conservation Biology **12**(3): 516-520.

Mouillot, D., et al. (2013). "Rare Species Support Vulnerable Functions in High-Diversity Ecosystems." Plos Biology **11**(5).

Around the world, the human-induced collapses of populations and species have triggered a sixth mass extinction crisis, with rare species often being the first to disappear. Although the role of species diversity in the maintenance of ecosystem processes has been widely investigated, the role of rare species remains controversial. A critical issue is whether common species insure against the loss of functions supported by rare species. This issue is even more critical in species-rich ecosystems where high functional redundancy among species is likely and where it is thus often assumed that ecosystem functioning is buffered against species loss. Here, using extensive datasets of species occurrences and functional traits from three highly diverse ecosystems (846 coral reef fishes, 2,979 alpine plants, and 662 tropical trees), we demonstrate that the most distinct combinations of traits are supported predominantly by rare species both in terms of local abundance and regional occupancy. Moreover, species that have low functional redundancy and are likely to support the most vulnerable functions, with no other species carrying similar combinations of traits, are rarer than expected by chance in all three ecosystems. For instance, 63% and 98% of fish species that are likely to support highly vulnerable functions in coral reef ecosystems are locally and regionally rare, respectively. For alpine plants, 32% and 89% of such species are locally and regionally rare, respectively. Remarkably, 47% of fish species and 55% of tropical tree species that are likely to support highly vulnerable functions have only one individual per sample on average. Our results emphasize the importance of rare species conservation, even in highly diverse ecosystems, which are thought to exhibit high functional redundancy. Rare species offer more than aesthetic, cultural, or taxonomic diversity value; they disproportionately increase the potential breadth of functions provided by ecosystems across spatial scales. As such, they are likely to insure against future uncertainty arising from climate change and the ever-increasing anthropogenic pressures on ecosystems. Our results call for a more detailed understanding of the role of rarity and functional vulnerability in ecosystem functioning.

Naughton-Treves, L., et al. (2005). "The role of protected areas in conserving biodiversity and sustaining local livelihoods." Annual Review of Environment and Resources **30**: 219-252.

The world's system of protected areas has grown exponentially over the past 25 years, particularly in developing countries where biodiversity is greatest. Concurrently, the mission of protected areas has expanded from biodiversity conservation to improving human welfare. The result is a shift in favor of protected areas allowing local resource use. Given the multiple purposes of many protected areas, measuring effectiveness is difficult. Our review of 49 tropical protected areas shows that parks are generally effective at curtailing deforestation within their boundaries. But deforestation in surrounding areas is isolating protected areas. Many initiatives now aim to link protected areas to local socioeconomic development. Some of these initiatives have been successful, but in general expectations need to be tempered regarding the capacity of protected areas to alleviate poverty. Greater attention must also be paid to the broader policy context of biodiversity loss, poverty, and unsustainable land use in developing countries.

Newbold, T., et al. (2015). "Global effects of land use on local terrestrial biodiversity." Nature **520**(7545): 45-+.

Human activities, especially conversion and degradation of habitats, are causing global biodiversity declines. How local ecological assemblages are responding is less clear-a concern given their importance for many ecosystem functions and services. We analysed a terrestrial assemblage database of unprecedented geographic and taxonomic coverage to quantify local biodiversity responses to land use and related changes. Here we show that in the worst-affected habitats, these pressures reducewithin-sample species richness by anaverage of 76.5%, total abundance by 39.5% andrarefaction-based richness by 40.3%. We estimate that, globally, these pressures have already slightly reduced average within-sample richness (by 13.6%), total abundance (10.7%) and rarefaction-based richness (8.1%), with changes showing marked spatial variation. Rapid further losses are predicted under a business-as-usual land-use scenario; within-sample richness is projected to fall by a further 3.4% globally by 2100, with losses concentrated in biodiverse but economically poor countries. Strongmitigationcan delivermuchmore positive biodiversity changes (up to a 1.9% average increase) that are less strongly related to countries' socioeconomic status.

Olson, D. M. and E. Dinerstein (2002). "The Global 200: Priority ecoregions for global conservation." Annals of the Missouri Botanical Garden **89**(2): 199-224.

A global strategy to conserve biodiversity must aim to protect representative examples of all of the world's ecosystems, as well as those areas that contain exceptional concentrations of species and endemics. Although lacking the richness of tropical forests, deserts, tropical lakes, and subpolar seas all Contain distinct species, communities and ecological phenomena. We analyzed global patterns of biodiversity to identify a set of the Earth's terrestrial, freshwaler. and marine ecoregions that harbor exceptional biodiversity and are representative of its ecosystems. We placed each of the Earth's ecoregions within a system of 30 biomes and biogeographic realms to facilitate a representation analysis. Biodiversity features were compared among ecoregions to assess their irreplaceability or distinctiveness. These features included species richness, endemic species, unusual higher taxa, unusual ecological or evolutionary phenomena, and the global rarity of habitats. This process yielded 238 ecoregions-the Global 200-comprised of 142 terrestrial, 53 freshwater, and 43 marine priority ecoregions. Effective conservation in this set of ecoregions would help conserve the most outstanding and representative habitats for biodiversity on this planet.

Parchman, T. L., et al. (2012). "Genome-wide association genetics of an adaptive trait in lodgepole pine." Molecular Ecology **21**(12): 2991-3005.

Pine cones that remain closed and retain seeds until fire causes the cones to open (cone serotiny) represent a key adaptive trait in a variety of pine species. In lodgepole pine, there is substantial geographical variation in serotiny across the Rocky Mountain region. This variation in serotiny has evolved as a result of geographically divergent selection, with consequences that extend to forest communities and ecosystems. An understanding of the genetic architecture of this trait is of interest owing to the wide-reaching ecological consequences of serotiny and also because of the repeated evolution of the trait across the genus. Here, we present and utilize an inexpensive and time-effective method for generating population genomic data. The method uses restriction enzymes and PCR amplification to generate a library of fragments that can be sequenced with a high level of multiplexing. We obtained data for more than 95 000 single nucleotide polymorphisms across 98 serotinous and nonserotinous lodgepole pines from three populations. We used a Bayesian generalized linear model (GLM) to test for an association between genotypic variation at these loci and serotiny. The probability of serotiny varied by genotype at 11 loci, and the association between genotype and serotiny at these loci was consistent in each of the three populations of pines. Genetic variation across these 11 loci explained 50% of the phenotypic variation in serotiny. Our results provide a first genome-wide association map of serotiny in pines and demonstrate an inexpensive and efficient method for generating population genomic data.

Rodrigues, A. S. L., et al. (2004). "Global gap analysis: Priority regions for expanding the global protected-area network." Bioscience **54**(12): 1092-1100.

Protected areas are the single most important conservation tool. The global protected-area network has grown substantially in recent decades, now occupying 11.5% of Earth's land surface, but such growth has not been strategically aimed at maximizing the coverage of global biodiversity. In a previous study, we demonstrated that the global network is far from complete, even for the representation of terrestrial vertebrate species. Here we present a first attempt to provide a global framework for the next step of strategically expanding the network to cover mammals, amphibians, freshwater turtles and tortoises, and globally threatened birds. We identify unprotected areas of the world that have remarkably high conservation value (irreplaceability) and are under serious threat. These areas concentrate overwhelmingly in tropical and subtropical moist forests, particularly on tropical mountains and islands. The expansion of the global protected-area network in these regions is urgently needed to prevent the loss of unique biodiversity.

Rudel, T. K., et al. (2005). "Forest transitions: towards a global understanding of land use change." Global Environmental Change-Human and Policy Dimensions **15**(1): 23-31.

Places experience forest transitions when declines in forest cover cease and recoveries in forest cover begin. Forest transitions have occurred in two, sometimes overlapping circumstances. In some places economic development has created enough non-farm jobs to pull farmers off of the land, thereby inducing the spontaneous regeneration of forests in old fields. In other places a scarcity of forest products has prompted governments and landowners to plant trees in some fields. The transitions do little to conserve biodiversity, but they do sequester carbon and conserve soil, so governments should place a high priority on promoting them. (c) 2005 Elsevier Ltd. All rights reserved.

Schwilk, D. W. and D. D. Ackerly (2001). "Flammability and serotiny as strategies: correlated evolution in pines." Oikos **94**(2): 326-336.

Fire may act as a selective force on plants both through its direct effects by killing or wounding susceptible individuals and through its effect on the environment: the post-fire environment may select specific physiological traits or life histories. We used phylogenetic independent contrasts to test the hypothesis that fire has selected for correlated evolution among alternative suites of traits in pines: a survival/avoidance suite characterized by thick bark, height, and self-pruning of dead branches; and a fire-embracing strategy in which plants invest little into survival, exhibit traits which enhance flammability, and use fire as a means to cue seedling establishment to the post-fire environment through serotinous cones. We created a set of alternative 'supertree' phylogenies for the genus Pinus from published sources. Using these alternative phylogenies, published ecological data for 38 pine species, and newly collected morphological data, we demonstrate that much variation in trait evolution occurs along a fire-surviving/fire-embracing axis. Pines vary in their susceptibility to ignition since a tree that retains dead branches is more likely to carry a fire into the canopy than a tree that self-prunes. The evolution of increased flammability may have altered evolutionary trajectories prompting an evolutionary switch from a fire-surviving to a fire-embracing life history. Alternatively, the fire-embracing strategy may in fact select for increased flammability to ensure canopy ignition and the realization of serotinous seed-release.

Tapias, R., et al. (2004). "Life histories of Mediterranean pines." Plant Ecology **171**(1-2): 53-68.

The life history of Spanish pines and their relation to fire as the main disturbance factor in their ecosystems was analysed. The primary ecological attributes studied were the canopy seed bank (onset of cone production, percentage and persistence of serotinous cones), seed and cone morphology, sprouting and bark thickness. Four ecological groups were separated Using multivariate cluster analysis and their life-history characteristics are discussed. Serotiny and early flowering in Pinus halepensis and P pinaster reflect their evader strategy in relation to fire as this character is advantageous to survive frequent crown fires and to attain successful post-fire recruitment. Late flowering and absence of serotinous cones in P nigra, P. sylvestris and P. uncinata indicate that their natural forest did not evolve under frequent crown fires. P canariensis and P pinea appeared in two single groups because of their sprouting capability and their seed size respectively. Intraspecific variation in P. pinaster was also analysed using the same criteria and high variability was found in its life history traits. A group of P. pinaster populations showed high levels of serotiny and thin bark as a possible adaptation to frequent stand-replacing crown fires. In contrast. a group of non- or weakly-serotinous populations seems to have evolved under a low-intensity fire regime where the best fitness corresponds to thick-barked individuals capable of surviving ground fires. Intermediate strategies were also evident in this species and were discussed in relation to the effect of different fire regimes caused by the understorey vegetation.

Tapias, R., et al. (2001). "Canopy seed banks in Mediterranean pines of southeastern Spain: a comparison between Pinus halepensis Mill., P. pinaster Ait., P. nigra Arn. and P. pinea L." Journal of Ecology **89**(4): 629-638.

1 Canopy seed banks were analysed in post-fire stands of Pinus halepensis, P. pinaster, P. nigra, and P. pinea. We determined age when flowering begins, age of first cone bearing, presence of serotinous cones and cone-opening temperatures. 2 By 15 years after the fire, P. halepensis had developed a large canopy seed bank (3-100 x 10(4) seeds ha(-1)). Fruiting started at 5 years of age. More than 86% of the cones were serotinous and had opening temperatures from 49.3 to 51.3 degreesC. Cones from adult trees opened at lower temperatures than those from young trees. 3 A 16-year-old P. pinaster stand had a smaller seed bank (12 000 viable seeds ha(-1)) and a lower percentage of serotinous cones (66.7%), with lower cone-opening temperature (45.8 0.8 degreesC) and later first fruiting (12 years) than any of our three P halepensis populations. 4 Populations of P. nigra and P. pinea did not show any fire adaptations: flowering was insignificant even 15 years after fire, and none of the cones produced were serotinous. 5 Serotinous cones represent a fire-survival strategy for P. halepensis and P. pinaster. Early flowering is also necessary for successful post-fire colonization in species or populations where crown fires are frequent. Late flowering and non-serotinous cones of P. nigra and P. pinea suggest that they may have evolved where ignition leads only to low intensity ground fires.

Turner, I. M. (1996). "Species loss in fragments of tropical rain forest: A review of the evidence." Journal of Applied Ecology **33**(2): 200-209.

1. A review of the literature shows that in nearly all cases tropical rain forest fragmentation has led to a local loss of species. Isolated fragments suffer reductions in species richness with time after excision from continuous forest, and small fragments often have fewer species recorded for the same effort of observation than large fragments or areas of continuous forest. 2. Birds have been the most frequently studied taxonomic group with respect to the effects of tropical forest fragmentation. 3. The mechanisms of fragmentation-related extinction include the deleterious effects of human disturbance during and after deforestation, the reduction of population sizes, the reduction of immigration rates, forest edge effects, changes in community structure (second- and higher-order effects) and the immigration of exotic species. 4. The relative importance of these mechanisms remains obscure. 5. Animals that are large, sparsely or patchily distributed, or very specialized and intolerant of the vegetation surrounding fragments, are particularly prone to local extinction. 6. The large number of indigenous species that are very sparsely distributed and intolerant of conditions outside the forest make evergreen tropical rain forest particularly susceptible to species loss through fragmentation. 7. Much more research is needed to study what is probably the major threat to global biodiversity.

Turner, M. G., et al. (1997). "Effects of fire size and pattern on early succession in Yellowstone National Park." Ecological Monographs **67**(4): 411-433.

The Yellowstone fires of 1988 affected >250 000 ha, creating a mosaic of burn severities across the landscape and providing an ideal opportunity to study effects of fire size and pattern on postfire succession. We asked whether vegetation responses differed between small and large burned patches within the fire-created mosaic in Yellowstone National Park (YNP) and evaluated the influence of spatial patterning on the postfire vegetation. Living vegetation in a small (1 ha), moderate (70-200 ha), and large (500-3600 ha) burned patch at each of three geographic locations was sampled annually from 1990 to 1993, Burn severity and patch size had significant effects on most biotic responses. Severely burned areas had higher cover and density of lodgepole pine seedlings, greater abundance of opportunistic species, and lower richness of vascular plant species than less severely burned areas. Larger burned patches had higher cover of tree seedlings and shrubs, greater densities of lodgepole pine seedlings and opportunistic species, and lower species richness than smaller patches. Herbaceous species present before the fires responded individually to burn severity and patch size; some were more abundant in large patches or severely burned areas, while others were more abundant in small patches or lightly burned areas. To date, dispersal into the burned areas from the surrounding unburned forest has not been an important mechanism for reestablishment of forest species. Most plant cover in burned areas consisted of resprouting survivors during the first 3 yr after the fires. A pulse of seedling establishment in 1991 suggested that local dispersal from these survivors was a dominant mechanism for reestablishment of forest herbs. Succession across much of YNP appeared to be moving toward plant communities similar to those that burned in 1988, primarily because extensive biotic residuals persisted even within very large burned areas. However, forest reestablishment remained questionable in areas of old (>400 yr) forests with low prefire serotiny. Despite significant effects of burn severity and patch size, the most important explanatory variable for most biotic responses was geographic location, particularly as related to broad-scale patterns of serotiny in Pinus contorta. We conclude that the effects of fire size and pattern were important and some may be persistent, but that these landscape-scale effects occurred within an overriding context of broader scale gradients.

Waide, R. B., et al. (1999). "The relationship between productivity and species richness." Annual Review of Ecology and Systematics **30**: 257-300.

Recent overviews have suggested that the relationship between species richness and productivity (rate of conversion of resources to biomass per unit area per unit time) is unimodal thump-shaped). Most agree that productivity affects species richness at large scales, but unanimity is less regarding underlying mechanisms. Recent studies have examined the possibility that variation in species richness within communities may influence productivity, leading to an exploration of the relative effect of alterations in species number per se as contrasted to the addition of productive species. Reviews of the literature concerning deserts, boreal forests, tropical forests, lakes, and wetlands lead to the conclusion that extant data are insufficient to conclusively resolve the relationship between diversity and productivity, or that patterns are variable with mechanisms equally varied and complex. A more comprehensive survey of the ecological literature uncovered approximately 200 relationships, of which 30% were unimodal, 26% were positive linear, 12% were negative linear, and 32% were not significant. Categorization of studies with respect to geographic extent, ecological extent, taxonomic hierarchy, or energetic basis of productivity similarly yielded a heterogeneous distribution of relationships. Theoretical and empirical approaches increasingly suggest scale-dependence in the relationship between species richness and productivity; consequently, synthetic understanding may be contingent on explicit considerations of scale in analytical studies of productivity and diversity.

Wake, D. B. and V. T. Vredenburg (2008). "Are we in the midst of the sixth mass extinction? A view from the world of amphibians." Proceedings of the National Academy of Sciences of the United States of America **105**: 11466-11473.

Many scientists argue that we are either entering or in the midst of the sixth great mass extinction. Intense human pressure, both direct and indirect, is having profound effects on natural environments. The amphibians-frogs, salamanders, and caecilians-may be the only major group currently at risk globally. A detailed worldwide assessment and subsequent updates show that one-third or more of the 6,300 species are threatened with extinction. This trend is likely to accelerate because most amphibians occur in the tropics and have small geographic ranges that make them susceptible to extinction. The increasing pressure from habitat destruction and climate change is likely to have major impacts on narrowly adapted and distributed species. We show that salamanders on tropical mountains are particularly at risk. A new and significant threat to amphibians is a virulent, emerging infectious disease, chytridiomycosis, which appears to be globally distributed, and its effects may be exacerbated by global warming. This disease, which is caused by a fungal pathogen and implicated in serious declines and extinctions of > 200 species of amphibians, poses the greatest threat to biodiversity of any known disease. Our data for frogs in the Sierra Nevada of California show that the fungus is having a devastating impact on native species, already weakened by the effects of pollution and introduced predators. A general message from amphibians is that we may have little time to stave off a potential mass extinction.

Wright, S. J. and H. C. Muller-Landau (2006). "The future of tropical forest species." Biotropica **38**(3): 287-301.

Deforestation and habitat loss are widely expected to precipitate an extinction crisis among tropical forest species. Humans cause deforestation, and humans living in rural settings have the greatest impact on extant forest area in the tropics. Current human demographic trends, including slowing population growth and intense urbanization, give reason to hope that deforestation will slow, natural forest regeneration through secondary succession will accelerate, and the widely anticipated mass extinction of tropical forest species will be avoided. Here, we show that the proportion of potential forest cover remaining is closely correlated with human population density among countries, in both the tropics and the temperate zone. We use United Nations population projections and continent-specific relationships between both total and rural population density and forest remaining today to project future tropical forest cover. Our projections suggest that deforestation rates will decrease as population growth slows, and that a much larger area will continue to be forested than previous studies suggest. Tropical forests retracted to smaller areas during repeated Pleistocene glacial events in Africa and more recently in selected areas that supported large prehistoric human populations. Despite many caveats, these projections and observations provide hope that many tropical forest species will be able to survive the current wave of deforestation and human population growth. A strategy to preserve tropical biodiversity might include policies to improve conditions in tropical urban settings to hasten urbanization and preemptive conservation efforts in countries with large areas of extant forest and large projected rates of future human population growth. We hope that this first attempt inspires others to produce better models of future tropical forest cover and associated policy recommendations.

Wunder, S. (2007). "The efficiency of payments for environmental services in tropical conservation." Conservation Biology **21**(1): 48-58.

Payments for environmental services (PES) represent a new, more direct way to promote conservation. They explicitly recognize the need to address difficult trade-offs by bridging the interests of landowners and external actors through compensations. Theoretical assessments praise the advantages of PES over indirect approaches, but in the tropics PES application has remained incipient Here I aim to demystify PES and clarify its scope for application as a tool for tropical conservation. I focus on the supply side of PES (i.e., how to convert PES funding into effective conservation on the ground), which until now has been widely neglected. I reviewed the PES literature for developing countries and combined these findings with observations from my own field studies in Latin America and Asia. A PES scheme, simply stated, is a voluntary, conditional agreement between at least one "seller" and one "buyer" over a well-defined environmental service-or a land use presumed to produce that service. Major obstacles to effective PES include demand-side limitations and a lack of supply-side know-bow regarding implementation. The design of PES programs can be improved by explicitly outlining baselines, calculating conservation opportunity costs, customizing payment modalities, and targeting agents with credible land claims and threats to conservation. Expansion of PES can occur if schemes can demonstrate clear additionality (i.e., incremental conservation effects vis-a-vis predefined baselines), if PES recipients' livelihood dynamics are better understood, and if efficiency goals are balanced with considerations of fairness. PES are arguably best suited to scenarios of moderate conservation opportunity costs on marginal lands and in settings with emerging, not-yet realized threats. Actors who represent credible threats to the environment will more likely receive PES than those already living in harmony with nature. A PES scheme can thus benefit both buyers and sellers while improving the resource base, but it is unlikely to fully replace other conservation instruments.