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COMMENTARY

Momentum Drives the Crash: Mass Extinction in the Tropics[1]

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The review and analysis presented by Wright and Muller-Landau (2006, this volume, henceforth "WML") provides a comprehensive overview of deforestation in tropical areas and it challenges the widely held view that large-scale species extinctions should be expected in these areas over the coming century (*e.g.*, Simberloff 1986, Laurance 1999, da Silva & Tabarelli 2000, Brooks *et al.* 2002, Sodhi *et al.* 2004). The thrust of WML's argument is as follows: Rural areas are being, and will continue to be, depopulated as socioeconomic conditions change and people are drawn to urban centers. This demographic shift will lead to a reduction in deforestation rates because a country's remaining forest cover is strongly correlated with the density of its rural human population (supported by statistical analysis of United Nations and Food and Agriculture Organization data). As such, natural forest regeneration via secondary succession will accelerate and indeed eventually overtake clearing rates, resulting in a net stabilization or increase in forest cover (within about 25 yr in tropical Asia and America and 100 yr in Africa). Their inference is that "the widely anticipated mass extinction of tropical forest species will be avoided." We deem this conclusion to be unlikely based on the following arguments (which we elaborate below): (1) the relationship between rural and urban population densities and deforestation rate is likely to be extremely complex (Gibson *et al.* 2000); (2) even if net tropical deforestation grinds to a halt within the next few decades, most essential habitat for the majority of species will have already been eliminated or severely degraded (Heywood & Stuart 1992); (3) forest structure and composition will have been altered radically in residual or regenerated forest stands, yet these biological attributes are likely to be as or more important for species persistence than total forest area (Brook *et al.* 2003, Battin 2004); and (4) the time lags observed between habitat loss and species extinction (Brooks *et al.* 1999) do not imply that a window of opportunity automatically opens for species recovery—this requires expensive, logistically challenging and unattainable conservation interventions for most species at risk.

The concept of *momentum* (an impetus, strength or continuity derived from an initial effort) forms the intellectual core of our argument. For illustration, consider the predictions for global warming during the 21st century driven by the exponential rise in atmospheric CO_2 (Keeling & Whorf 2004). Under the "business-as-usual" scenario of the Intergovernmental Panel for Climate Change (http://www.ipcc.ch/), emissions keep pace with industrial growth which leads to a predicted rise in mean global temperature between 1.5 and 4.5°C. Yet even if all anthropogenic sources of CO_2 were eliminated today, the momentum of accumulation of post-industrial-revolution atmospheric pollutants would still result in further temperature rises of 0.5–1.5°C (Mahlman 2001). Human and wildlife populations are similarly prone to be forced by such past momentum. In the developing world, the present day age structure of human populations is skewed heavily toward the younger cohorts, due largely to increases in average life expectancy over the 20th century (Bongaarts 2005). This will create a bulge of reproductive output even if replacement levels of approximately two children per woman are achieved. The surplus of young and predominantly untenured people (most being unable to inherit their parent's property) will not only induce migration to urban areas (as noted by WML), but also threaten virgin forests as they seek unsettled land on which to establish new agricultural plots (Coomes *et al.* 2000). A further and particularly telling example of biological momentum is discussed at the end of the commentary.

Other problems follow the assumption that a shift in human populations from rural to urban areas will necessarily lead to a large-scale reduction in deforestation rates. Two convincing predictions are clear from the United Nations and World Resource Institute (WRI; http://www.wri.org/) figures: (1) total human population size will continue to increase until about 2050, and (2) the relationship between rural and urban population size will become uncoupled

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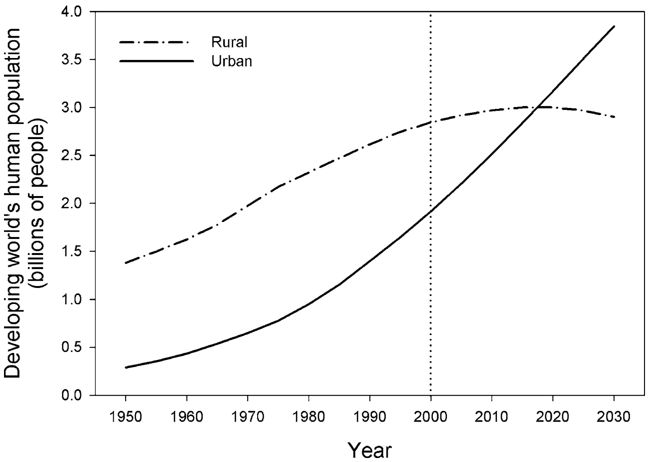

FIGURE 1. Trends of rural and urban human population growth in the world's developing countries. Rural and urban populations refer to the midyear populations of areas defined as rural and urban respectively by the World Resources Institute (WRI; http://www.wri.org/). Developing country grouping is based on lists developed by the Food and Agriculture Organization of the United Nations and published online by WRI. Vertical dashed line separates past and projected figures.

in the near future as rural populations stabilize or decline and urban populations continue to expand (Fig. 1). These forecasts make the job of predicting future stress on forests complex because even those people not residing in rural areas (and thereby not impacting forests directly) will nevertheless drive an increasing demand for basic necessities (food, timber for housing and fuel) and the raw materials for economic development (*e.g.*, mature timber for export markets) even if mediated by significant improvements in agricultural production and larger areas under plantation for timber. Given that the Millennium Ecosystem Assessment (MEA; http://www.millenniumassessment.org/) has predicted that rural poverty in developing regions will not improve (and may worsen) over the next 50 yr, the pressure exerted by these people on their environment is unlikely to decrease in the near future. Moreover, while the correlation between the logarithm of rural and urban population density in the developing world from 1950 to 2000 was 0.99 (based on WRI 2000 figures), it is predicted to drop to only 0.45 between 2000 and 2030 (Fig. 1). This casts doubt on the long-term veracity of the conclusion that "a strong relationship between percent forest remaining and rural population density is not improved by incorporating urban population density" and implies that WML's forest loss model based on total population size (which does not predict a halt to net deforestation in the near future) may be the more conservative and reliable predictor.

Afforestation via secondary forest succession offset one in every 6–7 ha deforested in the tropics in the 1990s (Wright 2005) and is predicted by WML to overtake eventually the rate of forest loss (see above). Although we agree that regenerated forests are considerably better for biodiversity than agricultural or urban landscapes (Sodhi *et al.* 2004) and that regenerated sites can have substantial species recovery after several decades (Grau *et al.* 2003, Dunn 2004), it remains indisputable that secondary tropical forests represent a depauperate community with a reduction or loss of ecosystem services (a point duly acknowledged by WML). These types of forest harbor substantially lower biodiversity compared to primary (old growth) forests and (1) are characterized by more open vegetation with a dispersed canopy and relatively sparse ground layer (Turner *et al.* 1997), (2) usually support a rather different community structure with a predominance of generalist species (Brook *et al.* 2003), and (3) can act as reproductive "sinks" that drain dispersing individuals from remnant primary habitats and in doing so diminish the viability of remnant populations (Battin 2004, Peh *et al.* 2005). A pertinent example comes from the heavily deforested island of Singapore which contains roughly ten times more secondary than primary forest, yet the former habitat supports only 60 percent as many plant species (Turner *et al.* 1997). Even in areas within close proximity to primary forest, only 75 percent of forest bird species were found to be using the secondary forests of Peninsular Malaysia (Peh *et al.* 2005). Old growth forests constitute a critical habitat for many tropical species that often have specific host dependencies, narrow geographical ranges, and a low tolerance to habitat fragmentation (*e.g.*, Soh *et al.* 2006)—a specter that walks hand-in-hand with the sporadic processes leading to the regeneration of secondary forest. Moreover, undisturbed forests will continue to be the preferred focus of both commercial logging companies and illegal ventures targeting valuable mature rainforest timber (together constituting the primary driver of deforestation in the tropics) and swidden farmers seeking undepleted soils (Bawa & Dayanandan 1997; see also MEA). Attempts to curtail these pressures have repeatedly met with opposition from governments promoting economic development and international trade over biodiversity conservation (Kull 2004, Sodhi & Brook 2006).

The extinction momentum implied by the species-area relationship, termed the "extinction debt" of past habitat loss (Tilman *et al.* 1994), is another critical hazard and inexorable threat that will drive future extinctions—even in a world with no net forest loss. Table 1 provides a detailed illustration of this point for the countries of Southeast Asia, showing that even if deforestation was halted by the year 2030, the percentage of species at risk of extinction due to habitat loss would be only 4.4 percent less than if deforestation continued at its present alarming rate. WML suggest that "the long time lags observed between habitat loss and species extinctions [will provide time] . . . for secondary forests to mature and reestablish habitat suitable for forest residents." Unfortunately, this period of ostensible recovery grace is a fallacy because the species within secondary forests (including large trees) previously driven to small population sizes are already committed to extinction (*sensu* Simberloff 1986). These species invoke the "small" population paradigm (Caughley 1994) because they are too small to be viable in the long term (Brooks *et al.* 1999). Ensuring any long-term persistence of these "living dead" (Janzen 1986) taxa would require expensive, broad-scale conservation interventions (Heywood & Stuart 1992) that are completely out of the question for tens of thousands of species facing inevitable, but not necessarily imminent, extinction (although efforts to save

TABLE 1. *Estimated percentage of endemic species committed to extinction (% Extinct) in Southeast Asia by 2030 under two scenarios of forest loss. S1 assumes the annual percentage rate of forest loss (ARFL) remains constant at levels observed between 1990 and 2000 ("Business as usual"), while S2 assumes a linear decline in ARFL to the point of zero net deforestation by 2030 ("Zero net loss"). Also tabulated are the estimated original forest cover, forest cover in the year 2000, and projected percentage forest cover in 2030 relative to original area for S1 and S2. Projections are based on the deforestation-extinction model described in Sodhi and Brook (2006).*

	Forest (000 Ha)			S1: Business as usual		S2: Zero net loss	
Locality	Original	2000	ARFL (%)	Forest (%)	Extinct (%)	Forest (%)	Extinct (%)
Indonesia	181,157	91,134	−1.50	32.0	26.0	40.4	21.3
Myanmar	65,755	33,519	−1.50	32.4	26.5	41.0	21.7
Thailand	51,089	17,107	−2.90	13.8	41.1	21.9	33.4
Malaysia	32,691	13,452	−1.40	27.0	29.3	33.6	25.1
Vietnam	32,452	5,015	−0.30	14.1	40.7	14.8	40.0
Philippines	28,416	2,405	−2.10	4.5	55.7	6.2	51.7
Laos	23,057	4,495	−0.50	16.8	47.1	18.1	45.6
Cambodia	17,652	11,562	−0.60	54.7	13.7	60.0	11.7
Brunei	527	267	−0.30	46.3	19.5	48.5	18.4
Singapore	54	0.2	0.00	0.4	67.1	0.4	67.1
SEA Total	432,850	178,956	−1.40	26.5	29.7	33.3	25.3

a few charismatic species such as *Rafflesia* and orangutans may bear fruit).

WML also argue that because tropical forest habitats seem to have retracted to smaller areas during the Pleistocene glacial events, tropical forest species are likely to be naturally resilient to large-scale deforestation. The flaw in this reasoning is that Ice Age pulses of forest contraction and expansion unfolded over many millennia (Morley 2000), whereas the current anthropogenic rescaling of habitats is occurring one or two orders of magnitude more rapidly. Furthermore, the degree of habitat fragmentation, inhospitability of the agricultural matrix surrounding forest remnants, and levels of human hunting are all likely to be considerably more severe in the contemporary situation compared to the past.

Past momentum will force a mass extinction in the tropics, even if WML's prediction of net deforestation rates declining to zero during this century is realized. WML appropriately identify caveats associated with their analyses; however, we argue that one of their major conclusions (a mass extinction in the tropics will be avoided) is far too optimistic given the balance of evidence. The situation is analogous to a motor vehicle (forest ecosystem) that has suffered from brake failure (constituent species reduced to below their minimum viable population size)—a catastrophic and potentially fatal crash cannot be avoided simply by cutting the engine (reducing a once high rate of deforestation) or shooting out the tires (active conservation interventions) because the inertia produced by its forward momentum (past forest losses) will assuredly propel it onward to collide with the brick wall of extinction.

In spite of the pessimistic outlook, successful conservation outcomes can emerge from enhanced public environmental awareness, adequately protected reserves, and the provision of socioeconomic incentives for conservation (du Toit *et al.* 2004). Given that many of the drivers of biodiversity loss (*e.g.*, international demand for rain forest timber; global warming) are issues that transcend national boundaries, any solution will need to involve an international and multidisciplinary strategy (da Silva & Tabarelli 2000, Sodhi & Brook 2006). Sound and well-directed scientific research coupled with incentive-driven training of local communities offer the most realistic path toward the protection of the biodiversity on which livelihoods and good health depend.

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