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The state and conservation of Southeast Asian biodiversity

Navjot S. Sodhi · Mary Rose C. Posa · Tien Ming Lee · David Bickford · Lian Pin Koh · Barry W. Brook

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Abstract Southeast Asia is a region of conservation concern due to heavy losses of its native habitats. In this overview, we highlight the conservation importance of Southeast Asia by comparing its degree of species endemism and endangerment, and its rate of deforestation with other tropical regions (i.e., Meso-America, South America, and Sub-Saharan Africa). Southeast Asia contains the highest mean proportion of country-endemic bird (9%) and mammal species (11%). This region also has the highest proportion of threatened vascular plant, reptile, bird, and mammal species. Furthermore, not only is Southeast Asia's annual deforestation rate the highest in the tropics, but it has also increased between the periods 1990–2000 and 2000–2005. This could result in projected losses of 13–85% of biodiversity in the region by 2100. Secondary habitat restoration, at least in certain countries, would allow for some amelioration of biodiversity loss and thus potentially lower the currently predicted extinction rates. Nonetheless, urgent conservation actions are needed. Conservation initiatives should include public education, sustaining livelihoods, and ways to enhance the sustainability of agriculture and increase the capacity

N. S. Sodhi (✉) · M. R. C. Posa · D. Bickford
Department of Biological Sciences, National University of Singapore, 14 Science Drive 4, Singapore 117543, Republic of Singapore
e-mail: dbsns@nus.edu.sg

T. M. Lee
Ecology, Behavior and Evolution Section, Division of Biological Sciences, University of California, San Diego, 9500 Gilman Drive, 92093-0116 La Jolla, CA, USA

L. P. Koh
Department of Ecology and Evolutionary Biology, Princeton University, 106A Guyot Hall, 08544-1003 Princeton, NJ, USA

L. P. Koh
Institute of Terrestrial Ecosystems, ETH Zürich, CHN G74.2, Universitätstrasse, 16 8092 Zurich, Switzerland

B. W. Brook
Research Institute for Climate Change and Sustainability, School of Earth and Environmental Sciences, University of Adelaide, Adelaide, SA 5005, Australia

of conservation institutions. Furthermore, these actions should be country-specific and not ignore areas heavily populated by humans, as they can also harbour high numbers of threatened species. We urge that cooperative conservation initiatives be undertaken and support (e.g., capacity-building) be given by more developed countries in the region and beyond.

Keywords Extinctions · Endangered species · Deforestation · Habitat loss · Species–area relationship

Introduction

Among the world's tropical regions, Southeast Asia (Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Timor-Leste, Thailand, and Vietnam) is of particular conservation concern because it has the highest rate of habitat loss (Sodhi et al. 2004; Sodhi and Brook 2006). Almost the entire Southeast Asia is considered a biodiversity hotspot because it harbours an exceptionally high number of endemic species that are threatened by the loss of >70% of original habitats (Myers et al. 2000). Further, Southeast Asia is highlighted as an area where past and present human-driven land-use changes are expected to cause extinctions across a wide range of taxa (Brook et al. 2003; Cardillo et al. 2006; Lee and Jetz 2008). However, environmental apathy, corruption, poor natural resource governance, poverty and lack of conservation funding remain formidable challenges for conservationists in Southeast Asia (Sodhi et al. 2004; Sodhi and Brook 2006; Posa et al. 2008).

This overview has three objectives. First, we highlight the conservation importance of Southeast Asia by comparing the degree of species endemism and endangerment, as well as the rate of deforestation in this region with that in other tropical areas. Second, we discuss the likely extent of extinctions in Southeast Asia due to deforestation. There has been a recent debate as to whether regenerating forests can dampen some of the deforestation-driven extinctions (Brook et al. 2006; Wright and Muller-Landau 2006; Gardner et al. 2007; Koh 2007; Laurance 2007). Therefore, we discuss our previously published extinction estimates (Brook et al. 2003; Sodhi and Brook 2006) in light of regenerating forests and other threats to biodiversity such as climate change, invasive species and fire. High human population density also jeopardizes biodiversity through facilitating habitat loss, the spread of invasive species and overharvesting (Cardillo et al. 2004; Sodhi et al. 2004). Thus, we correlate human population density with deforestation and species endangerment to illuminate implications for conservation. We restrict our overview to terrestrial realms but hope to inspire similar analyses for the region's equally threatened freshwater and marine realms (e.g., Halpern et al. 2008).

Southeast Asian biodiversity

The high species richness and endemism in Southeast Asia is linked to its complex geological history (Sodhi et al. 2004). The region's floral and faunal elements have diverse origins, having been brought together by the collision of several tectonic plates at different geologic times (Hall 1998). Shifting paleoclimates caused periodic fluctuations in sea level, in turn enabling migrations from the mainland to the Indo-malayan archipelago and isolating islands (Meijaard 2003). These processes, coupled with a tropical climate,

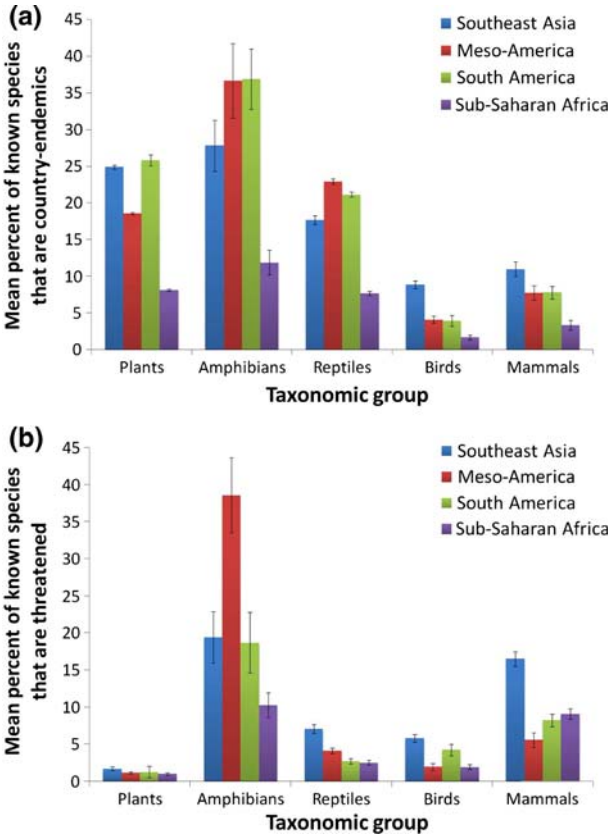

Fig. 1 Degree of species **a** endemism and **b** endangerment for vascular plants, amphibians, reptiles, birds, and mammals for the tropical regions of Southeast Asia (n = 9 countries), Meso-America (n = 13), South America (n = 12), and Sub-Saharan Africa (n = 41) (UNEP–WCMC 2004; IUCN 2006). *Error bars* represent standard errors

facilitated speciation and resulted one of the world's most biodiverse regions. Southeast Asia contains the highest mean proportion of country-endemic bird (9%) and mammal species (11%) and the second-highest proportion of country-endemic vascular plant species (25%) compared to the other tropical regions of Meso-America, South America, and Sub-Saharan Africa (Fig. 1a; UNEP–WCMC 2004). Southeast Asia also has the highest proportion of threatened species across all taxonomic groups (i.e., vascular plants, reptiles, birds and mammals) except amphibians (Fig. 1b; IUCN 2006). The proportion of endemic amphibians (28%) and reptiles (18%) in Southeast Asia is relatively lower than in the new world (Fig. 1a) and it has the lowest proportion of threatened amphibians among the tropical regions (Fig. 1b). However, this likely reflects the paucity of herpetological research in the region (see Sodhi et al. 2007, 2008b) rather than a lack of diversity in these taxa. Indeed, as recently as 2007, the first lungless frog was discovered on Borneo (Bickford et al. 2008a) and there are many amphibian and reptile species awaiting description. Furthermore, amphibians remain the most highly endangered of all terrestrial vertebrates in all areas and the fact that they are not as threatened in Southeast Asia as they are in other areas, makes their plight no less severe in Southeast Asia (see absolute values

from Fig. 1). The data above demonstrate the relatively elevated level of threat to Southeast Asia's highly endemic biota.

Deforestation rates in Southeast Asia

Not only is Southeast Asia's annual deforestation rate the highest among all tropical regions, it has also been recently increasing (Fig. 2a; FAO 2006). Less than 10% of Southeast Asia's forests are under some form of protection (World Conservation Union [IUCN] categories I–VI), which suggests that habitat loss in the region likely will continue (Fig. 2b; Iremonger et al. 1997; FAO 2006). Furthermore, many of the region's protected forests are also being degraded and destroyed by illegal logging activities (Curran et al. 2004; DeFries et al. 2005; Bickford et al. 2008b). During the period 1990–2005, many secondary forests in Southeast Asia were also being lost (Fig. 3), which only makes the story grimmer. The deforestation estimates we have used are based on the 2005 Forest Resource Assessment (FRA) of the United Nations Food and Agriculture Organization (FAO) and are undoubtedly prone to errors (see Grainger 2008). Therefore, our results should be interpreted with caution.

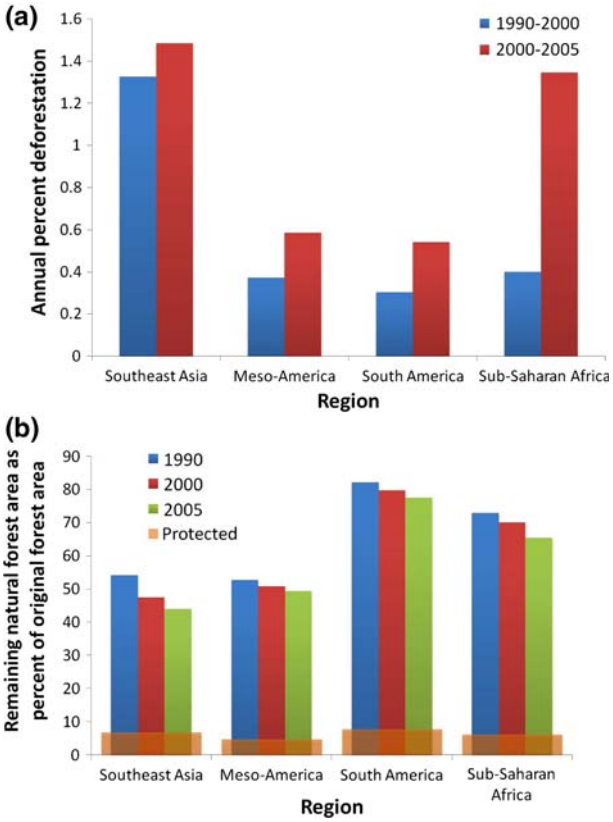

Fig. 2 **a** Annual percent deforestation of natural (primary and secondary) forests for the period 1990–2000 and 2000–2005; and **b** areas of remaining natural forest and protected forest for the tropical regions of Southeast Asia, Meso-America, South America, and Sub-Saharan Africa (Iremonger et al. 1997; FAO 2006)

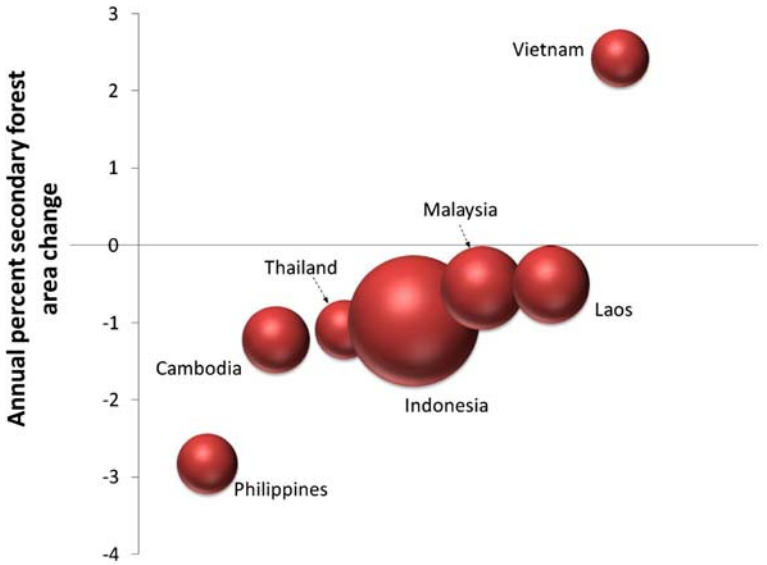

Fig. 3 Annual percent deforestation of secondary forests for the period 1990–2005 for the Southeast Asian countries of Cambodia, Indonesia, Laos, Malaysia, the Philippines, Thailand, and Vietnam (FAO 2006). *Bubble size* reflects the relative area of secondary forest remaining in each country

Projected biotic extinctions from Southeast Asia

The relationship between habitat area and the number of species of a region is typically characterized by the log-linear species–area relationship (SAR; Plotkin et al. 2000). The SAR has been used in a number of studies to predict future extinctions in Southeast Asia as a result of deforestation (Brooks et al. 1997; Brook et al. 2003). The broad regional projections by Brook et al. (2003) predicted that between 13 and 42% of all Southeast Asian species would be lost by 2100 due to the loss of 72–90% of habitat area—with the majority of the species already committed to extinction due to historical clearance of roughly 59% the region's original forest cover (Brook et al. 2006). An elaboration of this method by Sodhi and Brook (2006), using country-specific deforestation rates, implied that even these seemingly high estimates are likely to be conservative, because those countries with the greatest number of endemic species were also those which had experienced greatest historical or current rates of forest loss (e.g., Indonesia, Vietnam and the Philippines). As such, Sodhi and Brook (2006) estimated that 24–63% of Southeast Asian endemic taxa, representing 859–4,815 vertebrate species (including 66% of the region's birds and 85% of its mammals) and 8,343–48,043 species of vascular plants were at risk of extinction due to deforestation this century.

Yet, these SAR-based projections are admittedly a blunt tool for assessing future biodiversity loss because they ignore a number of real-world feedbacks on extinction risk, both positive and negative (see He and Legendre 1996; Rey et al. 1982). For instance, large swathes of tropical forest that were cleared over the last few decades to centuries for swidden agriculture or timber harvesting are now re-establishing as secondary forest. In some areas, the rate of re-growth is sufficiently rapid as to equalize or even overcome the rate of clearance of pristine habitat (Wright and Muller-Landau 2006). Additionally, there is evidence that a good proportion of forest species can survive in secondary forests,

selectively logged production forests and even exotic tree plantations (Peh et al. 2005; Barlow et al. 2007; Meijaard and Shiel 2008). Although these areas generally support fewer species than original primary forest, especially in the short term, it is reasonable to expect that secondary habitat restoration would allow for some amelioration of biodiversity loss (Wright and Muller-Landau 2006).

However, despite the above mentioned biases in these SAR-projections they still are likely to underestimate extinctions. This is due to additional impacts of unmodelled factors, such as climate change, invasive competitors and predators, acceleration of forest clearance driven by growing economic demand for mature rain forest timber, and perhaps most insidiously, by the synergistic interactions among these threats (Brook et al. 2008). For instance, deforestation also inevitably causes habitat fragmentation, which hampers dispersal and isolates populations. Logging trails increase access to forest interiors and thereby facilitates access by hunters. Fragmentation, loss of forest cover, and global climate change, could also cause a localised drying around edges of rain forest patches, a regional drop in evapo-transpiration rate, and broad-scale shifts in rainfall due a disruption of the Indian monsoon and El Nino–La Nina cycle, all potentially enhancing fire risk, water loss and thermal stress (Laurance et al. 2006; Brook et al. 2008; Knof and Zickfled 2008). All of these unknowns bias SAR extinction estimates in the same direction—underestimation. So most realistic (but unknown) impacts or synergies will make the region even more threatened than what is already anticipated.

The challenge, if predictions of biotic extinctions in Southeast Asia are to be improved (and ultimately mitigated), is for future research to focus on quantifying these general observations or theoretical expectations. For instance, detailed longitudinal studies across multiple habitat types are needed to assess the extent and length of time for faunal relaxation after disturbance as well as species recovery (or stability of diversity) following habitat restoration. Satellite monitoring of Southeast Asian forests has recently provided, and will continue to deliver, the type of robust spatial data on forest recovery rates needed for more detailed projections of future forest cover. As much as possible, these should be verified with ground truth information. Continual improvement in the down-scaled predictions of atmosphere-ocean coupled global circulation climate models (Intergovernmental Panel on Climate Change 2007) will yield more certainty in estimates of regional rainfall trends and temperature changes that will affect biodiversity. If this information can be adequately linked to vegetation-change and fire models, then improved predictions of extinction rates for Southeast Asia will no doubt emerge. But the reality is that given current limits to knowledge, the disturbingly broad SAR-based estimates of 13–85% extinctions by 2100 are as precise as we can currently derive.

Human density, deforestation and biodiversity endangerment

The growth of the human population and its greater demand for resources are the driving forces behind land transformation and resulting biodiversity losses (Vitousek et al. 1997). The link between high human population densities and risk to biodiversity is mainly indirect, but are nevertheless linked (Cincotta et al. 2000). We correlated human population density with forest cover and threatened species for the countries in Southeast Asia. A negative relationship was found between proportion of remaining forested areas and human population density (Fig. 4a). This correlation suggests that increasing human population density may make forests vulnerable as they are converted to agricultural or urban areas, or logged to provide timber. In addition, forests in heavily populated areas also remain

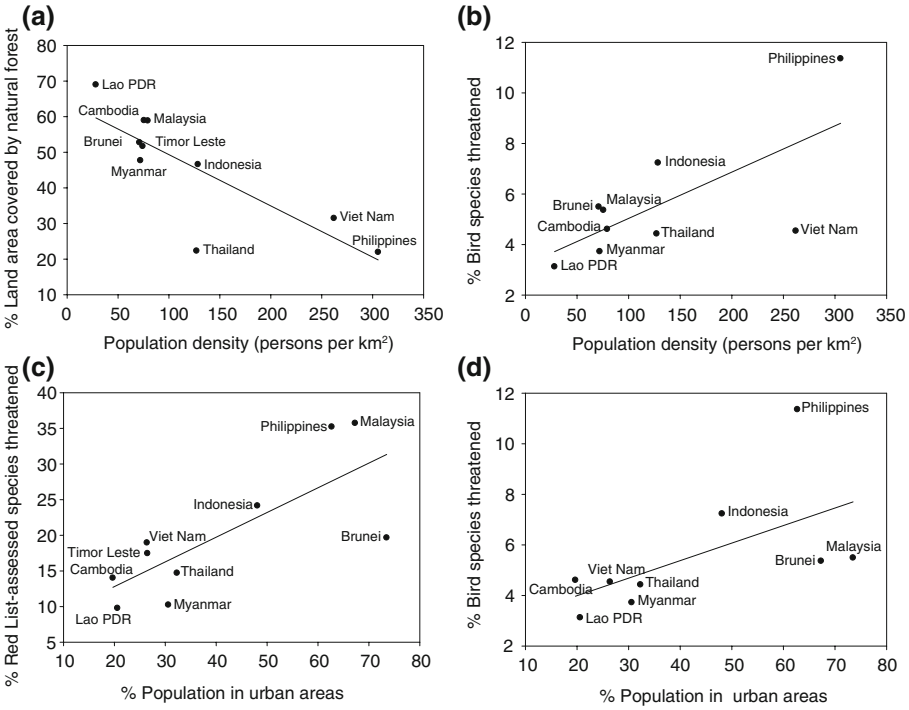

Fig. 4 Scatterplots of correlated biodiversity and socioeconomic indicators, with regression lines shown. Population density correlated with **a** the proportion of land still forested ($r_s = -0.82$) and **b** the proportion of bird species threatened in each country ($r_s = 0.71$). The percentage of the population found in urban areas correlated with **c** the proportion of vascular plant and vertebrate species assessed (see Fig. 1) for the IUCN Red List that are classified as Vulnerable, Endangered and Critically Endangered ($r_s = 0.77$) as well as **d** the proportion of bird species threatened in each country ($r_s = 0.71$). Singapore was excluded from the analysis due to extreme values. Spearman's rank correlations were significant for **a** and **c** at $P = 0.02$. Data sources: US Census Bureau (population density), World Resources Institute (urban population, number of known species) Food and Agriculture Organization of the United Nations Forestry Department (extent of natural forests), and The World Conservation Union Red List 2007 (number of threatened species)

vulnerable to overharvesting (Bulte and Horan 2002). Human population density as a whole in Southeast Asia has been increasing steadily over the past decade at a rate of 1.5% per annum (United Nations Statistics Division 2007), indicating that remaining forests will continue to face high risk of degradation both locally, and over the entire region.

A positive, but non-significant relationship between human population density and proportion of bird species threatened (i.e., in the vulnerable, endangered and critically endangered categories) as assessed by the IUCN was also found (Fig. 4b). Not surprisingly, we also correlated human population density with the proportion of threatened species of other taxa (plants, amphibians, reptiles and mammals) but found no significantly positive correlations, probably because of small sample sizes and poorly assessed status data. Because urbanization will almost certainly greatly expand in the future (Palmer et al. 2004), we determined whether human population in urban areas was correlated with the proportion of threatened species. The proportion of species of all taxa, as well as the subset of bird species that are threatened in each country, were all positively correlated with the percentage of the human population found in urban areas (Fig. 4c, d). However, not all correlations were statistically significant probably due to small sample sizes. These results

Table 1 Major threats and conservation imperatives for terrestrial realms for each country in Southeast Asia

Country	Major threat(s)/opportunities for biodiversity conservation	Conservation imperative(s)
Brunei Darussalam	High human development (Global HDI Rank: 30[a]; GDP per capita Rank: 4[b])	Invest more in the conservation efforts/building capacity in the regions
Cambodia	High rate of deforestation (1.3% natural forest lost annually from 1990–2005[c])	Protection of forests
	Corruption (Global Rank: 162[d])	Increase the capacity of conservation-related institutions
	Poverty (HPI-1 Rank: 85[a])	Integrate sustaining livelihood into conservation regimes
Indonesia	High rate of deforestation (1.7% natural forest lost annually from 1990–2005[c])	Protection of forests/reforestation
	Commercial logging (top tropical log producer from 2004–2007[e])	Reduce tropical timber demand/sustainable logging
	Illegal wildlife trade[f]	Curb illegal wildlife trade
	Oil palm production (12.5% annual growth rate from 1996–2006[g])	Sustainable oil palm production
	Corruption (Global rank: 143[d])	Increase the capacity of conservation-related institutions
Lao PDR	Rapid growth of agricultural production (80% from 1995–2005[g])	Sustainable and efficient agriculture
	Corruption (Global rank: 168[d])	Increase the capacity of conservation-related institutions
	Poverty (HPI–1 Rank: 70[a])	Integrate sustaining livelihood into conservation regimes
Malaysia	Commercial logging (top tropical log producer and exporter from 2004–2007[e])	Reduce tropical timber demand/increase sustainable logging
	Oil palm production (6.6% annual growth rate from 1996–2006[g])	Sustainable oil palm production
Myanmar	Few protected areas (4.63% of surface area[h])	Protection of forests
	High rate of deforestation (1.3% natural forest lost annually from 1990–2005[c])	Protection of forests/reforestation
	Rapid growth of agricultural production (57% from 1995–2005[g])	Sustainable and efficient agriculture
	Corruption (Global Rank: 171[d])	Increase the capacity of conservation-related institutions
Philippines	Dwindling natural forest (22% of land area in 2005[c])	Protection of forests
	High rate of deforestation (1.7% natural forest lost annually from 1990–2005[c])	Reforestation
	Corruption (Global Rank: 131[d])	Increase the capacity of conservation-related institutions
Singapore	Extreme deforestation (3% natural forest remaining in 2005[c])	Reforestation/Reintroductions/Wildlife Corridors
	High population density (6,667 persons per km^2 in 2007[i])	Limit human population density
	Few protected areas (2.24% of surface area[h])	Protection of forests
	High human development (Global HDI Rank: 25[a], GDP per capita Rank: 7[b])	Invest more in conservation efforts/capacity in the region

Table 1 continued

Country	Major threat(s)/opportunities for biodiversity conservation	Conservation imperative(s)
Thailand	Dwindling natural forest (22% of land area in 2005[c])	Protection of forests/Reforestation
	Oil palm production (5.5% annual growth rate from 1996–2006[g])	Sustainable oil palm production
Timor-Leste	Few protected areas (1.22% of surface area[h])	Protection of forests
	High population growth (3.4% annually for 2005–2015[a])	Human population control
	Corruption (Global Rank: 123[d])	Increase the capacity of conservation-related institutions
	Poverty (HPI-1 Rank: 95[a])	Integrate sustaining livelihood into conservation regimes
Viet Nam	Few protected areas (3.62% of surface area[h])	Protection of forests
	Illegal wildlife trade[j]	Curb illegal wildlife trade
	Rapid growth of agricultural production (69% from 1995–2005[g])	Sustainable and efficient agriculture
	Corruption (Global Rank: 123[d])	Increase the capacity of conservation-related institutions

GDP gross domestic product at purchasing power parity; *HDI* human development index; *HPI-1* human poverty index for developing countries

Data Sources: [a] United Nations Development Programme: Human Development Report 2007/2008; [b] The World Bank 2005 International Comparison Program; [c] Food and Agriculture Organization of the United Nations (FAO): Global Forest Resources Assessment 2005 (Forestry Sector); [d] Transparency International: 2007 Corruptions Perceptions Index http://www.transparency.org/; [e] International Tropical Timber Organization: Annual Review and Assessment of the World Timber Situation 2006; [f] Traffic reports http://www.traffic.org; [g] FAO, Selected Indicators of Food and Agricultural Development 1996–2006; [h] United Nations Environment Programme World Conservation Monitoring Centre World Database on Protected Areas http://www.unep-wcmc.org/wdpa/; [i] US Census Bureau: International Database http://www.census.gov/ipc/www/idb/; [j] Lin (2005)

suggest that threatened species may remain vulnerable in heavily populated areas (Cincotta et al. 2000; Cardillo et al. 2004) and given the congruence between high population densities and threatened species, conservation should not be ignored in urban areas (see also Miller 2005).

Conclusions and recommendations

All data suggest that Southeast Asian biodiversity remains extremely vulnerable to habitat loss. The protection of the region's remaining forests and biodiversity will require the integration of social issues (e.g., rural employment) into conservation planning (Bickford et al. 2008b; Posa et al. 2008; Sodhi 2008; Sodhi et al. 2008a). Corruption in countries such as Indonesia has resulted in high levels of illegal logging (Sodhi et al. 2007). Therefore, efforts are urgently needed to curb corruption for effective governance of existing "natural capital" of Southeast Asia. Additionally, for tangible conservation, the reliance of rural communities on natural resources should be minimized by creating employment opportunities (e.g., nature guides).

While the highest priority should be given to protecting primary habitats, conservation initiatives should not ignore areas heavily populated by humans. Conservation efforts in human-dominated landscapes must intensify and include public education, sustaining livelihoods and ways to enhance the sustainability of agriculture and strengthening of the capacity of conservation institutions. Additionally, where possible, reforestation, reintroductions and reestablishing severed habitat connections should be attempted in these landscapes.

The region is plagued by a staggering diversity of threats and imperatives (Table 1). Efforts need to be tailored to the conservation priorities in each country and enhanced through cooperative agreements among countries. Even within some countries, there may be multiple priorities for conservation (e.g., excessive bushmeat hunting and deforestation in Sulawesi), so even country-wide efforts should reflect the diversity of threats. We urge the higher income countries (Brunei Darussalam and Singapore) to invest more into conservation initiatives in poorer countries in the region (e.g., Indonesia and the Philippines). For example, Singapore can train biologists from the region and provide expertise in environmental management. Similarly, broader networks can be made with countries such as Japan and Australia to further facilitate capacity building and sharing of biodiversity information. In addition, cooperation within the region and beyond (e.g., China and South Korea) will be critical in curbing the illegal animal and timber trade. Amelioration of massive and ongoing environmental problems (e.g., Lohman et al. 2007) will only be successful with regional and global cooperation and in a region with such tremendous variation in problems and solutions, Southeast Asia faces a challenging task ahead.

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