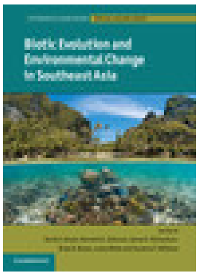

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17 - Southeast Asian biodiversity crisis pp. 434-462

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17

Southeast Asian biodiversity crisis

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17.1 Introduction

The International Year of Biodiversity, 2010, finds us in a state of severe ecological dysfunction and in the midst of a global biodiversity crisis. With our climate changing (IPCC 2007), our natural habitats decreasing in size and quality (Vitousek et al. 1997), our economically important species being over-harvested (Pauly et al. 1998) and our air and water becoming increasingly polluted (Hungspreugs 1988, Nriagu 1996, Galloway et al. 2008), we face some of the biggest challenges ever encountered by humanity. Globally we are currently losing species up to 1000 times faster than 'normal background' rates (Baillie et al. 2004). Among nine key 'planetary boundaries' that define a safe operating space for humanity, we have already far exceeded the threshold for biodiversity loss, threatening the functioning and resilience of the ecosystems on which we depend (Rockstrom et al. 2009). Despite scientists' best efforts to highlight the negative consequences of a 'business as usual' scenario and suggest ways to mitigate extinctions (e.g. Lubchenco 1998), global biodiversity continues to be lost at alarming rates (Baillie et al. 2004), leaving us now at a crossroads. While, on one hand, we are aware of what needs to be done to conserve and protect our future (Dietz et al. 2009), on the other hand, efforts thus far aimed at changing the destructive and wasteful lifestyles of our societies are inadequate to reverse the negative effects of humanity's actions on the planet.

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Within the larger context of a global biodiversity crisis, Southeast Asia stands apart – unfortunately outperforming all other regions in terms of deforestation, human population growth and biodiversity loss (Hannah et al. 1995, Laurance 1999, Achard et al. 2002, Sodhi and Brook 2006, Bradshaw et al. 2010). Although there have been several notable and recent reviews of this subject (Sodhi et al. 2004, Sodhi and Brook 2006, Sodhi et al. 2010), we aim to highlight some new insights into the main drivers, synergies and effects of the biodiversity crisis, the endemic problems of Southeast Asia, and suggest directions towards what we feel are some of the best and most realistic solutions. Specifically, we hypothesise that education and public awareness; restoration and reconnection of protected areas; and rethinking priorities and enhancement via incentives, economic policy and enforcement are the methods most likely to ensure a viable future for biodiversity. Only with a renewed sense of urgency, the right tools and analytical approaches, and coordinated efforts across local, regional and global scales, can we deal with a largely uncertain future.

17.2 Southeast Asian biodiversity and threat

Due to its complex geological history and island biogeography, Southeast Asia supports high levels of species richness and endemism, both in terrestrial and marine biomes (Sodhi and Brook 2006, Hoeksema 2007, Hall 2009). It has a diversity of tropical ecosystems, some of which, such as mangrove and peat swamp forests, reach their greatest extent and diversity within this region (FAO 2006, Page et al. this volume, Chapter 16). It also contains the 'coral triangle', an area regarded as the global centre of tropical marine biodiversity containing over 500 species of reef building coral and high fish species diversity (Hoeksema 2007, Tun et al. 2008, Bellwood et al. this volume, Chapter 9). However, concomitant with these high levels of biodiversity is a high degree of endangerment. The whole of Southeast Asia is comprised of four biodiversity 'hotspots', namely, Indo-Burma, Sundaland, Wallacea, and the Philippines (Myers et al. 2000). Moreover, the Philippines, part of the coral triangle, has also been identified as a top marine biodiversity hotspot with the highest level of threat (Roberts et al. 2002). Coral reef cover across the region continues to show an overall decline, with bleak prospects for recovery (Tun et al. 2008). An examination of species across various habitats within the region shows that nearly 30% of all species are threatened, with many species threatened in all major habitats (Fig 17.1). The high levels of endemism coupled with the small geographical ranges, and other physiological and life history characteristics of species have also made the Southeast Asian biota more susceptible to a number of extinction drivers (Fordham and Brook 2010). If current rates of habitat loss and exploitation continue unabated, widespread species declines and

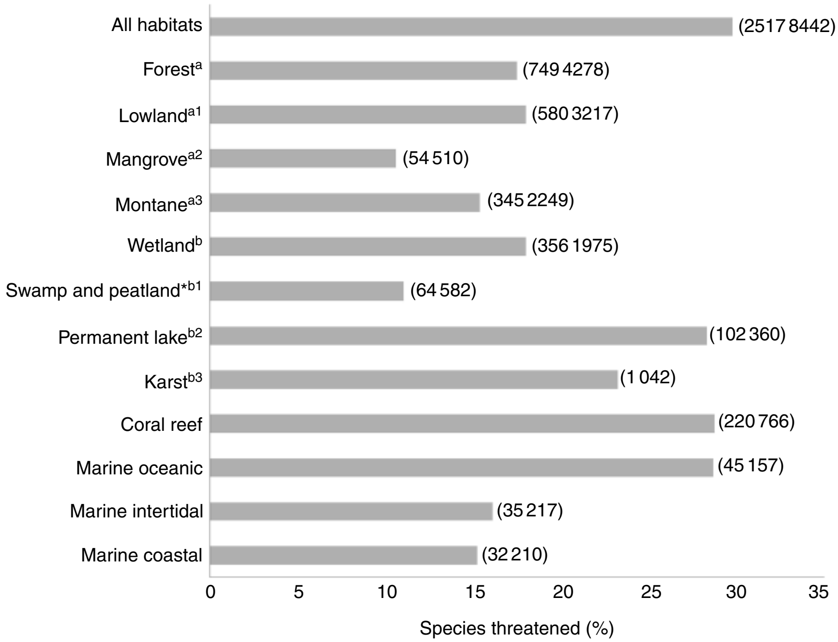

Figure 17.1 Number of species threatened (IUCN categories = Critically Endangered, Endangered, or Vulnerable) in major habitats within Southeast Asia. Bars represent the percentage of species threatened, while numbers in parentheses represent threatened and total number of species on the IUCN Red List (IUCN 2010).

[a] include species from [a1], [a2], and [a3]. [b] include species from [b1], [b2], and [b3]. * include species listed under tropical forest swamps.

losses are predicted to occur (Brook et al. 2006, Bradshaw et al. 2009, Sodhi et al. 2010). To examine the causes behind biodiversity loss in region, we will discuss the major drivers of extinction threat in the next section.

17.3 Drivers of biodiversity loss

17.3.1 Human population growth

The growth of human populations and increased demand for resources are the ultimate driving forces behind the loss of tropical biodiversity (Vitousek et al. 1997). In Southeast Asia, population density has been increasing steadily over the past decade at a rate of 1.4% per annum (UN Statistics Division 2008), bringing about land-use change and over-exploitation of natural resources (Giri et al. 2003, Sodhi et al. 2010). Human population density was found to be negatively correlated with percentage of remaining natural forest and positively correlated with percentage of threatened bird species within Southeast Asian countries (Sodhi et al. 2010). Similar trends are seen in increasing urban populations, and found to be positively correlated with percentage of plant and vertebrate species listed as Vulnerable, Endangered and Critically Endangered on the IUCN Red List (Sodhi et al. 2010). Even though these correlations are indirect measures, the link between human population growth and biodiversity loss is evident.

Some have suggested that the migration of rural dwellers to urban centres in tropical regions may alleviate the pressure that human population growth exerts on natural habitats (Wright and Muller-Landau 2006). Others, however, have emphasised uncertainties in this prediction because the relationship between rural populations and their surrounding environments is changing in response to the rapid industrialisation in developing nations (Laurance 2007). Despite the fact that rural populations are expected to decrease in certain regions, if overall human population continues to rise, the demand for natural resources is unlikely to decrease over time. Moreover, with economic globalisation, the bulk of demand for products has now shifted from local communities to international corporations (Hughes et al. 2003, Butler and Laurance 2008). A recent analysis showed that between 2000 and 2005, forest loss in the tropics was positively correlated with urban population growth and agricultural exports, demonstrating the trend towards industrial-scale, export-oriented production (DeFries et al. 2010). Thus, unless consumption patterns change, tropical forests will continue to face huge pressures to satisfy demands from a growing global urban population.

One endemic aspect of human population growth and improper governance in Southeast Asia is the *transmigrasi* program in Indonesia (Fearnside 1997), where people in overpopulated Java are relocated by means of a government programme, to other areas in Indonesia that are less populated. Unfortunately, this seemingly good idea has many unforeseen consequences that marginalise many local people that were originally living in these areas. The direct impacts of development and the accidental secondary effects of invasive species, fires and over-harvesting are all vastly increased in *transmigrasi* areas.

17.3.2 Loss, fragmentation and degradation of habitats

Habitat loss has had a more detrimental impact on tropical ecosystems than any other extinction driver (Sala et al. 2000, Sodhi and Brook 2006, Sodhi et al. 2008). Deforestation is currently one of the largest threats to terrestrial biodiversity in Southeast Asia (Sodhi et al. 2004). Forest areas are lost to commercial logging, conversion to agriculture, expansion of settlements, road building, mining and urbanisation. Analyses of satellite images show that relative annual deforestation rates in Southeast Asia were higher compared to all other tropical areas, both for the period of 1990–2000 (Mayaux et al. 2005) and 2000–2005 (Hansen et al. 2008), with forest loss being particularly severe in the Indonesian provinces of Sumatra and Kalimantan. The same trend was observed for mangrove forests (Mayaux et al. 2005) and approximately 50% of their original area has been lost (Tun et al. 2008).

Timber has represented one of the major exports from Southeast Asian countries since the 1950s, and Southeast Asia is still among the top producers of wood products for the global market (ITTO 2008). Due to poor forestry policies, logging was conducted at unsustainable levels for many decades (Ross 2001), using methods such as clear-cutting whereby most or all of the trees in a harvest area are cut down (Barbier 1993). Selective logging, where only particular tree species and sizes are extracted and a proportion of the forest is left intact, can still result in substantial forest degradation, affecting canopy height, surface area and species richness of trees in the harvest area (Foody and Cutler 2003, Okuda et al. 2003). A number of studies have examined the effects of selective logging on forest fauna, and even though there is evidence that logged forests can still support some species (e.g. Wells et al. 2007, Meijaard and Sheil 2008), the amount of species richness retained varies greatly across different taxa. More importantly, the community structure and composition of almost all secondary forests are markedly different from those of primary forests (Barlow et al. 2007).

Freshwater and wetland habitats are also being diminished and fragmented. Many rivers are being diverted to provide water supplies for agriculture and human settlements. The construction of dams, such as the Pak Mun Dam in Thailand, fragment fish populations by blocking movement, despite the addition of fish ladders (Roberts 2001). This is an especially critical issue in the Mekong River and its tributaries, because many fishes here make upstream migrations for breeding (Dudgeon 2000). Deforestation alters natural flow patterns of rivers and streams, causing large-scale changes in flow patterns, increased run-off, sedimentation and flash floods (Dudgeon 2000). These hydrological alterations are among the activities that threaten rivers, gallery forests and animals associated with freshwater habitats, such as endangered crocodilians, turtles and mammals, including orang-utans (*Pongo pygmaeus*) and proboscis monkeys (*Nasalis larvatus*).

Limestone karsts, a neglected biome that covers around 10% of the land area in Southeast Asia and recently recognised as important for harbouring high species diversity with many site endemics, are threatened by quarrying for use in cement (Clements et al. 2006). In Bornean karsts disturbed by quarrying, timber extraction and burning with secondary vegetation, the endemic Prosobranchia snail fauna was found to decrease in abundance (Schilthuizen et al. 2005). Extinctions of at least 18 plant species and perhaps two land snail species have been observed, with many more species possibly lost before they could be discovered due to the complete quarrying of karsts (Clements et al. 2006).

Currently, less than 10% of Southeast Asia's forests are under any form of protection (Sodhi et al. 2010). In addition, protected areas are not sufficiently conserved, and many appear to be 'paper parks' where weak governmental control and corruption leave room for illegal exploitation of natural resources within park boundaries (Laurance 2004, Smith et al. 2003). For example, in Indonesia, roughly 64% of reported protected areas are actually 'unclassified' and have no biodiversity protection (Bickford et al. 2008b). Ground-truthing in national parks and nature reserves showed signs of severe habitat degradation, overexploitation and hunting pressure in nearly all of them (Bickford et al. 2008b). More than 56% of protected lowland forests in Kalimantan was lost between 1985 and 2001, primarily due to illegal logging, including areas in national parks such as Gunung Palung where 38% of lowlands were deforested between 1999 and 2002 (Curran et al. 2004). On Sumatra, it was found that while protected areas had lower deforestation rates than unprotected areas, logging still continues within their boundaries (Gaveau et al. 2009). Adding to the direct pressure of habitat loss, protected areas are also becoming more ecologically isolated as deforestation and degradation continue in buffer zones and throughout the wider landscape (DeFries et al. 2005), raising many questions as to how effective terrestrial protected areas are in conserving Southeast Asia's forest biodiversity.

17.3.3 Wild fires

Natural forest fires have occurred in Southeast Asia since at least the Pleistocene, but the combination of human altered ecosystems and droughts caused by El Niño Southern Oscillation events has led to an increase in the number and intensity of catastrophic fires (Goldammer 2007, Field et al. 2009). Fire is also the cheapest, fastest and most efficient method of land clearance and is used in both small-scale shifting agriculture and large-scale plantations. As a result, anthropogenic fires have become a major driver of forest loss and degradation in the region.

Fires in Borneo during the 1982–83 drought consumed around 3.5 million ha of forest in East Kalimantan alone (Goldammer 2007). Similarly, over the 10-year period of 1997–2006, forest fires across Borneo affected 0.3 million ha in normal years and 1 million ha during El Niño years (Langner and Siegert 2009). Worryingly, during this period, fires also affected an average of 0.8% of the protected areas in normal years, increasing by up to five fold in Kalimantan during El Niño years (Langner and Siegert 2009). Impacts were found to be particularly severe in previously logged areas and timber concessions, caused by the addition of suitable fuel material during timber extraction (Goldammer 2007, Langner and Siegert 2009). In recent years there has also been a shift towards more fire events occurring in swamp forests compared to lowland dipterocarp forest.

Repeated burning increases fire susceptibility and can initiate the formation of fire climax grasslands, leading to cascading effects on animal populations and higher trophic levels. Furthermore, smoke from forest fires often has widespread effects across the Southeast Asian region (Lohman et al. 2007). For example, biomass burning in Indonesia has subsequently resulted in elevated levels of formate and acetate in rainwater collected in Singapore (Zhong et al. 2001). Because forest fires release gases that contribute to global warming and rainwater acidity, as well as produce smoke particles (polynuclear aromatic hydrocarbons) that could affect human health (Radojevic 2003), their wide impact on both the source and surrounding countries is profound.

17.3.4 Monoculture plantations

During the period 1990–97, agriculture was the main driver for land conversion in Southeast Asian tropical forests (Achard et al. 2002). Conversion to agriculture has detrimental impacts on overall ecosystem functioning, because intense agricultural activity depletes soil nutrients and induces erosion (Grubb et al. 1994). Furthermore, the shift from traditional farming practices to large-scale monoculture plantations has contributed to the loss of biodiversity that would otherwise be sustained in swidden ecosystems (Rerkasem et al. 2009).

High profitability and low suitability as a habitat for forest-dwelling species have made oil palm agriculture among the greatest immediate threats to biodiversity in Southeast Asia (Wilcove and Koh 2010). With the rising demand for vegetable oil and biofuel, oil palm has become one of the world's most rapidly expanding crops, with increases in production often coming at the expense of forestland (Fitzherbert et al. 2008). This trend is particularly apparent in Malaysia and Indonesia, which jointly produce more than 80% of the world's palm oil (Koh and Wilcove 2008, Wilcove and Koh 2010). For instance, in Malaysia, conversion of forests to oil palm accounted for 94% of the country's deforestation from 1990 to 2005 (Wilcove and Koh 2010). Oil palm plantations support low levels of faunal and floral diversity. For example, they now cover more than 15% of Sabah's land area but only sustain about 5% of the ground-dwelling ant species of the forest interior (Brühl and Eltz 2010). Reviewing results of various studies assessing the biodiversity value of oil palm plantations, Danielsen et al. (2009) found that plantations contained 23% and 31% of forest vertebrate and invertebrate species, respectively, compared with natural forests. Community composition of both flora and fauna change drastically, and plantations are usually dominated by a few abundant generalists and non-forest species, including invasives and pests (Fitzherbert et al. 2008, Danielsen et al. 2009). One compromise that has been suggested to mitigate such biodiversity losses is to restrict future expansion of oil palm agriculture to degraded habitats and pre-existing croplands (Koh and Wilcove 2008).

17.3.5 Overexploitation

Hunting pressure has increased immensely with increased human population density (Sodhi et al. 2004), resulting in extinctions caused by overhunting of wildlife for meat (Bennett 2002). In communities living close to tropical forests, bushmeat is still a major source of protein (Bennett and Robinson 2000). In Sarawak, for example, bushmeat is found in 67% of all meals of highland people (Bennett et al. 2000). With recent industrial developments, exploitation of local fauna has been further facilitated by increased access to forested areas through road building, deforestation and other land-use changes. Currently, wildlife is being extracted from tropical forests at approximately six times the sustainable rate (Bennett 2002). In Vietnam, this has caused the extirpation of up to 12 large vertebrate species (Milner-Gulland and Bennett 2003).

Overfishing and unsustainable fishing practices in freshwater rivers and lakes as well as in marine environments are causing population declines (Dudgeon 2000, Tun et al. 2008). The limited data available for freshwater fisheries indicate that fish stocks are declining, with decrease in fish size at maturity and reductions in total catches (Dudgeon 2000).

Fish biomass in coastal fisheries was found lowered to 5–30% of their unexploited level, with declines seen in all areas studied (Silvestre et al. 2003). With 70% of Southeast Asia's population living near the coastline (Lao PDR is the only landlocked country), marine fisheries are an important source of food. Many fishermen, especially in Indonesia, the Philippines, Thailand, Vietnam and Sabah, are resorting to destructive methods such as dynamite fishing and cyanide to maintain short-term income and obtain food (Tun et al. 2008).

In addition to local consumption, hunting is also driven by the international wildlife trade in commodities, pets, skins, ornaments and medicinal ingredients. Within the region, wildlife trade generates considerable revenue, and Southeast Asia remains one of the major centres for global wildlife traffic (e.g. Nijman et al. this volume, Chapter 15). An examination of international trade in CITES-listed animals showed that more than 30 million animals (representing around 300 species) and 18 million pieces of coral were exported from Southeast Asia between 1998 and 2007 (Nijman 2010). More alarmingly, undocumented illegal trade can be significantly greater than official exports (Nijman 2010). Therefore, the impact of wildlife trade on targeted species is likely to be much greater than our current estimates. For instance, at present, Indonesia is the largest exporter of frogs' legs in the world (Teixeira et al. 2001, Kusrini and Alford 2006), but there are already indications that harvesting patterns are unsustainable, warning that they may follow a similar trend of population crashes as previously observed in this industry in the US, Europe and South Asia (Warkentin et al. 2009). Moreover, the domestic Indonesian consumption of frogs is largely undocumented and has been estimated to be up to seven times the reported export volume (Kusrini and Alford 2006).

The export of many plants and animal parts from Southeast Asia for use in traditional Chinese medicine elsewhere includes everything from roots, bark, stems, leaves and flowers of plants to marine invertebrates and large terrestrial predators.

Turtle shells, for example, are made into a medicinal dessert and consumed for general health in Sinocultures. In Taiwan alone, an estimated 1989 metric tons of shells were imported from China, Indonesia and Vietnam between 1999 and 2008, with no evidence of reduction in trade volume in response to CITES listing of main target species (Chen et al. 2009b). The harvesting of sea cucumbers, another item considered as a medicinal and culinary delicacy, has also increased in the past few decades, leading to population collapses in various areas within the region (Manez and Ferse 2010). Threats from overexploitation are especially severe for charismatic animals and in Southeast Asia have resulted in the endangerment of the Sumatran rhino (*Dicerorhinus sumatrensis*), Asian elephant (*Elephas maximus*) and Malayan tiger (*Panthera tigris jacksoni*) (Clements et al. 2010). In addition to direct impacts on targeted species, loss of predators such as the Malayan tiger exert top-down effects that could potentially result in changes to predator–prey dynamics and trophic cascades.

17.3.6 Invasive species

With globalisation, an increasing number of exotic species are being introduced into new habitats, some of which become invasive and have negative effects on local ecosystems, possibly resulting in the extinction of native species. Therefore, invasive species are now recognised as an important threat to global biodiversity (Sala et al. 2000, Chapin et al. 2000, Molnar et al. 2008) and one of the leading causes of extinctions (Clavero and García-Berthou 2005). Tropical ecosystems have traditionally been regarded as less vulnerable to invasive species because of the more complete use of available resources and space by species-rich communities (Rejmanek 1996, Stachowicz et al. 1999). At present, the overall threat of invasive species on Southeast Asian biodiversity loss is still perceived to be low and there have been fewer reported harmful invasions relative to other regions. However, recent reviews hint that they may be a substantial but overlooked problem, even within relatively intact terrestrial ecosystems (Peh 2010). The number of marine invasive species in the region is likely to be higher than reported, given the correlation of invasions with high seaport traffic (Molnar et al. 2008). Where invasions have occurred, they can have serious consequences. In wetland communities in Thailand, for example, the invasive golden apple snail (*Pomacea canaliculata*) has resulted in the almost complete collapse of the aquatic plant community; altering the state and function of the ecosystems they occupy (Carlsson et al. 2004). Compared to other tropical regions, Southeast Asia may be more susceptible to invasion of exotic species, because it is composed of a large proportion of oceanic islands (Blackburn et al. 2004, Laurance and Useche 2009, Fordham and Brook 2010). However, the lack of research on invasive species in the region prevents a comprehensive assessment of their actual impact.

17.3.7 Climate change

Climate change will have widespread effects on the region and synergise with habitat loss, degradation and fragmentation as well as overexploitation in both terrestrial and aquatic ecosystems. This is because temperatures will increase and precipitation patterns will change. Predictions are that 20–30% of plant and animal species are likely to be at increased risk of extinction with a temperature rise of 1.5 to 2.5°C (IPCC 2007). Corals expel their zooanthellae symbionts in response to stress and overheating, and when thermal stress is severe and prolonged, most corals on a reef can bleach and die. Increases in carbon dioxide and temperature are expected to change the composition of coral reefs, because some species are more tolerant to climate change and coral bleaching than others (Hughes et al. 2003). Furthermore, coastal and island ecosystems will be exposed to increasing threats from rising sea levels and erosion (IPCC 2007, Fordham and Brook 2010). Besides marine habitats, freshwater systems will also be severely impacted. Models also suggest that changes in precipitation may result in both more severe floods and drier dry seasons, altering annual patterns that river systems have adapted to for centuries (Dudgeon 2000).

With global temperature predicted to rise by up to 6°C by the end of the century, the resilience of many ecosystems is likely to be exceeded (IPCC 2007). Though temperature increase in the tropics is expected to be less than in extra-tropical regions, the magnitude of impact on biodiversity will depend on species' physiological sensitivity to warming and their options for behavioural and physiological compensation (Huey et al. 2009). Given that tropical species normally experience less temperature variability, they may be less adaptive to temperature changes (Deutsch et al. 2008, Wright et al. 2009). Furthermore, some tropical species are already living in climate conditions close to or slightly above their thermal optima (Deutsch et al. 2008, Hughes et al. 2003, Huey et al. 2009) so that even slight increases in temperature may exceed their thermal tolerances (Colwell et al. 2008). Temperatures are projected to increase faster than species can evolve new adaptations, so many will need to shift their ranges to cooler habitats in order to survive. A study on the distribution and habitat association of mammals indicates that the distance to the nearest cool refuge is greater for tropical species, exceeding 1000 km for 20% of species examined by the end of the century (Wright et al. 2009). For the extensive coral reefs in Southeast Asia, we can expect large-scale disruptions, because they are immobile and have slow growth rates. Their temperature tolerance has developed over longer time scales than current rates of change, and thus they may be unable to evolve quickly (Hughes et al. 2003). Thus, the impact of temperature change on tropical biota may be much higher compared to that of extra-tropical regions.

Apparent upward shifts in terrestrial fauna of the region have already been noted in the elevational distribution of 94 common resident birds over a 28-year period

(Peh 2007), and in 102 species of moths over a 42-year period (Chen et al. 2009a). Elevation shift and poleward movement within the next century is likely to result in an increase in biodiversity in temperate regions and a decrease in Southeast Asia for the following reasons. First, in contrast to temperate ecosystems, tropical lowlands lack a source pool of species adapted to higher temperatures to migrate and occupy the empty niches once the original species are extinct or extirpated (Colwell et al. 2008). Second, the topography of Southeast Asia – island archipelagos with few mountains – prevents both altitudinal and latitudinal range shifts for most terrestrial species. The impact of changes in temperature and precipitation is particularly significant for amphibians and reptiles, because of their ectothermic metabolic rates and often temperature-dependent sex ratios and aquatic life stages. Based on current temperature change predictions, most of the amphibians and reptiles in Southeast Asia may reach the limit in their ability to adapt to climate change effects in less than 50 years (Bickford et al. 2010).

17.3.8 Pollution

Previously thought to be of less importance as an extinction driver (Sodhi et al. 2004), pollution has also become an emerging threat to biodiversity in Southeast Asia. Perhaps the greatest impact of pollution can be seen in marine and freshwater ecosystems (e.g. Cumberlidge et al. 2009). As countries develop economically and the scale of urbanisation and industrialisation expands, the expansion of agriculture, farming, deforestation, and near shore development has led to increased discharge of various pollutants into rivers and oceans (Hungspreugs 1988, Todd et al. 2010). Pollution is already ubiquitous in freshwater habitats in tropical Asia (Dudgeon 2000) and marine pollution is a widespread problem in the region (Todd et al. 2010). Increased sediment loads, eutrophication, toxic industrial compounds and litter can disrupt processes at the organismal level and cause direct mortality, as well as disrupt the structure and function of communities at all trophic levels (Todd et al. 2010). For example, sediment pollution in streams has resulted in downstream decreases in macroinvertebrates in Borneo (Yule et al. 2010), and agricultural practices and gold mining activities reduce viable habitat for already threatened species such as the flat-headed cat (*Prionailurus planiceps*) (Wilting et al. 2010) and the lungless frog (*Barbourula kalimantanensis*) (Bickford et al. 2008a). Coral reef degradation from marine pollutants could lead to the extinction of associated taxa, because although most coral species have a wide distribution in the region, lobsters and half of the fish and snail species have relatively restricted ranges (Tun et al. 2008).

There is still a lack of empirical studies on the impacts of acid rain, nitrogen deposition, and sulfur deposition on biodiversity in Southeast Asia (Todd et al. 2010). A global synthesis suggested that roughly 30% of the vegetation in Southeast Asia is affected by nitrogen and sulfur deposition (Dentener et al. 2006).

In particular, the mountainous regions in Southeast Asia, where soil sensitivity is relatively high, are thought to be more vulnerable to acidification (Bhatti et al. 1992) and nitrogen deposition (Bobbink et al. 2010). Recent studies indicate that, contrary to nitrogen-limited temperate ecosystems, the increase in nitrogen in tropical ecosystems may have negative effects on forest productivity (Barron et al. 2009), leading to further soil acidification and nutrient loss (Matson et al. 1999). Moreover, the reduction of nitrogen heterogeneity by atmospheric nitrogen deposition remains a factor contributing to vulnerability in plants, especially at the regeneration phase (Jones et al. 2002). Unlike Europe, North America or East Asia, the combination of low-speed near-surface winds, abundance of rain events and inefficient vertical mixing in convective clouds results in a relatively short transport range of areal pollutants in Southeast Asia (Engardt et al. 2005). In the case of sulfur, 60–70% of a country's emissions are deposited within its boundaries (Engardt et al. 2005). Therefore, as Southeast Asian countries continue to develop, acid rain may also become an increasing threat to the ecosystems in the region.

17.4 Future projections

17.4.1 Estimates of future biodiversity loss

Overall biodiversity loss in Southeast Asia is projected to be between 13 and 85% of known species by 2100 (Sodhi et al. 2010), with the majority of species considered already doomed to extinction because of past land conversion that has removed roughly 60% of the original forest cover in the region (Brook et al. 2006). Using country-specific deforestation rates, Sodhi and Brook (2006) estimated that 24–63% of Southeast Asian endemic taxa (859–4815 species of vertebrates and 8343–48 043 species of vascular plants) are at risk of extinction by the end of this century. Combining the current human footprint with future projections of temperature and precipitation change, biodiversity loss across Southeast Asia appears to be particularly elevated in centers of high human population density and along coastal regions (Fig 17.2).

17.4.2 Synergies among extinction drivers

Despite possible biases and limitations of future predictions, Sodhi et al. (2010) suggest that current projections, which are based solely on species-area relationships and current deforestation rates, may still be underestimates because they do not take into account the complexity of interactions between multiple extinction drivers. Extinction drivers are often examined separately, but recent evidence indicates that synergistic effects of multiple drivers are common in tropical forests (Stork et al. 2009) and likely to have a grave effect on species that are already threatened (Bradshaw et al. 2009). When synergistic effects are taken into account,

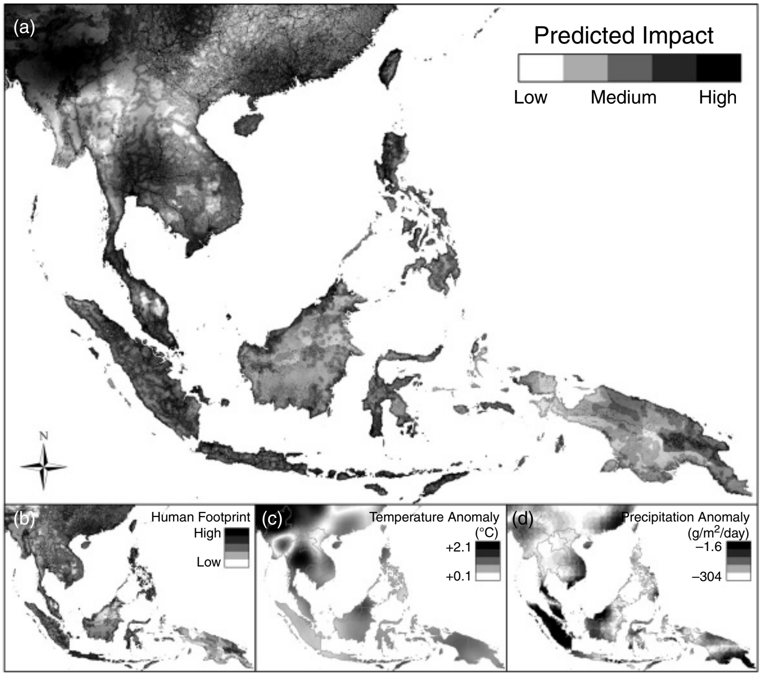

Figure 17.2 Predictions for biodiversity loss across Southeast Asia; (a) simplified model of predicted areas of impact on Southeast Asian biodiversity; (b) current human footprint; (c) predicted maximum monthly surface air temperature anomalies by 2050; (d) predicted maximum monthly precipitation flux anomalies by 2050.

In order to better visualise the areas that might be at higher possible threat due to climate change, we gathered the best available data on factors most responsible for changes to biotic systems. Temperature and precipitation data were downloaded from www.gisclimatechange.org (accessed on 25 August 2009) from the global CCSM projection dataset bounded at 22° to -12° latitude and 94° to 154° longitude. To develop the 50-year anomaly values of precipitation and temperature, ensemble average Climate Change Commitment scenario data for Surface Air Temperature (tas) and Precipitation flux (pr) were downloaded for years 2000 and 2050. Data were imported into Microsoft Excel (Microsoft Ltd.) and the 50-year monthly anomalies were calculated. For each latitude and longitude point (approximately 1.4° grid) the maximum monthly tas and maximum negative pr were identified and exported into Arcmap 9.3 (ESRI Ltd.).

Human impact data were downloaded from http://www.ciesin.columbia.edu/wild_areas/ (accessed 22 April 2010) and imported to Arcmap. World borders (wb) were downloaded from http://mappinghacks.com/data/world_borders.zip (accessed 25 August 2009). The tas and pr data were interpolated to raster format using inverse distance weighting, second power and six local points (Arcmap, spatial analyst extension) and cropped, along with elevation data, to land area using the wb mask. The tas, pr and elevation were then mapped as shown.

Calculation of impact was as follows: pr was squared to make the direction of reduced precipitation positive to match tas and human footprint layers. Tas, pr and human population declines and biodiversity losses will be greater than projections based on individual drivers (Brook et al. 2008). A pairwise combination of ten different extinction drivers on IUCN Red List threatened mammals, birds, and amphibians in tropical forests revealed significantly higher frequency of synergistic effects, suggesting that they may be the norm rather than the exception in causing biodiversity losses (Laurance and Useche 2009). Results from this study further indicated that the most important synergisms involve interactions between habitat loss or alteration, and other anthropogenic disturbances such as hunting, fire, exotic-species invasions or pollution (Laurance and Useche 2009). A closer look at current extinction rates also points to the rising threat of synergies with climate change, because it can interact with other extinction drivers on both local and global scales (Stork et al. 2009). Human impacts from overfishing, coastal development and pollution have been drivers of the massive decrease of coral reef species and have undermined reef resilience, already seen in the increase in bleaching events in the past 30 years, making them even more at risk from future climate change (Hughes et al. 2003).

The combination of extinction drivers and the resulting synergistic effects may deal a final blow to a species by pushing it below its minimum viable population, thus increasing its susceptibility to extinction via stochastic events (Brook et al. 2008). Moreover, with the growing populations and economic demands, rates of anthropogenic disturbances are likely to accelerate in the future. As such, the actual rate and number of extinctions in Southeast Asia could be much higher (Sodhi et al. 2010).

17.4.3 Adaptive responses

While the overall picture looks bleak, the resilience of natural systems has not been fully appreciated and we know little of the buffering capacity of ecosystems, their long-term resilience to stress and their response to restoration or reconnection. Moreover, there are many suites of species that have taken advantage of a human-dominated landscape, adapting to become human commensals and, in turn, increasing their ranges and niche breadth. These plants and animals are mostly considered 'weeds', but have become the most common organisms in the region (e.g. the common myna, *Acridotheres tristis*; catclaw mimosa, *Mimosa pigra*; and the fire ant, *Solenopsis invicta*). In all organisms, adaptive responses range from

Caption for Figure 17.2 (*cont.*) footprint were reclassified (slice, spatial analyst) to 255 equal interval units. Impact was then predicted as [0.5 × human footprint + 0.3 × tas + 0.2 × pr] based on our a priori perception that impacts on biodiversity will be based mostly on anthropomorphic disturbance, followed by temperature and precipitation changes. Maps are displayed overlaid with wb edges for clarity.

ecological to evolutionary in time, and from molecular to population size in space, so generalising is difficult. We do know that some species seem pre-adapted to generalised life histories and these species are most of the benefactors of a changing and human-dominated landscape. What we do not fully understand are the potential changes that more specialised species can make in response to variation in abiotic and biotic characteristics. Although most habitat specialists will probably not be able to adapt in a meaningful timeframe (relative to anthropogenic habitat changes), some might. This innate adaptive ability is under-appreciated and impossible to quantify across the range of species that co-exist in the habitats and ecosystems of Southeast Asia. Learning what species are able to modify their behaviours, diet preferences, phenologies, elevational and geographic ranges, for example, and how they are able to adapt, will be critical in our progress towards understanding how biodiversity will change in the future and what our best strategies will be for conserving biodiversity.

17.5 Country case studies

We feel that there are two poignant examples on either end of a continuum of responses to environmental problems in Southeast Asia. On one hand, Singapore embodies much of the biodiversity crisis in a modern city-state that sacrificed its biodiversity for economic development, while the Philippines underscores many fundamental problems and possible solutions. Although our tone remains realistic, we have chosen to embrace a more optimistic outlook and so balance these case studies to reflect both the harsh reality and the possible positive responses from both ends of the spectrum.

17.5.1 Singapore

Singapore presents a case in this region whereby maximised economic development has taken place at the expense of biodiversity (Sodhi and Brook 2006). The city-state has made tremendous gains in economic growth, but in the process has devastated its natural resource base and forested lands (now <5% of the land area). Researchers have found high percentage of local extinctions across a wide range of taxa; overall observed biodiversity loss was 28%, but simulations reveal that Singapore has lost as much as 50% of its species, if inferred extinctions are taken into account (Brook et al. 2003). Protected forests, comprising only 0.25% of the country's land area, harbour over 50% of its residual biodiversity (Brook et al. 2003). Despite the economic transformation, and the usual trend for highly developed countries to reverse some of their environmental legacy, Singapore unfortunately has recently been shown to have the highest environmental impact per capita (Bradshaw et al. 2010). This rank of environmental degradation is independent of economic factors, making Singapore a focal target for conservation efforts aimed at the societal level. As the epitome of the over-consumption epidemic, Singapore has some particularly easily targeted sectors for better performance in reducing environmental impact. Notable among these are the education and awareness sectors. Singapore can take a lead in becoming a sustainable tropical city and has all the expertise and technical abilities to do so within a reasonable timeframe.

17.5.2 The Philippines

The Philippines exemplifies the biodiversity crisis, with its remarkably high levels of endemism (Mallari et al. 2001), marine fish and invertebrate diversity (Roberts et al. 2002, Carpenter and Springer 2005), and its teetering position on the brink of ecological ruin due to the long history of natural resource extraction and exploitation that has already devastated its rainforest, mangrove and reef ecosystems (Bankoff 2007, Gomez et al. 1994, Primavera 2000). Of the 1007 Philippine vertebrate species assessed for the 2006 IUCN Red List, nearly 21% are classified as Threatened, as are 215 of the 323 plants that have been evaluated (Posa et al. 2008) – making the Philippines one of the hottest conservation hotspots (Myers et al. 2000, Roberts et al. 2002). Despite the dire situation and continuing socio-economic problems (e.g. widespread poverty, increasing population, large national debt) and political dysfunction (e.g. corruption, opposition by commercial interest groups), there are signs of progress and hope for biodiversity in the country (Posa et al. 2008). One of the driving positive factors has been the emergence of an environmental consciousness leading to the formation of civil society groups, which have advocated for better environmental policies and the decentralization of natural resource management (Utting 2000). Local communities are becoming more involved in managing their resources sustainably through a range of schemes including community based forestry and marine protected areas, as well as active representation in protected area management boards (Custodio and Molinyawe 2001, White et al. 2002, Lasco and Puhlin 2006). Notably, there is also a renewed interest by academics in biodiversity research and exploration, shown by the increase in the number of publications, and the many new species still being found and described (Posa et al. 2008).

17.6 Challenges and future directions

Given the amount of habitat that has already been lost and degraded in the region combined with the impacts of other extinction drivers mentioned above, the biodiversity crisis in Southeast Asia is accelerating (Sodhi et al. 2004, Bradshaw et al. 2009). There is an urgent need for conservation to err on the side of caution (Laurance 2007). Though there remains a level of uncertainty in the predictions of future extinctions (Sodhi et al. 2010), misplaced optimism may result in dire consequences for the preservation of Southeast Asian biodiversity (Laurance and Useche 2009). Urgent informed action is needed if the biodiversity crisis is to be averted. In this section we discuss the main hindrances and make suggestions regarding conservation actions by various sectors of society.

17.6.1 Poverty and economic priorities

Economic hardship in many Southeast Asian countries can contribute to biodiversity loss (Adams et al. 2004). Livelihoods of poor communities are often dependent on exploiting natural resources, so areas that are poverty stricken are found to overlap greatly with areas experiencing high levels of biodiversity loss (Fisher and Christopher 2007). Though the percentage of population in poverty has decreased in recent years, the percentage of people living on less than USD 1.25 a day is still considerably high in countries such as Cambodia (40.2%), Laos (44.0%), Philippines (22.6%) and Vietnam (21.5%) (Asian Development Bank 2009). Conflicts between maintaining the livelihood of communities in poverty and efforts to preserve biodiversity can arise when protected areas are set aside for conservation (Christie 2004, West et al. 2006). In light of the current economic status of Southeast Asian countries, their goal of having higher living standards through economic growth and development is only reasonable. It is perhaps no surprise, therefore, that short-term economic gains overshadow measures of sustainable management or protection of natural resources. The relationship between biodiversity conservation and poverty alleviation is complex and case-specific, encompasses both moral and pragmatic considerations, and requires cooperation and coordination between various government, conservation and humanitarian agencies (Adams et al. 2004). However, it is imperative that protection of the environment becomes a priority for Southeast Asian nations. Strong government commitment to reducing poverty and dependence of rural communities on resource exploitation through sustainable practices is needed. Relevant social issues must be addressed concurrently with biodiversity protection, such as land tenure and providing alternative livelihoods. Maintaining biodiversity and, in turn, the structures and functions of natural ecosystems, will ultimately be beneficial for human populations.

17.6.2 Education and environmental awareness

One of the most effective ways to produce far-reaching and long-term progress towards the conservation of biodiversity in Southeast Asia is to strengthen public education and ecological awareness. Better appreciation of the direct and long-term benefits of intact ecosystems, including the functional roles they play in flood protection, sustainable food production and clean water supply (Bradshaw et al. 2009, Kareiva and Marvier 2007) will build towards higher levels of conservation incentives and increased success for conservation in all related domains (i.e. governmental, local, NGO, etc.). Elsewhere, for example in Puerto Rico and Hispaniola, progress in the training of local students and wildlife professionals has promoted conservation awareness at local and national levels, subsequently influencing a growing ecotourism industry and driving national park management and conservation efforts (Latta and Faaborg 2009). Similarly in the Philippines, capacity building has led to significant developments in biodiversity conservation (Posa et al. 2008). To facilitate regional environmental education and awareness, high income countries, such as Brunei and Singapore, should invest more in the improvement of conservation initiatives in poorer countries in the region (e.g. Indonesia, Philippines), with much needed funds, training, and expertise in environmental management (Sodhi et al. 2010).

The use of charismatic endangered species can be extremely effective for educational and public awareness campaigns. Traditionally, medium- and large-sized mammals or birds have been used as flagship species, but concentrating efforts on these species results in a limited focus, neglecting other species groups or habitats that do not directly support these species. An example of other important potential areas for positive education and awareness action is in the recently rediscovered lungless frog in Kalimantan, Indonesia (Bickford et al. 2008a). As a highly unusual habitat specialist, the lungless frog captures interest because of its strange appearance and highly specialised ecology. There are excellent opportunities for using the lungless frog and other unfamiliar species as focal taxa for awareness campaigns and educational programmes. Moreover, the Indonesian government could take an active role in the conservation of this biodiversity flagship species, making a giant step forward in a socially responsible project in a remote area with very little infrastructure.

17.6.3 Certification schemes and public-pressure campaigns

In areas where the driving force behind land-use change has shifted from rural communities to large international corporations, public-pressure campaigns by conservation organisations (Butler and Laurance 2008) and certification programmes to reinforce international regulations (Warkentin et al. 2009) have been suggested as a means of coercing large corporations to become ecologically more responsible. Certification schemes, such as the Forest Steward Council (FSC) certification for timber extraction and the Roundtable of Sustainable Palm Oil (RSPO) for oil palm plantations, are currently present in a number of Southeast Asian countries, though overall implementation is still much in need (Dennis et al. 2008, Yaap et al. 2010). In these situations, establishing a reporting system to closely monitor each part of the exploration process will be necessary to maintain integrity of certification schemes (Warkentin et al. 2009, Wilcove and Koh 2010). The possibility of gaining enough public support in Southeast Asia to demand a change in the market remains debatable. Without increased environmental awareness, public-pressure for certifications is expected to have less effect in Southeast Asia compared to regions comprised of high-income countries such as Europe and North America (Butler and Laurance 2008). Nonetheless, successful examples can be seen in the Philippines where public advocacy has resulted in considerable progress in environmental protection legislations (Posa et al. 2008).

17.6.4 Local government law reinforcement

It is well known that political instability and lack of infrastructure in Southeast Asia have resulted in anaemic national institutions, lack of forest protection laws and poor enforcement of legislation (Bickford et al. 2008b, Laurance 1999, Sodhi et al. 2006). Furthermore, corruption in natural resource management (Smith et al. 2003) has led to overexploitation of forests, wildlife, fisheries and other natural resources, and consequently to biodiversity loss in this region (Laurance 2004). With the exception of climate change, major threats to tropical biodiversity are largely the responsibility of local governments and local populations (Wright et al. 2009). Conservation efforts can be made more effective through the establishment of integrated local management, local environmental legislation, as well as on-the-spot enforcement of measures against illegal activities. For example, improvements in regulating tropical logging practices is an immediate way to conserve functional tropical forest (Bradshaw et al. 2009), while overall improvements of park management is crucial to the success of protected areas in conserving native habitats and biodiversity in Southeast Asia (Sodhi et al. 2004, Bickford et al. 2008b). This can be further strengthened by regional cooperation that tackles threats that transcend national borders, such as the illegal wildlife trade and emissions from forest fires.

17.6.5 International monetary aid

As funding continues to be a limiting factor for conservation efforts in all places and at all levels (Posa et al. 2008), financial and technological support from international organisations and high-income nations will be critical to establish good governance of tropical biological resources through strong multilateral policy and concomitant socio-economic and administrative aid (Bradshaw et al. 2009). In particular, there are high hopes that Reduced Emissions from Deforestation and Degradation (REDD), relying on market and financial incentives to reduce deforestation and greenhouse gas emissions in the tropics, may provide a straightforward way to mitigate the effects of global climate change. REDD payments can be used to increase viable habitat for forest species by funding the protection of forests slated for development or expanding forest over marginal agricultural lands that have been abandoned (Venter et al. 2009, Wright et al. 2009). However, reduction of deforestation by REDD needs to be implemented with international and local policies that take biodiversity into account so as to maximise the quantity and, more importantly, the quality of conserved habitats (Grainger et al. 2009). Care must also be taken for REDD to be integrated into existing forestry management schemes that have already proven to be effective, because there is already concern that it will interrupt the trend of decentralisation, giving governments an incentive to take control of monetised forest carbon (Phelps et al. 2010). In addition to carbon credits for maintaining forested areas, biodiversity credits have also been proposed as a useful means of monetary incentive for conservation by treating biodiversity as a global market commodity or societal investment (Ferraro and Kiss 2002). The competitiveness of carbon-offset schemes, REDD, and biodiversity credits will ultimately depend on their present and future prices in relation to the profits from other land-use types (Wilcove and Koh 2010).

17.7 Overall suggestions

Besides conservation and rehabilitation of forested and degraded areas, future conservation efforts should invest in reforestation, species' reintroduction, and the restoration of habitat connectivity (Sodhi et al. 2010). Even though secondary forests appear to sustain fewer species, they are nevertheless able to buffer some of the effects of deforestation (Wright and Muller-Landau 2006). Just as the cessation of destructive activities, such as mining, has been shown to lead to partial recovery of biodiversity in previously affected areas (Yule et al. 2010), many degraded areas can be regenerated and their capacity to provide ecosystem services restored. Given the limited economic, logistical and technological capacity and low current commitment of Southeast Asian countries to conserve environmental assets in the face of developmental advancements, there can be no simple cure-for-all solution to decrease biodiversity loss (Bradshaw et al. 2009). To reach conservation aims, social issues will need to be integrated into conservation planning and tailored to each country and region (Bickford et al. 2008b, Sodhi et al. 2010).

17.8 Conclusions

Although progress towards the conservation of Southeast Asian biodiversity is slow and many obstacles still remain, it is clear that large steps have been made in both societal awareness, capacity building and science-based conservation decision making, and that a number of mechanisms for resource management and biodiversity protection are now in place. Increased involvement, organisation and networking of stakeholders from many sectors have resulted in encouraging trends for conservation in the region, although most are nascent. With a biodiversity crisis looming globally, and concentrated in the tropics, it is crucial to learn from the experience of countries such as the Philippines and Singapore, both regarding the perils of pursuing economic progress at the expense of biodiversity, as well as the strategies that may be effective in counteracting ecological degradation in the face of immense obstacles. Above all, it will be of vital importance to change the working philosophies of corporations and large institutions that have become more powerful than governments and can make lasting impacts simply through the vision of their leaders. The 'business-as-usual' schemes cannot continue by any definition. Science has the ability to get the answers and to find the solutions to our environmental problems; however, it is the will of the people that needs to change in order for the science to make a difference. Our next step is to find out how to determine the best possible ways to change peoples' minds, behaviours and interactions with their natural environment. Once we learn what these methods are, we then need to implement them across a broad range of human communities, targeting urban centres in particular.

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