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LEAD ARTICLE

Biodiversity conservation in Sri Lanka's novel ecosystems

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The dawn of the age of tropical novel forests is upon us and must not be ignored—Lugo (2009)

Despite continued forest conversion and degradation, forest cover is increasing in countries across the globe—Chazdon (2008)

ABSTRACT

With Sri Lanka's old-growth forests having been reduced to less than 20% of their pre-colonial extent, increasing areas of land, formerly heavily influenced by humans, are being allowed to return to secondary forests. These range from land recovering from swidden cultivation in the dry zone, through abandoned tea plantations in the lower-montane zone, to partly-logged forests throughout the country. Although the secondary vegetation of these 'emerging ecosystems' is often dominated by alien plant species and includes only a depauperate native flora, many threatened animals, ranging from amphibians to elephants, are able to utilize them for part or all of their life cycles. These novel ecosystems offer valuable conservation opportunities in two ways: (1) by increasing the area of occupancy of threatened species they contribute directly to a reduction in the level of threat; and (2) they provide a filter for triage, whereby threatened species that are intolerant of modified habitats could be awarded higher priority in the design of recovery plans. Available data suggest that among the Sri Lankan terrestrial vertebrates presently assessed as Endangered or Critically Endangered in the IUCN *Red List*, 12 of 14 mammal species, three of four reptile species and 40 of 48 amphibian species occur also in emerging ecosystems. Despite their impoverished plant diversity, therefore, such ecosystems should be viewed as a conservation opportunity rather than a threat; they should be incorporated into the national protected areas network and their biodiversity monitored, especially in relation to threatened species.Those that establish stable populations over multiple generations could be down-listed so that greater conservation attention could be allocated to threatened species obligatorily dependent on old-growth forests.

Key words: amphibians, mammals, endangered vertebrates, secondary forests, Red List

INTRODUCTION

Declines in populations, together with declines in areas of occupancy, extents of occurrence and/or the quality of habitat, determine the conservation status of the vast majority of the endemic Sri Lankan species that have been assessed as threatened as part of the IUCN's Red Listing process (IUCN, 2001, 2012). While declines in population have obvious consequences for the survival of species, the effects of declines in the quality and extent of habitat can be more difficult to assess.

It is well established, for example, that Sri Lanka's forest cover is diminishing rapidly and now stands at less than 20% of its pre-colonial extent (Fig. 1; Mattsson *et al.*, 2012; Perera, 2001). Legg and Jewell (1995) noted additionally that 23% of the island's forest cover consisted of 'sparse' (secondary) forest. Most recently, Perera and Tsuchiya (2009), in their study of forest cover in south-eastern Sri Lanka (an extent of 11,800 km^2 including the Yala National Park Complex and its surroundings), found that in the two decades spanning 1987-2006, forest cover halved (40.2% to 20.6%) while homestead vegetation doubled (16.4% to 30.1%) and mixed scrub-dominant vegetation increased by almost 20% (34.3% to 41.4%). While the decline in forest cover in this region, celebrated for its elephants, is even sharper than that for the island as a whole (Fig. 1), the increase in secondary vegetation is noteworthy.

Assuming such trends to be true for Sri Lanka generally, what has the effect of this decline in the quality and extent of habitat been on the island's elephants? Figure 2 shows the results of censuses and estimates made in the

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past half-century (1959–2011), which suggest a distinct increase in the elephant population; and this despite some 100–150 animals being killed by farmers annually in defence of themselves or their crops (de Silva and de Silva, 2007). Why then, is a species assessed as Endangered because of "a reduction in its area of occupancy and the quality of its habitat" (IUCN, 2012) apparently thriving despite a habitat whose extent and quality are clearly diminishing?

The resilience of elephants to such attrition appears to be at least in part attributable to the greater availability of grasses and other secondary vegetation in abandoned farmland (Olivier, 1978; Fernando *et al.*, 2005), together with their preference for forest-grassland interfaces (McKay, 1973). This is possibly in addition to the animals adapting their diets to crops such as rice, the extent of which doubled between 1959 and 2009 (Kikuchi, 1992; GOSL, 2012a). Could it be, then, that elephants have actually benefited from this "reduction in [their] area of occupancy and the quality of [their] habitat"?

Such a correlation does not, of course, imply that the elephant population has increased (or even remained stable) because of a loss of old-growth forest: but it does demonstrate that it has done so despite such loss. And if elephants, an Endangered species, can thrive in a habitat whose extent and quality is being continually eroded, can other threatened species do so, too?

This question is becoming increasingly relevant for several reasons. First, much of the deforestation that occurred in Sri Lanka over the past half century was because successive governments upheld the policy of reducing poverty and unemployment by promoting a rural peasantry dependent on small-holder subsistence agriculture. Demand for land was further exacerbated given that the human population doubled, to *ca* 20 million during this period (GOSL, 2012a). Unfortunately, the proportion of the island's urban population has remained static, at around 15% of the total over the past decade, notably low in comparison to other Asian countries (30% in India, 72% in Malaysia: UN, 2011).

If the new phase of economic and industrial activity that began in Sri Lanka after its civil war ended in 2009 leads it on a similar trajectory to those of its rapidly industrializing neighbours, the shift from a predominantly rural to an increasingly urban population is likely to allow increasing extents of rural farmland to return to forest, as is happening worldwide (Lugo, 2009; Marris, 2009). Such restoration could, in the dry zone, be achieved in as little as three decades (Cramer, 1993), whereas in the wet and montane zones succession occurs over much longer time frames (Pethiyagoda and Nanayakkara, 2011). In any event, it seems likely that increasing urbanization will precipitate an increase in the extent of secondary vegetation, though the relationship between urban population growth and the generation of secondary forest is too complex to be predicted reliably (Brook *et al.*, 2006).

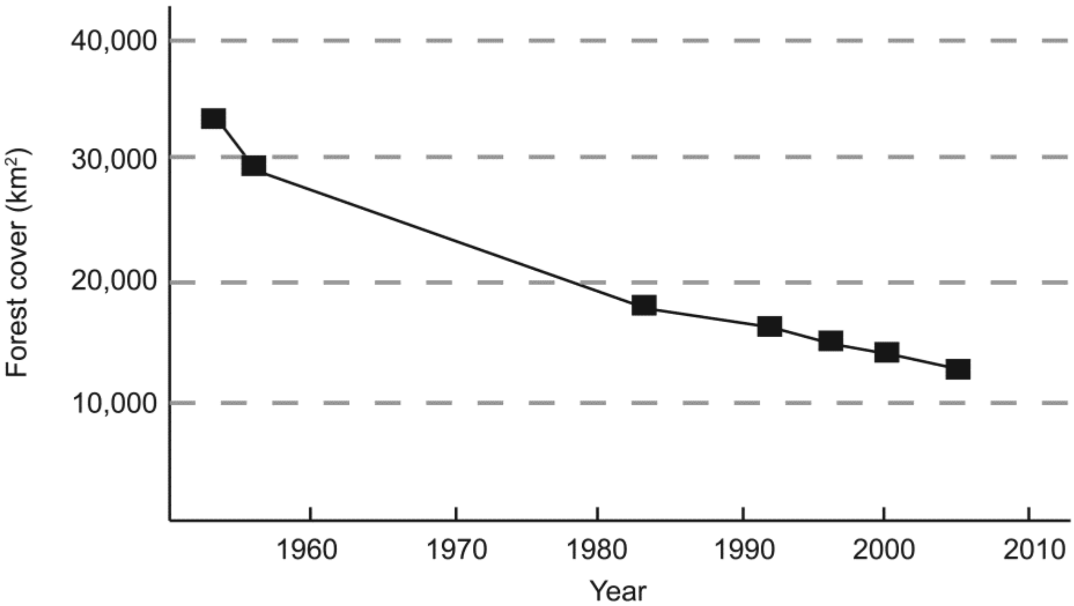

Figure 1. The decline of closed-canopy forest cover in Sri Lanka in the half-century since 1950 (adapted from Mattsson *et al.*, 2012).

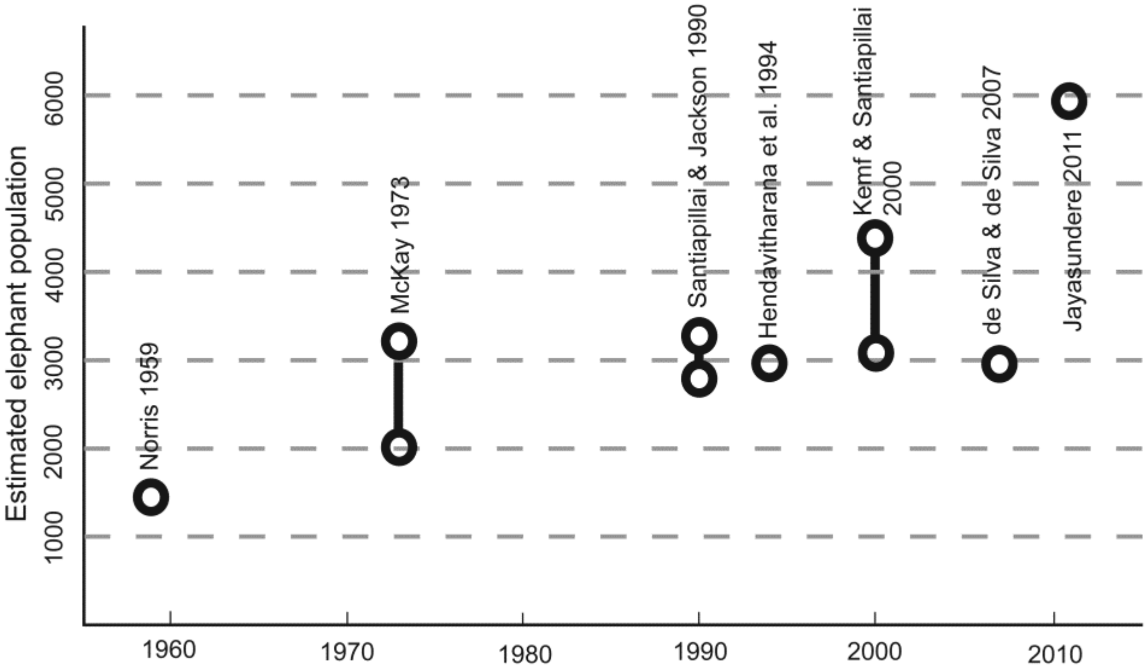

Figure 2. Estimates of Sri Lanka’s elephant population from *ca* 1960–2010, based on Norris (1959), McKay (1973), Santiapillai and Jackson (1990), Hendavitharana *et al*. (1994), Kemf and Santiapillai (2000), de Silva and de Silva (2007) and Jayasundere (2011).

Marris (2009) defined a ‘novel ecosystem’ as one that has been heavily influenced by humans but is not under human management. Importantly, in such ecosystems, species occur in combinations (e.g. because of alien species) and relative abundances that have not occurred previously within that biome (Hobbs *et al.*, 2006). Because of their impoverished biodiversity in the early stages of succession, novel ecosystems are often derided as ‘waste lands’, overlooked for conservation purposes and also omitted from the national protected areas network. Yet, experience both in Sri Lanka and elsewhere (see below) suggest that novel ecosystems offer valuable habitats, with many species being able to utilize such forests for all or part of their life cycle. What is more, the importance of novel ecosystems is poised to grow as Sri Lanka works to expand its forest cover and engages in restoration programmes.

To return to the above example, were elephants intolerant of secondary forests (i.e., novel ecosystems), they would be restricted to the few remaining patches of old-growth forest (if any) large enough to support herds perennially, resulting in a drastic reduction of their population and sharply increased degree of endangerment. The fact that they are not suggests that they may not be as gravely threatened as was supposed when they were assessed as Endangered, the assumed decline in the extent and quality of their habitat, at least in Sri Lanka, having been illusory.

In this article I argue that much of the Sri Lankan landscape is poised to be transformed into a matrix of novel ecosystems; that species tolerant of such ecosystems, by virtue of enjoying greater areas of occupancy (*sensu* IUCN, 2001), are less threatened than those that are not; and that this factor should be taken into account in the conservation assessment and planning processes so that species obligatorily dependent on old-growth forest are prioritized for attention.

Examples

Table 1 lists the terrestrial vertebrates from Sri Lanka that are assessed as globally Endangered (EN) or Critically Endangered (CR) in the IUCN Red List (IUCN, 2012). Birds are excluded because almost all ‘forest’ species also occur in novel ecosystems, while the degree of association between individual species and secondary forest remains unknown. Marine and freshwater species are excluded because the effect of novel terrestrial ecosystems on marine and aquatic biotas, if any, is unknown. In any event, none of the nine EN or CR freshwater fishes is restricted to streams within old-growth forest.

Table 1. The mammal, reptile and amphibian species that occur in Sri Lanka and are assessed as Critically Endangered (CR) or Endangered (EN) in the IUCN (2012) Red List, indicating records from old-growth (▲) and secondary (Δ) forests: data from www.iucnredlist.org; Goonewardene *et al.* (2006), Manamendra-Arachchi and Pethiyagoda (2005, 2007), Meegaskumbura and Manamendra-Arachchi (2005), Meegaskumbura *et al.* (2009), Wijesinghe and Brooke (2005), the reference collection of the Wildlife Heritage Trust at the National Museum, Colombo; and personal observations. *Bubalus arnee* (EN), though listed from Sri Lanka, is unlikely to occur there (Hedges *et al.*, 2008); '*Raorchestes*' *viridis* is a *Pseudophilautus*.

Mammals		
Crocidura hikmiya	EN	▲Δ
Crocidura miya	EN	Δ
Elephas maximus	EN	▲Δ
Feroculus feroculus	EN	▲Δ
Loris tardigradus	EN	▲Δ
Macaca sinica	EN	Δ
Mus fernandoni	EN	▲Δ
Prionailurus viverrinus	EN	▲Δ
Rattus montanus	EN	▲
Solisorex pearsoni	EN	▲Δ
Suncus fellowesgordoni	EN	▲Δ
Suncus zeylanicus	EN	▲
Trachypithecus vetulus	EN	▲Δ
Vandeleuria nolthenii	EN	▲Δ
Reptiles		
Calotes liocephalus	EN	▲Δ
Ceratophora tennentii	EN	▲Δ
Cophotis dumbara	EN	▲
Lankascincus deignani	EN	▲Δ
Amphibians		
Adenomus dasi	CR	▲
Adenomus kelaartii	EN	▲Δ
Duttaphrynus kotagamai	EN	▲
Duttaphrynus noellerti	EN	▲Δ
Fejervarya greenii	EN	▲Δ
Microhyla karunaratnei	EN	▲
Nannophrys marmorata	CR	▲Δ
Nannophrys naeyakai	EN	▲
Taruga eques	EN	▲Δ
Taruga fastigo	CR	▲
Taruga longinasus	EN	▲
Pseudophilautus alto	EN	▲Δ
Pseudophilautus asankai	EN	▲Δ
Pseudophilautus auratus	EN	▲Δ
Pseudophilautus caeruleus	EN	▲Δ
Pseudophilautus cavirostris	EN	▲Δ
Pseudophilautus cuspis	EN	▲Δ
Pseudophilautus decoris	EN	▲Δ
Pseudophilautus femoralis	EN	▲Δ
Pseudophilautus folicola	EN	▲Δ
Pseudophilautus frankenbergi	EN	▲
Pseudophilautus fulvus	EN	▲Δ
Pseudophilautus hoffmanni	EN	▲Δ
Pseudophilautus limbus	CR	▲Δ
Pseudophilautus lunatus	EN	▲Δ
Pseudophilautus macropus	CR	▲Δ
Pseudophilautus microtympanum	EN	▲Δ
Pseudophilautus mittermeieri	EN	▲Δ
Pseudophilautus mooreorum	EN	▲Δ
Pseudophilautus nemus	CR	▲
Pseudophilautus ocularis	EN	▲Δ
Pseudophilautus papillosus	CR	▲Δ
Pseudophilautus pleurotaenia	EN	Δ
Pseudophilautus poppiae	EN	▲Δ
Pseudophilautus procax	CR	▲Δ
Pseudophilautus reticulatus	EN	▲Δ
Pseudophilautus sarasinorum	EN	▲Δ
Pseudophilautus schmarda	EN	▲Δ
Pseudophilautus silus	EN	▲Δ
Pseudophilautus silvaticus	EN	▲Δ
Pseudophilautus simba	CR	▲Δ
Pseudophilautus singu	EN	▲Δ
Pseudophilautus steineri	EN	▲Δ
Pseudophilautus stuarti	EN	▲Δ
Pseudophilautus tanu	EN	Δ
Pseudophilautus viridis	EN	▲Δ
Pseudophilautus zorro	EN	▲Δ
Ramanella palmata	EN	▲Δ

It is seen from Table 1 that only two of 14 mammals occur exclusively in old-growth forest, while two others occur only in secondary-growth forests (the former two could be a sampling artefact given the modest sampling effort and that poor-quality forests are rarely sampled). Nekaris and Jayewardene (2004) noted that *Loris tardigradus* occurred at the highest density in secondary-growth vegetation in Kanneliya Forest while *L. lydekkerianus nordicus* was eight times more abundant in and around human habitations than [old-growth] forests.

Only one of the four EN or CR reptile species is restricted to old-growth forest, while in the case of amphibians, only eight of the 48 EN or CR species are restricted to old-growth forest, two being recorded only from secondary forests, the remainder from both habitat types.

The only Sri Lankan invertebrate group to be completely assessed for conservation purposes are the Gecarcinucoidea (freshwater crabs), of which Bahir *et al.* (2005) and IUCN (2012) treated 23 species as CR and a further 8 as EN. All 31 species were so assessed because of the small extent of their known range, almost all of them occurring also in modified or substantially disturbed habitats; no freshwater crabs are known exclusively from old-growth forests, and the main risk to this fauna remains the outright extirpation of local populations as a result of land-use change.

While most of the land-snail fauna remains to be assessed, Raheem *et al.* (2009) found 43 of the 57 species of land snails they recorded from 21 lowland wet-zone forest fragments to occur in both primary and secondary forests, only two being restricted to the former, 12 to the latter. In a separate investigation, Raheem *et al.* (2008) observed that 17 of 41 endemic land-snail species present in old-growth forest were present in home gardens within the same landscape, a single endemic that occurred in home gardens being absent from the forest.

Meanwhile, Amerasinghe (2010) found 21 of the island's inventory of 181 ant species (Dias 2006) inhabiting a single 0.4 ha home garden at Nawalapitiya.

Interpretation

The preceding examples need to be interpreted with caution for two important reasons. First, they are not based on a uniform methodology and depend on data derived from studies that sought to address different questions. Thus, the distance of secondary-forest plots from the nearest primary-forest reservoir, the quality of the intervening habitat, and the availability of vectors such as streams is in most cases unknown and likely different.

Second, there is no broadly applicable definition of 'undisturbed', 'old-growth' and 'secondary' forest, whether in terms of age or vegetation characterization. The Sri Lankan landscape has been modified by humans over several millennia and even 'pristine' sites may have been affected by historical disturbances including shifting cultivation and fire (Meyer, 1998; Gunatilleke and Pethiyagoda, 2012). Additionally, the age of secondary forest plots, and the degree of disturbance prior to regeneration being allowed to commence, are likely to affect the quality of successional vegetation substantially. For the purposes of the present article, I consider all these to be novel ecosystems: i.e., ecosystems formerly heavily influenced by humans but no longer under human management.

Finally, data on populations and expanses of habitat need to be interpreted with caution. In the case of elephants, for example, as pointed out by Fernando (2008), none of the previous population estimates have been made on the basis of a standardised, repeatable methodology. They are, at best, 'guesstimates' and at worst meaningless; the increasing trend suggested in Fig. 2 is in all likelihood illusory. Further, habitat preferences need to be examined at varying levels, both in time and space. Elephants' reputation as an edge species, for example, may not hold true at a landscape level, where there appears to be an association with dry forest, a rapidly-declining habitat type throughout the species' range (Fernando and Leimgruber, 2011). It is important to note also that gross estimates of the extent of emerging ecosystems do not reflect other factors such as the degree to which they are fragmented, which in turn has consequences for the kinds of animals that can occupy these habitats for their entire life cycle.

These caveats apply also to the datasets used to inform the Red List assessment process, which do not prescribe a methodology for the acquisition of population or habitat data. Such information as is available is used, with the assessors retaining the prerogative to recognize or reject data. Nevertheless, there can be little doubt that when assessors refer to declines in the extent and quality of [forest] habitat, what they have in mind is almost always primary forest (pers. obs.).

Secondary forests

The available data suggest that secondary forests in both the wet zone and the dry zone are able to harbour substantial animal diversity. Their increasing extent, and especially their potential to expand as Sri Lanka continues to industrialise and urbanise, demands that they be drawn into the conservation planning process sooner than later. Secondary-growth forests differ from old-growth forests also in another important respect: unlike the latter, which are mainly protected areas administered by the Department of Wildlife Conservation (DWC) or the Forest Department (FD), much secondary forest (especially if home gardens are included) is privately owned, providing for innovative public-private conservation partnerships.

Ecosystem services

Emerging ecosystems also play a valuable role in the provision of ecosystem services (Ellis *et al.*, 2012). Although not quantified, almost all the riparian 'forest' along rivers such as the Kelani and upper Mahaweli is secondary, much of it privately owned. The value of hydroelectricity and (pipe-borne) water from these rivers, *i.e.*, direct ecosystem services, exceeds Rs. 70 bn per year (CEB, 2011; NWSDB, 2010). Yet, there is no economic feedback to the ecosystem that facilitates this benefit. By comparison, the national conservation investment (*i.e.*, the total recurrent expenditure of the DWC and FD) in 2010 was only Rs. 1.2bn (GOSL, 2012b), just 1.7% of revenue from (renewable) water resources. An ecosystems tariff of just 1% on water supply and hydropower, for example, could yield Rs. 700 m annually as an incentive, for example, for landowners to enhance the ecological value of riparian lands. Even so modest a tariff would suffice to pay the owners of land 100 m on either side of 500 km of upland waterways an incentive of Rs. 70,000 per hectare per annum to allow the regeneration of secondary forest (which does not preclude agriculture, e.g. through under-planting with coffee or cocoa). Such incentives have been tested, *e.g.,* in Costa Rica, and yielded notable success despite incentives as low as US$ 50 per hectare per year (Langholz *et al.*, 2000). An appropriate regulatory regime could provide opportunities for enhancing the economic potential of such lands by allowing for the extraction of non-timber forest produce and also their value in the sequestration of carbon. A programme of this kind may, in addition to conserving both terrestrial and riparian biodiversity, diverting revenue to rural land-owners and engendering novel public-private partnerships, also serve to reduce erosion from sloping lands (a serious problem in the Sri Lankan highlands: Hewawasam *et al.*, 2003) and benefit aquatic biodiversity.

Conservation

Barlow *et al.* (2007) showed for a wide range of taxa including plants, insects and vertebrates, that 43–95% of species present in primary forest were represented also in secondary forest established in areas clear-felled, burned and bulldozed 14–19 y previously, though community structure and composition differed markedly between the two forest types. For amphibians, Vallan (2002) found 65 percent of primary-forest amphibian species to occur in a secondary forest in eastern Madagascar, almost identical to the results of Gardner *et al.* (2006) for amphibians in Brazilian Amazonia. As seen from Table 1, the proportion of amphibian species in secondary forest in Sri Lanka is even higher, perhaps at least in part a result of species intolerant of transition to secondary forest having already succumbed (21 Sri Lankan amphibian species were assessed Extinct by IUCN, 2012). These results appear consistent with the meta-analysis by Gardner *et al.* (2007) of 112 studies on the consequences of structural habitat change on amphibians and reptiles: one half to two-thirds of primary forest species in a given landscape were recorded also in secondary forest, with studies encompassing different age-classes of secondary forest indicating that species richness usually increased with stand age.

An objection potentially levelled against the conservation value of novel ecosystems is that they often harbour alien species (e.g., for land snails see Raheem *et al.*, 2008). Indeed, even in Sri Lanka, grasses, ferns and alien plants feature prominently in successional vegetation (see Gunaratne *et al.*, 2010). At a former tea plantation in Agrapatana (elevation 1540–1780 m), for example, Pethiyagoda and Nanayakkara (2011) found that 10 years after the removal of tea, 96% of woody stems represented alien species. Nevertheless, this 25 ha site harbours a substantial proportion of vertebrates found in old-growth montane forest, including 12 of the 15 amphibian species that occur in the nearby Agra-Bopath Forest Reserve (pers. obs.). What is noteworthy is that eight of these 12 amphibians are assessed as Endangered in the IUCN Red List (IUCN, 2012), ostensibly because of declines in the extent and quality of their [primary forest] habitat.

Alien species could also act as nurse trees to accelerate the establishment of late-successional native trees in restoration plots, as demonstrated by Ashton *et al.* (1997). Indeed, as pointed out by Ewel and Putz (2004), where they do not "unduly threaten surrounding ecosystems, alien species can be tolerated or even used to good advantage, if they provide essential ecological or socioeconomic services".

Red List

If so many species (see also Table 1) are tolerant of secondary forest, much of it poor in native-plant species, how is it that the Red List reflects, as noted by Stuart *et al.* (2008), that “habitat loss remains the number one threat to amphibians globally, with two-thirds (63%) of species affected, of which almost nine out of every ten species (87%) are threatened with extinction”? This, after all, was the consensus of the community of herpetologists who contributed to the assessment process. It would appear they (we: Manamendra-Arachchi and Pethiyagoda, 2005) chose to err on the side of caution, assuming in the absence of contrary evidence that restricted-range species occurring in old-growth forest would be unlikely to survive in secondary forests. The ‘data’ upon which these assessments were made in large measure stemmed from descriptive studies (*e.g.* taxonomic or inventory-orientated surveys) which neglected the ecology of the concerned species — they involved the “biased anthropocentric perceptions of the biodiversity value of different habitat types” referred to by Gardner *et al.* (2007).

Clearly, threatened species unable to utilize secondary forests should receive greater conservation attention than those that can (see Table 1) because of the higher extinction risk they face were their old-growth forest habitat to be lost. It is important to recognize, however, the great variety of novel-ecosystem types (e.g. early-successional grassland, shrubland rich in alien species); and that unlike old-growth forests, they and the value they offer to threatened species may be transient.

Plants

While there is room for cautious optimism with regard to the benefits emerging ecosystems bestow on threatened animals species, there is as yet no evidence from Sri Lanka of their benefit to the native flora. The conservation of Sri Lanka’s flora has received much less attention than its fauna, the data in Dassanayake and Fosberg (1980–2006), that as many as 61 endemic flowering-plant species (including 23 trees) had not been collected in the preceding 50 years, having passed almost unnoticed. The Red List (IUCN, 2012) declares 10 Sri Lankan plants Extinct, though Gunatilleke *et al.* (2008) reported that with about a third of the flora (1099 species) having been assessed, as many as 42 endemic angiosperms may have vanished. They also listed 81 micro-endemic species (including 26 trees) that are each restricted to a single site or locality. Because endemic and rare plants seldom number among pioneer plant species in secondary vegetation (Gunaratne *et al.*, 2010; Pethiyagoda and Nanayakkara, 2011), the value of emerging ecosystems to plant conservation is moot. Nevertheless, because of their ubiquity, the small areas of secondary vegetation in and around key centres of plant diversity such as Sinharaja and the Peak Wilderness provide valuable opportunities for the ex-situ conservation of threatened plant species, especially in expanding the areas of occupancy of the micro-endemic species that occur in nearby old-growth forest.

CONCLUSION

Emerging ecosystems in Sri Lanka harbour substantial endemic and threatened animal diversity. Despite their value to biodiversity conservation up to now lacking a strong empirical foundation, there is scope for optimism and they should be viewed as a conservation opportunity rather than a threat. Priority must be given to the assessment of their economic and biodiversity value, alongside incentives for their conservation. It is important, however, to recognize that emerging ecosystems are only ‘second best’. Nevertheless, when the ideal of preserving vast expanses of primary forest is no longer achievable given rising human-population pressure, there is no choice but to make the best of second best.

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