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Biodiversity gap analysis of the protected area system of the Indo-Burma Hotspot and priorities for increasing biodiversity representation

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ABSTRACT

Historically, designation of protected areas was biased toward specific habitats, resulting in insufficient representation of other habitats and their associated species. We identified gaps in current protected areas of the Indo-Burma Hotspot, proposed additional areas that could be included in PA systems of this hotspot to increase overall representation, and identified high priority areas for inclusion. Land cover types and threatened terrestrial vertebrate species were used as surrogates of biodiversity, and their representations were assessed using a gap analysis. Areas to be added to improve the hotspot's protected area systems were identified using Marxan software. High priority areas were selected based on irreplaceability and vulnerability. The representation of biodiversity in this hotspot is currently skewed in terms of habitats and species. There is a bias toward mammals in terms of representation (75%), while amphibians are not well represented (27%). With our optimal scenario, 21% of the hotspot's entire land area would need to be included in protected area systems, compared to 16% currently, to achieve more complete representation targets. Myanmar had the most additional areas required. Two-thirds of the additional areas needed to represent conservation features were <10 km^2. Several suggested areas were located along borders between multiple countries. Representation within protected areas in the Indo-Burma Hotspot can be significantly improved by focusing on maintaining and restoring linkages between smaller patches to create and sustain larger protected area networks. As part of this enhancement, trans-boundary collaboration among countries within the hotspot will be particularly important.

1. Introduction

The use of officially designated protected areas as a tool to manage biodiversity has been applied worldwide because of its ability to reduce threats to wildlife within their boundaries (Andam et al., 2008; McKinney, 2002). Ideally, when designing a protected area system, several principles should be applied including representation, complementarity, adequacy, efficiency and spatial compactness (Margules and Pressey, 2000). However, in practice, the design of protected areas has often been significantly influenced by political factors and usually biased toward specific areas with low economic value or limited development potential (Joppa and Pfaff, 2009). With limited consideration for their benefit to biodiversity or other conservation principles, many areas of high biodiversity significance (e.g. lowland evergreen forest, mangrove forest) remain largely unprotected (Margules and Pressey, 2000; Pressey et al., 1993).

An assessment of the status of global protected areas in 2004 indicated that total terrestrial protected areas approached 12% (Brooks et al., 2004). However, coverage varied substantially among bioregions from, for example, only 5% of temperate grasslands, savannas, and shrublands protected to 25% of temperate coniferous forests protected (Brooks et al., 2004). Moreover, the extent of occurrence of more than 12% of 11,633 species including terrestrial mammals, globally threatened birds, freshwater turtles and tortoises, and amphibians did not intersect with any protected area (Rodrigues et al., 2004). More recent studies indicate that in the tropics the percentage coverage and geography of protected areas within different tropical bioregions are notably different. The coverage varies from between 5 and 10% for dry broadleaf forests and coniferous forests to more than 20% for moist broadleaf forests (Jenkins and Joppa, 2009). While protected areas and surrounding areas of some regions in the tropics are generally large (e.g. the Amazon and Congo) and retain high levels of forest cover, the protected areas in other regions (e.g. the Atlantic Coast forest and West Africa) are small and show sharp reductions in forest cover at their boundaries (Joppa et al., 2008).

The Indo-Burma Hotspot defined by Mittermeier et al. (1999) is a biodiversity hotspot where large concentrations of endemic species

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are undergoing exceptional losses of habitat (Myers et al., 2000). Due to its high level of animal and plant endemism and limited remaining natural habitat, the Indo-Burma Hotspot ranks among the top ten biodiversity hotspots for irreplaceability and the top five for threat vulnerability (Mittermeier et al., 2004). Conservation planning within this hotspot has been conducted both at national level (Lao PDR — Robichaud et al., 2001; Myanmar — Aung, 2007; Thailand — Tantipisanuh and Gale, 2013) and regional level (Southeast Asia — Catullo et al., 2008; Indo-Burma Hotspot — Tordoff et al., 2012a) using different approaches. However, outcomes differed among the studies. While Robichaud et al. (2001) evaluated the representation of biodiversity of Lao PDR's current protected area system and identified priority areas for future conservation management; others did not indicate priorities among areas recommended for addressing gaps (Aung, 2007; Catullo et al., 2008; Tantipisanuh and Gale, 2013).

The Critical Ecosystem Partnership Fund (CEPF) presented an ecosystem profile of the Indo-Burma Hotspot in terms of (a) its biodiversity conservation importance; and (b) its socioeconomic, policy and civil society contexts (Tordoff et al., 2012b). The ecosystem profile defined species, sites and corridors that must be conserved to prevent biodiversity loss globally (754 species, 509 sites and 66 corridors in total) as well as key biodiversity areas (KBAs — the sites of global significance for biodiversity conservation; Langhammer, 2007). Species included in the CEPF profile were threatened species identified in the IUCN Red List. KBAs were selected based on the presence of four species groups: (1) globally threatened species, (2) restricted-range species, (3) congregations of species that concentrate at particular sites during some stage of their life cycle, and (4) biome-restricted species assemblages (Eken et al., 2004). The profile also defined priority species, sites and corridors for future conservation investment. However, although the KBA network was expected to include all sites that play a critical role in maintaining global populations of all species for which site conservation is essential, only species vulnerability and irreplaceability were accounted for, regardless of the overall representation of the species (Eken et al., 2004). Moreover, given the exclusive use of species representation used to identify KBAs, this network, if viewed as a protected area network, would provide neither representation nor adequate protection for many species, communities, and other elements of biodiversity.

Our study had the following objectives: (1) evaluate overall representation of the current protected area systems of the Indo-Burma Hotspot using both land cover types and threatened vertebrate species as conservation features; (2) determine the size and location of potential target areas to be incorporated into the Hotspot's protected area systems to increase the representation for all conservation features; (3) suggest high priority areas for conservation management; and (4) evaluate the representation of the protected area systems if all KBAs are included.

2. Materials & Methods

2.1. Study area

Our study area is the Indo-Burma Hotspot, which includes eastern Bangladesh, north-eastern India, most of Myanmar, part of Southern China, all of Lao PDR, Cambodia and Vietnam, most of Thailand and a small part of Peninsular Malaysia (Conservation International, 2014). The total area of this hotspot is approximately 2,400,000 km^2, of which 16.1% is covered by protected areas, at least on paper (IUCN and UNEP, 2014).

2.2. Conservation features & data sources

We used information on land cover and threatened species to define discrete conservation features. Thirteen land cover types retrieved from the Global Land Cover Map year 2009 were intersected with six ranges of elevation layers, resulting in 64 habitat features (Table 1). We used the dataset presented in Tordoff et al., (2012b) for the spatial distribution of KBAs for 199 threatened vertebrate species. This dataset was collated using published data via a desk-top survey and by consultation with surveyors, biologists and other wildlife experts (Tordoff et al., 2012b). This focused on four vertebrate taxonomic groups (30 amphibians, 40 reptiles, 68 birds and 61 mammals) listed by CEPF (see Appendix A). We did not include fish and marine mammals in our assessment because sets of KBAs for these species are still incomplete.

Spatial layers used in this study came from the following sources: (1) Land cover, downloaded from the ESA Global Land Cover 2009 Project; (2) elevation, downloaded from WorldClim (Hijmans et al., 2005); (3) KBAs, provided by CEPF (Birdlife International et al., 2013); (4) protected areas, downloaded from the World Database on Protected Areas (IUCN and UNEP, 2014); and (5) the human footprint index, developed by the Socioeconomic Data and Applications Center of Columbia University (Sanderson et al., 2002).

2.3. Evaluation of biodiversity representation within the existing protected area network

The representation of each conservation feature within the current protected area systems was evaluated by performing a gap analysis (Jennings, 2000; Possingham et al., 2006). The conservation feature layers were intersected with the protected area layer using ArcGIS 9.3 to determine the percentage of each conservation feature that fell within the boundaries of a protected area. For the targets of the representation levels that define whether conservation features have adequate representation, we did not set absolute targets for habitat features because there is still no explicit method to define or to assess whether a specified level is adequate. Therefore, we only stated the level of representation obtained for each habitat feature.

For the species features, representation targets for each species were set as a percentage of the area within all KBAs associated with that species. The following criteria were used in developing targets: (1) extent of occurrence, (2) frequency of occurrence, and (3) extinction risk (based on IUCN status). For the first criteria, targets were calculated following the methods of Rodrigues et al. (2004). Targets for species with narrow distributions (extent of occurrence <1000 km^2) were set to 100% of the area of associated KBAs, while widespread species (extent $>25{,}000$ km^2) were set to 10%. Targets for species with occurrence extents between 1000 and 25,000 km^2 were estimated from interpolation (ranging between 10% and 100% protection) using linear regression. For the second criteria, species inhabiting 1–3 KBAs were assigned representation targets of 30%, species within 4–6 KBAs were assigned 20%, species within 7–9 KBAs were assigned 10%, and no targets were assigned for species inhabiting >9 KBAs. For the third criteria, representation targets for species with CR status were set at 30%, for EN status targets were set at 20%, and VU status set to 10%. Targets from all criteria were summed and referred to as final representation targets (see Appendix A).

2.4. Additional areas determination

After evaluating the representation for all conservation features, the next step was to select additional target areas to be included in the current protected area systems to meet representation targets. In this study, five scenarios with different representation targets for conservation features were tested (the details of representation targets of each scenario are explained below). The entire hotspot was divided into small planning units, except the KBAs that were each assigned as a single planning unit. These planning units were then selected using Marxan software (http://www.uq.edu.au/marxan/). This software is a decision-support tool used to identify nearly optimal reserve networks in situations where there are multiple objectives (Ball et al., 2009; McDonnell et al., 2002). Marxan facilitates the application of a solution