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National emphasis on high-level protection reduces risk of biodiversity decline in tropical forest reserves

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ABSTRACT

Tropical protected areas have variable success in protecting their biodiversity. Many are experiencing biodiversity declines because of pressures such as logging, fire and hunting in their immediate surroundings, and inadequate protection inside the reserves. Here we assess how the national socio-economic context in which protected areas are embedded correlates with temporal trends in the condition of their biodiversity. Focussing on 60 protected areas arrayed across the world's major tropical regions, we examine the correlation between the biodiversity 'health' of protected areas and indices of human population size, wealth, governance quality, the environmental ranking of their respective nation, and national emphasis on reserve protection. We hypothesize that, after controlling for variability in socio-economic context, a country's emphasis on implementing high-protection reserves reduces the likelihood of biodiversity decline in its protected areas. We find that, after accounting for spatial non-independence and general socio-economic context, the best predictor of biodiversity trends within a tropical protected area is the country's overall emphasis on reserve quality, as measured by the proportion of IUCN Category I–IV reserves in nations' protected-area networks. This result suggests that national-level policies can have an important influence on the fate of biodiversity in tropical protected areas.

1. Introduction

According to the World Database on Protected Areas (IUCN and UNEP-WCMC, 2013), as of 2013 there were over 210,000 protected areas worldwide, of which approximately 46% are managed explicitly for biodiversity protection (IUCN Categories I–IV; explained below) (Dudley, 2008). The percentage of the Earth's land area under some form of legal protection has risen sharply from <4% in 1985 to nearly 15.4% by 2014 (Juffe-Bignoli et al., 2014).

Taken at face value, this trend is certainly a positive sign, but biodiversity is still in decline throughout most of the world, and it risks being degraded even further over the coming decades (Pimm et al., 2014). While protected areas can safeguard vegetation and minimize land-use pressures after establishment (Bruner et al., 2001; Geldmann et al., 2013; Carranza et al., 2014a), coverage is still inadequate because many endemic and threatened species are found entirely outside the global protected-area network (Rodrigues et al., 2004; Venter et al., 2014). Further, many protected areas – especially in the tropics – are failing to protect their biodiversity fully (Western et al., 2009; Laurance et al., 2012; Carranza et al., 2014b). A recent systematic review of protected-area effectiveness based on 76 studies concluded that, on average, the existence of a reserve protects at least some forest habitats, but evidence was inconclusive that they maintain populations of species better than do equivalent areas outside reserves (Geldmann et al., 2013). Patterns of deforestation inside and outside of protected areas are also highly variable among regions (Joppa et al., 2008), although Coetzee et al. (2014) determined via a global meta-analysis that protected areas generally have higher biodiversity values relative to comparable areas outside reserves.

There is a now a large and growing literature attempting to identify the conditions that promote effective conservation of biodiversity in protected areas. Quantifying such measures and correlates of success (and failure) are essential to justify continued expansion of the network and conservation investment in general (Parrish et al., 2003). The problem is that few protected areas have robust monitoring designs in place to measure biodiversity trends (Parrish et al., 2003; Ferraro and Pattanayak, 2006; Geldmann et al., 2013), such that many studies are obliged to measure proxies for 'success'.

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For example, deforestation pressures outside 36 protected areas were thought to signal future conservation failures within them (Naughton-Treves et al., 2005), an expectation that was corroborated by observations of declining biodiversity within tropical protected areas where outside pressures were relatively higher (Laurance et al., 2012). On a finer scale, the greatest differences in terms of threatening processes (land clearing, logging, hunting, fire, grazing) inside and outside tropical protected areas correlated most strongly with guard density, the deterrent level focused on illegal activity, border demarcation and the presence of direct-compensation programs for local residents (Bruner et al., 2001). Likewise, a comparison of 40 tropical protected areas to 33 community-managed forests suggested lower deforestation in the latter due to their higher relative community engagement (Porter-Bolland et al., 2012). The intensity of law enforcement and NGO support were the best predictors of great ape survival among 109 resource management areas in Africa (Tranquilli et al., 2012), and enforcement was the most effective contributor to reductions in poaching in Serengeti National Park (Hilborn et al., 2006).

A recent study based on validated interviews of 262 expert biologists across the tropics was the first to provide empirical evidence of biodiversity change in a large sample of protected areas (Laurance et al., 2012). They showed that biodiversity was being substantially eroded in about half of the reserves examined, with the remainder largely 'succeeding' in sustaining their biodiversity. In fact, a composite reserve 'health' index derived from an average trend of the ten best-studied guilds indicated that most (85%) of the protected areas examined had a health index $\leqslant 0$, indicating a variable but generally worsening overall trend in biodiversity. Further, a simple bivariate linear model suggested that improving on-the-ground protection (management) explained the most variation in reserve health (Laurance et al., 2012).

The suggestion that general management commitment, like the presence of field researchers (Laurance, 2013) and park rangers within a particular reserve improving its biodiversity prospects (Leverington et al., 2010), is tantalizing and merits further investigation. The problem is that such fine-scale budgetary and management details are missing for most parks (Bruner et al., 2004; Coad et al., 2013), and especially for most of the tropical protected areas for which a biodiversity health index exists. At the global scale, at least, there is clear evidence that some socio-economic indicators affect the environmental performance of a country, with increasing relative national 'wealth' in particular leading to poorer environmental outcomes (Bradshaw et al., 2010). We therefore asked a similar question of whether the national 'emphasis' on protected areas accounts for some of the variation in tropical reserve health. We hypothesize that the more a country 'invests' in reserves designed specifically to protect local biodiversity, the lower the likelihood that its protected areas will fail to achieve that protection. We therefore compared the reserve health index of Laurance et al. (2012) to the proportion of reserves within each nation categorized by the IUCN as established primarily for the reasons of biodiversity conservation (Categories I–IV) (Joppa et al., 2008) as an index of national conservation emphasis. We also controlled for other socio-economic differences among countries including country area, human population size, wealth, wealth inequality and corruption, while simultaneously accounting for spatial and national non-independence in the dataset.

2. Methods

2.1. Reserve health

Due to the paucity of long-term biodiversity trend data in tropical protected areas, we used the published data describing the biodiversity 'health' of 60 pan-tropical reserves within 36 countries (Laurance et al., 2012). The health index is an integrated assessment of biodiversity trends across 10 guilds deemed sensitive to environmental changes by local experts (Laurance et al., 2012). Six of these guilds are considered 'disturbance avoiders' (apex predators, large non-predatory vertebrates, primates, understory insectivorous birds, large frugivorous birds and large-seed old-growth trees), and the remaining four are generally 'disturbance-favouring' guilds (pioneer and generalist trees, lianas and vines, exotic animals and exotic plants) (Laurance et al., 2012). The health index for each reserve is an average of the mean trend values (-1 = declining abundance of disturbance-avoiding guilds or increasing disturbance-favouring guilds, 0 = no change and 1 = increasing dis turbance-avoiding/decreasing disturbance-favouring) across the guilds (Laurance et al., 2012).

2.2. Potential correlates

We were primarily interested in investigating the national conditions correlated with protected-area success as measured by this health index. Other socio-economic conditions being equal, we hypothesize that the national emphasis on gazetting high-protection reserves might partially predict the degree to which tropical protected areas are governed and supported. To that end, we compiled the country-level breakdown of protected areas by IUCN protection category from the World Database on Protected Areas (IUCN and UNEP-WCMC, 2013), as an index of such reserve support and governance.

Protected areas of IUCN Category (Dudley, 2008) Ia (Strict Nature Reserve), Ib (Wildnerness Area), II (National Park), III (Natural Monument or Feature) and IV (Habitat/Species Management Area) are generally considered those with the highest protection value and commitment (specifically managed for biodiversity protection), compared to categories V (Protected Landscape/Seascape) and VI (Protected Area with Sustainable Use of Natural Resources), which are subject to multiple-use management (Joppa et al., 2008). As such, the proportion of protected areas in the 'high-protection' categories (I-IV) might hypothetically predict a non-random component of the variation in protected area health (McDonald and Boucher, 2011). In our case, we calculated this proportion as Ia, Ib, II, IV/total number of protected areas (i.e., excluding Category III from the numerator, because such protected areas are generally small and "...include elements that have been influenced or introduced by humans"). However, the exclusion or inclusion of Category III protected areas made little difference to our conclusions (see Results).

As another metric of a country's emphasis on biodiversity conservation, we included two different composite rankings of environmental 'performance': an absolute environmental ranking (not accounting for resource availability), and a proportional ranking (i.e., relative to existing natural resource availability) (Bradshaw et al., 2010). The composite rankings are based on natural forest loss, habitat conversion, marine-species captures, fertilizer use, water pollution, carbon emissions and number of threatened species (Bradshaw et al., 2010).

Of course, the caveat of 'all other things being equal' means that we are obliged to control for other, country-specific geographical and socio-economic conditions. We therefore compiled the land area of each of the 36 countries as a control variable because total available area will dictate to some extent how many protected areas a country can harbour. We also included the total area under some form of protection per country as an additional control variable. We used this approach instead of including per-capita (e.g., per capita GNI) or proportional measures (e.g., proportion of area protected) because of the typical inflation of variances near proportional extremes and the conflation of influence when two