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The question of scale in threat analysis: a case study with Brazilian mammals

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Abstract

Rates of biodiversity loss are clearly associated with a reduction in the extent of original habitat. The most frequently used method to derive such estimates comes from the well-known species–area relationship. We explored the relationship between habitat loss and area for the Brazilian mammal fauna on a biome level (Atlantic Forest, Cerrado and the Brazilian portion of the Amazon basin), as well as on a smaller regional scale (the Rio Doce Valley of the Atlantic Forest). Habitat loss overestimates the number of threatened species when the entire species pool is considered (endemics and wide-ranging species). Restricting the analyses to the endemic species, the predicted extinction as a function of habitat loss in the Atlantic Forest and in the Cerrado is found to be greater than the number of taxa actually listed as threatened. This relation is reversed in the Amazon. When considering only the localized species pool for the Rio Doce Valley region of the Atlantic Forest, the function accurately predicts the number of extinctions resulting from habitat loss. We suggest that there is both theoretical and empirical evidence to suggest that threat analysis will generate more accurate estimates of species loss when conducted on a more local scale, particularly for the fauna of non-insular, continental regions. Furthermore, other phenomena affecting the likelihood of extinction of certain groups of species, such as hunting, need to be taken into account in order to better understand the dynamics of biodiversity loss.

There is little doubt that habitat destruction leads to the loss of biological diversity. But since we do not know, within two orders of magnitude, the number of species that exist, documenting human-induced extinction has proved problematical. As a result, this problem has been investigated using mostly the better-known groups such as birds and mammals. Attempts to estimate rates of biodiversity loss have usually focused on their response to the reduction in the extent of original habitat (Simberloff, 1982). According to May, Lawton & Stork (1995), one of the most common methods to derive such rates relies on the long-standing species–area relationship. Despite its wide use, the power of this relationship to accurately predict extinction rates has often been challenged (Whitmore & Sayer, 1992). Using the species–area relationship, Budiansky (1994) pointed to the fact that no significant correlation can be found between the degree of destruction of the Brazilian Atlantic forest (approx. 90% has already been decimated) and the number of species that should have become extinct, based on such biogeographical considerations. Brown & Brown (1992) noted that the Atlantic Forest should have already lost some 50% of its bird and butterfly fauna, but the number of confirmed extinctions is in fact extremely low.

Much of the difficulty in the interpretation of these results arises from poorly documented extinction records. Similarly, the dynamics that lead to final extinction are subject to variable time lags after the population has been reduced to levels below thresholds of demographic and genetic viability. Recognizing this problem, a number of recent studies (Heywood *et al.*, 1994; Pimm, Russel *et al.*, 1995; Brooks & Balmford, 1996; Brooks, Pimm & Collar, 1997) have considered extinction events, for analytical purposes, as being equivalent to the total number of species that, while still thriving with small populations, have been listed as

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threatened using methods that take into account their small probability of survival (Mace & Lande, 1991; IUCN, 1996). Taxa that have been considered threatened primarily as a result of habitat loss could, therefore, be interpreted as being on the way to extinction in the absence of any artificial intervention (Heywood *et al.*, 1994).

An alternative, more logical, approach would advocate that rates of species extinction should be more in line with the degree of habitat reduction when considering only endemic taxa of restricted geographical distributions rather than the full complement of regional diversity (Pimm, Russel *et al.*, 1995; Brooks, Pimm *et al.*, 1997). Pimm, Russel *et al.* (1995) and Brooks & Balmford (1996) used this approach and showed that the total number of endemic bird species already extinct and considered threatened could be fairly well estimated as a function of the loss of original habitat, both in a larger regional set comprising the Pacific region, as well as in more localized pools, such as that of the Brazilian Atlantic Forest. Even then, however, the results varied in accuracy depending on the geographical scale of the analysis (Pimm & Askins, 1995).

Exploring this issue, we have analysed data sets composed of the geographical distributions of Brazilian mammals, both at the biome-level and on a more localized scale, searching for patterns of species loss as a function of habitat reduction. This is the first analysis of this kind performed for mammals in all of South America. Over the past 6 years, Fonseca, Herrmann *et al.* (1996) have compiled data on the distribution of mammals in three Brazilian biomes (Atlantic Forest, Cerrado and the Brazilian portion of the Amazon basin), which included the classification of species as either endemic or wide-ranging. Furthermore, we have determined the occurrence of mammals in the more restricted Atlantic Forest area of the Rio Doce valley, which is in the state of Minas Gerais in southeastern Brazil (approx. 50 000 km^2), as a result of an in-depth study of the entire region over a 4 year period (Fonseca, Rylands *et al.*, 1994; Fonseca, 1997). For both data sets, we noted the species that have been officially listed as threatened with extinction (Fonseca, Rylands *et al.*, 1994), a process that entailed expert analysis based on the 1994 IUCN threatened category lists. Estimates of original habitat and the current extent of the natural vegetation were compiled from the most widely accepted sources for the Atlantic Forest (Fundação S.O.S. Mata Atlântica, 1995), for the Cerrado (Dias, 1994) and for the Amazon (INPE, 1996).

The estimates of mammalian species richness and endemism are as follows: the Brazilian Amazon, with 320 mammal species and 172 endemics; the Atlantic Forest, with 247 species and 91 endemics; and the Cerrado, with 165 species and 19 endemics (Fonseca, Herrmann *et al.*, 1996). The Rio Doce valley harbours 136 mammal species and 33 endemics (Fonseca, 1997). For the Atlantic Forest, we considered all species that occur in its general domain, including minor non-forest formations, to be endemic. A recent publication, based on a scientific workshop, provided the number of threatened mammals in the Atlantic Forest in the state of Minas Gerais (Machado *et al.*, 1998). The current extent of the Brazilian Atlantic Forest has been estimated as 8% of its original pre-Columbian cover. Figures for the Amazon and the Cerrado are 88% and 40%, respectively. The Rio Doce valley has already lost 90% of its original forest (Fonseca, 1997).

The total number of species predicted to be extinct as a function of habitat destruction was estimated from the species–area relationship $S = cA^z$, where S is the number of species, A is the area, and c and z are constants. As pointed out by Pimm, Russel *et al.* (1995), if a pristine area A_0 is reduced to A_n, the number of species S_0 should drop to S_n. Thus, the number of remaining species can be determined by the relationship: $S_n = S_0(A_n/A_0)^z$. The z value that we used in our analysis was the generally accepted, empirically derived 0.25 (Rosenzweig, 1995; see Brooks, Pimm *et al.*, 1997 for a recent discussion).

As noted by Pimm & Askins (1995), habitat loss consistently overestimates the total number of threatened species when endemics are lumped with wide-ranging taxa, and the same was true for our data set (Fig. 1). But our analysis did reveal, in both the Atlantic Forest and the Cerrado, that the number of endemic taxa predicted to be extinct (42 and 4, respectively) is three to four times larger than the number of endemics listed as threatened (15 and 1, respectively; Fig. 2). In the Amazon, this relation is reversed, and the number of species predicted to be extinct as a function of habitat loss (6) is a third of that recorded as threatened (18).

The two forest biomes investigated, the Amazon and the Atlantic Forest, harbour the largest numbers of species with poor conservation status (Fig. 2), but differ in the strength of their response in terms of currently recognized threatened species. Apart from the possibility that the species–area function may not be a good predictor of species loss, we consider that the underlying factors leading to this result may differ in the two regions. In the Atlantic Forest, the number of threatened endemics is 36% of the number of predicted extinctions.

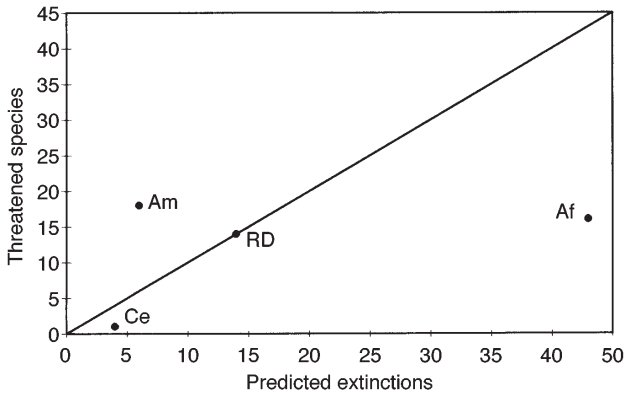

Fig. 1. Biome-level relationship between the number of threatened species and predicted extinctions of Brazilian mammals (Am, Brazilian Amazon; Af, Atlantic Forest; RD, Rio Doce Valley; Ce, Cerrado).

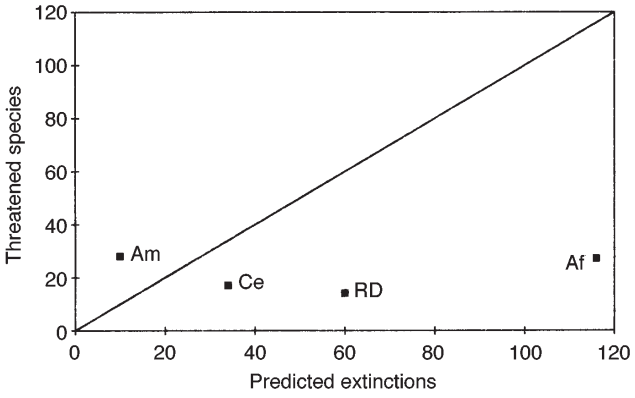

Fig. 2. Biome-level relationship between the number of threatened endemic species and predicted extinctions of Brazilian mammals (Am, Brazilian Amazon; Af, Atlantic Forest; RD, Rio Doce Valley; Ce, Cerrado).

The number of threatened species may be lower than expected due to the fact that most vegetation loss is quite recent, having mostly occurred in the last 40–50 years (Fonseca, 1985). Alternatively, hunting may explain the discrepancy between threatened species and predicted extinctions. However, we tend to dismiss this possibility because only a few of the Brazilian Atlantic Forest endemic mammals have become threatened due to hunting (Fonseca, Rylands *et al.*, 1994). Notable exceptions are the larger primates, such as the muriqui (*Brachyteles arachnoides*) and the howler monkey (*Alouatta fusca*).

In the Amazon, factors other than habitat destruction may have contributed disproportionately to the relatively large number of threatened species, above and beyond what would be expected. Almost all threatened Amazonian endemics (approx. 85%) are primates, a group traditionally targeted for hunting. Many primate species disappeared from large areas in the Brazilian Amazon long before any significant degree of habitat alteration occurred (Fonseca, Rylands *et al.*, 1994).

When considering the more localized mammalian pool of the Atlantic Forest's Rio Doce Valley, where nearly 90% of the forest has been lost, the number of threatened species fits perfectly with that of predicted extinctions (Fig. 2). This may indicate that threat analysis is more appropriate when performed on more localized, regional pools of species, rather than when conducted at much broader scales, such as whole biomes or continents. This interpretation does not contradict the results of Brooks, Pimm *et al.* (1997), which revealed a good fit for data on birds from insular southeast Asia. Rather, it brings new light to further attempts to use species–area relationships in non-isolated continental biomes.

Our results for the Cerrado lend support to these arguments. Given that the fairly large Cerrado biome has the lowest number of endemics among the geographical units being compared, just by chance a quite extensive degree of habitat destruction would be required to produce noticeable effects on its few restricted-range species. In summary, while there are indications that the species–area relationship continues to be useful in demonstrating the reality of biodiversity loss, the reliability of estimates may be quite scale-dependent, as recently suggested by Pimm & Askins (1995), Brooks & Balmford (1996) and Brooks, Pimm *et al.* (1997). Furthermore, other phenomena that affect the probability of extinction of certain taxa, such as hunting, clearly need to be taken into account.

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