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BIODIVERSITY RESEARCH

Predicting global abundance of a threatened species from its occurrence: implications for conservation planning

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ABSTRACT

Aim Global abundance is an important characteristic of a species that is correlated with geographical distribution and body size. Despite its importance these estimates are not available since reliable field estimates are either expensive or difficult to obtain. Based on the relationship between a species' local abundance and distribution, some authors propose that abundance can be obtained through spatial distribution data from maps plotted at different scales. This has never been tested over the entire geographical range of a species. Thus, the aim of this study was to estimate global abundance of the Neotropical primate *Brachyteles hypoxanthus* (northern muriqui) and compare the results with available field estimates.

Location From southern Bahia to Minas Gerais and Espírito Santo states, in the Brazilian Atlantic rain forest.

Methods We compiled 25 recent occurrence localities of *B. hypoxanthus* and plotted them in grid cells of five different sizes (1, 25, 50, 75 and 100 km per side) to evaluate the performance and accuracy of abundance estimates over a wide range of scales. The abundance estimates were obtained by the negative binomial distribution (NBD) method and corrected by average group size to take into account primate social habits. To assess the accuracy of the method, the predicted abundances were then compared to recent independent field estimates.

Results The NBD estimates were quite accurate in predicting *B. hypoxanthus* global abundance, once the gregarious habits of this species are taken into account. The predicted abundance estimates were not statistically different from those obtained from field estimates.

Main conclusions The NBD method seems to be a quick and reliable approach to estimate species abundance once several limiting factors are taken into account, and can greatly impact conservation planning, but further applications in macroecological and ecological theory testing needs improvement of the method.

Keywords

Atlantic forest, *Brachyteles hypoxanthus*, geographical range, negative binomial distribution, primates.

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INTRODUCTION

Global abundance is an important characteristic of a species and is correlated with geographical distribution, diet and body size (Brown, 1995). It is also one of the main parameters used in rarity and commonness categorization (Gaston, 1994; Yu & Dobson, 2000), thus being of great value for ecological model testing (MacArthur, 1960; Brown, 1995; Hubbell, 2001) and conservation planning (Jones, 1997; Hilton-Taylor, 2000). Despite its importance, global abundance estimates are not readily available, as reliable field estimates are either expensive or difficult to obtain, or both. Few studies have considered global abundances in the evaluation of macroecological models (Gaston & Blackburn, 1996; Murray *et al.*, 1998), usually relying on local abundance estimates to test these models (Brown, 1995; Gaston, 1996). Therefore, global abundances are available

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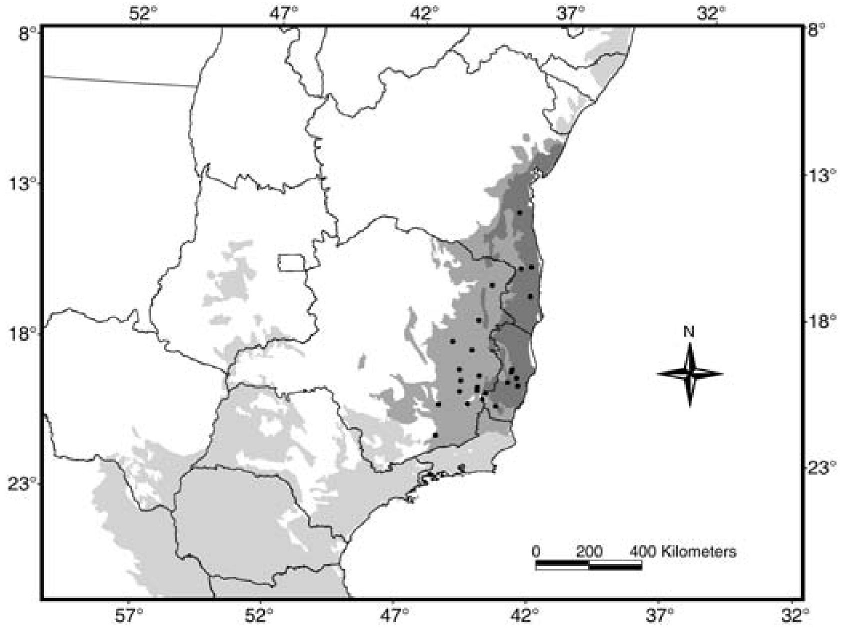

Figure 1 Geographical distribution of *Brachyteles hypoxanthus*. □ = Atlantic Forest; ▒ = Bahia interior forests; ■ = Bahia coastal forests; • = Localities of occurrence of *B. hypoxanthus*. Map on Hammer-Aitoff equal area projection.

for only a few endangered species (e.g. Kierulff & Rylands, 2003; BirdLife International, 2006a,b) and limited resources prevent obtaining these estimates for other species.

Based on the widely described, although not widely understood, relationship between local abundance of a species and geographical distribution (Brown, 1984, 1995; Gaston *et al.*, 1997, 2000), Kunin (1998) proposed a scale-independent index that could be used as a measure of species abundance, obtained through spatial distribution data from maps plotted at different scales. Recently, He & Gaston (2000) expanded Kunin's idea, fitting a negative binomial distribution (NBD) to the same kind of data used by Kunin (1998) in order to obtain a direct estimate of species abundance. The NBD is a probability distribution for aggregated populations which estimates an aggregation parameter k based on the total number of individuals in a sample, and the number of sample units with no individuals (Ludwig & Reynolds, 1988). The method of He & Gaston' inverts this relationship, and by assuming a scale-independent k, estimates the number of individuals in a sample (Kunin *et al.*, 2000) since the size of a sample unit corresponds to the area occupied by a single individual (He & Gaston, 2000). Although this assumption does not necessarily hold true (Conlisk *et al.*, 2007), the slight difference between pairs of scales makes it a plausible assumption (He & Reed, 2006; He & Gaston, 2007). This method has been used to estimate the abundance of different taxa at small to local scales, such as tree species in the Pasoh Forest Reserve of Malaysia (He & Gaston, 2000), flies in rotten fruit (Warren *et al.*, 2003) and large mammalian herbivores in Kruger National Park (Tosh *et al.*, 2004), but no attempt has been made to estimate the abundance of a species over its entire geographical range.

An adequate species to test He & Gaston's NBD method at large geographical scales is the northern muriqui, *Brachyteles hypoxanthus* (Kuhl 1840), one of the largest Platyrrhini primate species (Smith & Jungers, 1997) whose geographical range extends from southern Bahia to Minas Gerais and Espírito Santo, along the eastern Brazilian Atlantic rain forest (Strier, 2000). It is a threatened species, classified by the IUCN as critically endangered (Hilton-Taylor, 2000), but it is also one of the most studied primate species (see Strier & Boubli, 2006 and references therein) and recent abundance estimates obtained in the field are available for this species (Mendes *et al.*, 2005), enabling comparison with estimates provided by the NBD method.

METHODS

A compilation of 25 recent occurrence localities of *B. hypoxanthus* has been made (see Appendix S1 in Supporting Information), based on specimens housed at natural history museums (Museu Nacional do Rio de Janeiro and Museu de Zoologia da Universidade de São Paulo) and the literature (Fig. 1). The next step was to estimate the geographical range of *B. hypoxanthus*. Environmental variables such as climate, topography and ecoregions have been used to model the geographical range of species (e.g. Scott *et al.*, 2002). However, climate can be an ineffective variable to create models for species with broad latitudinal and elevational ranges (see examples in Hernandez *et al.*, 2006), which is the case of *B. hypoxanthus* (see Appendix S1). Analyses performed to model the geographical range of this species (C.E.V. Grelle, unpublished data) and that of other primate species from the Atlantic forest (Vilanova *et al.*, 2005) suggest that ecoregions are a fairly good surrogate of the potential distribution of these species.

Since abundance estimates can be accessed based on any two maps with different scales (Kunin, 1998; He & Gaston, 2000), the Atlantic Forest map was divided into grid cells of five different sizes (1, 25, 50, 75 and 100 km per side; in decimal degrees, 1 km is equivalent to 1′ at the equator) to evaluate model performance and the accuracy of abundance estimates over a wide range of scales. The 1 km scale was chosen because it roughly corresponds to the home range of a *B. hypoxanthus* group (Dias & Strier, 2003), thus meeting the requirement of the method (see below), and four subsequent scales were chosen in order to produce aggregation.

Abundance estimates were obtained by the NBD method (He & Gaston, 2000), calculated using the $N = Ak/a[(1 - Aa/A)^{-1/k} - 1]$ equation, where N is the estimated abundance, A is the total area where the species can potentially occur, k is the aggregation parameter, a is the scale and A_a is the area occupied by the species in the entire A area. The size of the ecoregions (Olson *et al.*, 2001) where *B. hypoxanthus* is present (Bahia interior and coastal forests) was considered to be a measure of its potential distribution (A) (see above). The estimated abundance N and the aggregation parameter k are obtained by solving the equation above at two different scales simultaneously (He & Gaston, 2000), since the abundance estimate N is independent of the scale under analysis. Although k is not independent of the scale (Conlisk *et al.*, 2007), the difference between pairs of scales can be considered negligible (He & Gaston, 2007). To evaluate grid saturation (a confounding factor in the analysis; Tosh *et al.*, 2004), area of occupancy percentage within each scale was calculated by dividing the number of cells occupied at a given scale by the total number of cells at that scale.

Due to the primate's social habits, abundance estimates by the NBD equation are likely to be biased. Since it is virtually impossible to determine the average area used by a single individual within a group (as required by the method; He & Gaston, 2000), the analyses were performed considering the area of the whole group, thus estimating the number of groups of *B. hypoxanthus*. To access the number of individuals, the abundances produced by the equation above were multiplied by average group size (28.2 individuals/group) reported in the wild (Strier, 1987, 1991; Lemos de Sá, 1988; Stallings & Robinson, 1991; Pinto *et al.*, 1993; Hirsch, 1995; Dias & Strier, 2003; Mendes & Ades, 2004). The predicted abundances were then compared to recent independent field estimates (Mendes *et al.*, 2005) to evaluate the accuracy of the NBD method.

RESULTS

NBD estimates were quite accurate in predicting *B. hypoxanthus* global abundance, once the gregarious habits of this species were taken into account. Average group size was an adequate correction factor for the abundance estimates, since the estimates produced for all pairs of scales analysed were consistently lower than the field estimates (855 individuals), but this estimate was always within the 95% confidence intervals produced by the NBD method (Table 1).

Coarser scale maps produced more imprecise abundance estimates, as the confidence intervals tend to increase. All confidence intervals produced by 1 km maps were about 40% of the abundance estimate, while those produced by maps coarser than 50 km ranged from 70 to 80%. At the smallest scales analysed, *B. hypoxanthus* had a low area of occupancy percentage within the study area (0.02% at 1 km and 10.75% at 25 km), but relatively high values were found at the coarser scales (24.62% at 50 km, 35.29% at 75 km and 43.48% at 100 km). Variation in the aggregation parameter (k) was small, ranging from 0.330 to 2.101 (Table 1) with no clear trend related to map scale, thus suggesting that spatial autocorrelation may not bias the results presented here, and its effects are negligible in this analysis.

Table 1 Estimated abundance (corrected by average group size), 95% confidence interval and aggregation parameter (k) for *Brachyteles hypoxanthus* using different scale pairs. Field estimates produced by Mendes *et al.* (2005) reported a global abundance of 855 individuals.

Scale pairs	Estimated abundance (N)	Aggregation (k)
1′ × 25′	705.1 ± 280.0	2.101
1′ × 50′	705.3 ± 287.2	0.480
1′ × 75′	705.4 ± 287.9	0.448
1′ × 100′	705.2 ± 287.1	0.485
25′ × 50′	819.2 ± 395.9	0.330
25′ × 75′	805.1 ± 383.5	0.364
25′ × 100′	788.5 ± 368.0	0.419
50′ × 75′	749.3 ± 511.5	0.405
50′ × 100′	700.5 ± 453.2	0.490
75′ × 100′	599.5 ± 472.4	0.635

DISCUSSION

Average group size was a reliable correction factor, as it produced estimates whose confidence intervals included the number of individuals reported in the field for all pairs of scales. Sample size does not seem to affect the accuracy of the estimates, as He & Gaston (2000) correctly predicted abundance of trees using many occurrences at small scales, and the small number of occurrences used to estimate the abundance of *B. hypoxanthus* over a large spatial range did not seem to affect confidence. It may be that sampling a large proportion of occurrences of the studied objects at the respective ranges is more important to reliability of the estimates than absolute sample size.

Unsurprisingly, estimates obtained through the use of finer scale maps provided more precise confidence intervals due to smaller areas of occupancy (10% or lower) than coarser ones that resulted in larger occupancy areas (from 20 to 45%). Similar results were also reported for plants in Malaysia (He & Gaston, 2000) and large mammals in South Africa (Tosh *et al.*, 2004), which seems to suggest that the maximum values of grid saturation able to produce reliable abundance estimates run around 10–20%.

Current theoretical (Kunin *et al.*, 2000) and empirical evidence (He & Gaston, 2007) suggests that NDB is not an adequate method to estimate abundance at geographical scales, but the results presented here contradict this affirmative. However, despite the positive results provided by the analysis using *B. hypoxanthus*, the fact that the method can produce reliable estimates does not guarantee that it should be readily applied to a wide range of species at geographical scales. *B. hypoxanthus* is an unusual species in that most, if not all, of the remaining populations are known and have fairly accurate abundance estimates obtained in the field. These two characteristics, along with its small geographical range, made it a good model species to test this method, but they are not shared by most of the known species, and so this method may not be applicable to the majority, since the correct location of existing populations, and even the knowledge of their existence, are requisites for method applicability.

Another limitation to using this method over geographical scales is the fact that only recent populations can be included in the database, since including localities without recently confirmed occurrences would result in false positives, thus overestimating the true abundance of the species. So, historical records must be used very carefully to produce abundance estimates, which reduces even more the number of species with available databases.

Despite the limitations on method applicability, it is still a valuable tool for global abundance estimation of species with restricted geographical ranges and whose populations are fairly well known, a situation quite common in threatened species. So this method could have great impact for conservation planning as it seems to be a quick and cheap approach to estimate the abundance of endangered species. For other applications of this method, such as macroecological and ecological theory testing, which involve species with wider geographical ranges or with incomplete distribution data, further development of the method is necessary, as pointed out by Kunin *et al.* (2000) and He & Gaston (2007).

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article.

Appendix S1 Localities of occurrence of *Brachyteles hypoxanthus*.