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BRIEF COMMUNICATION

How does the inclusion of Data Deficient species change conservation priorities for amphibians in the Atlantic Forest?

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Abstract Current knowledge is not sufficient to define extinction risk of Data Deficient (DD) species, and conservation planners may keep them out of conservation assessments and planning. However, systematic conservation planning may benefit with the inclusion of these species because they lead to more comprehensive conservation actions. Here, we investigated how the inclusion of DD species alters the spatial configuration of protected areas networks, using Atlantic forest amphibians as a case study. To investigate the influence of DD species inclusion, we developed three spatial conservation planning scenarios aiming to represent: (1) all threatened species; (2) all threatened species plus all DD species; and (3) all threatened species plus 30 % of DD species, following the proportion of threatened amphibian species worldwide. Our results show that the inclusion of DD species alters the spatial configuration of protected areas networks. Furthermore, there is a pattern with most cells in both planning scenarios for DD species being concentrated in the northern region of the Atlantic Forest. These cells are congruent with localities with recent description of DD species and might indicate sites with high potential for new species discoveries. The inclusion of DD species in systematic conservation planning may help to preserve important ecological traits and evolutionary features of biodiversity and indicate sites with high potential for future assessments and surveys. The use of DD species in conservation planning may help us to defy the Linnean shortfall and improve our knowledge about biodiversity.

Keywords Brazil · Biodiversity Hotspot · Systematic conservation planning · Spatial conservation prioritization · Extinction risk · IUCN

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Introduction

The International Union for the Conservation of Nature (IUCN) establishes a set of rules based on quantitative criteria to define species extinction risk (IUCN 1994). According to this rule-based method, species may be classified into one of eight different threat categories: Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC) and Data Deficient (DD) (IUCN 2001). The DD category is represented by species for which the available information is not sufficient to determine in which of the above-mentioned categories it should be classified into (IUCN 2001). From our incapacity to categorize such species, two important questions emerge: how many DD species are actually threatened? Should DD species be included in conservation assessment and planning? according to Mace et al. (2008), DD species should be afforded the same degree of protection as threatened species until more information is forthcoming, but this recommendation is usually ignored.

Systematic conservation planning tries to maximize the representation of important biological features (e.g. endemic species and habitat types) under a minimum or limited cost, to propose a set of priority sites for biodiversity protection (Margules and Pressey 2000). In some cases, conservation planners do not include DD species in such analyses (Fiorella et al. 2009, Loyola et al. 2009a), probably because information about their distribution or conservation status is still very uncertain. This uncertainty may affect the outcome of the analyses. However, one may argue that the inclusion of DD species in systematic conservation planning may change the spatial configuration of priority sites for biodiversity protection/management, therefore, providing indication of new sites to protect populations that may be threatened but still remain categorized as DD by science. Furthermore, one may advocate that these new sites would be an indicative of spatial knowledge deficiency (Brito 2010) and, consequently, these sites might have higher chances to hold undescribed species (Bini et al. 2006). This kind of comprehensive and conservative strategy may be important for the future persistence of DD species and, maybe, for yet unknown species. Therefore, a better understanding on how the inclusion of DD species might affect spatial conservation priorities may benefit future conservation actions to protect biodiversity.

Amphibians are an excellent taxonomic group for this kind of study because the group has a high number of DD species (ca. 25 %; 1,597 out of 6,285), as well as a significant number of threatened species (over 30 %; 1,895 out of 6,285) (IUCN 2011). Further, amphibian populations are declining worldwide (Eterovick et al. 2005; Stuart et al. 2004) and many amphibian DD species may be (or will likely be) under threat in the future (Becker and Loyola 2008), so they should be considered in conservation assessments and planning for biodiversity protection.

Here we developed systematic conservation planning scenarios for threatened amphibian species of the Atlantic Forest Biodiversity Hotspot to investigate the effects of including DD species on the spatial configuration of networks of priority sites for biodiversity protection. Our objectives are to tackle the following questions: (1) How does the inclusion of DD species change the spatial configuration of networks of priority sites? (2) How do the exclusion of sites unavailable for conservation (i.e. those without natural vegetation cover) and the inclusion of currently established protected areas change the networks of priority sites? (3) What benefits can we draw from the inclusion of DD species in spatial conservation prioritization?

Materials and methods

Study area and species data

We chose the Atlantic Forest as our case study because it is one of the 34 global Biodiversity Hotspots for conservation priorities (Mayers 1988, 1990, Mayers et al. 2000, updated by Mittermeier et al. 2004), having high rate of habitat loss (Teixeira et al. 2009)—one of the main factors that driving amphibians to extinction (Stuart et al. 2004; Becker et al. 2007). Further, almost 20 % of the Atlantic Forest amphibians (93 out of 431) are currently listed as DD species (IUCN 2011).

We retrieved species threat status and extent of occurrence maps from the IUCN Red List of Threatened Species database (IUCN 2011). We divided the Atlantic Forest into 11,461 equal-area grid cells of 0.1° × 0.1° latitude–longitude degree of spatial resolution (ca. 10.5 km side at the Equator) and used species' extent of occurrence maps to derive presence–absence matrices for threatened species and DD species along the entire biome. Eleven species are currently threatened (CR, EN or VU) in the Atlantic Forest, and 93 species are DD. Seventy percent of the species (86 out of 104) are endemics (Table S1).

Conservation planning scenarios

Conservation planning establishes specific targets for species representation as surrogate for species persistence over time. However, the requirements for survival vary markedly among species. For this reason, the exact thresholds used in our analyses for representing such targets do have a degree of arbitrariness. We used an approach recommended by Rodrigues et al. (2004) in which for a species with a geographic range smaller than 1,000 km^2, the representation target is 100 % of the range. For widespread species with a range size of more than 250,000 km^2, the target is 10 % of the range. For species with ranges of intermediate size, the target was interpolated between these two extremes using a log-linear regression (see Rodrigues et al. 2004 for details).

We used an optimization procedure to find the minimum set of sites capable of achieving the pre-determined targets mentioned above. Using this procedure, we developed three conservation planning scenarios: one to represent all threatened species, one to represent these species plus all DD species, and another one considering all threatened species plus random samples of 30 % of DD species. The decision to include all DD species is related with the suggestion that all DD species should receive the same degree of protection as threatened species (Mace et al. 2008), given the uncertainty of their extinction risk. The inclusion of 30 % of DD species is related to the global estimate of amphibian extinction risk, stipulated in 30 % by IUCN (2011). Given the uncertainty about DD species extinction risk, there are reasonable chances that, at least, 30 % of them might be truly under some degree of threat.

All conservation-planning scenarios were replicated in three analyses that vary in complexity. We developed three assessments: (1) an ideal one, in which we considered all grid cells as available for conservation, ignoring currently established protected areas; (2) an assessment in which we excluded all unavailable sites for conservation (i.e. those without remnant of natural vegetation cover); and (3) an assessment in which we included both habitat remnants and protected areas. We included only protected areas classified as I–IV IUCN categories (UNEP-WCMC 2010). We obtained data on natural vegetation cover from SOS Mata Atlântica, Instituto Nacional de Pesquisas Espaciais (2008).

To achieve the minimum set coverage in all conservation-planning scenarios we used the simulated annealing algorithm (Kirkpatrick et al. 1983) implemented in the MARXAN software (Possingham et al. 2000). The algorithm establishes an initial set of random areas and in each iteration swaps areas in and out of that set, measuring the change in cost according to a cost function. This procedure allowed us to identify minimum sets of sites to represent all species in the target group, and to compare different scenarios. Further, we did not control for cell aggregation in any of the three scenarios. For the three conservation-planning scenarios we set the optimization procedure parameters for 50 runs and one million iterations. Each run gave us a solution for the minimum set coverage for the group and each site had a frequency of occurrence when the 50 solutions were coupled. We used site selection frequency to create flexible minimum set coverage maps for all planning scenarios.

For the scenario considering all threatened species plus 30 % of DD species, we used the following approach to create the minimum set coverage map and to avoid spatial biases caused by any specific subset of DD species: (i) we created 50 random subsets of DD species, each one containing 30 % of the species of the entire DD pool; (ii) we included all threatened species into the subsets and ran a prioritization analysis for each new subset (i.e. 50 runs); (iii) for each prioritization analysis we took the best solution and found the number of times each cell occurred in the 50 best solutions; (iv) for each cell we divided this number of occurrences by the number of solutions (50) to achieve the site selection frequency under this scenario. A higher value of selection frequency indicates that a site is present in a great number of solutions and it is important for conservation-planning, being an estimate of site irreplaceability.

Spatial and temporal trends in DD species description

Finally, we assessed the year of description of amphibian DD species and associated them with grid cells to describe the spatial and temporal trends in descriptions. We obtained the year of description from the IUCN database (IUCN 2011). Description dates do not have a normal distribution and mean values are not representative. Therefore, we used the median of description date for each cell and plotted these values in a map of the Atlantic Forest to evaluate spatial and temporal trends in the description. Median values were calculated only for cells with three or more records of description dates.

Results

Our analyses indicate that 5.3–11.1 % of the Atlantic Forest should be protected to represent all threatened amphibians, depending on the conservation planning scenario and the complexity of the assessment (Table 1; Fig. 1a, d, g). This amount of area to be protected increases to 6.3 and 11.9 % when we included 30 % of DD species (Table 1; Fig. 1c, f, i), and 24.8 and 28.1 % when all DD species are included (Table 1; Fig. 1b, e, h).

Beyond the number of sites, the inclusion of DD species points to new directions for the selection of priority areas, in any conservation scenario (Fig. 1). While sites identified as priority to represent all threatened amphibians are concentrated in the central region of the Atlantic Forest with a few sites in the south, sites needed to represent these species plus all or 30 % of DD species are spread all over the biome with the majority of new sites located in the northern region of the Atlantic Forest.

Table 1 Comparison among each conservation planning scenario developed under three assessments that vary in complexity, number of priority cells with selection frequency higher than 75 %, the extension of prioritized area in the Atlantic Forest, percentage of prioritized area within protected areas (PAs), and percentage of additional area required to complement the level of representation already covered by protected areas

Complexity of assessment	Planning scenarios	Number of cells	% of prioritized area	% of overlap with PAs	% area to complement PAs
Ideal scenario	Only threatened species	699	6.1	1.4	na
	Threatened species + all DD	3224	28.1	3.7	na
	Threatened species + 30 % DD	759	6.6	1.5	na
Considering natural remnants	Only threatened species	609	5.3	1.2	na
	Threatened species + all DD	2846	24.8	3.4	na
	Threatened species + 30 % DD	725	6.3	1.4	na
Considering natural remnants + PAs	Only threatened species	1272	11.1	7.2	3.9
	Threatened species + all DD	3030	26.4	7.1	19.3
	Threatened species + 30 % DD	1365	11.9	7.2	4.7

Overlap between currently established protected areas and our spatial solutions is fairly small (Table 1). The percentage of priority sites that overlap with protected areas ranged from 1.2 to 3.7 % depending on the inclusion of all DD species or 30 % of them as well as the inclusion or exclusion of unavailable sites for conservation. When protected areas are included in the optimization process, this overlap increases to 7.2 %, which is expected since protected areas are forced to appear in the final solution.

The percentage of area needed to complement species representation attained by protected areas varies from 3.9 to 19.3 % (Table 1). When all threatened species and all DD species are considered, the total area that need to be protected is higher, and consequently, the area needed to complement protected area representation is also higher.

Our findings also show that there was a spatial pattern associated with the description dates of amphibian DD species in the Atlantic Forest. Despite the fact that some new species descriptions have occurred in the central or western regions of the biome, most of them occurred in the northern region (Fig. 2).

Discussion

Some recent studies have called the attention to the need of including species evolutionary history (e.g. Forest et al. 2007; Loyola et al. 2008a) and biological traits (e.g. Loyola et al. 2008a, b, 2009b; Becker et al. 2010; Carvalho et al. 2010; Loyola and Diniz-Filho 2010) in conservation planning, as a way to preserve communities more diversified in their history and ecology. If we decide to keep DD species out of conservation assessments and planning we assume the risk that important ecological traits and evolutionary features might be lost if these species turn out to be threatened and not protected, a possible scenario for several amphibian species around the world. In this way, their inclusion in systematic conservation planning may guarantee that biodiversity protection is maximized in the future. Moreover, the inclusion of DD species in spatial conservation planning may give different directions to pinpoint new sites for future conservation assessments.

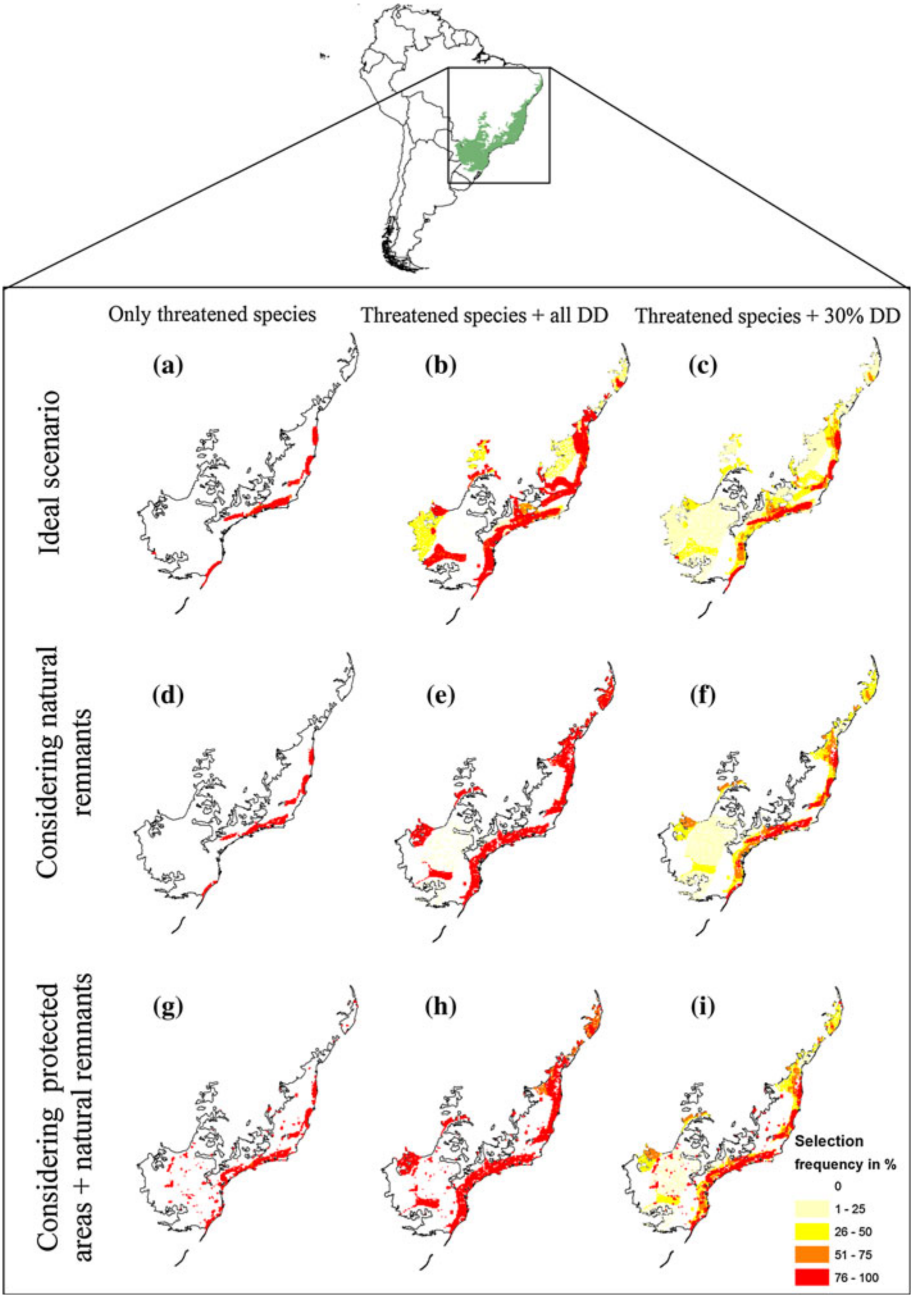

Fig. 1 Maps showing site (grid cell) selection frequency obtained in three different systematic conservation planning scenarios to safeguard (**a**, **d**, **g**) threatened amphibian species, (**b**, **e**, **h**) threatened species plus all data deficient species, and (**c**, **f**, **i**) threatened species plus 50 random samples of 30 % of Data Deficient species of the Atlantic Forest Biodiversity Hotspot. *Red cells* have higher values of irreplaceability

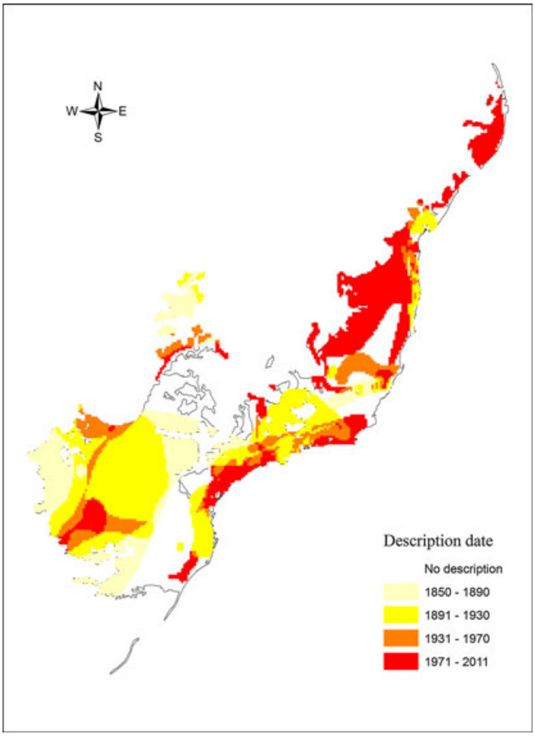

Fig. 2 Map showing the spatial trend in DD species description in the Atlantic Forest Biodiversity Hotspot. *Red cells* indicate more recent species descriptions

Our findings demonstrate that the inclusion of DD species in systematic conservation planning alters the spatial configuration of the solution. For example, when we included all or 30 % of DD species, most cells in both priority sets were located in the northern region of the Atlantic Forest, areas not tagged as important when only threatened species were considered. A recent analysis showed that the DD label, applied to a taxonomic entity (species), also seems to reflect a spatial knowledge deficiency (Brito 2010). Pinto and Grelle (2011) showed that point occurrence data are more associated with human population size than expected by chance alone, and Bini et al. (2006) have shown that areas with low biodiversity knowledge have higher probabilities to present new species discoveries. Therefore, if we include DD species in systematic conservation planning, we may increase our chances to protect localities not only with known species but also with species still unknown by science.

Recent descriptions of new amphibian species in the Atlantic Forest are concentrated in the northern region of the biome, a region that is probably undersampled because past surveys possibly directed their efforts to sites that are historically recognized as having greater values of biodiversity (Sastre and Lobo 2009), and also because the majority of research institutions and herpetologists in Brazil are concentrated in the southeastern region of the country. Araújo et al. (2009) call attention that even in São Paulo, one of the best-studied regions in Brazil, we can predict that there are many amphibian species yet to be described. Our findings show that sites indicated to DD species protection correspond to sites where new species descriptions have been made. Therefore, we reinforce the idea that including DD species in systematic conservation plans may help to preserve sites with great probabilities of holding species still unknown to science (Brito 2010) and to minimize the deleterious consequences of our ignorance on the number of living species, the so-called Linnean Shortfall (Whitakker et al. 2005).

Two other issues about the inclusion of DD species in conservation planning deserve attention: the increase in the number of sites and the implications of using all or only 30 % of amphibian DD species in the analyses. The increase in the number of priority sites when DD species are included is an expected change in priority-site networks given that we increase the number of target species to be represented (the more species you aim to represent the more sites you need to achieve such aim). However, the main focus of our study was not on the size of protected area networks, but on their spatial configuration and the relationships with spatial trends in new species discoveries. Despite the fact that our goal is to protect as much biodiversity as possible, we showed that including only 30 % of amphibian DD species in conservation plans could be a good starting point. With such action, we were able to represent 76 (84 %) of the sites represented in the solution with all DD species, and to identify the change in spatial pattern, where most priority sites tended to be located in the northern region of the Atlantic Forest.

Threatened by habitat loss and fragmentation, global climate change and diseases (Young et al. 2001; Pounds et al. 2006), amphibian populations are declining fast and conservation biology must direct its strategies to conserve as most species as possible (Becker and Loyola 2008; Brito 2008). Our approach demonstrated that, until we have more knowledge about DD species, conservation strategies may benefit with their inclusion in systematic conservation planning, not only for the conservation of species *per se*, but because they are likely to pinpoint sites with high potential to hold new species, increasing our knowledge about amphibian biodiversity.

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