ORIGINAL PAPER

Reserve selection and persistence: complementing the existing Atlantic Forest reserve system

Míriam Plaza Pinto · Carlos Eduardo Viveiros Grelle

Abstract This study is an exercise to check the efficiency of the existing reserve system, and to show how systematic conservation planning—using information available and the complementarity concept—can improve the basis for decisions and minimize costs. We verified the performance, in number of cells and primate species representation, of the existing Atlantic Forest (Brazil) reserve network with a quarter-degree resolution grid, with 1,884 cells. We used occurrence data of 20 endemic primate species, and the maps of 237 existing reserves. Reserve networks were selected to represent primate species first considering no pre-existing reserves in Atlantic Forest, and then, considering the existing reserve system, taking into account the minimum area for viable population of the larger species (Northern muriqui *Brachyteles hypoxanthus*). Reserve selection was carried out using the complementarity concept implemented by a simulated annealing algorithm. Primate species representation (at least one occurrence in the network) could be achieved with 8% of the existing reserve system (nine cells in relation to the 120 in the existing reserve system). We found that today's reserve system represents 89% of endemic primate species, excluding the species Coimbra Filho's titi monkey (*Callicebus coimbrai*) and Marcgraf's capuchin (*Cebus flavius*). The networks selected without considering existing reserves contained nine cells. The networks selected considering existing reserves (120 cells), had two new cells necessary to represent all the primates. This does not mean that a viable alternative is to start from zero (i.e., nonexistent reserves). Identifying critical supplementary areas using biodiversity information to fill the gaps and then starting "conservation in practice" in these areas should be priorities.

Keywords Brazilian Atlantic forest · Complementarity · Efficiency · Gap analysis · Irreplaceability · Primates · Simulated annealing

M. P. Pinto (✉)
Programa de Pós-Graduação em Ecologia, Laboratório de Vertebrados, Departamento de Ecologia, Universidade Federal do Rio de Janeiro, Cx. P. 68020, Rio de Janeiro, RJ CEP 21941-590, Brazil
e-mail: miriamplazapinto@yahoo.com.br

C. E. V. Grelle
Laboratório de Vertebrados, Departamento de Ecologia, Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brazil
e-mail: grellece@biologia.ufrj.br

Introduction

Reserve selection has traditionally occurred opportunistically without a priori definition of explicit objectives for biodiversity conservation (Pressey et al. 1993; Pressey 1994). In general, areas of low economic value or with scenic, cultural, indigenous, and recreational value have been selected for reserves. Reserves are often selected individually, as if they were not part of a reserve network. However, nowadays it is known that the use of explicit criteria to establish reserves results in more efficient strategies for biodiversity conservation (Pressey et al. 1993; Possingham et al. 2000; Diniz-Filho et al. 2007; Pinto et al. 2007).

Networks with too many areas, but not guarantying the representation of the elements of biodiversity, are the main consequence of reserve selection without explicit objectives (Pressey 1994). Efficient selection of priority areas for conservation should represent all conservation targets with the minimum possible cost (the area—or the number of areas when we have a regular grid—is frequently used as a measure of cost when economic costs are not considered in the study; Cabeza and Moilanen 2001; Lawler et al. 2003). This reserve selection problem is currently solved using algorithms based on the concept of complementarity (Margules et al. 1988; Margules and Pressey 2000). Complementarity measures the extent to which an area contributes to the representation of underrepresented features in the existing set of areas (Pressey et al. 1993; Margules and Pressey 2000). A single reserve solution gives no indication of the importance of each site because usually there are many alternative networks that can meet targets; then the frequency of occurrence of the cells in these alternative networks may be more informative. This metric is related to the irreplaceability concept, and measures the potential of replacing a site with others in the region (Pressey et al. 1994; Ferrier et al. 2000).

The Atlantic Forest biome contains several reserves of different sizes in the coastal and interior region. This biome is a species-rich global hotspot, an area with several endemic species of plants (40% of the plants from this biome are endemic) and high conversion rates (Myers et al. 2000). For example, Atlantic forest is the home of a diversified and unique fauna of primates (Rylands et al. 1996). Extinction rates are likely to be higher in biodiversity hotspots which are geographically restricted with high species endemism, heavy habitat loss and rapidly increasing human populations (Cincotta et al. 2000). Tropical forest hotspots have already lost, on average, 90% of their forest cover (Brooks et al. 2002; see also Laurence 2007), including the forest reduction of Atlantic forest (Grelle et al. 1999). As result of this forest reduction, many species of vertebrates are faced with extinction (Grelle et al. 1999, 2005; Brooks et al. 2002), and the Order Primates has the highest number of threatened species of all Brazilian mammals (Grelle et al. 2006). Taxonomy of the primates species Atlantic forest are well defined, and the species occur in evergreen and semidecidous forests along Atlantic forest, in more than 600 localities (Grelle 2000; Silva-Junior 2001; Oliveira and Langguth 2006).

A contentious point, less explored in analysis of reserve selection, is the viability of populations (Gaston et al. 2002; Pressey et al. 2007). It is clear that we should preserve more than species, and ecological and evolutionary processes should be taken into account in the planning of a reserve network. Thus, the reserve network should be efficient to maintain viable populations. In addition, recently a population viability analysis was performed on the northern muriqui (*Brachyteles hypoxanthus*, Brito and Grelle 2006). Endemic to the Atlantic forest, this species and the congeneric southern muriqui (*B. arachnoides*) are the larger primates of this biome. An area of at least 11,570 ha is required to maintain a genetically viable population of *B. hypoxanthus* (Grelle 2006). This

information can be used to test the efficiency of the Atlantic Forest reserve network for primates, since it is the minimum area necessary for the larger endemic primate species, and assuming that the size of the area needed to maintain viable populations is directly related to the body size of the species. Thus, primates represent a useful group to test the efficiency of the existing reserve system in Atlantic forest, paying attention to the viability of populations.

There are several studies in systematic conservation planning research that verify if existing reserves represent some part of biodiversity, a task commonly known as gap analysis (Rodrigues et al. 2004; O'Dea et al. 2006; Araújo et al. 2007; Ceballos 2007), including a recent study performed with South American mammals (Tognelli 2007). But there is no study focusing on Atlantic Forest primates, a group with many threatened species in a threatened hotspot. Does the existing Atlantic Forest reserve system efficiently represent all primate species? We verified the performance of the existing Atlantic Forest reserve network in representing primate species. Then we used primate occurrence data to select reserve networks based on the complementarity concept to complement the existing reserve system.

Materials and methods

A grid with a quarter-degree cell resolution was superimposed on the map of the Atlantic Forest biome in Brazil. We excluded all cells that contained >50% of Atlantic Forest; this left a total of 1,884 cells. In each of these cells, reserve areas were calculated using maps of strict reserves (those that correspond to the I—IV categories defined by IUCN) overlaid by the grid. When a reserve occupied more than one cell its area was calculated separately in each cell. Two reserves with any area that occupied the same cell had that areas summed.

There are 20 species of primates endemic to Atlantic forest: brown howler monkey (*Alouatta guariba*), southern muriqui (*Brachyteles arachnoides*), northern muriqui (*B. hypoxanthus*), Coimbra Filho's titi monkey (*Callicebus coimbrai*), coastal black-handed titi (*C. melanochir*), black-fronted titi monkey (*C. nigrifrons*), masked titi (*C. personatus*), Barbara Brown's titi (*C. barbarabrownae*), buffy-tufted-ear marmoset (*Callithrix aurita*), buffy-headed marmoset (*C. flaviceps*), Geoffroy's marmoset (*C. geoffroyi*), wied's black-tufted-ear marmoset (*C. kuhlii*), Marcgraf's capuchin (*Cebus flavius*), black-horned capuchin (*C. nigritus*), crested capuchin (*C. robustus*), yellow-breasted capuchin (*C. xanthosternos*), black-faced lion tamarin (*Leontopithecus caissara*), black lion tamarin (*L. chrysopygus*), golden lion tamarin (*L. rosalia*), and golden-headed lion tamarin (*L. chrysomelas*). Occurrence data of these 20 endemic primate species from this biome was previously obtained elsewhere (Grelle 2000; Silva Junior 2001; Oliveira and Langguth 2006), and this dataset can be obtained upon request to the authors. The species *Callicebus barbarabrownae*, although considered endemic to the Atlantic forest (Kobayashi 1995), was excluded from the analysis because its occurrence was not detected in the biome map used, probably due to the scale of map. This species occurs in semi-decidous forests along rivers inside Caatinga biome (Marinho-Filho and Veríssimo 1997). The georeferenced data were converted to presence/absence data in the grid cells which are the units of analysis. In each cell, richness was calculated by summing the number of species present.

Complementarity reserve selection has two basic purposes. The first is to find reserve networks that represent target amounts of all biodiversity information used in the study. And the other purpose is to find networks with the minimum possible cost (Possingham

et al. 2006), in this case, the minimum number of cells. We selected reserve networks to represent primate biodiversity through the following three approaches:

Approach A—Considering no pre-existing reserves (put at zero—no cell was included *a priori* in the network);

Approach B—Grid cells with more than 5,000 ha of existing reserves were accounted for in the network;

Approach C—Grid cells with more than 11,500 ha of existing reserves were accounted for in the network.

We chose 11,500 ha area because it is the minimum area needed for viable populations for the larger primate species, and 5,000 ha area trying to incorporate some reality related to actually reserves sizes (see more about this in Discussion). Protected areas covering less than 5,000 ha (in approach B) and 11,500 ha (in approach C) were not considered present in he network.

In approaches B and C we verified which primate species were represented by the existing reserve cells considered. These considered pre-existing reserves do not represent all the primate species and were complemented with new areas. We also compared the Atlantic Forest reserve network efficiency with what would be expected by chance from random networks with the same number of cells selected 10,000 times.

Reserve selection was carried out using the simulated annealing algorithm in SITES software (which is an ArcView interface for the MARXAN software; Andelman et al. 1999; Possingham et al. 2000, 2006). The simulated annealing algorithm optimizes objective functions with explicit conservation goals. It was run 200 times with 10,000,000 iterations for each approach. Most of the solutions—called here best solutions—represented all the primate species with the minimum number of cells, but some did not. So, we took the 100 first best solutions to map the irreplaceability of the cells. A simple measure of irreplaceability is the frequency of each cell in the networks selected, indicating its relative importance for complementarity solutions (Meir et al. 2004). The highest degree of irreplaceability is when a cell occurs in the 100 representation solutions.

Results

The richest cells for the endemic primate species are widely spread over the Atlantic Forest biome; some concentrated in the mideast region and one cell in Bahia state, in the northeast region (Fig. 1). The species *Cebus nigritus* has the highest number of occurrences, in 119 cells (Table 1). In contrast, *Callicebus coimbrai* and *Leontopithecus caissara* occurred in just three cells of this biome (Table 1).

The networks selected in approach A, where the existing reserve system was not considered, contained nine cells. This is the minimum number of cells necessary to represent all endemic primate species in Atlantic Forest. The irreplaceability map (Fig. 2) shows that this system is very flexible. Only one cell in the northeast region has the highest irreplaceability value, occurring in 78 of 100 solutions.

Considering all the cells with more than 5,000 ha of existing reserves (approach B), we have 120 cells previously put in the network of actual reserves. These cells represented 89% of primate species, more than expected by chance ($P = 0.004$) when compared to the representation of 10,000 reserve networks with 120 cells (Fig. 3a). The species *Callicebus coimbrai* and *Cebus flavius* were not represented in this reserve system. The networks selected to complement this system contained two new cells (Fig. 4). The new cells were in
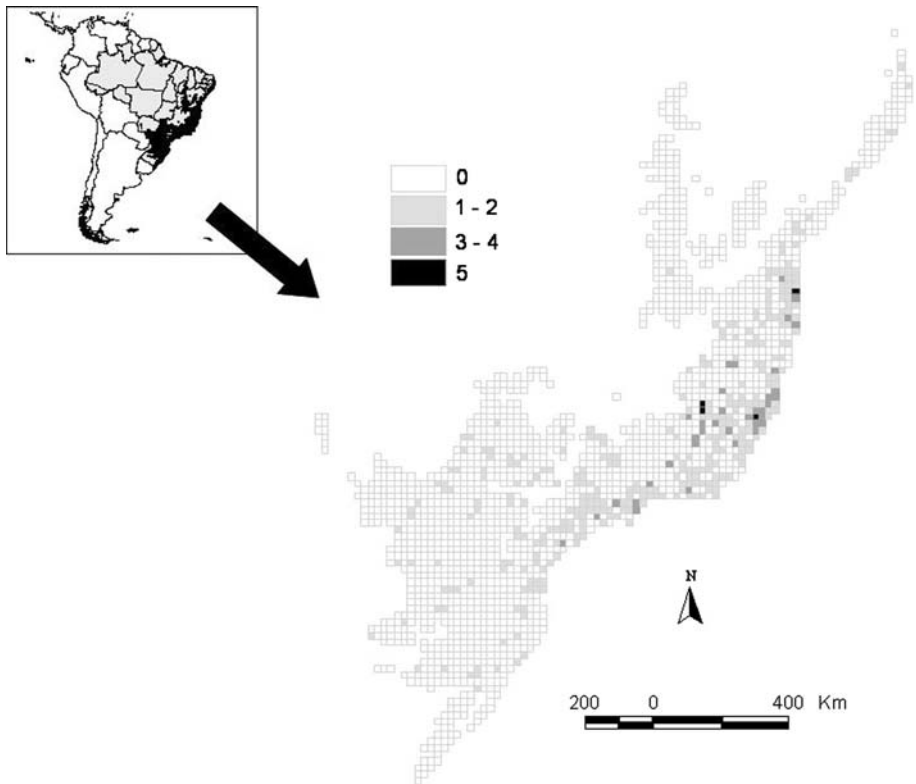
Fig. 1 Spatial pattern of endemic primate richness in the Atlantic Forest biome, in number of species

the northeast region and are not completely irreplaceable, allowing several options between adjacent cells.

Seventy-seven cells were considered having more than 11,500 ha of existing reserves (approach C). This reserve system represented 68% of primate species, not more than expected by chance alone ($P = 0.1359$) when compared to the representation of primate species in 10,000 reserve networks with 77 cells (Fig. 3b). The underrepresented species were *Callicebus coimbrai*, *Callithrix kuhlii*, *Callicebus melanochir*, *Cebus xanthosternos*, *Leontopithecus chrysomelas*, and *Cebus flavius*. The networks selected to complement this system contained three new cells (Fig. 5). The new cells are not completely irreplaceable, allowing several options between adjacent cells, and are located on the coast of the northeast region.

Discussion

This study has a conservative approach from the viewpoint we used point locality data (Rondinini et al. 2006; see also O'Dea et al. 2006), but even then the networks selected to represent primates are flexible; none of the cells were completely irreplaceable. The low commission errors of using point locality data increase our confidence that the areas selected will contain the target species. The use of species range in this assessment would

Table 1 Species included in the reserve selection procedures

Species (scientific name)	Number of occurrences (number of cells)	States of occurrence	Number of representations in the existing reserves (approach B)	Numbers of representations in the existing reserves (approach C)
Alouatta guariba	83	BA, MG, ES, RJ, SP, PR, SC, RS and Argentina	9	7
Brachyteles arachnoides	29	RJ, SP and PR	12	9
Brachyteles hypoxathus	27	BA, MG, and ES	5	2
Callicebus coimbrai	3	SE	0	0
Callicebus melanochir	12	BA, MG and ES	1	0
Callicebus nigrifrons	22	MG, RJ and SP	2	2
Callicebus personatus	20	MG and ES	4	3
Callithrix aurita	59	MG, RJ and SP	11	7
Callithrix flaviceps	16	MG and ES	1	1
Callithrix geoffroyi	47	MG, BA and ES	4	3
Callithrix kuhlii	15	BA and MG	1	0
Cebus flavius	4	RN, PB and AL	0	0
Cebus nigritus	119	MG, ES, RJ, SP, PR, SC, RS, and Argentina	19	11
Cebus robustus	28	BA, MG and ES	6	4
Cebus xanthosternos	12	BA	1	0
Leontopithecus caissara	3	SP and PR	1	1
Leontopithecus chrysomelas	19	BA	2	0
Leontopithecus chrysopygus	6	SP	2	2
Leontopithecus rosalia	11	RJ	1	1

Brazilian States abbreviations *AL* Alagoas, *BA* Bahia, *ES* Espírito Santo, *MG* Minas Gerais, *PB* Paraíba, *PR* Paraná, *RJ* Rio de Janeiro, SC Santa Catarina, *SE* Sergipe, *SP* São Paulo, *RN* Rio Grande do Norte, *RS* Rio Grande do Sul

increase type I errors; the species is considered to be present in the cell or in the reserve when, in fact, it is not (O'Dea et al. 2006). Incompleteness and spatial bias towards places recorded are the main problems of point locality data (Rondinini et al. 2006), but we preferred to maintain a conservative approach in this study. Networks selected using point locality data are larger than when range distributional data are used. Even then, the reserve network found in Approach A is smaller than the existing reserve system. This reserve network size is partially explained by the targets stated in the methodology—at least one point locality of each species must be in the networks selected. From this viewpoint—targets stated—the study approach is not conservative. A more conservative approach would require more than one point locality representation of each species.

In our dataset, all species occur in more than one cell. This explains the fact that none of the cells is completely irreplaceable, or clearly, that all the cells selected in one solution can be replaced by another cell in another solution. When a species occurs in just one cell, this cell is irreplaceable by definition, because only that cell can represent that species
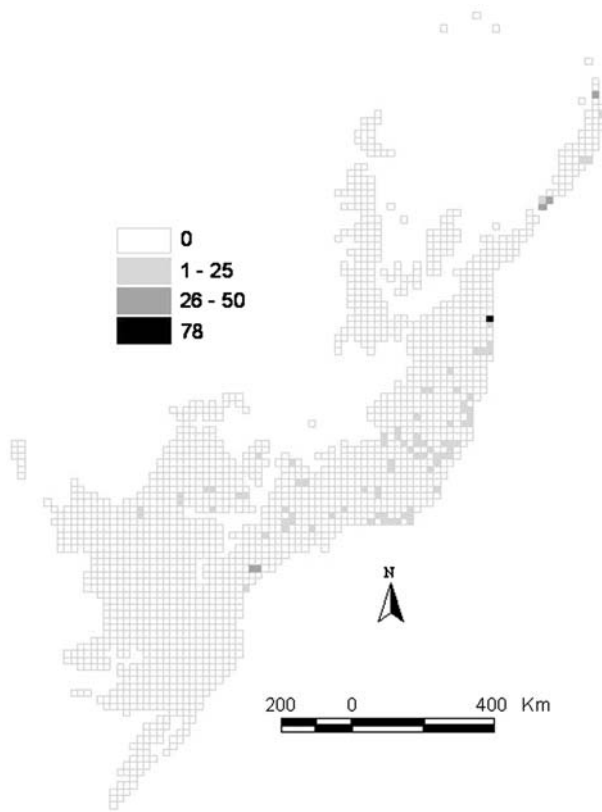
Fig. 2 Irreplaceability map of approach A, considering no existing reserves in Atlantic Forest, obtained using the 100 best reserve networks solutions

(Carwardine et al. 2007). The species with the fewest number of occurrences were *Callicebus coimbrai* and *Leontopithecus caissara*, which occurred in three cells. These two species are classified as Critically Endangered (IUCN 2007); the first one is known to occur at only six small forests fragments in the state of Sergipe, where 99% of the forests have been destroyed, and the second one is a rare species (IUCN 2007).

Primate species representation could be achieved with 7.5% (nine cells) of the existing reserve system (120 cells), if we previously consider reserves with more than 5,000 ha, or with 11.7% (nine cells) of the existing reserves (77 cells), if we previously consider those with more than 11,500 ha. Some existing reserves from Atlantic Forest do not contain any primate species, as the dry forests reserves from the interior region of the biome. If the system were put at zero, efficiency in cost and representation would probably be achieved in a smaller network (Fig. 2), even with the incorporation of more realistic criteria such as persistence (Araújo et al. 2004) or sociopolitical factors (Williams et al. 2003). Using the area of the cell as an indicator of cost—like we did here—is effective to minimize reserve network size, but is not a direct minimization of land value costs (Underwood et al. 2008), which is also an important topic to be considered in conservation planning (Bode et al. 2008). A grid cell that is very prone for agriculture practices can be selected in our study (but we do not know since this data was not considered), but it would not enter in a
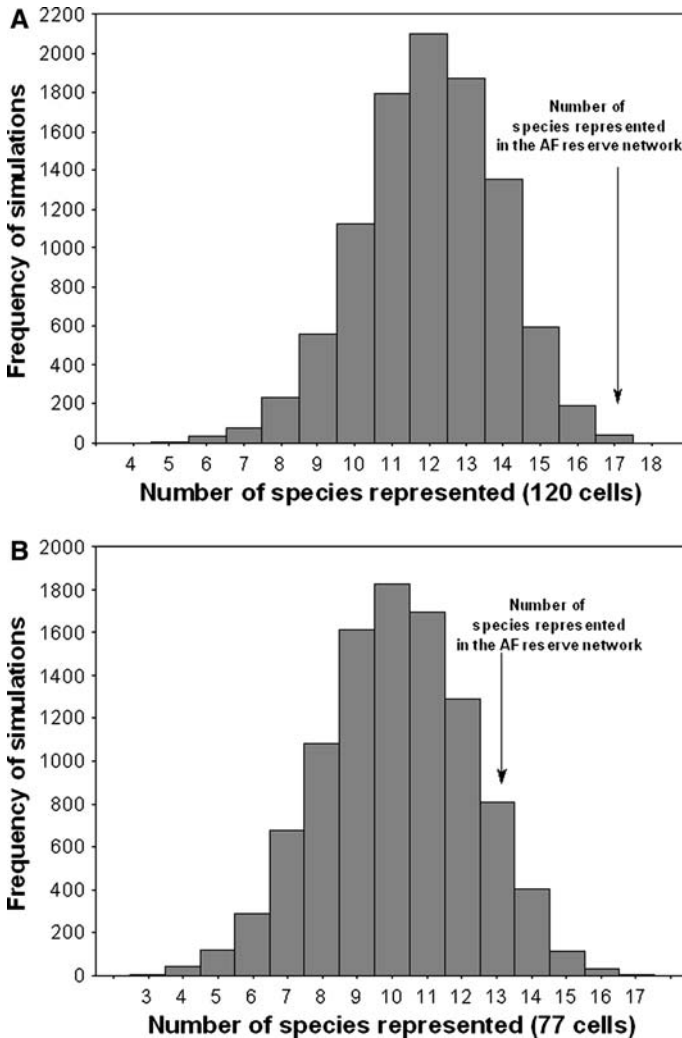
Fig. 3 Frequency distribution of number of primate species represented in 10,000 random networks with 120 cells (**a**) and with 77 cells (**b**)

network selected considering land value, unless one of the target species just occurs in that expensive cell.

The minimum reserve area that determines whether a cell is always included in the network can be chosen in relation to minimum area necessary for a viable population, guaranteeing its persistence. But this criterion varies from species to species in multiple species reserve selection approaches. Here we used two minimum reserve sizes (5,000, and 11,500 ha) as criterion to consider the conservation unit in the reserve network. 11,500 ha is the minimum area necessary to house viable populations of *Brachyteles hypoxanthus*, without suffering demographic stochasticity and genetic erosion (Brito and Grelle 2006). However, the average size of the actual existing Atlantic Forest reserves is 10,200 ha (Pinto et al. 2006), and most reserves in the Atlantic Forest are less than 10,200 ha (Silva
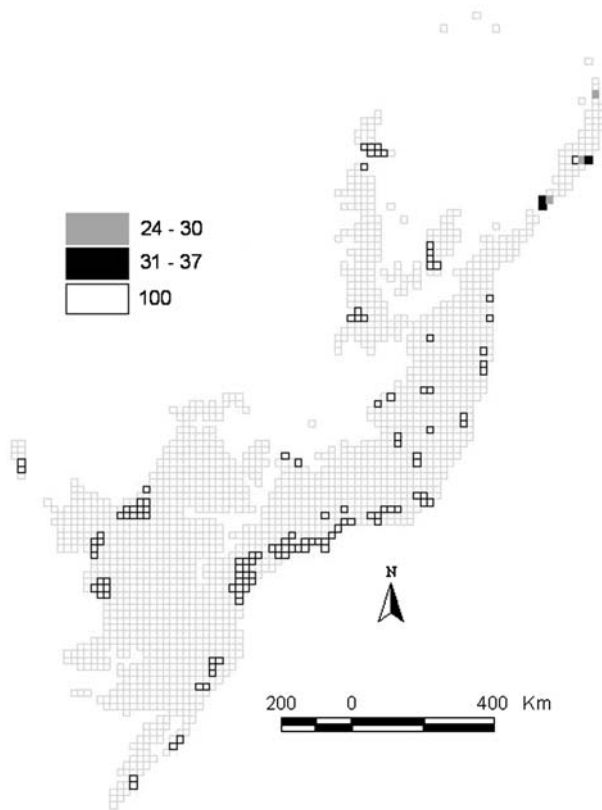
Fig. 4 Irreplaceability map of approach B solutions, previously considering cells with more than 5,000 ha of existing reserves, obtained using the 100 better reserve networks solutions. *Cells outlined*, that occur in 100 of the 100 networks, are those forced to be selected in the network

and Casteleti 2003). This generates a frequency distribution of reserve areas skewed to right, with the median much smaller than the mean. Thus, if we used just approach C (see "Methods") a lot of actual reserves would not be considered in our analysis of reserve selection. So we also fixed cells with more than 5,000 ha reserves in approach B.

It is important to note that when we only consider reserves with at least 11,500 ha, some species from the southeast coastal region are not represented. This can be observed in the irreplaceability map (Fig. 5), since new reserves to complement the actual system were selected in the southeast region. The randomizations tests also demonstrated that the 5,000 ha reserve area per cell system represents more primate species than expected by chance. But when the minimum viability area for the larger primate species is used as a criterion of area, the 11,500 ha reserve area per cells network—that is smaller, obviously— does not represent more primates than expected by chance. Thus, the realistic approach actual reserve network is relatively effective, but the persistence one is definitely not.

The fact that a smaller network could be achieved does not mean that a good alternative is to ignore the existing reserve network; this would be neither practical nor sensible (Pressey and Cowling 2001). Existing reserves may have existing infrastructure and management as well as legal protected status, and also may be recognized and respected by
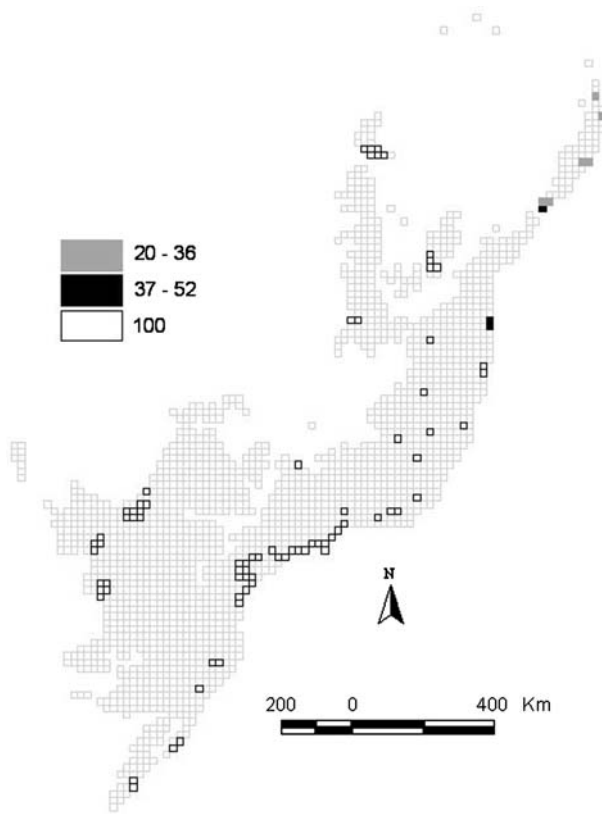
Fig. 5 Irreplaceability map of approach C solutions, previously considering cells with more than 11,500 ha of existing reserves, obtained using the 100 better reserve networks solutions. *Cells outlined*, that occur in 100 of 100 networks, are those forced to be selected in the network

local people with whom relationships have been established (O'Dea et al. 2006). These areas may also have biological importance; although we are evaluating here the primate biodiversity, this is just a little piece of the spectrum of biodiversity that must be conserved in Atlantic Forest. We exercise here a check of quality and efficiency of the existing reserve system, and try to stimulate the use of analytical tools and available information to improve the basis on which conservation decisions are made (Whittaker et al. 2005). Identifying critical supplementary areas needed to fill the gaps should be a priority (O'Dea et al. 2006). Otherwise, we can consider that the Atlantic Forest network relatively represents primate biodiversity considering it was not selected with that purpose.

The existing reserve system of Atlantic Forest is not cost-effective. A hypothetic reserve selection ignoring existing reserves clearly shows this. Even though the existing reserve system is large for the information used and for the targets stated in this study and not efficient for primate conservation, the incorporation of explicit objectives and targets from now on would effectively help systematic conservation planning.

References

Andelman S, Ball I, Davis F, et al. (1999) SITES v. 1.0: an analytical toolbox for designing ecoregional conservation portfolios. Technical report, The Nature Conservancy, Australia. Available via http://www.biogeog.ucsb.edu/projects/tnc/toolbox.html

Araújo MB, Williams PH, Cabeza M et al (2004) Would climate change drive species out of reserves? An assessment of existing reserve-selection methods. Glob Change Biol 10:1618–1626. doi:10.1111/j.1365-2486.2004.00828.x

Araújo MB, Lobo JM, Moreno JC (2007) The effectiveness of Iberian protected areas in conserving terrestrial biodiversity. Conserv Biol 21:1423–1432

Bode M, Wilson KA, Brooks TM et al (2008) Cost-effective global conservation spending is robust to taxonomic group. Proc Natl Acad Sci USA 105:6498–6501. doi:10.1073/pnas.0710705105

Brito D, Grelle CE (2006) Estimating minimum area of suitable habitat and viable population size for the northern muriqui (Brachyteles hypoxanthus). Biodivers Conserv 15:4197–4210. doi:10.1007/s10531-005-3575-1

Brooks TM, Mittermeier RA, Mittermeier CG et al (2002) Habitat loss and extinction in the hotspots of biodiversity. Conserv Biol 16:909–923. doi:10.1046/j.1523-1739.2002.00530.x

Cabeza M, Moilanen A (2001) Design of reserve networks and the persistence of biodiversity. Trends Ecol Evol 16:242–248. doi:10.1016/S0169-5347(01)02125-5

Carwardine J, Rochester WA, Richardson KS et al (2007) Conservation planning with irreplaceability: does the method matter? Biodivers Conserv 16:245–258. doi:10.1007/s10531-006-9055-4

Ceballos G (2007) Conservation priorities for mammals in megadiverse Mexico: the efficiency of reserve networks. Ecol Appl 17:569–578

Cincotta RP, Wisnewski J, Engelman R (2000) Human population in biodiversity hotspots. Nature 404:990–992. doi:10.1038/35010105

Diniz-Filho JAF, Bini LM, Pinto MP et al (2007) Conservation biogeography of anurans in Brazilian Cerrado. Biodivers Conserv 16:997–1008. doi:10.1007/s10531-006-9010-4

Ferrier S, Pressey RL, Barret TW (2000) A new predictor of irreplaceability of areas for achieving conservation goals, its application to real-world planning, and a research agenda for further refinement. Biol Conserv 93:303–325. doi:10.1016/S0006-3207(99)00149-4

Gaston KJ, Pressey RL, Margules CR (2002) Persistence and vulnerability: retaining biodiversity in the landscape and in protected areas. J Biosci 27(suppl 2):361–384. doi:10.1007/BF02704966

Grelle CEV (2000) Aerografia de primatas endêmicos da Mata Atlântica Tese de Doutoramento Museu Nacional, Universidade Federal do Rio de Janeiro, Rio de Janeiro

Grelle CEV, Fonseca GAB, Fonseca MT et al (1999) The question of scale in threat analysis: a case study with Brazilian mammals. Anim Conserv 2:149–152. doi:10.1111/j.1469-1795.1999.tb00060.x

Grelle CEV, Alves MAS, Bergallo HG et al (2005) Prediction of threatened tetrapods based on the species-area relationship in Atlantic forest. J Zool (Lond) 265:359–364. doi:10.1017/S0952836905006461

Grelle CEV, Paglia AP, Silva HS (2006) Análise dos fatores de ameaça à extinção estudo de caso com mamíferos brasileiros. In: Rocha CFD, Bergallo HG, van Sluys M et al (eds) Biologia da conservação essências. RiMa, São Carlos

IUCN (2007)The World Conservation Union. 2007 IUCN red list of threatened Species. http://www.iucnredlist.org. Cited on 02 October 2008

Kobayashi S (1995) A plylogenetic study of titi monkeys, genus Callicebus, based on cranial measurements: i phyletic groups of Callicebus. Primates 36:101–120. doi:10.1007/BF02381918

Laurance WF (2007) Have we overstated the tropical biodiversity crisis? Trends Ecol Evol 22:65–70. doi:10.1016/j.tree.2006.09.014

Lawler JJ, White D, Master LL (2003) Integrating representation and vulnerability: two approaches for prioritizing areas for conservation. Ecol Appl 13:1762–1772. doi:10.1890/02-5337

Margules CR, Pressey RL (2000) Systematic conservation planning. Nature 405:243–253. doi:10.1038/35012251

Margules CR, Nicholls AO, Pressey RL (1988) Selecting networks of reserves to maximise biological diversity. Biol Conserv 43:63–76. doi:10.1016/0006-3207(88)90078-X

Marinho-Filho J, Veríssimo EW (1997) The rediscovery of Callicebus personatus barbarabrownae in northeastern Brazil with a new western limit for its distribution. Primates 38:429–433. doi:10.1007/BF02381883

Meir E, Andelman S, Possingham HP (2004) Does conservation planning matter in a dynamic and uncertain world? Ecol Lett 7:615–622. doi:10.1111/j.1461-0248.2004.00624.x

Myers N, Mittermeier RA, Mittermeier CG et al (2000) Biodiversity hotspots for conservation priorities. Nature 403:853–858. doi:10.1038/35002501

O'Dea N, Araújo MB, Whittaker RJ (2006) How well do Important Bird Areas represent species and minimize conservation conflict in the Tropical Andes? Divers Distrib 12:205–214. doi:10.1111/j.1366-9516.2006.00235.x

Oliveira MM, Langguth A (2006) Rediscovery of marcgrave's capuchin monkey and designation of a neotype for Simia flavia Schreber, 1774 (Primates, Cebidae). Bol Museu Nac 523:1–16

Pinto LP, Bedê L, Paese A (2006) Mata Atlântica brasileira: os desafios para conservação da biodiversidade de um hotspot mundia. In: Rocha CFD, Bergallo HG, van Sluys M (eds) Biologia da conservação: essências. RiMa, São Carlos

Pinto MP, Mathias PVC, Blamires D et al (2007) Selecting priority areas to conserve Psittacines in the Brazilian cerrado: minimizing human-conservation conflicts. Bird Conserv Int 17:13–22. doi:10.1017/S0959270906000578

Possingham H, Ball I, Andelman S (2000) Mathematical methods for identifying representative reserve networks. In: Ferson S, Burgman M (eds) Quantitative methods for conservation biology. Springer, New York

Possingham HP, Wilson KA, Andelman SJ (2006) Protected areas: goals, limitations, and design. In: Groom MJ, Meffe GK, Carroll CR et al (eds) Principles of conservation biology. Sinauer Associates, Sunderland

Pressey RL (1994) Ad hoc reservations: foward or backward steps in developing representative reserves systems? Conserv Biol 8:662–668. doi:10.1046/j.1523-1739.1994.08030662.x

Pressey RL, Cowling RM (2001) Reserve selection algorithms and the real world. Conserv Biol 15:275–277. doi:10.1046/j.1523-1739.2001.99541.x

Pressey RL, Humphries CJ, Margules CR et al (1993) Beyond opportunism: key principles for systematic reserve selection. Trends Ecol Evol 8:124–128. doi:10.1016/0169-5347(93)90023-I

Pressey RL, Johnson IR, Wilson PD (1994) Shades of irreplaceability: towards a measure of the contribution of sites to a reservation goal. Biol Conserv 3:242–262

Pressey RL, Cabeza M, Watts ME et al (2007) Conservation planning in a changing world. Trends Ecol Evol 22:583–592

Rodrigues ASL, Andelman SJ, Bakarr ML et al (2004) Effectiveness of the global protected area network in representing species diversity. Nature 428:640–643. doi:10.1038/nature02422

Rondinini C, Wilson KS, Boitani L et al (2006) Tradeoffs of different types of species occurrence data for use in systematic conservation planning. Ecol Lett 9:1136–1145. doi:10.1111/j.1461-0248.2006.00970.x

Rylands AB, Fonseca GAB, Leite YL (1996) Primates of the Atlantic Forest: origin, distribution, endemism and communities. In: Norconk M, Rosenberger A, Garber P et al (eds) Adaptive radiations of neotropical primates. Plenum Press, New York

Silva JMC, Casteleti CHM (2003) Status of biodiversity of the Atlantic Forest of Brazil. In: Galindo-Leal C, Câmara IG (eds) The Atlantic Forest of South America: biodiversity status, threat, and outlook. Island Press, Washigton

Silva Junior JS (2001) Especiação nos macacos-prego e caiararas, gênero Cebus Erxleben, 1777 (Primates, Cebidae) Tese de Doutoramento . Universidade Federal do , Rio de Janeiro

Tognelli MF (2007) How well do protected areas represent the terrestrial mammal fauna of South America? In: Kelt DA, Lessa EP, Salazar-Bravo J (eds) The quintessential naturalist: honoring the life and legacy of Oliver P. Pearson. University of California Publications in Zoology, California, p 134

Underwood EC, Shaw MR, Wilson KA et al (2008) Protecting biodiversity when money matters: maximizing return on investment. PLoS On 3:e1515. doi:10.1371/journal.pone.0001515

Whittaker RJ, Araújo MB, Jepson P et al (2005) Conservation biogeography: assessment and prospect. Divers Distrib 11:3–23. doi:10.1111/j.1366-9516.2005.00143.x

Williams PH, Moore JL, Toham AK et al (2003) Integrating biodiversity priorities with conflicting socio-economic values in the Guinean-Congolian forest region. Biodivers Conserv 12:1297–1320. doi:10.1023/A:1023092100942