A BIODIVERSITY CONSERVATION VISION FOR SERRA DO MAR ECOREGION IN THE ATLANTIC FOREST GLOBAL BIODIVERSITY HOTSPOT

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Summary

Atlantic forest is the fifth hotspot in the world ranking out of 25, 70% of Brazilian population lives in the forest's former domain and less than 10% of the pristine vegetation is left. Hill chains and coastal plains of the Serra do Mar Ecoregion in South and Southeastern Brazil bear the largest forest fragments, many endemic species and the last viable populations of jaguars, goldenlion tamarins, wooly spider monkeys and black-fronted piping guans. Considering the lack of biological knowledge and the opportunistic creation of protected areas, we produced a conservation plan based on targets for biodiversity distribution patterns and ecological process. We combined a biodiversity distribution surrogate based on vegetation and geomorphologic mapping, species distribution modeling (primates, birds, butterflies and amphibians), C-Plan and Marxan decision-support tools and a cost analysis in order to make a gap analysis and to establish medium term conservation strategies for the Ecoregion. The preliminary results indicate that 34% of the selected targets are unprotected under the actual

Introduction

The Serra do Mar Ecoregion harbors a very rich and endangered biodiversity for example, 8 species of primates, 75 species of snakes, over 500 species of birds and more than 1,000 species of butterflies. There are no exclusive species of the whole Serra do Mar Ecoregion, but instead, there are species whose main distribution area is superposed to that of the Ecoregion, and species of restricted distribution, which are endemic to part of the Ecoregion. His high diversity fauna is relatively well known due to its location in the most developed and populated portion of the Brazilian territory. Several fauna and flora species of the Serra do Mar Ecoregion are shared with neighboring Ecoregions, mainly the Upper Paraná and the Bahia Coastal Forests.

The Serra do Mar Ecoregion with 13 million ha covers part of seven Southern and Southeastern Brazilian states (Espírito Santo, Minas Gerais, Rio de Janeiro, São Paulo, Paraná, Santa Catarina and Rio Grande do Sul), and 496 municipalities (figure 1). It is the most developed and intensely populated area in Brazil, therefore, it is the economic center of the country. The population reaches 48 million inhabitants and the largest urban centers of the country, São Paulo and Rio de Janeiro, are located there. The economy is based on industrial and services rendered activities. The main forms of extensive land-use are ranching, agriculture and reforestation of exotic species (*Pinus* and *Eucalyptus*). Historically, the first two activities contributed immensely to the deforestation of the Atlantic Forest. Currently, tourism is another important sector of the economy that represents a great pressure on the remaining forest of the Ecoregion, largely due to sights located in attractive protected and coastal areas. This activity, with potential to implement actions in favor of conservation, is carried out without planning and infrastructure.

Because of its high vulnerability, Serra do Mar is a priority Ecoregion to WWFBrasil. The Systematic Conservation Planning approach (SCP - Margules & Pressey, 2000) was used in the development of a medium term Biodiversity Conservation Vision, in order to identify priority actions for conservation. Important principles like representativeness, complementarity, efficiency, persistence, flexibility and irreplaceability were applied with the use of decision support systems.

This identification included the following steps (Grooves, 2003) : i) identification of conservation targets; ii) analysis and processing of available information; iii) representation analysis of the protected areas system; iv) definition of conservation goals; v) viability evaluation of the conservation targets; vi) reserve selection and design; vii) threat analysis and priorities definition.

Objective

Our objective is to generate a biodiversity conservation plan for Serra do Mar ecoregion, identifying gaps and proposing actions to improve the protected areas network, based on systematic conservation framework. This Biodiversity Vision should allow, at the same time, an efficient resources allocation and a strategic implementation of conservation activities.

Methods and results

Identifying conservation features

We have adopted a combination of biotic and environmental features (Cowling & Heijniss, 2001; Pressey *et al.,* 2000), considering species and ecosystems distribution.

We chosen 259 conservation features for Serra do Mar Ecoregion: 1. endangered, endemic and indicator species and 2. phytogeomorphologic units, an environmental unit based on geomorphology and vegetation mapping, as a surrogate to ecosystems.

Phytogeomorphologic units

Our basic inputs were GIS layers (1:250.000) for geomorphology, present and Pre-Colombian vegetation cover. Two phytogeomorphologic (PGU) maps were created by intersecting the pre-Colombian and present vegetation cover and geomorphology map, to analyze the present and past scenarios. These phytogeomorphologic layers have 169 units after a specialist evaluation where small units and inconsistencies were eliminated.

Normally, to define conservation targets government and non-government organizations use ecosystems remnant area percentage, e.g., the Constitution of Goiás State defines that 20% of present ecosystem areas must be protected. As we intended to see the differences between this common situation and a ideal one where the targets are based in the original forest coverage, we calculated two set of targets, one based on remnant forest coverage and the other one on Pre-Colombian coverage.

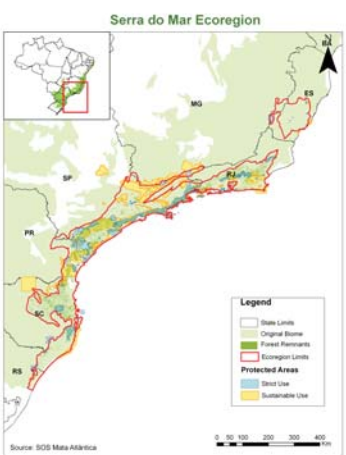

Figure 1-Study area

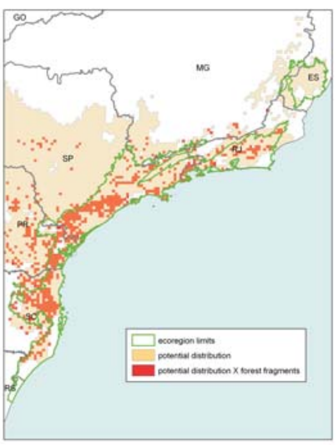

Figure 2 Brachyteles arachnoides potencial distribution modelled by GARPs

We defined 30% as a quantitative target for each PGU layer. As we considered 10.000 ha the minimum size of a viable reserve, this value was defined for UPGs with an area between 10.000 and 33.000 ha to avoid targets smaller than 10.000 ha threshold (Table 1).

Table 1. Targets to the phyto-geomorphologic units to the present scenario

Area (ha)	Target
100 < 10.000	All available areas
10.000-33.000	10.000 ha
> 33.000	30%

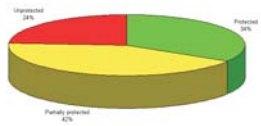

Figure 5

Species

As surrogates we have selected endangered an endemic species of well known taxonomic groups, such as primates, birds, carnivores, palms and amphibians, whose link to forested environments and response to anthropogenic interventions were highlighted during the last decades (IUCN 2003 and Brazilian official Red List of Threatened species IBAMA).

They amount to 90 species: 24 amphibians, 48 birds, 9 mammals and 9 palms. The spatial distribution for those species with more than 20 occurrences was obtained with the modeling software GARP(*Genetic Algorithm for Rule-set Prediction*) (Pereira, 2003) (figure 2). The distribution of species with less than 20 records was gotten from the maps compiled by specialists and from de database of NatureServe and Global Amphibians Evaluation (Patterson *et al.* 2003; Ridgley *et al.* 2003 and (http://www.globalamphibians.org).

The goals for species distribution were defined to assure their long time persistence. The basic criterion was to protect different populations to each species with a minimum population size and with a minimum separation distance between the populations to guarantee a healthy genetic variability. We assumed as minimum population size a number of 500 individuals for each species (viable minimum population *sensu* Gilpin & Soulé, 1986; Boyce, 1992), and, using some species density values (Machado, 2000; Fonseca *et al.*, 1994; Rodrigues *et al.,* 2002; Miranda, 2004), we estimated a conservation target to protect the minimum area of habitat necessary to support the survival of a population of 500 individuals. The minimum number of populations for each species and minimum separation distances between the populations were defined with help of specialists (see Table 2 for some examples)

Table 2. Examples of conservation targets(threatened and endemic species).

Populatio number	Minimum area (ha)	Minimum Separation (km)	Species	Common names
1	50.000	00	*Formicivora erythronoto*	Black-hooded antwren
5	10.000	40	*Callithrix aurita*	white ear marmoset
2	30.000	40	*Panthera onca*	Jaguar
5	30.000	40	*Pipile jacutinga*	Black fronted piping guan

Estimation of irreplaceability metric

The Serra do Mar Ecoregion was subdivided into 4176 discrete hexagons with 5000 ha, denominated planning units (PUs). The Arcview and C-plan softwares (C-Plan, 2001) were used to create a unique data base that contains the present conservation features distribution data by PUs, PU tenure status (available or already protected) and the present and pre-Colombian feature targets.

The irreplaceability (Ferrier *et al.*, 2000) was calculated based on this dataset for each one of the PUs. These values give an importance measure of each PU for the achievement of established conservation targets. The irreplaceability was calculated to the two sets of targets, present and pre-Colombian, and presented in the maps (Figures 3 and 4). How was expected, a visual map inspection shows that the number of irreplaceable units is greater in the pre-Columbian scenario than in the present and the target could not be achieved for 179 cases (69%) or it is necessary to use all remnant PGU area.

Considering only the present forest remnants targets, a conservation gap analysis was executed using C-Plan, indicating the features protection status (protected, partially protected and unprotected) in the present reserve system (Figure 5). It shows that present reserve system gives full protection only for 34 % of conservation features set.

Cost analysis

The identification of the best PUs to be incorporated into the reserve system should be based on the biological irreplaceability and in other two variables: cost and boundary length. The cost and the boundary length analysis of the different possible solutions for PU selection permit to infer the cost-benefits ratio and to determine the most effective solution.

The cost to add PUs in protected areas is not homogeneous, varying with the spatial context. A cost surface was created to estimate the PUs cost by means of elaboration data map for any land use and infrastructure features that could have positive or negative impact on the biodiversity conservation, e.g., roads and rivers. After that, we did a weighted sum of the distance maps (see the PO-152 side by side for more details). We also did a flag analysis (Nijkamp, 1998) to classify the municipalities comprised by the study area according socioeconomic variables, like governance, demographic density, mining etc, which could be relevant.

Priority areas identification

As there are countless possible combinations to achieve the targets for the conservation features, the decision theory problem is to identify which one has the minimum cost. This question in a mathematical way is a minimization problem which solution is to find a global minimum of a cost function like:

$$Fcost = cost + blw \; bl + (cfw * p)$$

cost = PU cost estimated by the cost surface; **blw** = boundary length weight; **bl** = boundary length; **cfw** = conservation feature weight; **p** = penalty associated with each under represented conservation feature.

This cost function is a sum of three members:
(i) the first one is the cost sum of the PUs; **(ii)** the second one is related to the aggregation degree of the

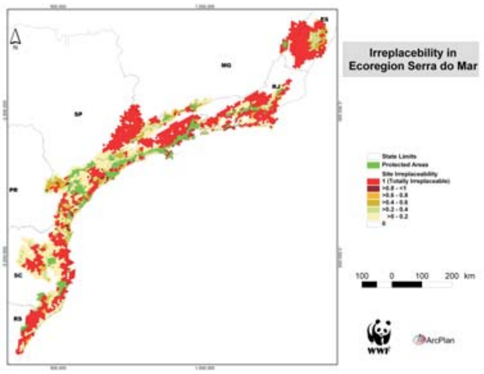

Figure 3.Irreplacebility calculated for targets defined as percentages of Pre-Colombian forest cover

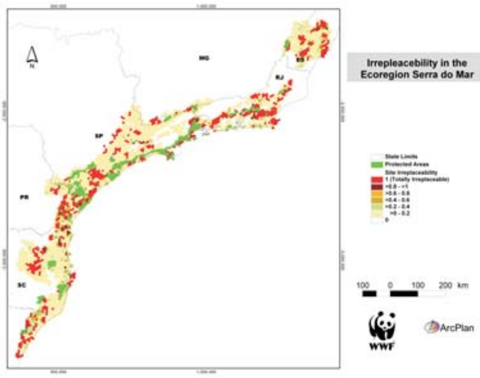

Figure 4.Irreplacebility calculated for targets defined as percentages of present forest cover

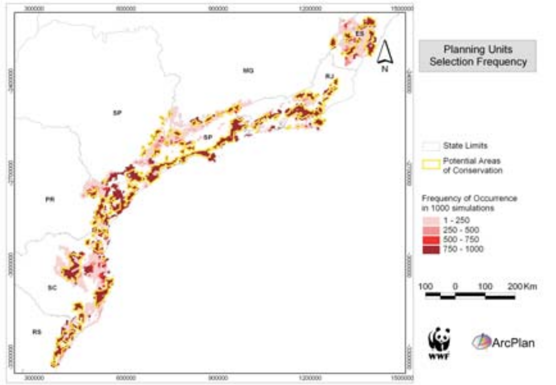

Figure 6.Best solution and summed solution maps calculated by Marxan software

selected PUs; **(iii)** the third one is related to the feature richness of the PU set.

We utilize the Marxan software (Ball & Possingham, 2000) and a simulated annealing algorithm (Possingham *et al*, 2000) to estimate the global minimum or best solution. The algorithm was executed with a 1000 runs to guarantee that the solution found is a good estimate. We chose the best one of all runs (Figure 6).

To calculate the best solution in a realistic way we only have made use of the present targets set. The minimum cost solution obtained to reach 100% of the conservation targets has 76 priority regions.

Another result of the Marxan is the number of times that a PU is included in the best solution. This is a good estimate of PU importance like irreplaceability and facilitates the identification of priorities in the process of implementing new reserves in the actual protected area system (Figure 6).

Conclusion

The SCP approach, is considered a powerful analytical tool to identify conservation priorities to the Serra do Mar Ecoregion:

1. the updating process of the conservation planning is much easier than an unique, static and inflexible map of priority conservation areas. As the system is dynamic, the conservation success (new protected areas) and new available knowledge could be incorporated into the database and new conservation priorities could be recalculated;
2. as the irreplaceability is a quantitative metric, the subjectivity of the whole conservation priorization process is reduced specially if compared with other approaches based just in specialists, taxonomy and biogeography;
3. the integration among the different kinds of information from the conservation features is more objective with the use of a discrete sampling unit as the PU;
4. using Cplan we could execute a gap analyses with two different scenarios, present and Pre-Colombian, and detect the more vulnerable ecosystem and the impossibility to protect a minimum desired target (30% of the original areas) for many conservation features except if some ecosystems restoration practices are implemented. The Pre-Colombian evaluation would be a very useful information to make a vulnerability analysis in the next step of SCP, the post-selection of priority regions;
5. instead of a priority conservation area set, the conservation features database could be the basis of a conservation action plan, including protected area creation and implementation, forest fragments connection and forest restoration.

Our learning lessons until now are basically: building capacity to handle a SCP approach and data compilation are very time-consuming steps; involving stakeholders is always much more difficult than expected; SCP as a conservation framework is a very effective way to integrate different conservation approaches (species, ecosystems, landscape units, etc.) from different organizations; as move from conservation planning exercises to a public policy is a complicated step in the usual low financial resources scenario, it is fundamental evaluate implementation alternatives as economic tools, e.g. environmental services payments, tradeable forest protection obligations, etc.

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