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How many vascular plant species are there in a local hotspot of biodiversity in Southeastern Brazil?

Quantas espécies de plantas vasculares existem em um *hotspot* local de biodiversidade no sudeste do Brasil?

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Abstract

Scientific information about the distribution of species richness and diversity is necessary for full comprehension of our evolutionary heritage forming a powerful tool for the development of nature conservation strategies. The aim of this article was to estimate the vascular plant species richness of the *campos rupestres* from the Itacolomi State Park (ISP) in order to verify the park´s classification as a local hotspot of biodiversity and to outline the *status quo* of knowledge about biodiversity in the region. For that, the species richness of two phytosociological surveys of 0.15 ha each were extrapolated using (a) the species-area relationship fitted by the power and the logarithmic model as well as (b) the taxon ratio model. The taxon ratio model estimates total vascular plant species richness to 1109 species using seven different taxa. Extrapolations of different fittings of the species-area relationships calculate the complete park's richness to values between 241 and 386 (logarithmic model), and 3346 to 10421 (power model). These extrapolations are far beyond realistic: the logarithmic model underestimates the park´s species richness, because more than 520 vascular plant species have already been registered in the park. On the other hand, it is not plausible that one-fourth or more of all species registered so far in the Atlantic Tropical Forest Biome occur in the ISP as indicated by the extrapolation with the power model. The most realistic estimation was achieved by the taxon ratio model. Although confidence intervals are large, the species richness estimated by this method legitimates the classification of the ISP as a local hotspot of biodiversity, but this value also outlines the lack of knowledge about biodiversity in this region and the urgent need for more taxonomical and ecological research.

Key words: *campos rupestres,* species-area relationship, taxon ratios, Espinhaço Mountain Range.

Resumo

Informação científica sobre a distribuição de riqueza e diversidade de espécies é necessária para a compreensão plena da nossa herança evolutiva formando uma ferramenta poderosa para o desenvolvimento de estratégias de conservação de natureza. O objetivo deste trabalho constituiu-se em estimar a riqueza de plantas vasculares nos campos rupestres do Parque Estadual do Itacolomi (PEI) para justificar a sua classificação como um *hotspot* local de biodiversidade e para delinear o *status quo* do conhecimento sobre a biodiversidade na região. Para isso, o número de espécies encontradas em dois levantamentos fitossociológicos de 0,15 ha cada foi extrapolado usando (a) a relação espécie-área ajustada pelo modelo de potência e pelo modelo logarítmico bem como (b) o modelo de relação de táxons. O modelo de relação de táxons estimou a riqueza total para 1.109 espécies usando sete diferentes táxons. Extrapolações de diferentes modelos da relação espécie-área estimaram a riqueza

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total dos campos rupestres do parque para valores entre 241 e 386 (modelo logarítmico) e 3346 e 10421 (modelo de potência). As extrapolações da relação espécie-área foram muito além do real: o modelo logarítmico subestimou a riqueza de espécies do parque, porque há mais de 520 espécies de plantas vasculares registradas para o parque. Por outro lado, não é plausível que um quarto ou mais das espécies registradas no Bioma Mata Atlântica ocorra no PEI como a extrapolação do modelo de potência indicou. A estimativa mais realista foi alcançada pelo modelo de relação dos táxons. Embora os intervalos de confiança sejam grandes, a riqueza de espécies estimada por esse método justificou a classificação do PEI como um *hotspot* local de biodiversidade. A riqueza estimada de espécies também destacou a falta de conhecimento sobre a biodiversidade da região e a necessidade urgente de mais pesquisas taxonômicas e ecológicas.

Palavras-chave: *campos rupestres*, relação espécie-área, relações táxon, Serra do Espinhaço.

Introduction

Species richness and diversity are intriguing subjects that ecologists seek to understand in the context of evolutionary and ecological processes (e.g., Hubbell, 2001; Webb *et al.,* 2002; Cavender-Bares *et al.,* 2009; HilleRisLambers *et al.*, 2012). For full comprehension of our evolutionary heritage (May, 2011), mankind is trying to answer questions such as “How many species are there on earth?” or even in a specific country or site (May, 1988; Scotland and Wortley, 2003; Mora *et al.*, 2011). Such information is relevant because the knowledge about the distribution of extant species richness and diversity as phenomena provides powerful tools for the prediction of extinction rates caused by human impacts or climate change (Lewis, 2006), the development of conservation policies (Brooks *et al.*, 2006; Killeen and Solórzano, 2008; Pardini *et al.*, 2009; Ribeiro *et al.*, 2009) and the declaration of superregional or local biological hotspots (Myers *et al.*, 2000; Orme *et al.*, 2005). As a piece of scientific information, the number of species (e.g., vascular plant) within a region is not only an important figure for nature conservation and landscape planning (Williams *et al.*, 2004; Arponen *et al.*, 2009; Gastauer *et al.*, 2013), but it is also a measure for the state of current taxonomic and ecological research (Mora *et al.*, 2011). There are about 250,000 to 300,000 vascular plant species in the world (IUCN, 2007), nearly 20% of them occurring in Brazil (Giuletti *et al.*, 2005; Lewinsohn and Prado, 2005). This is not a very precise evaluation, but its improvement requires enormous effort, that is far beyond the possibilities of many countries from the world. Achieving reliable numbers for species richness in a certain region is constrained by the fact that many species are neither registered for the region or – even worse – are not described yet. Lacking human resources to sample, identify, describe and archive all species from some regions form a bottleneck to evaluate all this diversity, especially in megadiverse and emergent countries as Brazil. This problem is aggravated by the fact that we are living in a period of extinction crises (Millenium Ecosystem Assessment, 2005; Lewis, 2006; Chen and Hui, 2009), so that many species might disappear even before they have been censused and described.

Therefore, the complete species richness from the world, for states, provinces or regions is rather estimated by extrapolation than being the result of expensive, complete censuses (Raven, 1985; Grassle and Maciolek, 1992; Briggs and Snelgrove, 1999; Bebber *et al.*, 2007; Joppa *et al.*, 2010), although statistical methods to answer these questions have been discussed controversially (Mora *et al.*, 2011; Colwell *et al.*, 2012).

The species-area relationship is one of the best examined patterns of ecology (Rosenzweig, 1995; Lomolino, 2001). Although area is not the only predictor of species richness (He and Hubbell, 2011), extrapolations based on this well accepted principle of macroecology are widely accepted (Condit *et al.*, 1996; Pimm and Raven, 2000). The taxon ratio model proposed by Colwell and Coddington (1994), on the other hand, is little explored in scientific literature. As it uses the ratio of well-studied taxa within a small survey and a geographical entity to estimate whole species richness, it seems to be independent of sample effects.

Extrapolations by both tools should reveal important insights about the distribution of and the knowledge about biodiversity in megadiverse Brazil. This country possesses two global hotspots of biodiversity on its territory, the Cerrado and the Atlantic Rainforest (Myers *et al.*, 2000), which are characterized by high species richness and a high degree of endemism (Mendonça *et al.*, 2008; Stehmann *et al.*, 2009). *Campos rupestres* (rock-field), azonal montane ecosystems, replace vegetation of both hotspots usually above 900 m ASL in Southeastern Brazil (Magalhães, 1966; Ribeiro and Walter, 1998). The ecosystem is characterized by an open vegetation with a negligible tree layer (Alves and Kolbeck, 2010) and is bound to a mosaic of rocky outcrops and shallow white sands in the mountain ranges from Minas Gerais, Bahia and Goiás states of Brazil (Alves *et al.*, 2007). Also showing similarity to other azonal outcrop vegetations from the Neotropics (Alves and Kolbeck, 2010), this species-rich and diverse ecosystem with many endemics (Conceição *et al.*, 2007; Menini Neto *et al.*, 2007; Gastauer *et al.*, 2012) is composed by specific plant communities (Alves *et al.*, 2007; Conceição and Pirani, 2005).

The aim of this paper was to estimate the total number of vascular plants of all *campos rupestres* from the Itacolomi State Park, Minas Gerais, Brazil, by the taxon ratio model and by extrapolations of the species-area relationship. Both tools were stressed as much as possible in order to combine a suitable level of certainty with the lowest possible effort to match the challenge of biodiversity evaluation with available human effort.

Methods

This study was carried out in the Itacolomi State Park (ISP), Minas Gerais, Brazil. This park comprises 7543 ha in the South of the Espinhaço Mountain Range that are covered mainly by Seasonal Semidecidual Forests and *campos rupestres* (Drummond, 2005), the latter corresponding to 44% (3319 ha) of the area of the park (Fujaco *et al.*, 2010).

Within the park, two phytosociological surveys of 0.15 ha in Calais (20°25’ S, 43°30’ W) and Lagoa Seca (20°26’ S, 43°29’ W), each divided in 15 plots of 10 x 10 m, were carried out. Distance between both surveys is 2.7 km (Figure 1, Gastauer *et al.*, 2012).

To estimate vascular plant species richness of *campos rupestres* from the ISP, the taxon ratio model proposed by Colwell and Coddington (1994) was applied. For that, we assumed that the average ratio, i.e. S_{TT}:S_{TS} (S_{TT} = total number of species from a single, well-studied taxon from the ISP, and S_{TS} = number of species from that taxon registered within a smaller survey), is constant across different taxa. From a triage of seven well-studied taxa from the park, an average taxon ratio was estimated for extrapolation purpose. From the distribution of taxon ratios, 95% confidence intervals (95% CI) were computed to evaluate statistical support of analysis.

Furthermore, extrapolations of the species-area relationship from both surveys were generated. For that, we calculated the average number of species of groups of two, four, seven, and finally all the 15 plots of each survey. Only neighboring plots were grouped. Then, both species-area relationships were fitted and extrapolated to the whole area of *campos rupestres* from the ISP using the power model $S = c * A^z$ proposed by Arrhenius (1921) as well as the logarithmic function $S = a * \log(A) + b$ (Gleason, 1922; Rosenzweig, 1995; Dengler, 2009). Here, S is the number of species, A is the area, c, z, a, and b are the fitting parameters. The rarefactions were tested to reliability by (i) downscaled to one m^2, (ii) by correlation coefficient, and (iii) by F statistics after linearization due to log-transformation of area (logarithmic model) and all values, respectively (power model).

As sampled plots do not form a continuous area, but are arranged in three rows with distances within and between rows of ten meters (for details see Gastauer *et al.*, 2012), we computed the species-area relationship considering two different areas as upper and lower limit for extrapolation. The upper limit is computed correlating observed species richness with the real sample area (100 m^2 per plot and 1500 m^2 per survey), while for lower limit the real sampled area is boosted by the area between plots resulting in an area of 400 m^2 per plot and 6000 m^2 per survey).

For the calculation of fitting parameters, a complete linear least square fitting routine was run for linearized values (LINEST function from the Microsoft Excel™ package) that returns the mean values as well as their standard deviations (SD) for the fitting parameters. Inserting mean values in the equations of each model returns the expected number of species. 95% CI for this extrapolation were calculated using mean values ±1.96 × SD of each fitting parameter. For lower bound of 95% CI, 1.96 × SD was subtracted from each fitting parameter, for upper bound, it was added.

Results

A total of 161 species were detected in both study sites, 23 of them occurring in both surveys (Table 1). Seventy-six species were sampled in Lagoa Seca and 107 in Calais.

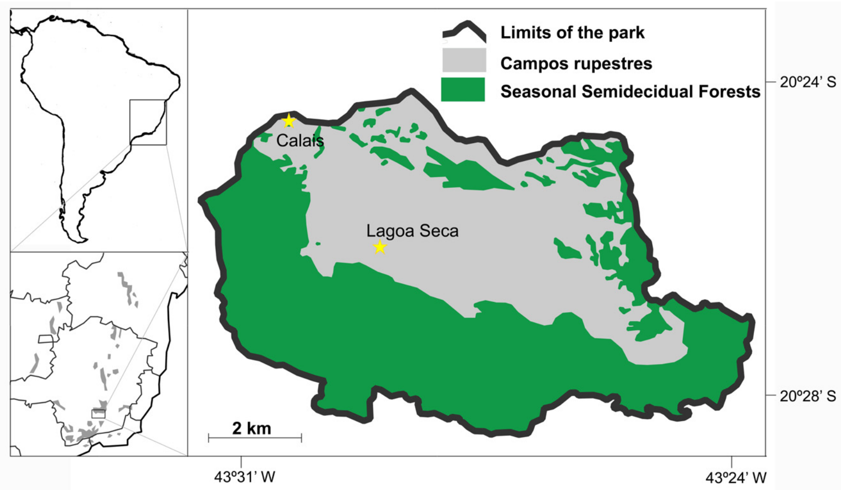

Figure 1. Geographic location of the study sites in the Itacolomi State Park (ISP), Minas Gerais, Brazil, and its position in South America (upper left) and Southeastern Brazil (lower left).

Table 1. Species found in phytosociological surveys of 0.15 ha carried out in Lagoa Seca and Calais, Itacolomi State Park, Minas Gerais State, Brazil. For geographical position of study sites, see Figure 1. Species are sorted by their affiliation to families.

	Lagoa Seca	Calais
Lycopodiophyta		
Selaginellaceae		
Selaginella sp. 1	x	
Pteridophyta		
Anemiaceae		
Anemia ferruginea Humb. & Bonpl. *ex* Kunth		x
Blechnaceae		
Blechnum imperiale H. Chr.		x
Dennstaedtiaceae		
Pteridum aquilium (L.) Kuhn		x
Doryopteridaceae		
Doryopteris ornithopus (Mett.) J. Sm	x	
Gleicheniaceae		
Dicranopteris flexuosa (Schrad.) Underw.		x
Polypodiaceae		
Polypodium pectinatum L.		x
Angiosperms - Magnoliids		
Annonaceae		
Guatteria villosissima A. St.-Hil.		x
Aristolochiaceae		
Aristolochia sp. 1	x	
Angiosperms - Monocots		
Bromeliaceae		
Cryptanthus schwackeanus Mez	x	
Cyperaceae		
Fimbristylis sp. 1	x	
Rhynchospora consanguinea (Kunth) Boeck.	x	
Rhychnospora corymbosa (L.) Britton		x
Rhychnospora cf. *tenuis* Willd. ex Link		x
Rhynchospora sp.1	x	
Rhynchospora sp.2	x	
Rhynchospora sp. 3		x
Scleria corymbosa Roxb.		x
Scleria hirtella Sw.	x	x
Trilepis microstachya (C.B. Clarke) H. Pfeiff.	x	x
Cyperaceae sp. 1	x	x
Cyperaceae sp. 2	x	
Cyperaceae sp. 3	x	x
Cyperaceae sp. 4		x
Commelinaceae		
Dichorisandra thyrsiflora J.C. Mikan		x
Tradescantia diuretica Mart.		x
Dioscoreaceae		
Dioscorea sp. 1		x
Hypoxidaceae		
Hypoxis decumbens L.		x
Iridaceae		
Neomarica cf. *glauca* (Klatt) Sprague	x	
Sisyrinchium vaginatum Spreng.		x
Orchidaceae		
Coppensia blanchetii (Rchb. f.) Campacci	x	
Coppensia warmingii (Rchb.f.) Campacci	x	

Table 1. Continuation

	Lagoa Seca	Calais
Epidendrum denticulatum Barb. Rodr.	x	
Habenaria cf. *rupicola* Barb. Rodr.	x	
Habenaria sp. 1	x	
Sacoila lanceolata (Aubl.) Garay		x
Sophronitis sp. 1	x	
Poaceae		
Andropogon leucostachyus Kunth		x
Apochloa poliophylla (Renvoize & Zuloaga) Zuloaga & Morrone		x
Aristida sp. 1	x	
Axonopus siccus (Nees) Kuhlm.		x
Chloris sp. 1		x
Eragrostis acuminata Döll		x
Ichnanthus bambusiflorus (Trin.) Döll	x	x
Melinis minutiflora P. Beauv.		x
Otachyrium versicolor (Döll) Henrard	x	
Panicum pseudisachne Mez	x	x
Panicum wettsteinii Hack.	x	x
Paspalum coryphaeum Trin.	x	
Paspalum hyalinum Nees ex Trin.		x
Paspalum multicaule Poir	x	
Paspalum notatum Alain ex Flüggé		x
Paspalum plicatum Pers.		x
Pennisetum setosum (Sw.) Rich.		x
Poa cf. *annua* L.		x
Schizachyrium sanguineum (Retz.) Alston	x	x
Sporobolus metallicola Longhi-Wagner & Boechat	x	x
Urochloa decumbens (Stapf) R.D. Webster		x
Poaceae sp. 1	x	
Poaceae sp. 2	x	x
Poaceae sp. 3		x
Smilaceae		
Smilax coriifolia A. DC.	x	
Velloziaceae		
Vellozia compacta Mart. ex Schult. f.	x	
Xyridaceae		
Xyris cf. *plantaginea* Mart.	x	
Xyris sp. 1	x	
Xyris sp. 2	x	
Angiosperms - Eudicots		
Acanthaceae		
Ruellia macrantha Lindau		x
Amaranthaceae		
Amaranthaceae sp. 1		x
Apiaceae		
Eryngium paniculatum Cav. & Dombey ex F. Delaroche	x	
Apocynaceae		
Oxypetalum appendiculatum Mart.		x
Araliaceae		
Hydrocotyle quinqueloba Ruiz & Pav.	x	
Asteraceae		
Acanthospermum australe (Loefl.) Kuntze		x
Achyrocline satureioides (Lam.) DC	x	x
Baccharis aphylla (Vell.) DC	x	
Baccharis camporum DC.		x

Table 1. Continuation

	Lagoa Seca	**Calais**
Baccharis dracunculifolia DC.		x
Baccharis platypoda DC.	x	
Baccharis reticularia DC.	x	
Baccharis serrulata DC.	x	x
Baccharis sp. 1	x	x
Chaptalia nutans (L.) Pol.		x
Cyrtocymura scorpioides (Lam.) H. Rob.		x
Eremanthus crotonoides (DC.) Sch. Bip.		x
Eremanthus erythropappus (DC.) MacLeish	x	x
Eremanthus incanus (Less.) Less	x	x
Eupatorium sp. 1		x
Koanophyllon adamantium (Gardner) R.M. King & H. Rob.	x	
Mikania nummularia DC.	x	x
Mikania sp. 1	x	
Pterocaulon lanatum Kuntze		x
Richterago amplexifolia (Gardner) Kuntze	x	
Senecio adamantinus Bong.	x	x
Stenocline sp. 1	x	
Stevia clausseni Sch. Bip. ex Baker		x
Trichogonia sp. 1		x
Vernonia sp. 1		x
Vernonia sp. 2		x
Boraginaceae		
Varronia curassavica Jacq.		x
Campanulaceae		
Lobelia camporum Pohl	x	
Droseraceae		
Drosera montana A. St.-Hil.	x	
Fabaceae		
Aeschynomene elegans Schltdl. & Cham.		x
Chamaecrista flexuosa (L.) Greene		x
Chamaecrista rotundifolia (Pers.) Greene		x
Crotalaria sp. 1		x
Dalbergia brasiliensis Vogel		x
Desmodium adscendens (Sw.) DC.		x
Desmodium barbatum (L.) Benth.		x
Inga sessilis (Vell.) Mart.		x
Mimosoideae sp. 1		x
Periandra mediterranea (Vell.) Taub.		x
Senna reniformis (G. Don) H.S. Irwin & Barneby		x
Stylosanthes viscosa (L.) Sw.		x
Zornia reticulata Sm.		x
Lamiaceae		
Hyptis homolophylla Pohl ex Benth.	x	x
Hyptis monticola Mart. ex Benth.	x	
Lentibulariaceae		
Genlisea repens Benj.	x	
Utricularia amethystina Salzm. ex A. St.-Hil. & Girard	x	
Lythraceae		
Cuphea carthagenensis (Jacq.) J.F. Macbr.		x
Cuphea sp. 1		x
Diplusodon buxifolius (Cham. & Schltdl.) A.DC.		x
Malpighiaceae		
Banisteriopsis campestris (A. Juss.) Little		x
Byrsonima variabilis A. Juss.	x	x
Heteropterys sp. 1		x

Table 1. Continuation

	Lagoa Seca	Calais
Malvaceae		
Sida linifolia Cav.		x
Wissadula sp. 1		x
Melastomataceae		
Cambessedesia hilariana (Kunth) DC.	x	x
Lavoisiera cf. *cataphracta* DC.	x	
Leandra cf. *atropurpurea* Cogn.	x	
Miconia pepericarpa Mart. ex DC.		x
Miconia sp. 1		x
Miconia sp. 2		x
Microlicia crenulata Mart.	x	
Microlicia sp. 1	x	
Microlicia sp. 2	x	
Microlicia sp. 3		x
Tibouchina cardinalis Cogn.	x	
Tibouchina multiflora Cogn.		x
Myrsinaceae		
Ardisia solanacea Roxb.	x	
Myrsine umbellata Mart.	x	
Myrtaceae		
Myrcia amazonica DC.		x
Myrcia eryocalix DC.	x	
Myrcia splendens (Sw.) DC.	x	x
Myrcia subcordata DC.	x	
Polygalaceae		
Polygala paniculata L.	x	x
Polygala violaceae Aubl.		x
Proteaceae		
Roupala montana Aubl.	x	
Rosaceae		
Rubus brasiliensis Mart.		x
Rubiaceae		
Diodella teres (Walter) Small		x
Borreria verticillata (L.) G.Mey		x
Rutaceae		
Dictyoloma vandellianum A.H.L. Juss.		x
Salicaceae		
Casearia sylvestris Sw.		x
Sapindaceae		
Matayba marginata Radlk.		x
Solanaceae		
Brunfelsia brasiliensis (Spreng.) L.B. Sm. & Downs	x	
Schwenckia americana L.		x
Solanum americanum Mill.		x
Solanum cf. *erianthum* D. Don	x	x
Verbenaceae		
Lantana camara L.		x
Lantana lilacina Desf.		x
Lippia hermannioides Cham.		x
Stachytarpheta commutata Schauer	x	
161 species	**76**	**107**

The taxon ratios for seven well studied taxa vary from 3.5 to 9.5 and amount 6.88 on average (95% CI 5.47, 8.30, Table 2). Under these assumptions, the total number of species within the park´s *campos rupestres* is estimated to 1109 species with 95% confidence intervals ranging from 881 to 1336 (Table 2).

With correlation coefficients above 0.99, species-area relationships from both surveys were fitted significantly by the power as well as by the logarithmic model (Table 3). Downscaling the SAR to one m^2 produces negative species richness using the logarithmic model. According to the power model, the average species richness of one m^2 is between 2 or 3 (Lagoa Seca, lower and upper limit of estimation) and 2 to 4 (Calais), respectively. Extrapolating the logarithmic model to the whole park's *campos rupestres* area results in an overall plant species richness of 241 (from Lagoa Seca, lower limit) and 386 species (Calais, upper limit). Using the power model, the number of vascular plant species within the park's *campos rupestres* is estimated between 3346 and 6109 (Lagoa Seca) or 5569 to 10421 (Calais, Table 3).

Discussion

Considering the studies cited in Table 2 plus the 161 species found within our two surveys, 520 species have already been detected within the park's *campos rupestres*. Further surveys (e.g. Peron, 1989; Casarino *et al.*, 2009) might enrich the list.

This fact discards the extrapolations from the species accumulation curve using the logarithmic model because they underestimate the vascular plant species richness of the *campos rupestres* from the ISP below the number of already registered species. This interpretation is supported by the fact that downscaling of this model leads to negative species richness in one m^2 – this is definitely not plausible.

But the extrapolations of the species-area relationships by the power model should be analyzed with caution as well, although this model is well studied and generally well accepted (Brown *et al.*, 2002; Martin and Goldenfield, 2006). Good fittings and plausible results for downscaling lead into temptation to upscale these models. Nevertheless, it is not likely that one-fourth of all species from the Atlantic Tropical Forest (Stehmann *et al.,* 2009) or more coexist in the small ISP. This overestimation by the power model as well as the underestimation by the logarithmic model are due to the fact that the true species-area relationship in a log-log space is triphasic and of sigmoid form (Rosenzweig, 1995) with scale-dependent inclination (Condit *et al.*, 1996; Conner and McCoy, 2001; Hubbell, 2001; Condit *et al.*, 2004; Dolnik and Breuer, 2008). For extrapolations from a very small survey to very large areas as in our case, we need models that reduce the inclination in dependence of scale, perhaps in function of similarity as proposed by Krishnamani *et al.* (2004). To apply their calculations, we need more study sites within the ISP, which contradicts our goal to extrapolate vascular plant species richness of the ISP's *campos rupestres* from minimal sampling effort.

Another possibility to avoid the problem of scale dependent inclination is the application of fix inclinations that have been found in other studies comprising more magnitudes. Rosenzweig (1995) suggests an inclination of 0.25 for linearized species area relationships of terrestrial plant communities, which is generally well accepted (Pimm and Raven, 2000). The insertion of this value in the extrapolation equation estimates the overall vascular plant species richness of the ISP to 1116[3], the same magnitude as the taxon ratio model. But this must be coincidence.

What remains is the taxon ratio model. With that, the vascular plant species richness of all *campos rupestres*

Table 2. Taxon ratios between total number of species found within the Itacolomi State Park, Minas Gerais State, Brazil, and number of species found in two phytosociological surveys including estimation of the park's plant species richness as proposed by Colwell & Coddington (1994). CI: confidence interval.

Source	Taxon	Total number in park's *campos rupestres*	Number of species in our survey	Taxon ratio	Estimated number of species
Dutra *et al.* (2008)	Caesalpinoideae	13	2	6.5	1047
Dutra *et al.* (2009)	Papilionidae	28	8	3.5	564
Rolim (2007)	Pteridophytes	38	4	9.5	1530
Almeida (2008)	Asteraceae	219	27	8.11	1306
Alves (1990)	Orchidaceae	36	6	6	966
Batista *et al.* (2004)	*Habernaria*	15	2	7.5	1207.5
Rolim (2011)	Melastomataceae	71	12	5.92	953
*** * * Total**		**420**	**61**	**6.885**	**1109**
(95% CI)				(5.470, 8.300)	(881, 1336)

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[3] The number of expected species is $(A_0/A_1)^z{*}S_{Obs}$, where A_0 is the area for which the extrapolation should be carried out, A_1 is the originally sampled area, z is the inclination and S_{Obs} is the number of observed species. The above cited value is achieved, when we define A_1 as the sample area of one survey (0.15 ha) and S_{Obs} as the mean richness found in each survey (91.5). Applying other combinations, like lower limits or joining both study sites, produces different values.

Table 3. Power and logarithmic fittings of the species accumulation curves of the surveys from Lagoa Seca and Calais and their extrapolations to the overall vascular plant species richness of the park's *campos rupestres*, Itacolomi State Park (ISP), Minas Gerais State, Brazil. # (1m^2) is the species richness expected in one m^2. Values in brackets are lower and upper bounds of 95% confidence intervals, SD is standard deviation for each fitting parameter retrieved from a complete linear last square curve fitting routine.

Survey	Limit	Fitting parameters	# (1m^2)	# (ISP's *campos rupestres*)
		Power model		
Lagoa Seca	Upper	c = 3.31 ±1.149 z = 0.434 ±0.023 $R^2 = 0.991$, $F_{1;3} = 350.89$	3 (2, 5)	6109 (1814, 18081)
	Lower	c = 1.812 ±1.187 z = 0.434 ±0.023 $R^2 = 0.992$, $F_{1;3} = 350.89$	2 (1, 3)	3346 (525, 12163)
Calais	Upper	c = 4.157 ±1.169 z = 0.452 ±0.026 $R^2 = 0.990$, $F_{1;3} = 302.77$	4 (3, 5)	10421 (3101, 32244)
	Lower	c = 2.212 ±1.212 z = 0.452 ±0.026 $R^2 = 0.990$, $F_{1;3} = 302.77$	2 (1, 3)	5569 (1048, 20786)
		Logarithmic model		
Lagoa Seca	Upper	a = 19.417 ±1.068 b = -67.994 ±6.433 $R^2 = 0.991$, $F_{1;3} = 330.74$	-68 (-81, -55)	268 (219, 317)
	Lower	a = 19.417 ±1.068 b = -94.912 ±7.800 $R^2 = 0.991$, $F_{1;3} = 330.74$	-95 (-110, -79)	241 (190, 293)
Calais	Upper	a = 28.154 ±1.408 b = -100,755 ±8.485 $R^2 = 0.993$, $F_{1;3} = 399.79$	-101 (-117, -84)	386 (322, 451)
	Lower	a = 19.417 ±1.068 b = -67.994 ±6.433 $R^2 = 0.991$, $F_{1;3} = 330.74$	-140 (-160, -119)	348 (280, 416)

from the ISP is estimated to the magnitude of 1100 species. Although the 95% confidence intervals are high, this seems to be a realistic value, as more than 520 species have already been registered and censuses of many species-rich and abundant families like Poaceae, Cyperaceae, Velloziaceae and Rubiaceae are still lacking. Surely, there are many first records for the ISP and not yet described species waiting for their discovery (Almeida, 2008; Almeida and Carvalho-Okano, 2010).

Giulietti *et al.* (1997) guessed that there might be found about 4000 plant species within the Espinhaço Mountain Range, where most of Brazilian *campos rupestres* are situated. On the other hand, Stehmann *et al.* (2009) compile a – still incomplete – list of 14,000 plant species that occur in the Atlantic Rainforest biome. From that, 3,740 species occur in rocky formations. Further species are still to be registered or to be described. Low similarity of nearby study sites (Lemes, 2009; Gastauer *et al.*, 2012) indicate that overall *campos rupestres* vascular plant species richness should be higher than ISP's richness and give confidence and plausibility to our extrapolations of the taxon ratio model.

We estimated that there might be found about 1100 vascular plant species in the *campos rupestres* of the ISP on an area of only 33 km^2. Except some studies not considered in our count (Peron, 1989), the occurrence of only 520 species has already been published. This shows that there is still a lot of taxonomic work to be done to achieve a complete list of vascular plants of the ISP.

The expected species richness of the ISP corresponds to about 2% of the Brazilian flora and about 0.004% of all vascular plants from the world. It also corresponds to about one-fourth of all species from the *campos rupestres* ecosystem. This emphasizes the exceptional species richness of *campos rupestres* in general, but especially in the Southern Espinhaço Moutain Range (Drummond, 2005), and underlines the importance of the ISP for the conservation of biological resources. Furthermore, these figures justify the park's declaration as a (local) hotspot of biodiversity.

Beside an evaluation of the species richness in an important reserve and the declaration of the ISP as a local hotspot of biodiversity, our findings provide a better assessment of extant species richness and diversity by a well-known tool. Nevertheless, there still remain some uncertainties, so that the precision of this estimation and the knowledge about biodiversity and its underlying evolutionary and ecological processes in the region should still be improved.

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