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Avian inventory of the cerrado region, South America: implications for biological conservation

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Summary

The distribution of the ornithological localities in the cerrado region of South America is analysed. When plotted out, the distribution of total sampling localities appears to be even. However, when only those localities at which birds have been sampled in any depth (> 80 specimens collected or >100 species recorded) are considered a different pattern emerges: c.70% of the cerrado region has never been satisfactorily sampled for birds, and similar or worse situations have been reported for other groups of organisms. Priority areas for future ornithological exploration in the cerrado region are most of the states of Tocantins, Maranhão, and Mato Grosso do Sul, southern Goiás, and western Minas Gerais. In these areas, inventory efforts could be focused mainly on the avifaunas of tropical dry forests, gallery forests and "campos rupestres". Because the biological diversity in the cerrado region is poorly known and most of this region has already been modified by human activity, it is suggested that the most feasible way to define both a set of priority areas for conservation and a coherent reserve system is to focus analyses on ecosystems and landscapes rather than on species, subspecies or populations.

A distribuição das localidades ornitólogicas na região do cerrado, América do Sul, é analisada. Quando todas as localidades são plotadas em um mapa, o inventário das aves nessa região parece ser bem distribuido. Entretanto, quando somente aquelas localidades que tem sido amostradas com certa intensidade (>80 espécimes coletados ou >100 espécies registradas) são plotadas, um padrão bastante distinto é encontrado: cerca de 70% da região do cerrado tem nunca sido amostrada satisfatoriamente para aves, e situações similares ou piores tem sido também descritas para o inventário de outros grupos de organismos. Áreas prioritárias para futuras explorações ornitológicas na região do cerrado são grande parte dos estados do Tocantins, Maranhão e Mato Grosso do Sul, sul de Goiás e oeste de Minas Gerais. Nestas áreas, inventários poderiam ser direcionados principalmente para as avifaunas de florestas secas tropicais, florestas de galeria e campos rupestres. Em virtude da diversidade biológica na região do cerrado ser pouco conhecida e de grande parte dessa região já ter sido modificada pelas atividades humanas, é sugerido que a melhor estratégia para definir um conjunto de áreas prioritárias para conservação e um coerente sistema de reservas seria concentrar análises sobre ecossistemas e paisagens ao invés de espécies, subespécies ou populações.

Introduction

For optimal conservation of genetic resources, it is of central importance to know what they are, how they vary, and where they may be found (Brown

1987). Unfortunately, details about the taxonomy, range and geographical variation of most living organisms are lacking, and this type of information is very expensive to acquire in large quantity.

As a response to the alarming rate of habitat destruction in the highly diverse tropical regions, conservationists have worked quickly, first to identify priority areas for conservation and secondly to guarantee that significant portions of those areas can be legally protected. Most of the decisions made during the process of identification and selection of priority areas have been based on the available information on some few indicator groups (e.g. birds, butterflies, mammals, vascular plants), which were selected mainly because their taxonomy and distributions are better known than those of other taxonomic groups (Wetterberg *et al.* 1976, Brown 1977, Mittermeier 1988, Gentry 1992, ICBP 1992, Prance 1994).

A point that has not been examined in detail is the quality of the available information on the taxonomy and ranges of the indicator groups used in conservation studies in tropical regions. This is important because inadequate or incomplete information on species limits and distribution can strongly bias our view of the major patterns of species richness and endemism at the regional and continental scales (Heyer 1988, Nelson *et al.* 1990, Gentry 1992, Brown and Brown 1993) and thus introduce several problems in the definition of conservation priorities.

In this paper I analyse the distribution of bird sampling sites in the second largest ecological region in South America, the "cerrado region". I show that much of this region has never been adequately sampled for birds and that large parts of biologically poorly known areas within it have already been drastically modified by human activities. I conclude that the ecosystem approach rather than the species approach is the only way to define a coherent strategy for the conservation of the poorly studied biological diversity of this region.

Study area

For the sake of simplicity I use the name "cerrado region" to designate the morphoclimatic domain of the cerrados, as proposed and delimited by Ab'Saber (1977, 1986). This region encompasses 1.5–1.8 million km^2 located mainly in central Brazil, with small extensions into north-east Paraguay and eastern Bolivia (Figure 1).

Most of the cerrado region is located on large blocks of crystalline or sedimentary plateaus, whose continuity is broken by an extensive, but discontinuous, network of peripheral depressions (Ab'Saber 1983, Brasil and Alvarenga 1989). The plateaus have a flat to gently rolling surface at altitudes ranging from 500 to 1,700 m and are covered mainly by cerrado. Cerrado, which covers around 85% of the total area of the cerrado region (Eiten 1972), is a semi-deciduous to evergreen savanna-like vegetation growing on nutrient-poor, often deep and well-drained soils (Eiten 1972, 1990, Furley and Ratter 1988). Throughout its range, the cerrado vegetation varies much in physiognomy and composition (Eiten 1972, 1990, Furley and Ratter 1988, Ratter and Dargie 1988). Five main physiognomy types of cerrado are generally recognized by botanists (Eiten 1972): (1) cerradão, a dense forest type with more or less closed canopy;

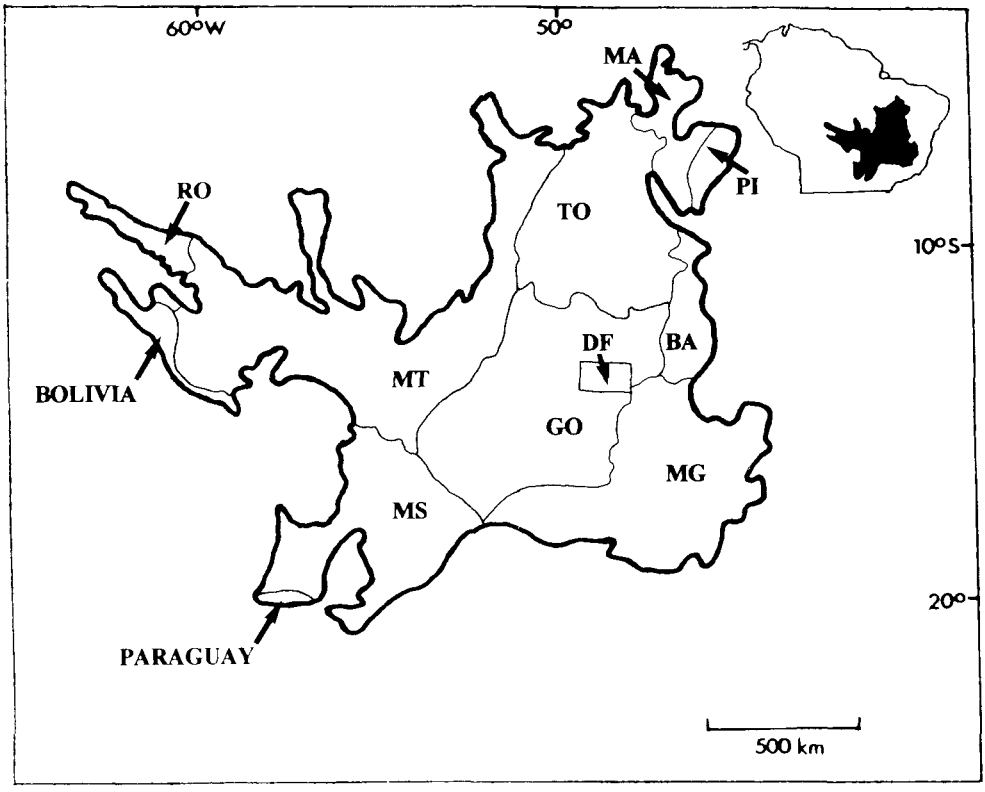

Figure 1. The limits of the cerrado region, South America. Brazilian states are: RO, Rondônia; MT, Mato Grosso; MS, Mato Grosso do Sul; MA, Maranhão; PI, Piauí; BA, Bahia; DF, Distrito Federal; GO, Goiás; MG, Minas Gerais.

(2) cerrado *sensu stricto*, woodland with closed scrub and more scattered trees than in cerradão; (3) campo cerrado, more open scrub with a few trees; (4) campo sujo, grassland with scattered shrubs; and (5) campo limpo, grassland with few or no taller woody plants. Besides cerrado, other types of savanna vegetation with a distinct flora also occur in small patches on the plateaus. They are the "campos rupestres" ("rocky campos") and "miscellaneous lithosol campos" (Giullietti and Pirani 1988, Eiten 1990). Gallery forests on plateaus are generally narrow and grow on belts of cambisols or hydromorphic soils rich in organic matter along rivers and streams (Eiten 1990). Gallery forests are evergreen, having trees on average 20-30 m tall and an understorey with dense low growth (Ribeiro *et al.* 1983).

Peripheral depressions are flat pediplains ranging in altitude from 100 to 500 m. The landscape pattern on these depressions is much more heterogeneous than that on the plateaus, as it includes different types of vegetation (broad gallery forest, tropical dry forests, cerrado and seasonally flooded grasslands) distributed in a mosaic fashion. Tropical dry forests are particularly associated with peripheral depressions and, in some cases (e.g. the Rio Paranã valley), are the dominant type of vegetation. Tropical dry forests are

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deciduous or semi-deciduous, growing on patches of mesotrophic soils derived from basic rocks such as limestone (Ratter *et al.* 1978). They have trees on average 20–45 m tall. Tree species common in the tropical dry forests of the cerrado region are *Astronium urundeuva*, *Piptadenia macrocarpa*, *Chorisia* sp., *Tabebuia* sp., *Cavallinesia arborea* and *Cedrella fissilis* (Ratter *et al.* 1978).

The cerrado region has a tropical seasonal climate with a dry period (May to September or October) coincident with the coldest months of the year (Nimer 1979). The average annual rainfall in this region varies between 1,250 and 2,000 mm, and the average annual temperature between 20 and 26°C (Nimer 1979).

Methods

I prepared a complete list of ornithological localities in the cerrado region based on the gazetteers published by Paynter and Traylor (1991) and Vanzolini (1992) plus my own collection sites. I evaluated the research effort allocated to each locality, based on (1) an extensive survey of all relevant literature on the avifauna of the cerrado region published up to 1994 (Silva in press b); (2) complete lists of specimens of birds from the cerrado region housed at the Field Museum of Natural History (FMNH) and Museum of Natural Science, Louisiana State University (LSUMZ); and (3) a study of some unpublished major bird collections from the cerrado region housed at the American Museum of Natural History (AMNH), Museu de Zoologia da Universidade de São Paulo (MZUSP), Museu Nacional, Rio de Janeiro (MNRJ), and Museu Paraense Emílio Goeldi (MPEG). From the pool of ornithological localities in the cerrado region, I selected those that could be considered as "minimally sampled", defining such a locality as having either (1) more than 80 specimens of birds collected by one or more collectors during the last two centuries or (2) a species list containing more than 100 species prepared by an experienced ornithologist by using sight records, specimen collections or both. It is, of course, the case that these two criteria are subjective and, naturally, open to criticism. I used them because they were the most helpful limits to pinpoint those localities whose avifaunas have received at least some attention by naturalists in the last two centuries.

I prepared a base map of the cerrado region divided into 186 one-degree quadrats. Of these, 76 quadrats encompassed also parts of other regions adjacent to the cerrado region. In such cases, I considered in the subsequent analyses only parts of the quadrats situated within of the limits of the cerrado region. After this, I tallied the total number of localities per quadrat and prepared two different density maps: one including all ornithological localities and another including only the "minimally sampled" localities.

In order to determine in a rough fashion the current levels of landscape modification in the cerrado region, I used a map of the Brazilian vegetation (FIBGE 1988) that distinguishes between native landscapes (i.e. those still covered by the original or slightly altered vegetation) and modified areas (i.e. covered by pastures, agricultural fields and human settlements); to this, in some critical areas, I added personal observations made since the map's publication. Then, I classified each quadrat on the base map of the cerrado region into one of these three coarse categories of landscape modification: low (less than 30%

of the quadrat modified), intermediate (30–70% modified) and high (more than 70% of the quadrat modified).

Results

I was able to find a total of 504 ornithological localities for the cerrado region. Plotting these on the base map (Figure 2a) could give the general impression that the avian inventory in the cerrado region is evenly distributed, even though 59 quadrats (32.2%) have had no single ornithological locality and most quadrats have only one or two localities (Figure 3). However, when only localities that meet the requirements for being considered "minimally sampled" (Table 1) are plotted, a different picture emerges (Figure 2b). Most of the quadrats (73.6%) have never been sampled minimally for birds (Figure 3) and the majority of those that have been investigated have only a single sampling locality (Figure 3).

The highest density (five localities) of "minimally sampled" localities in the cerrado region is located near the cities of Goiânia and Anápolis (Figure 2b). Small density peaks (3–4 localities) are found (Figure 2b) around Jaraguá (Goiás), Lagoa Santa (Minas Gerais), Cuiabá (Mato Grosso), Brasília (Distrito Federal), and two quadrats around or in the Parque Nacional Noel Kempff Mercado (Santa Cruz, Bolivia).

The landscape in the cerrado region has been widely altered by human activities (Figure 4). Most of the quadrats have high (37.6%) or intermediate (30.6%) levels of landscape modification. Quadrats with low level of modification (31.8%) are mainly in the periphery of the region (Figure 4). "Minimally sampled" localities are mainly in quadrats with high (49.0%) and intermediate (21.5%) levels of landscape modification. Nevertheless, most of the quadrats (58.4%) with high levels of landscape modification have never been sampled for birds (compare Figures 2b and 4).

Discussion

Status of the biological inventory

The distribution of localities in the cerrado region that have been "minimally sampled" for birds (Figure 2b) clearly shows many gaps in our knowledge of the avifauna. Around 70% of the cerrado region has never been satisfactorily sampled for birds. Interestingly, this percentage is similar to that reported for Brazilian Amazonia (Oren and Albuquerque 1991). Altogether these two studies suggest that the two largest ecological regions in South America remain poorly explored for birds, and that one must be very cautious when interpreting patterns of species richness and endemicity at a continental scale which are generated using the information currently available in the literature and in natural history museums.

There are few quantitative studies on the distribution of sampling localities in the cerrado region for other groups of organisms. However, situations similar to or worse than that found for the bird inventory have been described for the inventories of mammals (Silva unpubl. data), frogs (Heyer 1988), lizards (Vanzolini and Brandão 1986, Vanzolini 1988) and termites (R. Constantino *in*

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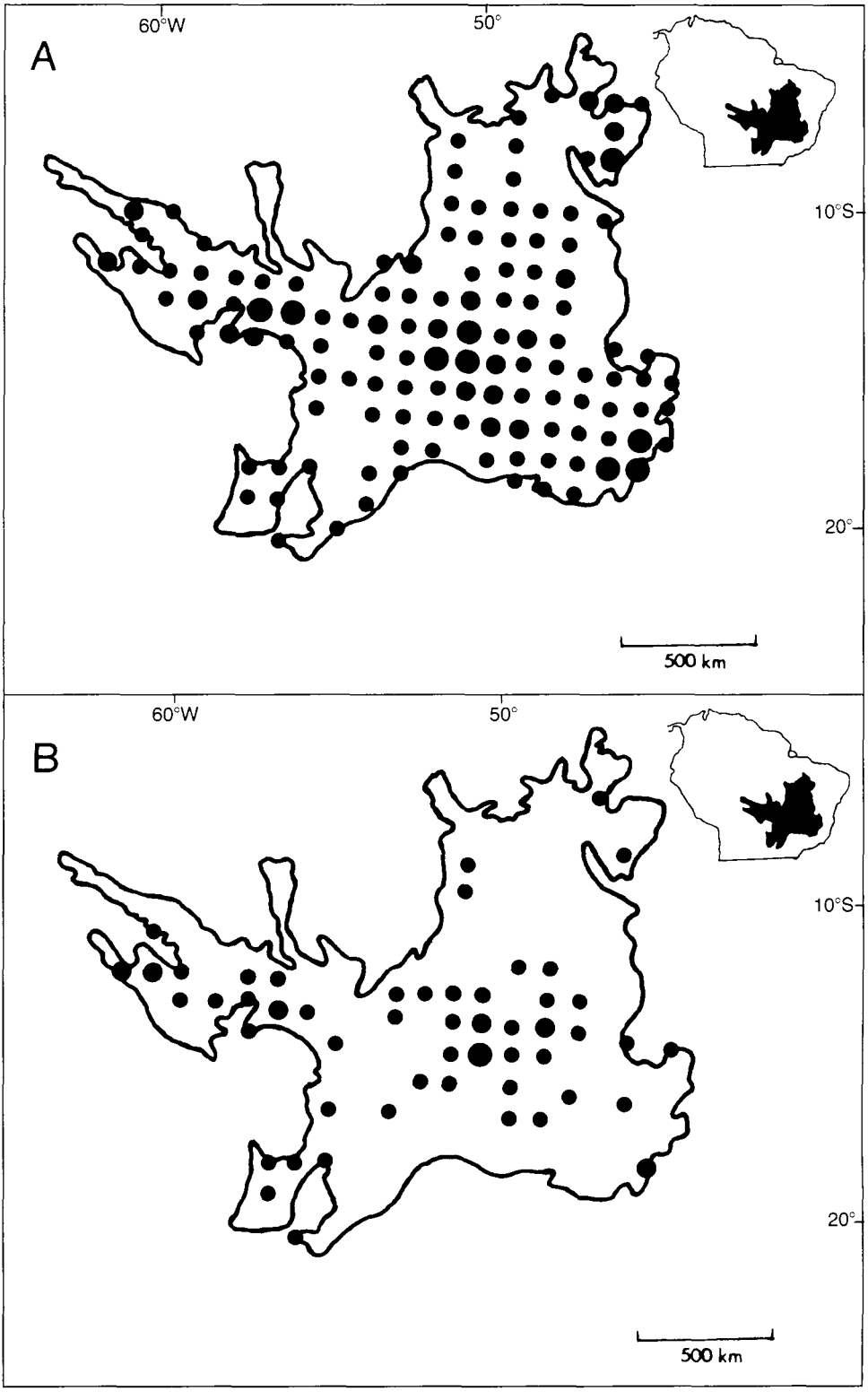

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litt. 1995). The following statement by Heyer (1988) about frog inventory seems to describe very well the situation of the biological inventory for most groups of animals and plants in the cerrado region: "Our knowledge of frogs of the caatingas and cerrados is so rudimentary that even basic questions regarding their distributions are unanswerable at present".

Strategies for future biological research in the cerrado region will differ from group to group, according to their ecological requirements as well as to the distribution of previous sampling efforts. In most groups, intensive inventories covering as many different parts of the cerrado region as possible are urgently required. An adequate starting point for the inventory of these poorly known groups should be to focus sampling efforts primarily on areas with a high level of habitat modification (Figure 4), where the probability of species loss is potentially high.

In birds, the priority areas for further ornithological inventory work in the cerrado region are of course those that have never been sampled for birds. Among them, I give first priority to regions with a high level and second priority for regions with intermediate and low levels of landscape modification. First-priority areas are (not in order of importance): (1) most of the states of Tocantins, Maranhão and Mato Grosso do Sul; (2) southern Goiás; and (3) western Minas Gerais. Second-priority areas are those parts of the cerrado region in Mato Grosso, Piauí and Bahia as well as those in Paraguay and Bolivia.

Because the cerrado region is composed of a mosaic of different types of vegetation that harbour different avifaunas (Sick 1965, Cavalcanti 1988, Silva 1989, Rocha *et al.* 1990), it is necessary to evaluate which habitats are expected to harbour more bird species new to this region. Silva (in press b) has pointed out that around 70% of the breeding avifauna of the cerrado region is composed of species partially or totally dependent on forests, a habitat type that covers less than 15% of this region. Studies on the avifauna of the two main types of forest in the cerrado region (tropical dry forests and gallery forests) have indicated significant differences in species composition between forest types as well as between sites of similar forest type but located in different sectors of the region (Silva unpubl. data). Because of the patchy distribution of their habitats, forest birds have usually very restricted ranges in the cerrado region, and some are endemic to special sectors of it (e.g. Rio Araguaia valley and Rio Paranã valley). In contrast, open-vegetation birds (those inhabiting the cerrado vegetation, campos rupestres and grasslands) are generally widespread within the cerrado region. Notable exceptions to this pattern are four species (*Augastes scutatus*, *Asthenes luizae*, *Polystictus superciliaris* and *Embernagra longicauda*) whose ranges are surprisingly restricted to a small area covered by "campos rupestres" in the Espinhaço Range, in the eastern border of the cerrado region (Silva in press a). Based on these aspects of the region's avian biogeography, it is possible to predict that more species will be added to the cerrado region avifauna if

Figure 2. Number of localities per quadrat in the cerrado region, South America. A, all localities: blank = 0; • = 1–7; medium filled circle = 8–14; large filled circle = > 14. B, only those localities regarded as "minimally sampled": blank = 0; • = 1–2; medium filled circle = 3–4; large filled circle = >5.

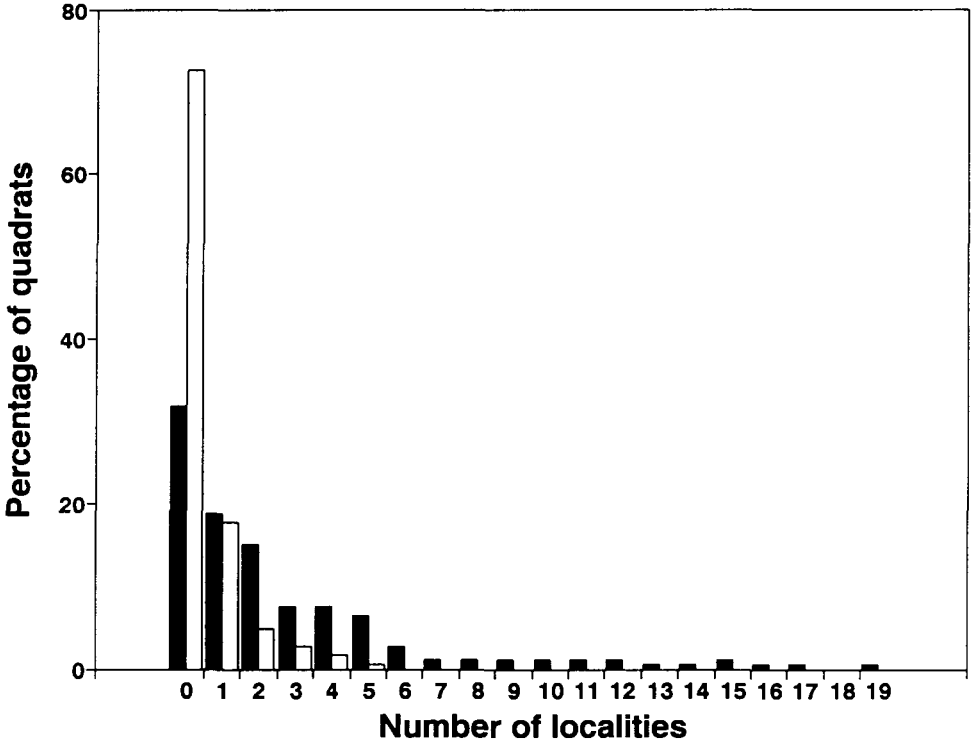

Figure 3. Distribution of the number of ornithological localities per quadrat in the cerrado region, South America. Black (all localities, n = 504), white (localities regarded as "minimally sampled", n = 85). Note that most of the quadrats in the cerrado region have no single "minimally sampled" locality.

inventories are focused on tropical dry forests and gallery forests rather than on open vegetation. However, special attention must also be paid to a detailed inventory of the avifauna of the patches of "campos rupestres" on the high plateaus of Goiás, Tocantins, Mato Grosso and Minas Gerais. This habitat has a very peculiar flora, with a high number of endemic species (Giullietti and Pirani 1988), and it will not be surprising at all if future studies reveal new species or subspecies of bird and of other groups of organisms associated with this very special type of vegetation.

Implications for conservation

Conservation of the biological resources in the cerrado region has received little attention in recent decades. So far, only 0.7% of the total area of the region is protected as national parks or ecological stations. In addition to having an unsatisfactory system of conservation areas, the native vegetation has been rapidly modified by human activities. The percentage of habitat modification to date has been estimated to be between 37 and 50% (Ratter and Dargie 1988, Dias 1990), but the actual area modified is probably over 50% (Figure 4). By using any one of these estimates, the percentage of habitat modification in the

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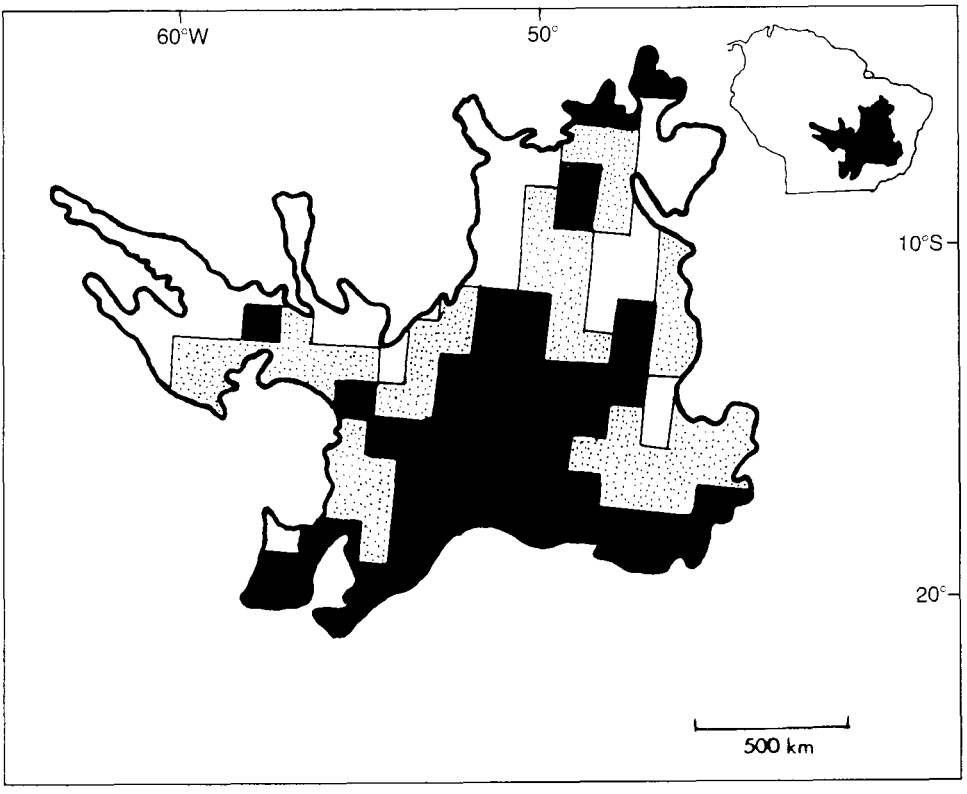

Figure 4. Geographical distribution of the levels of landscape modification per quadrat in the cerrado region, South America. Blank, low level of modification (quadrats with <30% of their area modified); stippled, intermediate level of modification (quadrats with 30–70% of their area modified); black, high level of modification (quadrats with >70% of their area modified).

cerrado region will be around 4–8 times as much as that reported for Brazilian Amazonia (Skole *et al.* 1994).

Ideally, measures to protect the biological resources of a large region should be based on abundant biological data. At the present rate of gathering taxonomic and distributional data on the flora and fauna of the cerrado region, a thorough mapping of the major biodiversity patterns in this region will take at least several decades to be completed and will require large amounts of both time and money, which are unavailable at present. Even if datasets for the best known groups of organisms (e.g. birds and some families of plants) could be improved rapidly, one could not be sure that critical analyses of these datasets would indicate the same set of conservation priorities. In fact, animals and plants in the cerrado region seem to have little congruence in their patterns of species richness and endemism. For instance, whereas the avifauna associated with the cerrado vegetation will vary very little in composition within the region, this will not be the case for plants. In a pioneer study on the floristic composition of 26 sites of the cerrado vegetation, Ratter and Dargie (1988)

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Table 1. Localities considered as "minimally sampled" for birds in the cerrado region, South America

Locality	Country	State/ Department	Latitude	Longitude
Agua Limpa, Fazenda	BR	DF	15°57'S	47°56'W
Alto do Palácio	BR	MT	19°14'S	43°29'W
Amambai, rio	BR	MS	23°05'S	55°13'W
Anápolis	BR	GO	16°20'S	48°58'W
Aquidauana	BR	MS	20°28'S	55°48'W
Aragarças	BR	GO	15°55'S	52°15'W
Aricá-Mirim, Fazenda	BR	MT	15°59'S	55°55'W
Arinos	BR	MG	15°53'S	46°01'W
Aruanã	BR	GO	14°54'S	51°05'W
Barra do Garças	BR	MT	15°53'S	52°15'W
Brasília	BR	DF	15°47'S	47°55'W
Cáceres	BR	MT	16°04'S	57°41'W
Campo Grande	BR	MS	20°27'S	54°37'W
Cavalcante	BR	GO	13°48'S	47°30'W
Chapada dos Guimarães	BR	MT	15°26'S	55°45'W
Chavantina	BR	MT	14°40'S	52°21'W
Conceição do Mato Dentro	BR	MG	19°01'S	43°25'W
Coxim	BR	MS	18°30'S	54°45'W
Cuiabá	BR	MT	15°35'S	56°05'W
Dumbá	BR	MT	14°27'S	51°01'W
El Encanto, Arroyo	BO	SC	14°30'S	60°40'W
Emas, Parque Nacional das	BR	GO	8°45'S	52°45'W
Esperança, Fazenda	BR	GO	15°38'S	49°43'W
Ferreiro	BR	GO	15°36'S	50°37'W
Flores de Goiás	BR	GO	14°34'S	47°04'W
Florida, 60 km ESE	BO	SC	14°42'S	60°39'W
Florida, 86 km ESE	BO	SC	14°50'S	60°25'W
Formiga, Fazenda	BR	GO	15°27'S	49°32'W
Formosa	BR	GO	15°32'S	47°20'W
Formoso	BR	GO	13°37'S	78°54'W
Formoso, Fazenda	BR	MS	21°16'S	56°40'W
Gama, Engenho do	BR	MT	15°10'S	59°15'W
Gilbués	BR	PI	9°50'S	45°21'W
Goiânia	BR	GO	16°40'S	49°16'W
Goiás (= Goiás Velho)	BR	GO	15°56'S	50°08'W
Harmonia, Fazenda	BR	MS	21°15'S	56°42'W
Huanchaca Dos	BO	SC	14°34'S	60°40'W
Huanchaca Uno	BO	SC	13°55'S	60°45'W
Iaciara	BR	GO	14°09'S	46°40'W
Inhumas	BR	GO	16°22'S	49°30'W
Ipameri	BR	GO	17°43'S	48°09'W
Janaúba	BR	MG	15°48'S	43°19'W
Jaraguá	BR	GO	15°45'S	49°20'W
Jataí	BR	GO	17°53'S	51°43'W
Jordão, Ribeirão	BR	MG	18°26'S	48°06'W
Lagoa Santa	BR	MG	19°38'S	43°53'W
Las Torres	BO	SC	13°40'S	60°50'W
Los Fierros	BO	SC	14°25'S	61°10'W
Los Fierros savanna	BO	SC	14°30'S	61°00'W
Luziânia	BR	GO	16°15'S	47°56'W
Macaúba	BR	TO	10°31'S	50°30'W
Matogrosso	BR	MT	15°00'S	59°57'W

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Table 1 cont.

Locality	Country	State/ Department	Latitude	Longitude
Minaçu	BR	GO	13°32'S	48°15'W
Moira	BO	SC	14°40'S	61°25'W
Mossâmedes	BR	GO	16°07'S	50°11'W
Nerópolis	BR	GO	16°25'S	49°14'W
Nova Veneza	BR	GO	16°23'S	49°19'W
Pandeiros, Riacho	BR	MG	15°42'S	44°36'W
Paracatu	BR	MG	17°13'S	46°52'W
Pedras, Furo das	BR	TO	10°37'S	50°33'W
Pindaíba	BR	MT	14°58'S	52°19'W
Pirapora	BR	MG	17°21'S	44°56'W
Pirenópolis	BR	GO	15°51'S	48°57'W
Piso Firme	BO	SC	13°36'S	61°57'W
Pitangueiras, Fazenda	BR	MS	20°52'S	56°55'W
Planaltina	BR	DF	15°37'S	47°40'W
Porto Esperidião	BR	MT	15°51'S	58°28'W
Posse	BR	GO	14°05'S	46°22'W
Recanto Passárgada	BR	MT	15°44'S	56°05'W
Riachão	BR	MA	7°22'S	46°37'W
Rio Manso, Represa do	BR	MT	14°45'S	56°00'W
Rio Verde	BR	GO	17°43'S	50°56'W
Romaria	BR	MG	18°53'S	47°38'W
Roncador, Rio	BR	GO	16°52'S	50°43'W
Rondonópolis	BR	MT	16°28'S	54°38'W
Santa Isabel do Morro	BR	TO	11°34'S	50°40'W
Santo Antonio do Leverger	BR	MT	15°52'S	56°05'W
São Domingos	BR	GO	13°24'S	46°19'W
São Vicente, Ruínas de	BR	MT	14°30'S	59°45'W
Serra das Araras, Estação Ecológica	BR	MT	15°39'S	57°13'W
Tangará da Serra	BR	MT	14°38'S	57°29'W
Tesouras, Rio	BR	GO	14°36'S	50°51'W
Tomé Pinto, Fazenda	BR	GO	15°43'S	49°20'W
Trindade	BR	GO	16°40'S	49°30'W
Uruaçu	BR	GO	14°30'S	49°10'W

Countries: BR, Brazil; BO, Bolivia. States or departments: BA, Bahia; DF, Distrito Federal; GO, Goiás; MA, Maranhão; MT, Mato Grosso; MS, Mato Grosso do Sul; MG, Minas Gerais; PI, Piauí; SC, Santa Cruz; TO, Tocantins.

surprisingly found that only 27 of the total of 485 plant species recorded occurred at 15 or more sites, and no less than 230 were found at only a single site.

Given the limited information available on patterns of biological diversity in the cerrado region, the use of approaches based on species, subspecies or populations is not suitable for determining conservation priorities for this region. A feasible approach could be to focus instead on ecosystems and landscapes. The ecosystem or landscape approach has been regarded as the only way to conserve organisms and ecological processes in biologically poorly known or unknown regions (Franklin 1993). The logic behind such an approach is that by analysing the large-scale variation in ecosystems or landscapes of a region, it will be possible to design a reserve system that encompasses most of this variation and consequently conserves most of the regional biodiversity

(Franklin 1993). Conservation priorities and reserve system design for the cerrado region could be made quickly and cheaply by using the ecosystem approach, mainly because excellent maps of soil, vegetation, topography and geology at adequate scale (1:250,000) and covering most of this region are already available from the reports of the Project RADAMBRASIL. In addition to reserve planning, new legal mechanisms to reduce the rate of habitat modification in the cerrado region must be adopted as soon as possible. I suggest that the conversion of areas of tropical dry forest, gallery forest and cerradão into pastures and agricultural fields should be permanently prohibited and that new projects in areas currently covered by cerrado vegetation should be temporarily banned until their impact on the flora and fauna can be rigorously assessed.

Ensuring that the biological diversity in the cerrado region can be conserved appropriately is a major challenge to governments and conservationists alike, as powerful economic interests are behind the process of habitat destruction in central Brazil (Vanzolini 1980, Willis and Oniki 1992). It is very important that international conservation agencies include the cerrado region among the highest priorities for biological investigation and conservation in the Neotropical region.

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References

Ab'Saber, A. N. (1977) Os domínios morfoclimáticos da América do Sul. Primeira Aproximação. *Geomorfologia* 52: 1–21.

Ab'Saber, A. N. (1983) O domínio dos cerrados: introdução ao conhecimento. *Rev. Serviço Público* 111: 41–55.

Ab'Saber, A. N. (1986) Geomorfologia da região. Pp.88–124 in J. M. G. Almeida, Jr, ed. *Carajás: desafio político, ecologia e desenvolvimento*. São Paulo: Editora Brasiliense.

Brasil, A. E. and Alvarenga, S. M. (1989) Relevo. Pp.53–72 in A. C. Duarte, ed. *Geografia do Brasil: região Centro-Oeste*. Rio de Janeiro: FIGBE-Diretoria de Geociências.

Brown, A. K. and Brown, J. H. (1993) Incomplete data sets in community ecology and biogeography: a cautionary tale. *Ecol. Applications* 3: 736–742.

Brown, K. S., Jr (1977) Centros de evolução, refúgios quaternários e conservação de patrimônios genéticos na região neotropical: padrões de diferenciação em Ithominae (Lepidoptera: Nymphalidae). *Acta Amazonica* 7: 75–137.

Brown, K. S., Jr (1987) Conclusions, synthesis and alternatives. Pp.175–196 in T. C. Whitmore and G. T. Prance, eds. *Biogeography and quaternary history in tropical America*. Oxford: Clarendon Press.

Cavalcanti, R. B. (1988) Conservation of birds in the cerrado of central Brazil. Pp.59–66 in P. D. Goriup, ed. *Ecology and conservation of grassland birds*. Cambridge, U.K.: International Council for Bird Preservation (Techn. Publ. 7).

Dias, B. F. de S. (1990) Conservação da natureza no cerrado brasileiro. Pp.583–640 in M. N. Pinto, ed. *Cerrado: caracterização, ocupação e perspectivas*. Distrito Federal, Brazil: Editora Universidade de Brasília.

Eiten, G. (1972) The cerrado vegetation of Brazil. *Bot. Rev.* 38: 201–341.

Eiten, G. (1990) Vegetação. Pp.9–65 in M. N. Pinto, ed. *Cerrado: caracterização, ocupação e perspectivas*. Distrito Federal, Brazil: Editora Universidade de Brasília.

FIBGE (1988) *Mapa de vegetação do Brasil*. Rio de Janeiro: Fundação Instituto Brasileiro de Geografia e Estatística.

Franklin, J. F. (1993) Preserving biodiversity: species, ecosystems, or landscapes? *Ecol. Applications* 3: 202–205.

Furley, P. A. and Ratter, J. A. (1988) Soil resources and plant communities of the central Brazilian cerrado and their development. *J. Biogeogr.* 15: 97–108.

Gentry, A. H. (1992) Tropical forest biodiversity: distributional patterns and their conservational significance. *Oikos* 63: 19–28.

Giullietti, A. M. and Pirani, J. R. (1988) Patterns of geographic distribution of some plant species from the Espinhaço Range, Minas Gerais and Bahia, Brazil. Pp.39–69 in P. E. Vanzolini and W. R. Heyer, eds. *Proceedings of a workshop on Neotropical distribution patterns*. Rio de Janeiro: Academia Brasileira de Ciências.

Heyer, W. R. (1988) On frog distribution patterns east of the Andes. Pp.245–274 in P. E. Vanzolini and W. R. Heyer, eds. *Proceedings of a workshop on Neotropical distribution patterns*. Rio de Janeiro: Academia Brasileira de Ciências.

ICBP (1992) *Putting biodiversity on the map: priority areas for global conservation*. Cambridge, U.K.: International Council for Bird Preservation.

Mittermeier, R. A. (1988) Primate diversity and the tropical forest. Case studies from Brazil and Madagascar and the importance of the megadiversity countries. Pp.145–154 in E. O. Wilson, ed. *Biodiversity*. Washington, D.C.: National Academy Press.

Nelson, B. W., Ferreira, C. A. C., da Silva, M. F. and Kawasaki, M. L. (1990) Endemism centres, refugia and botanical collection density in Brazilian Amazonia. *Nature* 345: 714–716.

Nimer, E. (1979) *Climatologia do Brasil*. Rio de Janeiro: IBGE.

Oren, D. C. and Albuquerque, H. G. (1991) Priority areas for new avian collections in Brazilian Amazonia. *Goeldiana Zool.* 6: 1–11.

Paynter, R. A. and Traylor, M. A. (1991) *Ornithological gazetteer of Brazil*. Cambridge, Mass.: Museum of Comparative Zoology.

Prance, G. T. (1994) The use of phytogeographic data for conservation planning. Pp.145–163 in P. L. Forey, C. J. Humphries and R. I. Vane-Wright, eds. *Systematics and conservation evaluation*. Oxford: Clarendon Press.

Ratter, J. A. and Dargie, T. C. D. (1988) An analysis of the floristic composition of 26 cerrado areas in Brazil. *Edinburgh J. Bot.* 49: 235–250.

Ratter, J. A., Askew, G. P., Montgomery, R. F. and Gifford, D. R. (1978) Observations on forests of some mesotrophic soils in central Brazil. *Revta. Brasileira Bot.* 1: 47–58.

Ribeiro, J. F., Sano, S. M., Macêdo, J. and Silva, J. A. (1983) Os principais tipos fisionômicos da região dos cerrados. *Bol. Pesquisa (EMBRAPA-CPAC)* 21: 1–28.

Rocha, I. R. D., Cavalcanti, R. B., Filho, J. S. M. and Kitayama, K. (1990) Fauna do Distrito Federal. Pp.389–412 in M. N. Pinto, ed. *Cerrado: caracterização, ocupação e perspectivas*. Distrito Federal, Brazil: Editora Universidade de Brasília.

Sick, H. (1965) A fauna do cerrado. *Arq. Zool. São Paulo* 12: 71–93.

Silva, J. M. C. (1989) Análise biogeográfica da avifauna das florestas do interflúvio Araguaia-São Francisco. M.Sc. dissertation, University of Brasília.

Silva, J. M. C. (in press a) Biogeographic analysis of the South American cerrado avifauna. *Steenstrupia*.

Silva, J. M. C. (in press b) Birds of the cerrado region, South America. *Steenstrupia*.

Skole, D. L., Chomentowski, W. H., Salas, W. A. and Nobre, A. D. (1994) Physical and human dimensions of deforestation in Amazonia. *Bioscience* 44: 314–323.

Vanzolini, P. E. (1980) Questões ecológicas ligadas à conservação da natureza no Brasil. *Biogeografia* 16: 1–22.

Vanzolini, P. E (1988) Distributional patterns of South American lizards. Pp.317–342 in P. E. Vanzolini and W. R. Heyer, eds. *Proceedings of a workshop on Neotropical distribution patterns*. Rio de Janeiro: Academia Brasileira de Ciências.

Vanzolini, P. E. (1992) *A supplement to the ornithological gazetteer of Brazil*. São Paulo: Museu de Zoologia, Universidade de São Paulo.

Vanzolini, P. E. and Brandão, C. R. F. (1986) Diretrizes gerais para um levantamento faunístico. Pp.208–213 in J. M. G. Almeida, Jr., ed. *Carajás: desafio político, ecologia e desenvolvimento*. São Paulo: Editora Brasiliense.

Wetterberg, G. B., Pádua, M. T. J., Castro, C. S. and Vasconcellos, J. M. C. (1976) Uma análise de prioridade em conservação da natureza na Amazônia. *PRODEPEF (Projeto de Desenvolvimento e Pesquisa Florestal, PNUD/FAO/IBDF) Série Técnica* 13: 1–44.

Willis, E. O. and Oniki, Y. O. (1992) Losses of São Paulo birds are worse in the interior than in Atlantic forests. *Ciência e Cultura* 44: 326–328.

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