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Use of forest fragments by blue-winged macaws (*Primolius maracana*) within a fragmented landscape

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Abstract Parrots are the most threatened group of birds in the world, mainly because of the reduction and fragmentation of their natural habitats. However, few studies have investigated the dynamics of parrot populations in disturbed landscapes on a broad scale. In this paper, we studied the ecological interactions of the vulnerable blue-winged macaw (*Primolius maracana*) in a fragmented landscape surrounding a large protected park in southeastern Brazil. We sampled 36 forest fragments that varied in size, characteristics, degree of isolation and type of surrounding matrix in order to assess the importance of habitat features on the maintenance of these birds. Blue-winged macaws were recorded in 70% of the satellite remnants that were sampled, which included large and small blocks of forest. These areas were used as sites for feeding, nesting or overnight rests, and also provided connectivity for birds' displacements. However, the frequency of macaw visits varied among the remnants, and this was related to habitat features such as patch size, human use of surrounding land, and the proximity to the protected park, to urban areas and to the birds' roosting areas. In general, landscape-scale parameters explained more of the variation in the frequency of visits by macaws than did patch-scale parameters. These results demonstrate the importance of landscape mosaics for the survival of blue-winged macaws.

Keywords Parrots · Threaten species · Atlantic forest · Forest fragmentation · Habitat use · Scale of analyses

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Introduction

The current extinction crisis has become of great concern in the last decades (Soulé 1987; Wilson 1988; Pimm 1995; Brooks 2000). Recent estimates indicate that one out of eight species of birds has a high risk of becoming extinct in the next 100 years (BirdLife International 2000). These endangered birds included the Psittacidae, the most threatened group, with at least 28% of its species facing some risk of extinction (BirdLife International 2000). The loss and fragmentation of natural habitats are the main causes of the decline of most threatened parrots (BirdLife International 2000).

The blue-winged macaw (*Primolius maracana*) (Vieillot), is a parrot species that is currently considered near-threatened to extinction (BirdLife International 2004). This species was once widespread throughout Brazil, eastern Paraguay, and northern Argentina, but showed a marked retraction in its range in the second half of the 20th century, particularly in the southern portion of its historical distribution (southern Brazil: Belton 1994; Bornschein and Straube 1991; Rosário 1996; Benke 2001; Argentina: Chebez 1996; de la Peña 1999; Paraguay: Lowen et al. 1996; Clay et al. 1998; summarized in Nunes 2003). This reduction in range has been attributed primarily to habitat loss (Olmos 1993) since there is so little forest remaining across most of this species' original distribution (see Fundação SOS Mata Atlântica and INPE 1998).

In São Paulo state, the blue-winged macaw was once widespread in semideciduous forests, but these have been drastically reduced to less than 2% of their original extent (Viana and Tabanez 1996) and the species is now restricted to just a few sites (Nunes 2003). The Caetetus Ecological Station (CES) is one of the largest and most important remnants of semideciduous forest in São Paulo state (Cullen et al. 2000), and it has the largest population of blue-winged macaws in the southern part of this species' original range (Nunes 2000). This population is currently estimated at approximately 150 birds (Nunes 2000). A mosaic of forest remnants, coffee plantations and pasture dominates the landscape around Caetetus, and could be important for maintaining this macaw and other local animal species.

In this study we examined the effects of habitat fragmentation on blue-winged macaws on a broad scale, attempting to assess the interactions of species with the landscape composition and spatial configuration. Such information is especially important for the conservation of parrots, since studies on a patch-level scale have suggested that some parrot species, especially large bodied ones such as macaws, usually do not thrive in small fragments (Aleixo and Vielliard 1995; Willis 1979; Uezu et al. 2005). However, the high mobility of some parrot species allows them to use, or at least to reach, small remnants within fragmented landscapes (Fischer and Lindenmayer 2002; MacNally and Horrocks 2000; Marsden et al. 2000), from which less-mobile species tend to be excluded (Villard and Taylor 1994). Moreover, animal movements tend to vary according to the configuration of the landscape and matrix characteristics (Fischer and Lindenmayer 2002; Roshier 2003).

In this study, we examined the dynamics of a vulnerable parrot species in a fragmented landscape by looking beyond patch boundaries. We examined habitat used by macaws in a series of forest fragments that varied in size, characteristics, degree of isolation, and position within the matrix around the reserve. These data allowed us to assess the importance of different traits in determining the landscape used by the macaws.

Methods

Study area and sampling sites

The study was done in fragments of native vegetation around the Caetetus Ecological Station (Lat 22°24′S, Long 49°42′W), near Gália, in west-central São Paulo state, Brazil (Fig. 1). The reserve, a 2,178 ha forest patch, is the largest block of protected forest in its region. The forest is mainly semideciduous, with a high seasonality and a partial fall of leaves from some trees during the cool, dry season (April–September). The landscape around the reserve is composed of small remnants of native vegetation forest, pastures, and coffee and rubber plantations. The native remnants are mainly semideciduous forest, along with secondary forest and some forest-savanna transitional areas.

We used a 1:250,000 vegetation cover map, produced by Instituto Florestal (Kronka et al. 1994), to select 36 forest patches within a 25 km radius of the CES (Fig. 1). The map was edited to allow corrections and updates, based on the LandsatTM satellite image of April 2001 and using the software Spring 3.5 (Camara et al. 1996). The fragments were randomly selected from the map and stratified by size, with classes of 10–30 ha, 31–50 ha, 51–70 ha, 71–100 ha, 101–200 ha, and > 200 ha. We selected six fragments from each size class for sampling a variety of forest habitats.

Bird recording methods

We searched for blue-winged macaws in the 36 fragments around Caetetus, between August 7th and October 7th 2001, to assess the use of these areas by the species. The frequency of visits by blue-winged macaws was recorded by direct counting at strategic points of observation (Nunes and Betini 2002). In this method, we counted macaws from two points of high visibility around each of these 36 forest fragments. The pairs of point-counts were located outside the remnant in question, but close to its border, and were distant from each other. At each point we delimited the length of forest border where the macaws should be recorded, starting from the area of visibility of the observer. These lengths were estimated in loco or calculated later using Global Positioning System (GPS) and Geographical Information System (GIS) tools, and varied among the point-counts (mean + SD = 544.2 ± 153.8 m).

From both strategic point-counts, we recorded all movements of macaws flying out of or into the forest fragment, over a period of 7.5 h, during one morning (6:00–10:30 h) and one afternoon (15:00–18:00 h). For each visual contact with macaws, we recorded the route of the flocks (into or out of the fragment), the number of individuals, the time, the direction of flight and any relevant observations. A blue-winged macaw visitation index was calculated for each sampled fragment as the total number of records of individuals flying into the fragment divided by the sum of the border length sampled by the two observers (records of macaws/km).

Habitat data

We related the blue-winged macaw visitation index to features of the fragments and their surrounding landscapes. Based on the edited Caetetus map, we calculated landscape metrics and indices using GIS ArcView 3.2 with the extension Spatial

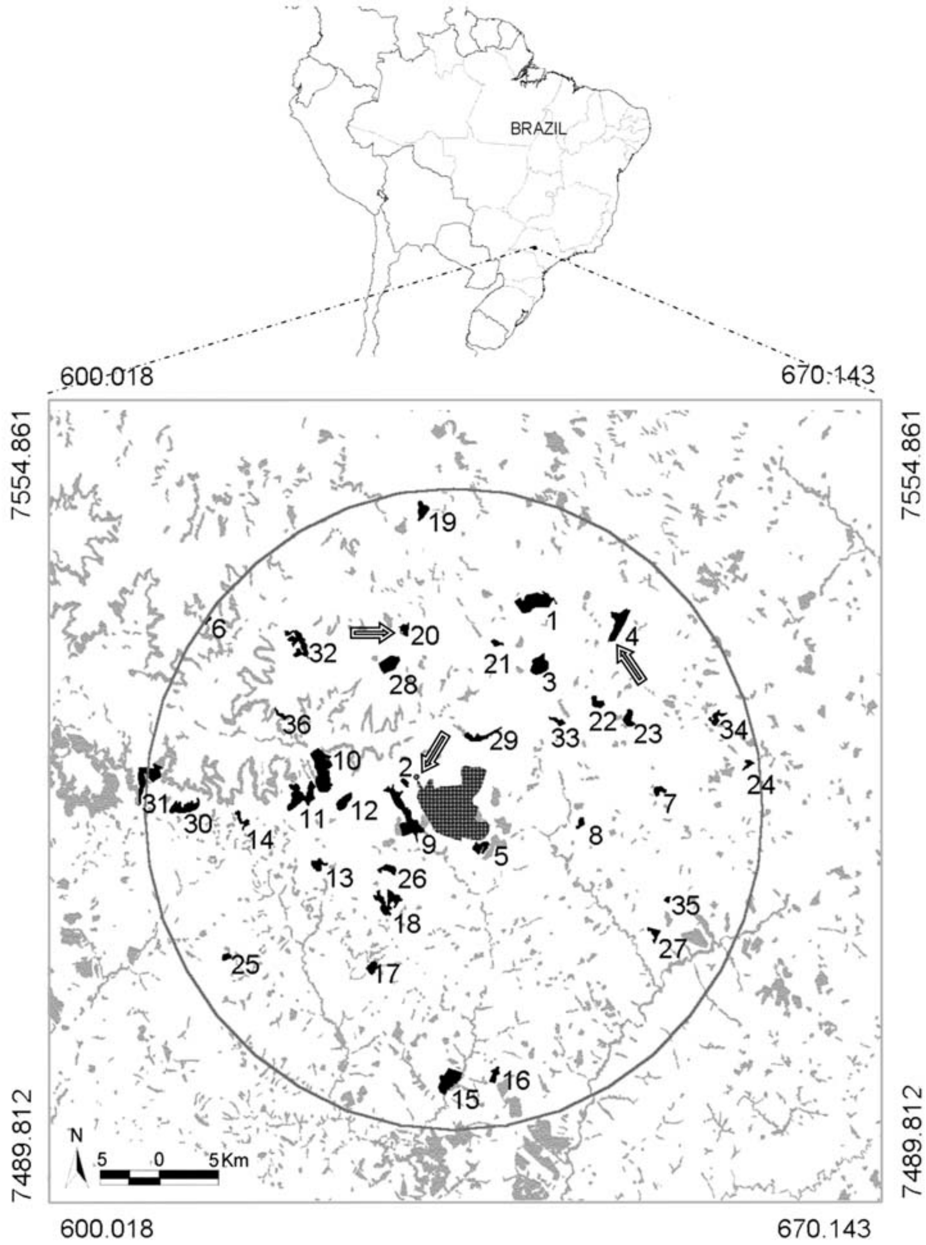

Fig. 1 Location of Caetetus Ecological Station in south-east Brazil and the study area in a 25 km radius (UTM co-ordinate system, zone 22). The reserve is indicated by the hatch pattern patch, the sampled fragments by the black patches, the non-sampled fragments by the gray patches, and the matrix by the white background. The arrows indicate the location of blue-winged macaw comunal roosts

Analist 1.1 (ESRI 1996a,b) and the software Fragstats 3 (McGarigal et al. 2002). Three features of fragments were considered: their vegetation category (C) (old-growth forest or secondary forest), size (S) and shape (SI) (shape index; see

Table 1 Landscape indices used to access habitat use by blue-winged macaw around Caetetus Ecological Station, São Paulo, Brazil

Index	Formula	Description	Units	Range
Shape index of the patch (SI)	SI = P/P_{min}	P = perimeter of the patch P_{min} = minimum perimeter possible for a maximally compact patch of the corresponding patch area	Non-dimensional	1—no limit
Isolation index (II)	II = $\sum[NPA/(DNP)^2]$	NPA = neighboring patch area in a 3 km radius from the focal patch DNP = nearest distance between the focal patch and the neighboring patch	Non-dimensional	0—no limit

Table 1). Five features of the surrounding landscapes were also considered: isolation (II) (isolation index; see Table 1), the main land use of the surroundings (LU) (pasture, coffee, citric or *Eucalyptus* plantations), distance to the protected area, Caetetus Ecological Station (DC), distance to the closest city (DCC) and distance to a known macaw sleeping roost (DR).

The variables were tested for normality and, when necessary, transformed to achieve normality. The following transformations were used for the indicated variables: square root for the blue-winged macaw visitation index and for the distance to a known macaw roost (srtDR), and natural logarithms for fragment size (log S), fragment shape index (log SI) and fragment isolation index (log II). The variables distance to Caetetus Ecological Station and distance to the closest city were not transformed.

The possible correlations between each pair of explanatory variables were also examined since such a relationship could create multicollinearity problems in multiple models. Univariate analyses were run between explanatory variables and the blue-winged macaw visitation index. Pearson's product–moment correlations (between quantitative variables) and one-way ANOVA (among categorical and quantitative variables) were used for these statistical analyses.

The multiple linear regression model was used to quantify the relationships among groups of explanatory variables and the blue-winged macaw visitation index. Construction of the multiple regression model and selection of the variables were done by evaluating the best fit using statistical procedures for diagnosis that included the inspection of assumptions, significances, coefficients of correlation, multicollinearity problems and leverages. All statistical analyses were done with Statistica 6.0 software (StatSoft 2001).

Table 2 Remnants of native vegetation in a 25 km radius around the Caetetus Ecological Station (196343.75 ha), south-east Brazil

Category	Total area of cover (ha)	Number of fragments	Mean size (ha)	SD of size (ha)
Forest	16915.59	821	20.60	86.87
Secondary forest	16326.9	974	16.76	37.88
Savanna	4510.71	125	36.08	62.10
Forested savanna	798.21	51	15.65	15.90
Swamp	1810.71	53	34.16	44.13
Total	40362.12	2,024	123.25	246.88

Results

The native vegetation around the protected area covers approximately 25% of the study area (25 km radius), and is greatly reduced and highly fragmented, with marked variation in shape and size among remnants (Table 2, Fig. 1). Within this landscape, we observed flocks of blue-winged macaws and other species of parrots, including scaly-headed parrots (*Pionus maximiliani*), white-eyed parakeets (*Aratinga leucophthalmus*), yellow-chevroned parakeets (*Brotogeris chiriri*), reddish-bellied parakeets (*Pyrrhura frontalis*) and blue-winged parrotlets (*Forpus xanthopterygius*).

The blue-winged macaws occurred throughout the landscape around the protected area and were extremely mobile, usually crossing the landscape at mid-high altitude and landing in patches of native vegetation, isolated trees in the matrix, and agricultural fields. We observed macaws feeding on coffee bushes (*Coffeea arabica*, Rubiaceae), one of the main crops in the region, and other exotic fruits such as chinaberry tree (*Melia azedarach*, Meliaceae).

We located three macaw sleeping roosts within the study area (roost 1: Lat 49°44′S, Long 22°16′W; roost 2: Lat 49°43′S, Long 22°23′W; and roost 3: Lat 49°34′S, Long 22°17′W). Two of these (roost 1 and 2) were in isolated guapuruvus trees (*Schizolobium parahyba*, Leguminosae) on pasture, an canopy species which usually shows many hollows of fallen branches, and one roost (roost 3) was in trees at a fragment edge. We counted the maximum number of blue-winged macaws during 1 day in each roost and we recorded: 23 macaws at roost 1, 38 macaws at roost 2, and 30 macaws at roost 3. Such roosts do not hold all the population of blue-winged macaws of the region, because there are some macaws that roost in small flocks in the Caetetus Ecological Station and other forests fragments, and we cannot assure that all comunal roosts were found in this study.

We recorded macaws, either visually or aurally, in 29 of the 36 sampled fragments. However, aural-only records and those of individuals flying out of patches were not included in the visitation indices, which left 25 patches for which the species was recorded. We obtained 173 records of macaws flying to satellite patches around the protected park, usually in pairs (56,6%) but also in groups of up to eight individuals; larger groups were seen on a few occasions.

The species was easily detected in all of 29 fragments, mainly within the first 3 h of sampling, suggesting we detected all fragments visited by blue-winged macaws (Fig. 2). Macaws flew into patches mainly during the morning (8–10 h) and left the

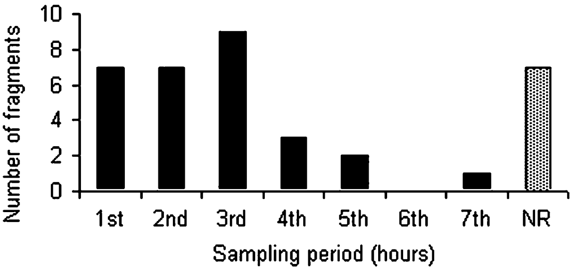

Fig. 2 Sampling period (hours) during which blue-winged macaws were first recorded in each fragment around the Caetetus Ecological Station, SP, Brazil. NR—fragments where macaws were never recorded

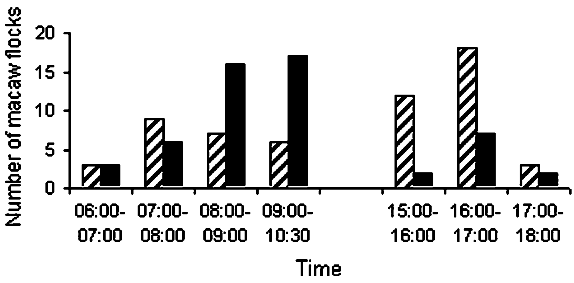

Fig. 3 Variation in the routes of blue-winged macaw flocks during the day in satellite forest fragments around the Caetetus Ecological Station, SP, Brazil. The bars represent the direction of flight of the flocks: black bars—towards the forest patch, hatched bars—away from the forest patch

patches mainly during the afternoon (16–17 h) (Fig. 3). In general, there was no significant difference between the number of records of macaws arriving and leaving the fragments [Wilcoxon matched pairs test, $Z = 0.042$, $n = 36$, $P > 0.05$], which suggested that most of these records probably corresponded to the same individual on two-way flights. Hence, the use of records of only one-way flights in the visitation index avoided the double counting of individuals.

Significant associations were found between pairs of landscape metrics and indices, despite the fact that each of them measured a peculiar feature of the landscape: shape was positively correlated with size [Pearson's product–moment $r = 0.433$, $P < 0.025$], distance to Caetetus was positively correlated with distance to a known macaw roost [$r = 0.597$, $P < 0.001$], and vegetation categories were not equally distributed over different distances to a known macaw roost [ANOVA, $F_{(2,33)} = 3.286$, $P > 0.05$].

The frequency of blue-winged macaw visits was associated with certain features of the patch and landscape (Appendix 1). The visitation index was positively correlated with patch size [$r = 0.414$, $P < 0.025$] and negatively correlated with distances to a known macaw roost [$r = -0.686$, $P < 0.001$] and with distances to the Caetetus Ecological Station [$r = -0.493$, $P < 0.001$] (Fig. 4). The main type of land use around the patches (LU) also affected the blue-winged macaw visitation index [$F_{(3,32)} = 4.511$, $P > 0.025$] since the index mean was lower in patches surrounded by pasture than by other land uses [Tukey HSD test, $P > 0.05$] (Fig. 5).

A dichotomous variable "pasture versus non-pasture" was derived from "the main land use of the surroundings" variable and showed that patches surrounded by pastures had a lower visitation index [t test, $t_{(34)} = 3.595$, $P < 0.001$], and were smaller in size [$t_{(34)} = 2.151$, $P < 0.05$], farther from Caetetus Ecological Station [$t_{(34)} = 14.474$, $P < 0.025$] and farther from a known macaw roost [$t(34) = 3.554$, $P < 0.025$].

In the best fit multiple regression model, the frequency of visits of macaws was explained by size and distance to a known macaw sleeping roost, as well as by distance to the closest city, a non-significant variable in univariate analyses [$r = 0.055$, $P > 0.05$] which now showed a significant positive association with the visitation index. Hence, larger fragments, which are closer to blue-winged macaw roosts and farther from urban localities, are likely to be chosen by macaws during their movements. This multivariate model was highly significant [$F_{(3,32)} = 15.843$, $R^2 = 0.597$, $P < 0.001$] and explained almost 60% of the variation in the visitation index.

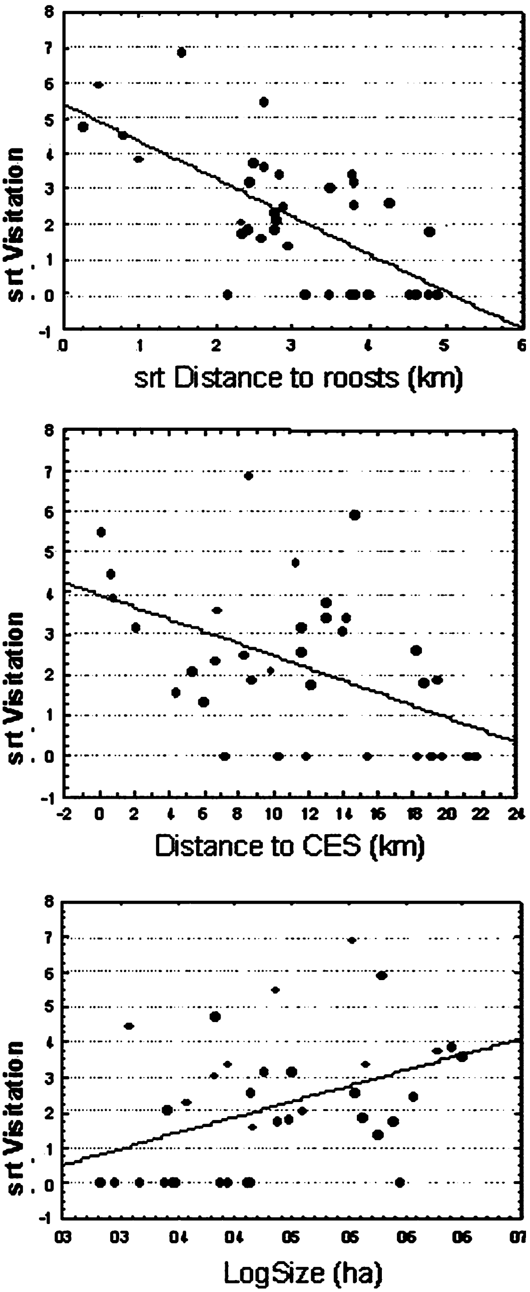

Fig. 4 Relationships between the visitation index for blue-winged macaws and habitat features that were significant in Pearson's product–moment correlations in the fragments around Caetetus Ecological Station, SP, Brazil

The variable "distance to Caetetus Ecological Station" was not included in the multiple model, despite its significant correlation with the visitation index in univariate analyses. Distance to Caetetus Ecological Station was highly correlated to distance to a known macaw sleeping roost, which resulted in redundant information for these variables. This correlation probably reflected the fact that one of the three

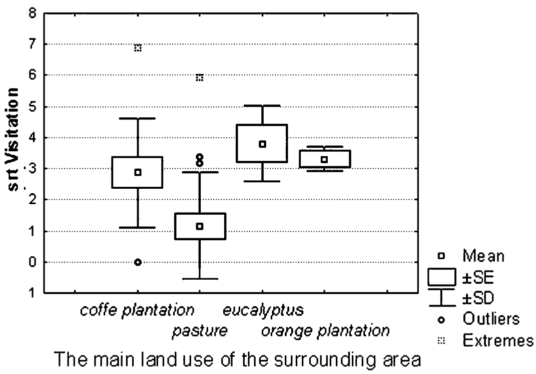

Fig. 5 Means visitation indices for blue-winged macaws in satellite forest fragments in relation to the land use of the surrounding area around the Caetetus Ecological Station, SP, Brazil

roosts was located less than 1 km from the edge of the reserve. Despite this strong correlation, when the variable "distance to Caetetus Ecological Station" replaced "distance to a known macaw sleeping roost" in the multiple model, the explanatory power of the model was reduced [$F_{(3,32)} = 6.588$, $R^2 = 0.381$, $P < 0.025$].

The relationship between the blue-winged macaw visitation index and landscape features was unaffected by the main land use of the surroundings or the dichotomous variable "pasture versus non-pasture" in a multivariate model. Since neither of the latter two variables improved the model they were not included in the multiple model.

Discussion

Habitat selection

Our results revealed the ability of the vulnerable blue-winged macaw to thrive in a mosaic of landscape containing only 25% of the original native forest, even so we do not have information if this population is stable or in decline. The presence of macaws was not restricted to large blocks of forest and the species was managed to spread into the fragmented landscape and adapted their foraging behavior to include exotic species. Such tolerance and adaptability to habitat modification have also been reported for the other two species of *Primolius*, the blue-headed macaw (*P. couloni*) and the yellow-collared macaw (*P. auricolis*) (del Hoyo et al. 1997; Juniper and Parr 1998).

During the study, we frequently recorded blue-winged macaws flying to, and landing in, anthropogenic landscapes and forest fragments around the Caetetus Ecological Station. Such observations suggested that blue-winged macaws included these areas in their home-range. A similar pattern was also observed in Sooretama Biological Reserve (Espirito Santo state, Brazil), where the species left the reserve in the morning to travel to orange plantations and small satellite forest fragments and then returned in the afternoon (Marsden et al. 2000).

The blue-winged macaw was recorded in nearly all of the fragments sampled in the Caetetus region, but the frequency of visits varied according to characteristics of the fragments and their surroundings. The landscape features around the fragments (such as distance to the Caetetus Ecological Station, distance to the closest city, distance to a known macaw sleeping roost and the main land use of the surroundings) explained more of the variation in the visitation index than actual measured features of the fragments (such as shape index and vegetation category). This pattern has been observed for generalist and highly mobile species (Naugle et al. 1999; Price et al. 1999; Graham and Blake 2001; Suarez-Seoane and Baudry 2002) because most of them can cross open areas and use small fragments of non-specific quality (Villard and Taylor 1994; Andrén 1994).

Among the landscape-scale parameters, distance to a known macaw sleeping roost and distance to the closest city showed the strongest associations with the frequency of visitations. Distance to Caetetus Ecological Station was also important, but its high correlation with the distance to a known macaw sleeping roost hindered the interpretation of the relative effects of both variables: distance to a known macaw sleeping roost could cause the distance to Caetetus Ecological Station to show a spurious correlation with visitation rate or, perhaps, both features were simultaneously important for patch selection by the birds, what would be reflecting the dispersion of flocks of macaws that sleep in the roosts and others that sleep in trees inside the reserve.

The tendency to gather at sleeping roosts is a common behavior among parrots (Chapman et al. 1989), particularly in fragmented environments where they can find isolated trees that provide greater visibility for security (Gilardi and Munn 1998). Such roosts apparently serve as information centers where parrots can gather at the end of the afternoon to spend the night and leave at dawn to feed (Chapman et al. 1989). The short distance between some blue-winged macaw roosts and an adjacent fragment could result in a high frequency of visits since it is energetically more economical to visit close fragments than distant ones (Eckert and Randall 1988).

The correlation between the visitation index and the distance to Caetetus Ecological Station could be explained by the ‘‘mainland’’ effect (Wiens 1997; Hanski 1998). The reserve, which is the largest patch of forest in the region, would correspond to a core area that serves as a source of macaws that disperse to other patches. Hence, the forest remnants closest to the Caetetus Ecological Station would receive more macaws than more distant fragments. Conversely, the correlation between the visitation index and the distance to the closest city may reflect the influence of disturbance factors that operate in areas close to cities, where there is considerable human activity.

The presence of pasture as the main type of landscape surrounding the fragments negatively affected the frequency of blue-winged macaw visits, perhaps because of the smaller amount of native vegetation left on cattle ranches. There is extensive cattle ranching in the region around the Caetetus Ecological Station, and this has produced large areas of deforestation. Brazilian law compels landowners to preserve at least 20% of the Atlantic forest on their property, but this law is rarely if at all enforced, and most farms do not have native vegetation on their land. Indeed, cattle ranches usually keep only a few isolated trees in their pastures to provide shade for the cattle. Consequently, this landscape can markedly influence habitat connectedness and the distance between patches.

We had expected that isolation would be highly related to a lower frequency of blue-winged macaw visits because it is generally an important factor for mobile organisms in highly fragmented landscapes (Andrén 1994). However, there was no significant correlation between these two parameters, perhaps because the distance involved in these analyses (3 km) was not large enough to detect such relationship, particularly considering the high mobility of macaws. Among the patch-scale parameters, only fragment size was significantly associated with the frequency of macaw visits. The size of a fragment is usually an important factor in explaining the number of species that inhabit an area (MacArthur and Wilson 1967; Price et al. 1999; Graham and Blake 2001; Miller and Cale 2000), especially for sedentary and restricted animals (Blake and Karr 1987; Naugle et al. 1999; Boulinier et al. 2001; Lee et al. 2002). The occurrence of very mobile frugivores is also affected by patch size because of interactions with the abundance and diversity of fruit resources (Price et al. 1999). However, these species are often influenced by a combination of fragment and landscape features (Graham and Blake 2001; Price et al. 1999).

The visitation index was not related to fragment shape, which means that the species was unaffected by the proportion of edges in the patches. Indeed, our observations indicated that blue-winged macaws were not restricted to mature forest since we regularly observed them perched at the edges of fragments. In addition, there was no significant difference between the visitation indices for old-growth and secondary forest patches. This may reflect the plasticity of blue-winged macaws to explore different types of forest. In contrast, the vegetation category apparently affected the choice of roosting sites, which tended to be closer to fragments of old-growth forest.

Unexplained variation in the visitation index in the multiple regression model may be due to some differences in patch-level factors among fragments, such as quality and availability of resources, and vegetation structure. The inclusion of data with finer spatial and temporal resolution should improve the performance of our model, however our model with coarser resolution data was managed to explain a great part of variation of the visit index.

Implications and recommendations for conservation

The presence of a large block of semideciduous forest (Caetetus Ecological Station) may have precluded the local extinction of the blue-winged macaw in the region, at moment. The Caetetus Ecological Station represents a core area for this macaw, because it is unknown whether landscapes containing only small fragments could sustain macaw populations. Price et al. (1999) suggested that a net of fragments can maintain highly mobile frugivores, but that some species can be lost when the fragment size falls below a certain threshold. In our study, patch size was an important predictor of blue-winged macaw sightings, which means that preservation of Caetetus Ecological Station is key to uphold the blue-winged macaw population at the region of our study.

However, small fragments may also be important for the species' survival, and the ability of blue-winged macaws to use a range of different forest fragments indicates the importance of a mosaic of habitats to contribute to the maintenance of this species in such fragmented region. Small fragments provide landscape connectivity for blue-winged macaw in Caetetus region, by offering shelter and rest for the birds during movement, and work as extra sites for feeding, overnight roosts, and may be for nesting. Since this study was done during the dry season, usually a period of food scarcity for parrots (Galetti 1993), the relevance of these areas for the conservation of blue-winged macaws is even greater. These findings are important because they show the necessity of up scaling conservation strategies to protect these parrots.

On the region of our study, it is needed to look at beyond the Caetetus boundaries. Hence, the survival of the blue-winged macaw also depends on the co-operation of land owners, since most of the extra-reserve fragments are privately owned. There is a need to encourage the conservation of remnants of native vegetation on surrounding private land, particularly the large fragments near roosts and the Caetetus Ecological Station. The presence of patches of trees in the matrix may be important too, because they tend to increase the connectivity of the landscape (Bolger et al. 2001; Fischer and Lindenmayer 2002; Graham and Blake 2001).

Efforts must be concentrated on conserving the population of *P. maracana* in the region of the Caetetus Ecological Station because this is the largest remaining population of this species in the southern part of its distribution (Nunes 2003). This population could serve as a source of blue-winged macaws for the colonization of other areas from which the species has been extinguished. The conservation of "source populations", at the extreme of geographic distribution of species which respond factors at landscape scale, tends to be vital for maintaining these species' regional occurrences (see Wilson et al. 2002). Therefore we expect that a fortuitous extinction of the population at Caetetus could have a wider negative impact on the species' geographic distribution as a whole.

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Appendix

Appendix 1 The fragments sampled, their features and the visitation indices for blue-winged macaws

Fragment	C	LU	S (ha)	SI	II	DCC (km)	DC (km)	DR (km)	Bwm visit index
1	Forest	Coffee plantations	321.21	1.75	1.01	1.34	13.01	6.22	14.00
2	Forest	Coffee plantations	21.78	1.28	88.25	6.19	0.66	0.59	20.00
3	Forest	Coffee plantations	164.97	1.23	1.41	6.19	8.76	5.79	3.39
4	Forest	Pasture	200.61	1.72	0.68	1.37	14.70	0.21	35.00
5	Secondary forest	Eucalyptus	78.75	1.98	1759.46	8.32	0.09	6.84	30.00
6	Forest	Coffee plantations	19.17	1.40	1392.96	1.73	21.26	15.95	0.00
7	Secondary forest	Orange plantations	45.99	1.41	4.14	2.90	14.03	12.17	9.23
8	Forest	Pasture	31.41	1.34	2.05	6.70	7.20	13.99	0.00
9	Forest	Eucalyptus	363.96	2.61	1274.88	3.08	0.70	0.97	14.71
10	Forest	Orange plantations	394.47	1.71	418.54	2.29	6.83	6.87	12.90
11	Forest	Coffee plantations	260.46	2.21	543.56	0.92	8.28	8.28	6.06
12	Forest	Coffee plantations	99.09	1.36	5.83	2.41	5.34	5.37	4.17
13	Forest	Pasture	70.38	1.52	3.73	7.74	11.61	14.44	10.00
14	Secondary forest	Pasture	51.03	2.31	26.61	4.12	14.25	14.20	11.36

Appendix 1 continued

Fragment	C	LU	S (ha)	SI	II	DCC (km)	DC (km)	DR (km)	Bwm visit index
15	Forest	Pasture	218.88	1.45	722.60	7.49	18.58	23.01	3.13
16	Secondary forest	Pasture	51.57	1.60	27.68	6.76	18.35	23.69	0.00
17	Forest	Eucalyptus	63.00	1.28	115.10	7.74	11.65	14.48	6.45
18	Forest	Coffee plantations	191.79	2.68	3.04	2.06	5.98	8.59	1.82
19	Forest	Coffee plantations	87.93	1.41	1.15	4.08	19.42	7.59	3.33
20	Forest	Coffee plantations	46.62	1.17	1.74	7.50	11.27	0.06	22.45
21	Secondary forest	Pasture	30.69	1.54	1.41	5.29	9.87	7.71	4.35
22	Forest	Pasture	60.57	1.37	0.85	3.63	10.33	4.58	0.00
23	Forest	Pasture	78.84	1.45	21.48	2.90	12.18	5.47	2.99
24	Secondary forest	Pasture	32.40	1.71	3.33	5.37	21.57	14.57	0.00
25	Forest	Pasture	29.52	1.22	11.19	8.75	19.74	20.53	0.00
26	Secondary forest	Pasture	64.08	1.80	2.54	0.53	4.38	6.63	2.50
27	Secondary forest	Pasture	47.79	1.77	4.53	6.21	15.45	22.73	0.00
28	Forest	Coffee plantations	151.74	1.27	3.52	9.32	8.55	2.38	47.37
29	Forest	Coffee plantations	90.90	2.56	121.91	11.58	2.09	5.92	10.00
30	Forest	Coffee plantations	159.03	1.86	24.75	2.70	18.18	18.17	6.67
31	Forest	Pasture	230.76	2.31	6688.39	4.40	21.30	21.32	0.00
32	Secondary forest	Eucalyptus	172.89	3.14	1.62	4.87	12.99	7.99	11.43
33	Secondary forest	Coffee plantations	35.73	1.73	2.77	7.11	6.67	7.61	5.26
34	Forest	Pasture	63.18	2.34	12.01	3.81	19.19	10.09	0.00
35	Secondary forest	Pasture	16.83	1.18	1.64	4.71	15.46	22.72	0.00
36	Forest	Pasture	23.67	1.85	2380.85	8.02	11.90	12.11	0.00

Abbreviations: C, category; LU, main land use in the surroundings; S, size; SI, shape index; II, isolation index; DCC, distance to the closest city; DC, distance to the Caetetus Ecological Station; DR, distance to the closest macaw roost; Bwm, blue-winged macaw

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