

## DRY FRUITS AND THE ABUNDANCE OF THE BLUE-AND-YELLOW MACAW (*ARA ARARAUNA*) AT A CERRADO REMNANT IN CENTRAL BRAZIL

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**Resumo.** – Frutos secos e abundância da Arara canindé (*Ara ararauna*) em um remanescente de cerrado do Brasil central. – As araras são importantes predadores de sementes em áreas Neotropicais e, tipicamente, exploram mosaicos de vegetação conforme a disponibilidade de recursos. Nesse estudo, examinei as relações entre a disponibilidade de recursos alimentares (flores e frutos) e a abundância da Arara canindé (*Ara ararauna*), em um remanescente de cerrado do Brasil central. Também, analisei a ecologia alimentar dessa arara nesse habitat. Durante quase todo ano as araras ocorreram em número reduzido no remanescente. Porém, ao final da estação seca as araras foram abundantes, simultaneamente a um pico de frutificação. Nesse período, muitas árvores estavam carregadas de frutos secos, dentre os quais os produzidos por *Vatairea macrocarpa*. As araras consumiram intensamente sementes imaturas de *V. macrocarpa*, enquanto utilizaram moderadamente outras espécies. Como o período de abundância das araras foi restrito a breve frutificação em *V. macrocarpa*, a disponibilidade desses frutos nutritivos, potencialmente, causou um influxo de araras para o remanescente. Portanto, considerando os hábitos generalistas dessa espécie, os remanescentes que incluem populações amplas de plantas importantes para canindé são cruciais, pelo menos durante períodos específicos, para persistência dessa arara em paisagens fragmentadas do Brasil central.

**Abstract.** – Macaws are mobile pre-dispersal seed predators from Neotropical forests. They wander within habitat mosaics to exploit food resources as they became available. I examined the relationship between food production and the abundance of the Blue-and-Yellow Macaw (*Ara ararauna*), at a ‘cerrado’ remnant in central Brazil. Additionally, I analyzed macaw feeding ecology in this habitat. During most of the time, only a few macaws occurred at the remnant. However, macaw abundance abruptly increased in the late dry season, coincident with a major peak of fruit production. At that time, a large number of trees bore dry fruits, notably the large fruit crops produced by *Vatairea macrocarpa*. Macaws foraged extensively for the large and soft unripe *V. macrocarpa* seeds, and seldom used other fruits. Because macaw abundance coincided with the brief fruiting in *V. macrocarpa*, potentially this abundant and nutritive food source caused an influx of macaws to the cerrado remnant. Therefore, considering both the generalist habitat and food requirements of this macaw, at least during specific periods, those remnants which include high abundance of plants important for macaws may contribute to their persistence, even in fragmented landscapes of central Brazil. *Accepted 5 May 2006.*

**Key words:** Psittacidae, parrots, cerrado, abundance, feeding ecology, food resources, canopy phenology, forest fragment.

### INTRODUCTION

Macaws, the largest psittacines, may be both habitat and foraging specialists (e.g., *Anodo-*

*rhynchus*; Collar 1997, Sick 1997). However, most species in the *Ara* genus exploit a wide range of plant food resources, ranging from nectar to seeds of several plant species (Roth

1984, Collar 1997, Sick 1997). In fact, these mobile parrots often forage for seeds, hence are considered important seed predators (Trivedi *et al.* 2004). Therefore, they potentially increase tree species diversity in Neotropical forests due to their impact on the breeding success of common species. Consequently, the probability of recruitment of rare species is enhanced (Janzen 1970, Dirzo & Miranda 1990). Despite their generalist feeding habits, macaws mostly forage in the canopy, and may periodically experience food shortage due to the seasonal flowering and fruiting patterns in this forest layer, which is particularly pronounced in the dry forests (Frankie *et al.* 1974, Bullock & Solis-Magalanes 1990, Ramírez 2002). Thus, because macaws do not have all-purpose territories, to overcome such recurrent food shortages they usually move to more favorable areas according to the availability of food resources (Roth 1984, Renton 2001). In fact, parrots are well known for their movements, at diverse spatial scales, either to search for food resources, or to shift from roosts to foraging areas (Chapman *et al.* 1989). Therefore, among causal factors, the availability of food resources may strongly influence parrot local patterns of abundance (Bonadie & Bacon 2000, Wirminghaus *et al.* 2001, 2002).

The Blue-and-Yellow Macaw (*Ara ararauna*) is among the most widespread macaws occurring from southern Central America to most of the interior of South America. Although locally abundant in much of its former range, the Blue-and-Yellow Macaw has declined in many regions due to habitat loss and pet trade (Collar 1997). This macaw inhabits a wide range of habitat types from the dry and semi-open cerrado (a kind of South American savanna) to tall rain forest (Collar 1997, Sick 1997). Particularly, the Blue-and-Yellow Macaw uses palm rich-habitats, especially *Mauritia* stands, both for roosting and breeding (Collar 1997, Renton 2004,

pers. observ.), whereas it forages in several vegetation types (Roth 1984, Collar 1997). In recent years, the cerrado has been cleared, so that extensive areas have been reduced to remnants within a mosaic of pasturelands and agricultural areas (Ratter *et al.* 1997). Despite the fragmentation of cerrado, parrots such as the Blue-and-Yellow Macaw continue using remnants as foraging areas (pers. observ.). Hence, to improve our knowledge of the Blue-and-Yellow Macaw's local patterns of abundance and feeding ecology, I examined flower and fruit production at a large patch of cerrado, surrounded by pasture lands, to evaluate their relationship with the Blue-and-Yellow Macaw abundance and their use of plant food resources.

## METHODS

*Study area.* This study was conducted from January to December 2004, in a rectangular remnant of tall and dense cerrado (cerradão), which as a habitat type resembles the dry forests, mostly due to a low and continuous canopy (height around 10 m), besides the pronounced deciduous pattern during the dry season (Ribeiro & Walter 1998). The area is of approximately 600 ha (3 x 2 km, Municipality of Três Lagoas, State of Mato Grosso do Sul, Brazil; 51°48'W, 20°46'S, elevation 340 m). Cerrado conversion in this region (eastern side of Mato Grosso do Sul) has produced landscape mosaics of pastures, isolated trees, riparian forest remnants, *Mauritia* stands remnants, as well as cerrado remnants (pers. observ.). In the remnant, characteristic trees include *Qualea parviflora*, *Copaifera langsdorffii*, *Dipteryx alata*, *Magonia pubens*, *Pterodon emarginatum*, and *Vatairea macrocarpa*. The canopy in this remnant is 6–10 m tall, but emergent trees may reach 12–14 m. From June to September, most tree species drop their leaves, contributing to an obvious deciduous pattern. Annual rainfall is around 1400 mm, most of

which (70–80%) occurs from October to March (wet season). During the wet season temperature averages 24°C, whereas during the dry season (April to September), an average of 17°C is recorded. Frosts may occur in the coldest months.

*Flower and fruit production.* To select trees for sampling flower and fruit production, I established 26 points (400 m apart from each other) along four 3-km-long parallel permanent access trails. The trails were also 400 m apart from each other, and the two outermost ones were 200 m distant from the edges. The two inner trails included seven points, so that the first and the last points were 300 m from the edges. On the other hand, the external trails had six points, so that the extreme points were 500 m from the border. At each point, the 10 nearest trees with diameters at breast height (DBH) equal to or greater than 20 cm were numbered with aluminum tags. This criterion was adopted to assure the inclusion of canopy and emergent trees. Also, a tree was selected only if at least 80% of the crown could be observed from the forest floor. This random sample included 31 tree species whose importance for Blue-and-Yellow Macaw was unknown. Individual crowns were monitored between the 20<sup>th</sup> and the 25<sup>th</sup> of each month from January to December 2004 for the presence of flowers and fruits with the aid of 8 x 40 binoculars. The abundance of flowers and fruits was ranked on a relative scale, ranging from total absence (0) to the full crown capacity (4) of a given phenophase (Fournier 1974). Thus, the sum of abundance scores resulted in monthly indexes of abundance of flowers, or fruits. Tree species were identified by comparison with samples in the herbarium at the Universidade Federal do Mato Grosso do Sul (Campus Três Lagoas); nomenclature follows Lorenzi (1994, 1998). The analysis of dispersal syndromes was out of the scope of this study, hence, the

fruits were classified only according to the presence of fleshy edible parts, rather than dispersal features (zoochory, autochory, and anemochory). Thus, tree species whose diaspores included pulp or aril were assigned as species with fleshy fruit, whereas those ones with dry mesocarp were classed as species with dry fruits.

*Blue-and-Yellow Macaw abundance.* I used point counts to sample macaw abundance because this technique is adequate to assess parrot populations in closed habitats (Casagrande & Beissinger 1997, Marsden 1999). In fact, I counted macaws to assess variations in their occurrence at the remnant and to compare with food resources production, instead of assessing macaw density at the remnant. Those points established to evaluate flower and fruit production were also used as survey stations. Two mornings (also between days 20 and 25 of each month) without rain or heavy mist were selected to count macaws (13 points/morning) each month. All census work was carried out from 06:30 h to approximately 10:00 h in the dry season, and from 06:00 to 09:30 h in the wet season. At each point, all Blue-and-Yellow Macaw seen or heard during 10 min were recorded, irrespective of the distance from the survey station. To avoid double counting of macaws, each morning I surveyed macaws using points from trails which were spaced by 800 m. Moreover, whenever I detected at least one perched individual, I recorded its relative position on a map, which included the compass directions and concentric circles with radius from 0 to 400 m (bands of 100 m). Macaws recorded at different overlapping points were counted only once. Macaws typically do not defend all purpose territories, are highly monogamous, and often give loud contact calls. Hence, intense seasonal nuptial/territorial vocalizations are unusual (Collar 1997, Sick 1997). So, I assumed that they were

TABLE 1. Items of plant species eaten by Blue-and-Yellow Macaws (*Ara ararauna*), number (percentage) of feeding records, and number of macaws recorded foraging on each plant species in the cerrado remnant (municipality of Três Lagoas, State of Mato Grosso do Sul, Brazil, 2004).

Plant taxa	Items	Months	Number	
			Feeding records (%)	Macaws
Arecaceae				
<i>Acrocomia aculeata</i>	Pulp	May, June	2 (3.0)	4
<i>Syagrus oleraceae</i>	Pulp	August	1 (1.5)	2
Caryocariaceae				
<i>Caryocar brasiliense</i>	Seed	December	3 (5.0)	10
Leguminosae				
<i>Dymorphandra mollis</i>	Seed	June	1 (1.5)	2
<i>Hymenaea stygonocarpa</i>	Seed	July	2 (3.0)	6
<i>Vatairea macrocarpa</i>	Seed	September	39 (68.0)	86
Sapotaceae				
<i>Pouteria ramiflora</i>	Seed	January	1 (1.5)	2
Vochysiaceae				
<i>Qualea grandiflora</i>	Seed	July	2 (3.0)	6
<i>Qualea parviflora</i>	Seed	April, May	6 (12.0)	14
<i>Vochysia cynammorea</i>	Seed	July	1 (1.5)	4
Total			58	136

equally likely to be detected during both seasons. The macaws observed and/or heard flying by over the forest canopy (macaws calling continuously from different positions while detected above the canopy) were not recorded, because the closed canopy made it difficult to follow them landing at a specific remnant.

*Blue-and-Yellow Macaw use of food resources.* Every month, I walked the trails for 20 h, from 06:00 to 11:00 h and from 15:00 to 18:00 h, the period of macaws peak activity. Whenever at least one feeding macaw was detected, I recorded: a) tree species, b) food resources (flower or fruit), c) part eaten (petal, nectar, pulp, or seed), d) number of foraging macaws, and e) time and date. Macaws usually spent prolonged periods (more than 10 min., pers. observ.) foraging at a given crown. To avoid resampling macaws feeding on a specific food source during an observation period, I always

walked only once trails spaced by 800 m in one direction. Thus, a feeding record consisted of at least one macaw feeding on a food source, irrespective of time spent foraging and amount of food ingested. As the feeding records were used in correlation analyses, I only used the initial observation to assure independence among foraging samples (Hejl *et al.* 1990). Moreover, most Neotropical parrots are opportunistic feeders and will include in their diet food items that make up relatively large, but only seasonally available, portions of biomass that serves as potential food. Hence, it is valid to use the initial observation of birds feeding on such resources, because it can be assumed that the birds are equally likely to be seen feeding on any abundantly available food source. Conservative analysis assumes that feeding records were correlated with food resources production regardless of the number of foraging macaws. However, to improve the analysis on the extent of food

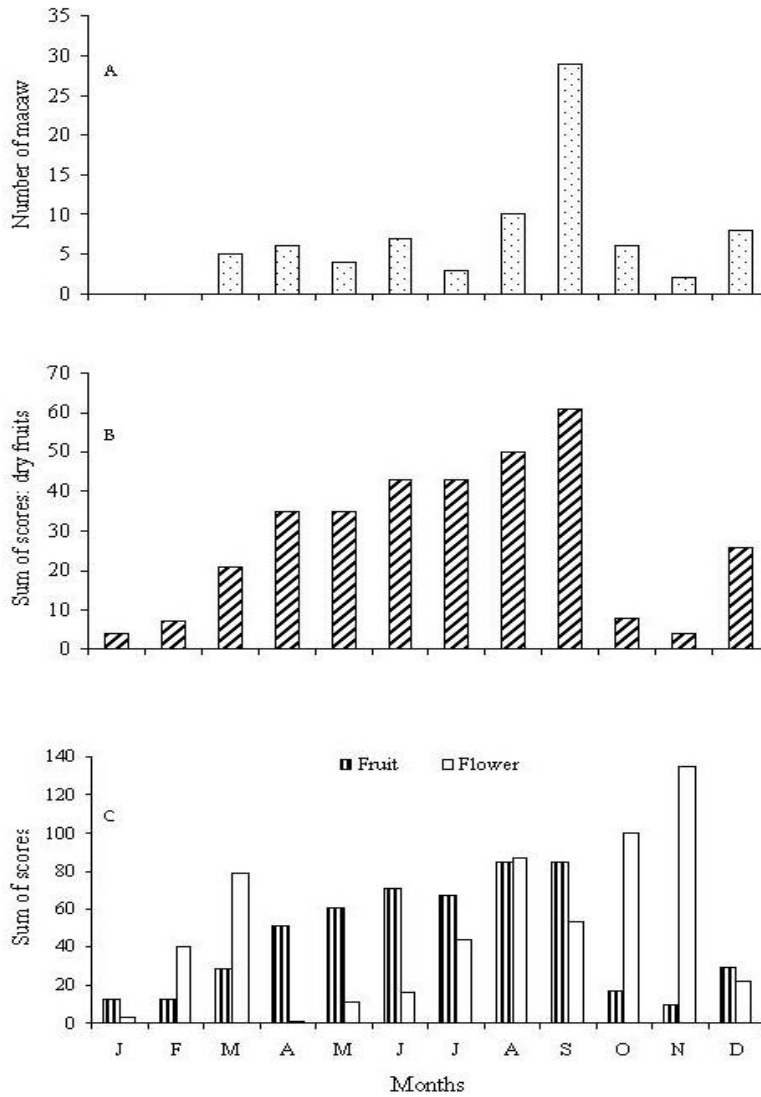


FIG. 1. Seasonal variations in the number of Blue-and-Yellow Macaws (*Ara ararauna*) (A), dry fruit production (values result from the sum of scores, see methods) (B), and flower and fruit production (also the sum of scores) (C), in the cerrado remnant (municipality of Três Lagoas, State of Mato Grosso do Sul, Brazil, 2004).

source use, I provided the number of foraging macaws together with the proportion of every food item used by them (Table 1).

*Analysis.* The total number of Blue-and-Yel-

low Macaws recorded every month from the 26 survey stations was taken as a monthly index of macaw abundance. To evaluate the relationship between macaw abundance and food plant production, Spearman correlation

was used. The monthly indices of both resources and macaw abundance were taken as variables. To compare seasonal variations in fruit production (by the monthly sum of scores), I used Kruskal-Wallis test. In this respect, I compared four periods of the year corresponding to the late wet season (January–March), the early dry season (April–June), the late dry season (July–September), and the early wet season (October–December). As Blue-and-Yellow Macaws exhibit generalist feeding habits, which may imply the use of the most abundant resources, I evaluated niche breadth in both seasons using the standardized Hurlbert's niche-breath index, because it incorporates a measure of the proportional abundance of resources used (Hurlbert 1978). To calculate this parameter, I used the sum of scores of fruiting trees, as well as the number of individuals observed feeding on a particular source. Therefore, a value close to 0 indicates dietary specialization, and a value close to 1 indicates a broad diet (Hurlbert 1978).

## RESULTS

*Flower and fruit production.* The 31 tree species monitored for phenological analysis represent 16 families. Common species included: *Qualea parviflora* ( $n = 41$ , 16% of sampled trees,  $n = 260$ ), *Copaifera langsdorffii* (31, 12%), *Dipteryx alata* (24, 9%), *Vatairea macrocarpa* (15, 6%), and *Magonia pubescens* (11, 4%), whereas several species were represented by one or two individuals (i.e., *Coupeia grandiflora*, *Andira cujabensis*, *Pouteria torta*, and *Tabebuia aurea*). Most species (22, 71%) produced dry fruits. Furthermore, trees with dry fruits dominated the phenology sample (69%).

Three flowering peaks were recorded. The first, in the late wet season, resulted mostly from flower production in the abundant *C. langsdorffii*, whereas the second, in the late dry season, resulted mainly from flowering in

*Magonia pubescens* and *V. macrocarpa*. Finally, a pronounced peak occurred in the early wet season, resulting from flowering in two abundant species, *Qualea grandiflora* and *Q. parviflora* (Fig. 1). Fruiting progressed from the late wet to the late dry season with a minor peak in June and a pronounced one in August–September. The first resulted from fruiting in *C. langsdorffii*, *D. alata* (both with fleshy fruits), and *M. pubescens* (dry fruits). Conversely, the major fruiting peak in the late dry season resulted mostly from fruiting in *Astronium fraxinifolium*, *Q. parviflora*, and *V. macrocarpa*, all of which bore dry fruits, and potentially wind-dispersed seeds (suggested by winged diaspores). After such fruiting episodes, fruit production declined abruptly up to November. In December, fruiting recovered with the onset of fruit production in *M. pubescens* and *Q. parviflora* (Fig. 1). Hence, tree community exhibited a significant seasonal variation in general fruit production, as well as in dry fruit production, which comprised much of the fruiting pattern ( $H = 9.0$ ,  $P < 0.05$ , and  $H = 9.3$ ,  $P < 0.05$ , respectively, Fig. 1).

*Blue-and-Yellow Macaw abundance.* The occurrence of macaws at the remnant varied substantially through the year. During most months few or no macaws were counted during the surveys, but in the late dry season macaw abundance increased abruptly so that, in September, almost 30 macaws were recorded. Macaw abundance coincided with the major peak of fruit production, resulting from the large fruit crops of species with dry fruits. Such fruits comprised 60 and 72% of the peak of fruit production in August and September, respectively (Fig. 1). Specifically, macaw abundance overlapped the massive fruiting in *V. macrocarpa*, by far the most used species by macaws (see results below). Therefore, macaw abundance paralleled the fruiting pattern ( $r_s = 0.63$ ,  $P < 0.05$ , Fig. 1), and particularly dry fruit production ( $r_s = 0.71$ ,  $P <$

0.05, Fig. 1), which included most species available to macaws (Table 1).

*Use of food resources.* Macaws foraged on 10 plant species from five families, in a total of 58 feeding records, which included 136 individuals (Table 1). In particular, they exploited fruits from Leguminosae, because four species comprised 74% of their diet. Conversely, they seldom used plants from other families (Table 1). Unripe seeds from dry fruits were dominant in their diet, with the exception of palm fruits from which they used the pulp (Table 1). Macaws seldom foraged in the remnant during the rainy months (October–March), exploiting only two species (Table 1). In this period, niche breadth was narrower than ( $B' = 0.05$ ) in the dry season ( $B' = 0.40$ ), when macaws often used the remnant as foraging area. Particularly, macaws extensively foraged for the large crops of *V. macrocarpa* fruits, which comprised much of the fruiting pattern (September peak: 21.2%,  $n = 85$  – sum of scores, Fig. 1). In September, when dry fruits were plentiful (Fig. 1), macaws exploited only *V. macrocarpa* fruits, which were their major food item (68% of the feeding records), whereas most other dry fruits formed a minor proportion of resources consumed by them (Table 1). Nevertheless, another four species were used, at least moderately, by macaws. In the early dry season macaws mostly foraged on *Q. parviflora* seeds, whereas in the middle of the dry season *Hymenaea stygonocarpa* seeds and *Acrocomia aculeata* fruit pulp were eaten also. Finally, in the early rains, macaws foraged for *Caryocar brasiliense* seeds (Table 1).

## DISCUSSION

*Flower and fruit production.* The marked seasonality of flower and fruit production in the studied cerrado reinforces its similarity with dry forest because, in such habitats, flowering

and fruiting patterns exhibit pronounced seasonal peaks (Frankie *et al.* 1974, Bullock & Solis-Magallanes 1990, Griz & Machado 2001).

The flowering pattern suggested two strategies with respect to fruiting and seed dispersal. The massive flowering from the middle to the late dry season included species whose diaspores matured during the windy months, just before the early rains. Seeds from such species usually do not undergo dormancy and seedling establishment occurs with the onset of rains. On the other hand, species that flower in the early wet season produced fruits with seeds which, after dispersal, remain dormant up to the next rainy season (Oliveira 1998).

Dry fruits predominated during the late dry season when leaf shedding was highest, potentially to avoid excessive water loss (Borchert 1994). Therefore, the leafless canopy favors wind flow, improving the removal and dispersal of diaspores (van Schaik *et al.* 1993). Such fruits, abundantly produced in the dry forests, are extensively used by parrots (Renton 2001), and were the major food resources for Blue-and-Yellow Macaws in this cerrado remnant. This kind of dense cerrado, unfortunately, is progressively being reduced to small and isolated remnants within a matrix of pasture lands and agricultural areas (Ratter *et al.* 1997), for which adequacy for Blue-and-Yellow Macaws and other canopy frugivores is uncertain.

*Macaws and abundance of food resources.* Blue-and-Yellow Macaws usually wander over different habitat types for purposes such as breeding, roosting, and foraging. Hence, they exhibit movements within habitat mosaics in a daily, monthly, and seasonal basis, so that their occurrence at a given habitat is not uniform (Collar 1997, Sick 1997, Gilardi & Munn 1998). Nevertheless, despite of this generalist pattern of habitat use, Blue-and-Yellow

Macaws are progressively declining, mostly due to habitat loss, similarly to other canopy frugivores (Willis 1979). In the State of São Paulo, macaws are scarce or locally extinct due to the expansion of both sugar cane plantations and pasture lands (E. O. Willis pers. com., Willis & Oniky 2003). The region in which the studied remnant is located is now completely fragmented due to the accelerated increase of pasture lands. As some bird species have persisted, in the deforestation process, using a mosaic of woodlots according to resource availability (Graham 2001), potentially this is also the case of Blue-and-Yellow Macaws in the fragmented cerrado.

The occurrence of Blue-and-Yellow Macaws in the cerrado remnant varied substantially over time, so that higher numbers of individuals coincided with a massive dry fruit production during the late dry season. At that time, only *Dipteryx alata* and *Copaifera langsdorffii* bore fleshy fruits, which, in spite of their importance for other parrot species (Galetti 1993, Collar 1997), were not used by Blue-and-Yellow Macaws. From the available food resources, macaws extensively foraged only for *Vatairea macrocarpa* fruits. Hence, the correlation between the availability of *V. macrocarpa* fruits and their use by Blue-and-Yellow Macaws suggests this resource is the major cause for the influx of macaws to the remnant in the late dry season. While foraging for *V. macrocarpa* fruits, macaws ate the large and soft seeds only at the stage of ripeness. Therefore, such ephemeral adequacy for consumption may explain the brief abundance of macaws, since they used neither young nor ripe fruits (pers. observ.). Additionally, in 2004, *V. macrocarpa* fruited massively in comparison with the previous year (Ragusa-Netto unpubl.). Such inter-year variation of fruit production may account to explain the higher number of macaws in the remnant at the end of the dry season, since the temporal variation of food resources production strongly affects

parrots local abundance (Bonadie & Bacon 2000; Ragusa-Netto 2004, 2005, in prep.). However, although this study suggests a strong relationship between macaws and a food plant, only a long term study may clarify the extension of interactions between macaws and their major food resources.

The Leguminosae are one of the most important plant families in the Neotropical dry forests (Bullock & Solis-Magallanes 1990, Griz & Machado 2001), as well as in the cerrado (Ribeiro & Walter 1998). A substantial proportion of species produce dry fruits (Lorenzi 1994, 1998; Griz & Machado 2001) on which parrots often forage (Roth 1984, Galetti 1993, Renton 2001), although flowers may be important, especially during the dry season (Galetti 1993, Ragusa-Netto 2004). Besides being abundant in the cerrado, fruits from Leguminosae are nutritive, mainly due to the high lipid and protein content of their seeds (Almeida *et al.* 1998). Presumably, this may be the case of the large, soft *V. macrocarpa* seeds. Therefore, the combination of massive production, nutritional quality, and the easy removal from the winged fruits (pers. observ.) makes these seeds an important food for macaws.

The other species (mainly *Qualea parviflora*) exploited by Blue-and-Yellow Macaws were represented by few individuals or produced small fruit crops during this study. Apparently, their moderate consumption may be related to the lesser availability of these resources because, for example, seeds from *Cariocar brasiliense* (only two trees in the phenology sample) are among the most important food resources for Blue-and-Yellow Macaw in the cerrado (Sick 1997, Ragusa-Netto unpubl.).

In the surrounding areas, macaws forage on a collection of habitat types, and I have observed them exploiting the gallery forests for *Inga* pods, *Mauritia* stands for ripen nuts, and other smaller cerrado remnants as well as



isolated trees for the fruits of *Cariocar brasiliense*, *Qualea gradiflora*, and *Q. parviflora*, besides *Vatairea macrocarpa*. These observations reinforce the importance of such species in the diet of macaws at cerrado. Farmers usually preserve such trees because they are useful for shading the cattle. Moreover, the Três Lagoas town potentially is also an important foraging area for macaws. Yearly, from November to February, they move daily in large numbers from roosts to the town to exploit *Anacardium occidentale* and *Caryocar brasiliense* fruits. Such species with nutritive seeds (Almeida *et al.* 1998) are often present in the back yard of residences. Hence, these fruits are massively available every year.

The feeding ecology of Blue-and-Yellow Macaws remains poorly known, but available data suggest it is one of the most generalist of macaws (Roth 1984, Collar 1997, Sick 1997, Gilardi & Munn 1998, this study). Such dietary flexibility is potentially the major trait for the macaw's persistence in fragmented landscapes. However, the accelerated deforestation of Brazilian cerrado (Ratter *et al.* 1997) has reduced the availability of resources important for the maintenance of large populations of macaws. Over their wide distribution, a rich set of tree species may influence their spatial and temporal patterns of abundance. Therefore, we urgently need to improve our knowledge both on macaw foraging and population ecology to allow the formulation of adequate conservations plans.

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