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article

Surface fire drives short-term changes in the vegetative phenology of woody species in a Brazilian savanna

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Abstract: We evaluated the effects of fire on the vegetative phenological behavior (crown foliage cover, sprouting, mature and young leaves) of woody species at two sites in the Brazilian savanna, one of which had been accidentally burned. We used generalized additive mixed models to test the hypothesis that: 1) fire damages total foliage cover, thus leading to changes in vegetative phenological patterns. As this hypothesis was corroborated, we also tested whether 2) the damage caused by fire to the total crown foliage cover and mature leaves is greater in evergreen than in deciduous species, and 3) the negative effects of fire on vegetative phenology persist after the first fire-free year. The first two hypotheses were corroborated, but the third was not. Fire effects on total crown foliage cover and mature leaves were greatest during the first three months following the fire, and were significantly greater in evergreen species. For shoots and young leaves, the greatest differences found between three and seven months post-fire. On the other hand, no differences were observed in phenological events between burned and unburned sites in the second year post-fire, indicating that marked effects of the fire were only observed over a short period. Our results showed immediate negative effects on the vegetative phenophases, but also that these effects are transient, and cannot be discerned after the first fire-free year.

Keywords: *crown foliage cover, deciduity, fire ecology, phenology, sprouting.*

SILVÉRIO, D.V., PEREIRA, O.R., MEWS, H.A., MARACAHIPES-SANTOS, L., SANTOS, J.O., LENZA, E. **A passagem do fogo resulta em mudanças de curto prazo para a fenologia vegetativa de espécies lenhosas em um cerrado stricto sensu.** Biota Neotropica. 15(3): e20140077. http://dx.doi.org/10.1590/1676-0611-BN-2014-0077

Resumo: Avaliamos os efeitos do fogo sobre o comportamento fenológico vegetativo (cobertura de copa, brotação, folhas jovens e folhas adultas) de espécies lenhosas em dois sítios de cerrado *sensu stricto*: um queimado acidentalmente e outro não queimado. Usamos modelos aditivos mistos generalizados para testar a hipótese de que 1) o fogo danifica a cobertura de folhas das copas, o que resulta em alterações nos padrões fenológicos vegetativos das espécies; sendo isso verdadeiro, testamos se 2) os danos causados pelo fogo na cobertura de copa e nas folhas adultas são maiores em espécies sempre verdes do que em espécies decíduas e se 3) os efeitos negativos do fogo sobre a fenologia vegetativa persistem após um ano sem fogo. As duas primeiras hipóteses foram corroboradas, mas a terceira não. Os efeitos do fogo na cobertura de folhagem da copa e nas folhas adultas foram maiores após três meses da ocorrência do fogo e significativamente maiores para espécies sempre verdes. Para brotação e folhas jovens, as maiores diferenças foram entre três e sete meses após a queimada. Por outro lado, não foram percebidas diferenças entre os eventos fenológicos vegetativos dos sítios no segundo ano após a ocorrência do fogo, o que indica que os efeitos do fogo foram expressivos apenas por curto período. Os nossos resultados mostraram que o efeito do fogo sobre os eventos fenológicos vegetativos é negativo e mais intenso logo após a ocorrência da queimada, mas também que estes efeitos são temporários, e não são mais percebidos após o primeiro ano da ocorrência do fogo.

Palavras-chave: *cobertura de copa, deciduidade, fogo, fenologia, rebrota.*

Introduction

Natural wildfires have occurred in the Brazilian Cerrado for thousands of years (Miranda et al. 2002, Miranda & Sato 2004, Mistry et al. 2005), leading to many morphological, physiological and functional adaptations in the vegetation of this biome (Coutinho 1982, Hoffmann 1999). These adaptations include the marked suberization of trunks and branches (Hoffmann & Moreira 2002), increased investment in reserves of carbohydrates and nutrients (Hoffmann & Moreira 2002), and high sprouting capacity (Hoffmann 1999, Hoffmann & Moreira 2002, Hoffmann & Solbrig 2003). These adaptations appear to be effective against the damage caused by less severe, occasional natural wildfires (Medeiros & Fiedler 2004, Miranda & Sato 2004), but the increasing human occupation of the Cerrado region, which began in the early 1950s, has altered the natural fire regime, increasing the frequency of fires, and altering seasonal patterns (Klink & Machado 2005). A number of recent studies (Frost & Robertson 1987, Moreira 2000, Miranda et al. 2002, Hoffmann et al. 2009) have indicated that the adaptations of Cerrado plants may be less effective in this modified scenario, given observed increases in mortality rates and modifications in recruitment patterns.

The available data indicate that fire damage has immediate effects on both vegetative and reproductive phenophases (Hoffmann 1998, Miranda et al. 2002). As the high temperatures of the flames causes abscission of the leaves, the foliage of woody species is damaged immediately (Miranda et al. 2002, Hoffmann & Solbrig 2003). Negative effects are also seen in the number of flowers (Felfili et al. 1999) and fruits produced (Landim & Hay 1996, Hoffmann 1998, Felfili et al. 1999). However, some species (mainly herbs and shrubs) may benefit from fire damage, which may actually intensify vegetative propagation (Hoffmann 1999, Hoffmann et al. 2009). Even though these studies have provided important insights into the vegetative and reproductive responses of woody savanna species to fire damage, little is known of the immediate effects of fire on deciduous and evergreen species, the persistence of these effects over time or their influence on the timing of vegetative phenological events in the woody plants of savanic physiognomies of the Brazilian Cerrado. In order to better understand the effects of fire on the vegetative phenological events of the woody species, we tested the following hypotheses: 1) given that the foliage of the tree crown can be destroyed by the flames or damaged by the flow of hot air (Miranda et al. 2009), there will be immediate damage to the leaf cover, leading to alterations in the pattern of vegetative phenological events during subsequent months; 2) considering that deciduous species lose all their leaves during the dry season (Lenza & Klink 2006), the effects on the foliage and mature leaf cover will be greater in evergreen in comparison with deciduous ones; 3) the negative effects of fire damage on vegetative phenology persist after the first fire-free year.

Material and Methods

1. Study area

We conducted this study in an area of cerrado *sensu stricto* (the main savanna formation of the Brazilian Cerrado; see Oliveira-Filho & Ratter 2002) in the Bacaba Municipal Park (14°41' S, 52°20' W), a 492 ha protected area in Nova Xavantina, a municipality in the Brazilian state of Mato Grosso. The regional climate is Aw according to Köppen's classification (Silva et al. 2008), with a mean annual temperature of 24°C and annual rainfall of approximately 1500 mm (INMET, 2012). The soils are deep, well drained, and acidic (pH $<$ 5), and have high levels of exchangeable Aluminum and low concentrations of Calcium and Magnesium (Marimon-Junior & Haridasan 2005).

2. Data collection

We monitored the vegetative phenological events in the woody species found in two cerrado plots 100 m apart, representing: 1) burned and 2) unburned or control habitat. On May 2008, we marked 236 adult individuals representing 25 species in the burned plot (see Table S1 at http://dx.doi.org/10.6084/m9.figshare.1304520). On September 2008, this plot was burned accidentally. As no fires were recorded in the park during the preceding five years, a great deal of flammable material had accumulated, resulting in flames that attained a height of 5 m, reaching the canopy (Mews et al. 2013). No precipitation had been recorded during the four months prior to the fire. On the day the fire occurred, the relative humidity of air was 41%, the temperature of the air was 29°C, with a maximum of 40°C and minimum of 17°C, and mean wind speed was 2 km h^{-1} (INMET 2012). We marked 138 adult individuals in the unburned plot in September 2008 (a week after fire occurrence in September 9th), representing 13 of the woody species found in the burned plot (see Table S1 at http://dx.doi.org/10.6084/m9.figshare.1304520). These 25 species accounted for 70% of the individuals and 62.5% importance value index (IVI) of the woody community of this site (Gomes et al., 2011). Species representing all four vegetative phenological groups (*sensu* Lenza & Klink 2006) were present in both of our study plots (see Table S1 at http://dx.doi.org/10.6084/m9.figshare.1304520). We sampled only individuals with no evidence of damage on trunk, and to ensure independence, individuals of the same species must be at least 10 m apart.

We recorded the vegetative phenological events every fortnight starting in May 2008 in the burned plot and in September 2008 in the unburned plot, with both plots being monitored simultaneously from September 2008 until September 2010. For each individual, we estimated: 1) total crown foliage cover (denominated crown foliage); 2) the proportion of the crown foliage composed of leaves with complete morphological and structural features (mature leaves); 3) the proportion of the crown foliage composed of recently formed leaves with expanded blades but without the morphological characteristics of mature leaves (young leaves); 4) initial bud development with initial leaf formation (shoots or sprouts). We visually estimated the phenophase intensity (PI) applying the method suggested by Fournier (1974). This is based on a semi-quantitative interval scale of five categories (0 to 4), where: 0 = lack of the phenophase, 1 = intensity of 1–25%, 2 = 26–50%, 3 = 51–75%, and 4 = 76–100%.

3. Numerical analysis

We tested the hypotheses applying generalized additive mixed models, or GAMMs (Pinheiro & Bates 2000, Wood 2006). The first two hypotheses were tested using the first year post-fire data (September 2008 to September 2009), considering

Evergreen with Continuous Growth (ECG) and Evergreen with Seasonal Growth (ESG) species as evergreen and Deciduous (DEC) and Brevideciduous (BDC) species as deciduous (see Table S1 at http://dx.doi.org/10.6084/m9.figshare.1304520). In order to test the third hypothesis, we used the second year post-fire data (September 2009 to September 2010). The GAMMs are suitable for phenology studies because they permit the analysis of non-linear responses and the identification of random factors, such as temporal autocorrelation, which are common in phenology studies (Wood 2006, Hudson et al. 2010, Polansky & Robbins 2013, Rabasa et al. 2013).

We evaluated the relevance of differences between sites for each phenophase by selecting models based on Akaike's Information Criterion, or AIC (Burnham & Anderson 2002). For each hypothesis and phenophase, we adjusted three distinct predefined models: (M1) This is the simplest model included only phenophase intensity (PI) as a function of time (in this case, the model evaluates the smooth function of the PI over time, representing seasonality – Table 1); (M2) In addition to evaluating the occurrence of seasonality, this model also verified difference in the PI between sites, but without taking possible interaction between factors into account. This is a semi-parametric model in which the difference between sites is calculated as a linear function (see Wood 2006 and Polansky & Robbins 2013); and (M3) This is the most complex model, which considers PI as a function of time, and its potential interaction with the smooth function of the data for the two sites (Table 1). The AIC indicated that the data were best adjusted to a Poisson distribution (with square root link), and this distribution was used in all the models. We also included, in each model: (a) species as a random factor, and (b) temporal autocorrelation in the data (autocorrelation structure for a corCAR1 continuous time interval: Pinheiro & Bates 2000). We assessed the significance of random factors through the graphic adjustment of the residuals and the confidence intervals of the parameters, as well as correlograms. We conducted these analyses using the R package *mgcv* (Wood 2006, R Core Team 2012).

We assessed the possibility that both sites presented similar vegetative phenological behavior prior to disturbance by applying Pearson's correlation coefficient, r (ZAR 1999) between the MODIS (MOD13A1) enhanced vegetation index (EVI) and our crown foliage cover data at the two sites (NASA 2012). We used the same correlation (r) to evaluate the relationship between crown foliage cover and the MODIS EVI time series, in order to evaluate the representativeness of the phenological events of the two study populations in relation to those of the community as a whole. The leaf area of cerrado *sensu stricto* is influenced by both tree and grass layer, but they have similar pattern throughout the year and is strongly correlated to remotely sensed vegetation indices, such as the EVI (Hoffmann et al 2005).

Results

In the unburned plot, a significant relationship (79%) was found between crown foliage cover and the EVI values ($r = 0.790$, $N = 30$, $p < 0.05$; Figure 1), although this relationship was even stronger (90%) in the burned plot ($r = 0.902$, $N = 46$, $p < 0.05$; Figure 1). The correlation between the pre-burned MODIS EVI of the two sites was 97% ($r = 0.975$, $N = 16$, $p < 0.05$, Figure 1), indicating that the vegetative phenology of the study species was representative of that of the woody community as a whole.

The fire resulted in significant modifications of all the vegetative phenophases (crown foliage, mature leaves, shoots, and young leaves) during the first year after the fire (September 2008 to September 2009). The model that included the differences between plots and the interaction with the smooth function (M3) provided the best adjustment for the data on crown foliage, mature leaves, and sprouting events (Table 2). However, M2, which also included the differences between plots, was the best model for the data on young leaves (Table 2). The parameters of the best models were significant for all phenophases (see Table S2 at http://dx.doi.org/10.6084/m9.figshare.1304639) and thus corroborated our first hypothesis. The results indicated a delay of almost two months in the recovery of the crown foliage, more intense leaf production during the six months following the fire, and, finally, early leaf production during the subsequent sprouting season in the burned plot in comparison with the unburned one (Figure 2).

The intensity of the crown foliage was still low in the burned plot during the subsequent five months, although the two plots were characterized by similar levels of intensity during the rest of the first year following the fire (Figure 2a). We also verified an absolute reduction in mature leaf cover in the burned plot, which remained close to zero for approximately one month after the fire, although the crown foliage then recovered rapidly (Figure 2c). Mature leaf cover was already above 75% three months following burning, with similar levels of intensity being recorded at both sites from this moment onwards, until the end of the first year post-fire. The fire damage also modified the intensity of the production of young leaves and shoots. Between three and seven months after the fire, these phenophases were more intense in the burned plot in comparison with the unburned one. In the unburned plot, the intensity of sprouting and young leaves reached similar levels only by the mid-rainy season, that is, December (Figures 2b, d).

Table 1. Summary of the basic parameterized generalized additive mixed models for each vegetative phenophase of the woody species studied in Nova Xavantina, Mato Grosso, Brazil. PI = Phenophase intensity; data = time series; SI = site; s = smooth function; b = beta.

Model	Equation	Description
Model 1 (M1)	$PI \sim s(data)$	Seasonality of phenophase intensity (PI)
Model 2 (M2)	$PI \sim s(data) + b(SI)$	Seasonality of the PI at the different sites (SI), where the difference between sites is calculated by adding a beta value (with no possibility of interaction).
Model 3 (M3)	$PI \sim s(data) + s(SI)$	Seasonality of the PI for the different sites estimated by calculating independent smooth functions for each factor.

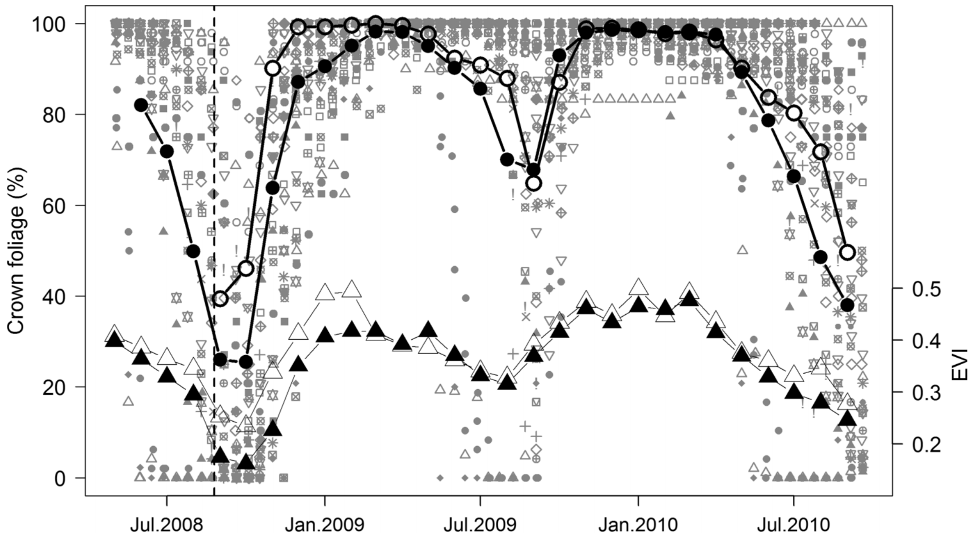

Figure 1. Crown foliage cover in the burned (●) and unburned (○) plots and MODIS enhanced vegetation index (EVI) for the burned (▲) and unburned (△) plots in an area of Cerrado savanna area in Nova Xavantina, Mato Grosso, Brazil. Different symbol represent distinct species. The dotted line indicates when the fire occurred.

The fire had a greater effect on the evergreen species in comparison with the deciduous ones, in relation to both the crown foliage and mature leaf cover. In the case of the evergreen species, the models that included the differences between sites provided the best fit for the data (Table 2), with significant parameters (see Table S2 at http://dx.doi.org/10.6084/m9.figshare.1304639). However, the inclusion of the difference between sites did not result in any improvement in the adjustment of the models for the deciduous species (Table 2). These results fully support the second hypothesis. The crown foliage cover of evergreen species decreased sharply in the burned plot, whereas in the unburned plot, there was no significant reduction in the intensity of these phenophases, even at the end of the dry season (Figure 4). Even so, the phenophase intensity (for crown foliage and mature leaves) of the deciduous species in the unburned plot was reduced by less than 20% following the fire, indicating that the vegetative events of these species were less affected by fire (Figure 4).

During the second year following the fire, the inclusion of the differences between sites did not result in any improvement of the adjustment of the models for any of the vegetative phenophases (Table 2). These results are inconsistent with the third hypothesis, i.e., that the negative effects of the fire on vegetative phenophases will persist after the first year following the fire (Figure 3, Table 2), but rather provide evidence of the capacity of the woody species of the cerrado to recover their

Table 2. Model selection parameters for four vegetative phenophases in burned and unburned plots in an area of Cerrado savanna in Nova Xavantina, Mato Grosso, Brazil, for the first (2008-2009) and second (2009-2010) years following a wildfire. The Akaike Information Criterion (AIC) in bold type indicates the best-fit model for the given parameter. df = degrees of freedom; Loglik = logarithm of the likelihood ratio.

	df	Year 1		Year 2		Evergreen		Deciduous	
		AIC	Loglik	AIC	Loglik	AIC	Loglik	AIC	Loglik
Crown foliage									
M1	6	-22.37	17.18	**-394.56**	203.28	-162.50	87.25	**36.95**	-13.47
M2	7	-29.71	21.86	-389.89	201.94	-159.78	86.89	39.37	-13.68
M3	9	**-34.95**	26.48	-34.95	26.47	**-169.35**	93.67	107.87	-47.93
Shoots									
M1	6	321.19	-154.60	**157.91**	-72.95				
M2	7	333.75	-159.88	427.18	-206.59				
M3	9	**319.11**	-150.55	164.26	-73.12				
Mature leaves									
M1	6	58.98	-23.49	**-197.98**	104.98	-50.67	31.33	**-14.89**	12.44
M2	7	8.35	2.82	-196.52	105.25	-30.86	22.43	-13.08	12.54
M3	9	**-54.78**	36.39	-190.80	104.39	**-85.42**	51.71	18.75	-1.37
Young leaves									
M1	6	264.49	-126.24	**98.93**	-43.46				
M2	7	**236.57**	-111.28	111.91	-48.95				
M3	9	348.95	-165.48	115.27	-48.63				

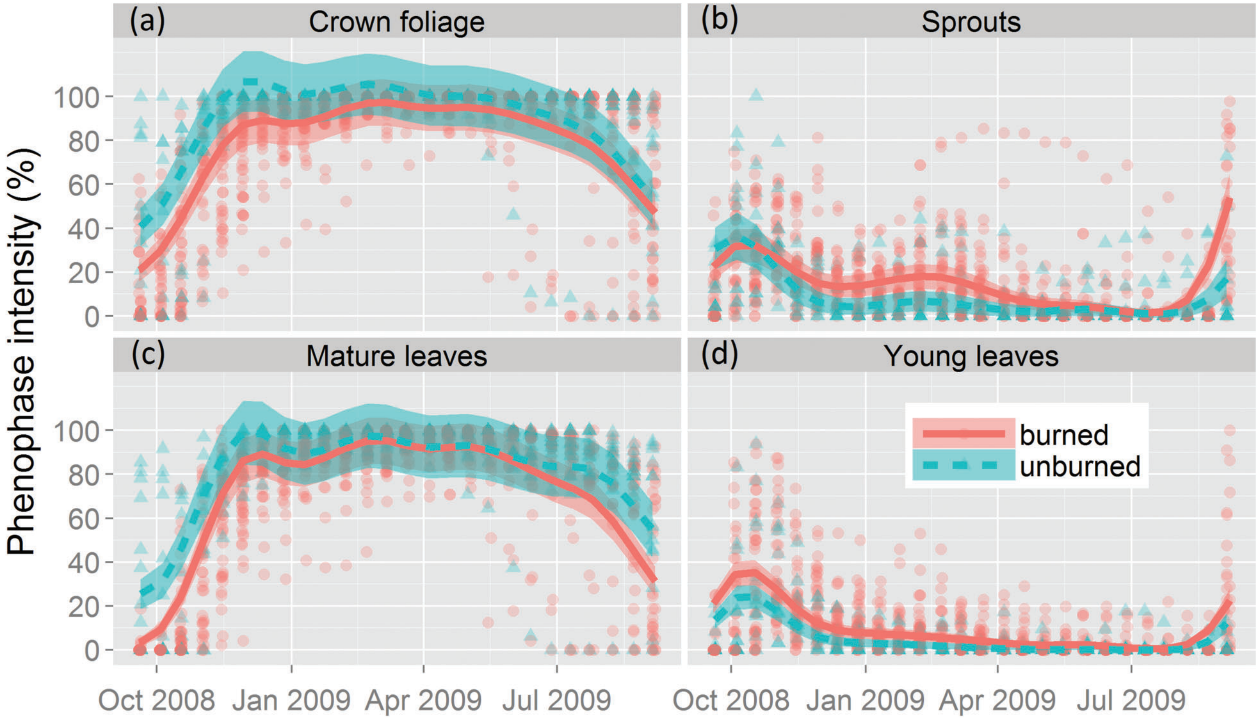

Figure 2. Phenological behavior predicted by the best model (M3, see material and methods) for the four vegetative phenophases of the woody species monitored in burned and unburned plots of Cerrado savanna in Nova Xavantina, Mato Grosso, Brazil. The points indicate the mean phenophase intensity of each species in the burned (▲) and unburned (♦) plots. Shaded areas represent the confidence intervals (alpha = 0.05).

vegetative phenology patterns. In the case of mature leaves, there was little difference in the AIC values for models M1 and M2 (difference = 1.46; Table 2). In spite of this, the fixed parameter of difference between plots in M2 was not significant (t = -1.5; p = 0.132). This result reinforces the idea that the effects of fire on the vegetative monitoring in the present study cannot be detected once the vegetation has recovered for a year.

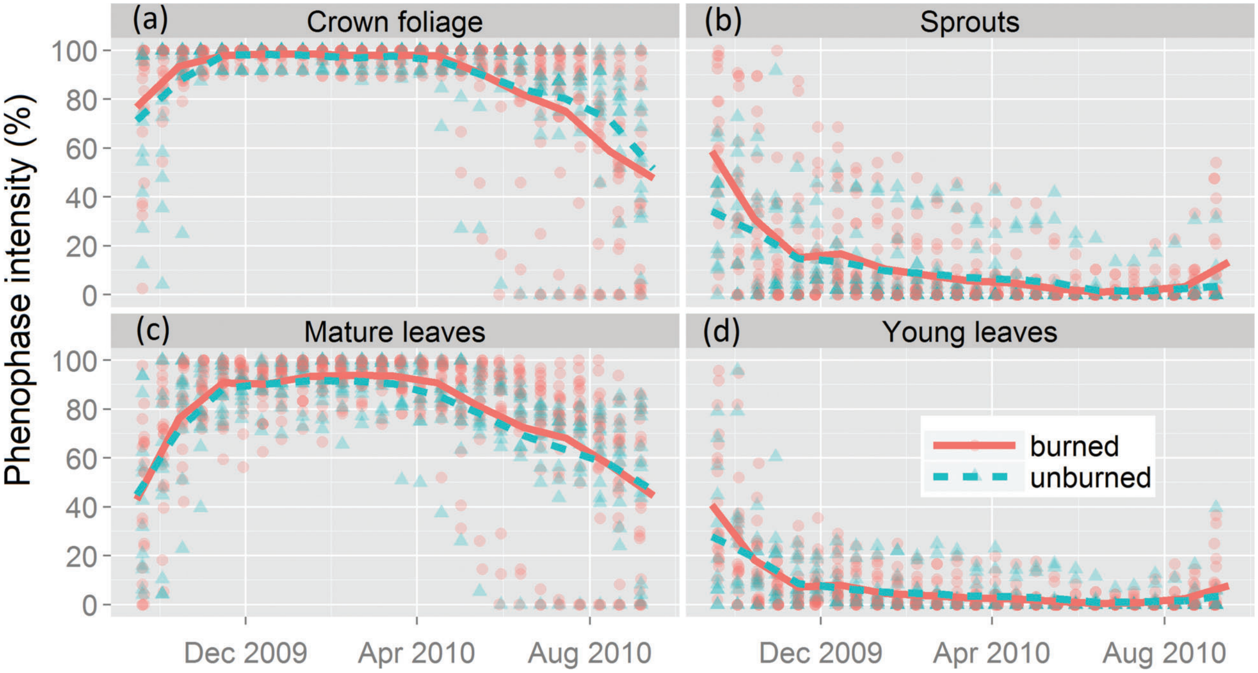

Figure 3. Phenological behavior predicted by the best model (M3, see material and methods) for the four vegetative phenophases of the woody species monitored in burned and unburned plots of Cerrado savanna in Nova Xavantina, Mato Grosso, Brazil. The lines represent the arithmetic mean of the phenophase intensity, and the points indicate the mean phenophase intensity for each species monitored in the burned (▲) and unburned (♦) plots.

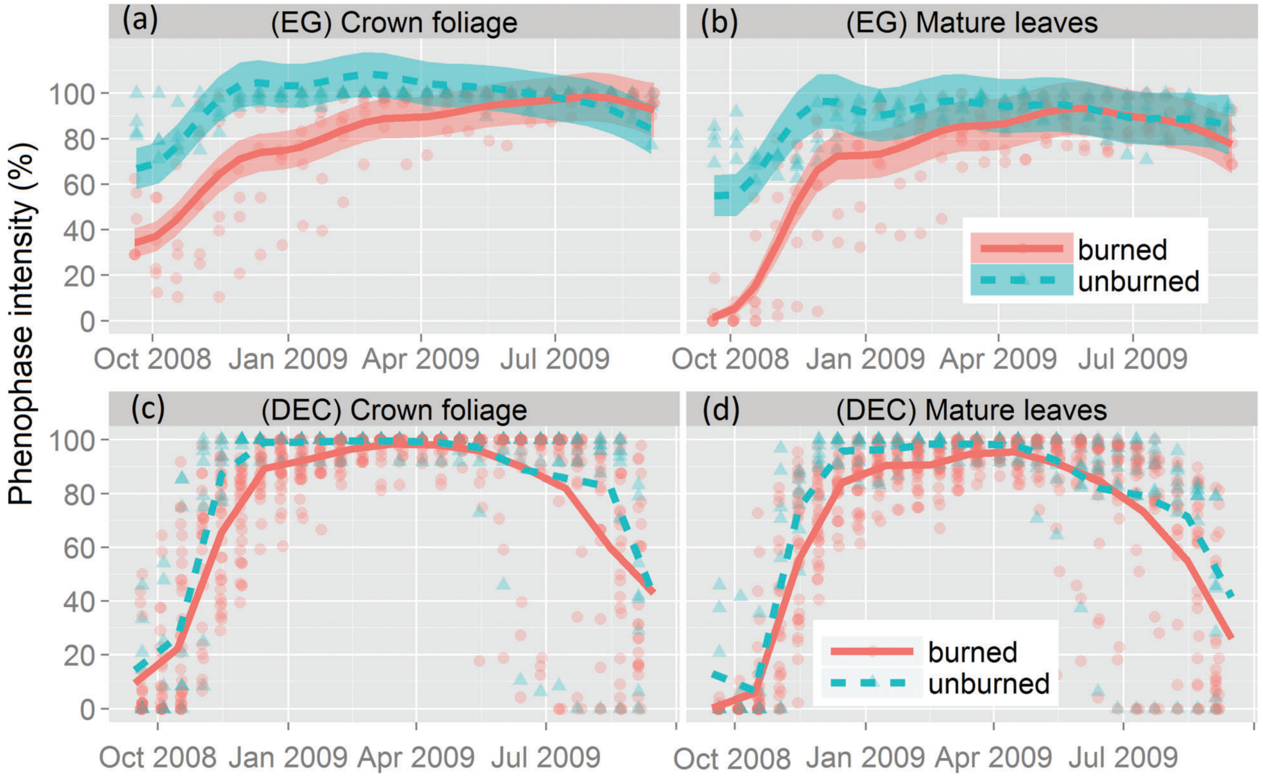

Figure 4. Vegetative phenological behavior of the crown foliage and mature leaves predicted by the best model for the evergreen species (EG) and arithmetic mean of the phenophase intensity for deciduous species (DEC) monitored in the burned and unburned plots of Cerrado savanna in Nova Xavantina, Mato Grosso, Brazil. The points indicate the mean phenophase intensity of each species monitored in the burned (▲) and unburned (♦) plots. Shaded areas represent the confidence intervals (alpha = 0.05).

Discussion

The significant fire damage caused in the crown foliage, shoots and young leaves indicates an immediate response of the vegetative phenophases of woody species. Woody species of the cerrado are known to concentrate the production of new leaves at the end of the dry season (August and September) (Felfili et al. 1999, Lenza & Klink 2006, Oliveira 2008). This typical pattern was recorded in both sites, but burned plot presented high levels of sprouting during rainy season also. The intense production of shoots and young leaves reflected the response of the individuals to burning and the recovery of the foliage. The more intense production of leaves in the burned plot nearly one year after burning may represent an additional phase in the recovery of the foliage. These results indicate that woody species of cerrado are not only characterized by the sprouting capacity of their subterraneous organs (Hoffmann 1998, Moreira, 2000, Miranda et al. 2002), but also their epigeous recovery mechanisms for fire damage, such as a capacity for intense sprouting during a period of up to 12 months following a fire.

The deciduity and sprouting capacity of woody cerrado species are interpreted as evolutionary adaptations to frequent fire events (Oliveira 2008). Even though deciduous (DEC) or brevideciduous (BDC) species lose all their leaves at the end of dry season (Lenza & Klink 2006), we observed that fire may have significant negative effects on the vegetative phenophases of the community as a whole. The pre-burned crown foliage intensity of the DEC and BDC species was lower than 20%. These species accounted for 64% of the study species (see Table S1 at http://dx.doi.org/10.6084/m9.figshare.1304520), which may account for the community's reduced crown foliage cover when the fire occurred (Figure 1 and 2a). The high correlation between the EVI and the crown foliage intensity in the unburned plot indicates that the study species are representative of the local woody vegetation, and support our prediction of negative effects on the vegetative phenophases of the community as a whole. Similarly, the high correlation between the pre-burned EVI of both sites is evidence of the similar phenological behavior of the undisturbed vegetation, and provides support for the conclusion that the differences observed between the study plots are primarily a consequence of the fire event. However, soil fertility and soil water content are also important factors associated to the three productivity and vegetation structure (de Assis et al. 2011, Oliveira-Filho & Ratter 2002). Results of a early study show that soil fertility tend to be similar in our study area even if vegetation structure is different (Marimon-Junior & Haridasan 2005) and possible variation in soil water content should be reduced given that studied sites are flat and adjacent.

Analyzing the phenological groups (evergreen *vs.* deciduous) separately, the immediate fire damage to the crown foliage cover was due primarily to the loss of foliage in the evergreen species with continuous and seasonal growth, which still presented high crown foliage cover (68%), even at the end of the dry season. In their analysis of adjacent habitats that had been either subject to frequent fires over a 20 year period, or protected from these events, Moreira et al. (2000) found that eight of the 10 study species strongly related to the fire-protected environments were evergreen, whereas the two tree species that were strongly related to the frequent-fire habitats

(*Bowdichia virgilioides* and *Piptocarpha rotundifolia*) were deciduous (Lenza & Klink 2006). Woody species of the cerrado usually have deep roots, enabling them to reach water even during the dry season (Scholz et al. 2002, Franco et al. 2005), and crown foliage recovery preceding the rainy season (Lenza & Klink 2006, Oliveira 2008). In this case, the natural occurrence of fires over the past million years (Vicentini 1993, Miranda et al. 2009) may have gradually eliminated evergreen species in favor of deciduous ones. In this scenario, the ongoing increase in the frequency of fires in the Brazilian cerrado resulting from the increase in human activities occurring over the past few decades (Miranda et al. 2009) may result in a further reduction in the relative importance of evergreen species, through the reduction or extinction of local populations, resulting in an increase in the seasonality of savanic physiognomies of the Brazilian Cerrado and further changes in litter production and nutrient cycling.

Although the immediate damage to vegetative phenophases, the effects of the fire did not persist for long. Physical and chemical changes in the environment resulting from the passage of the fire appear to favor the recovery of the vegetative phenophases of trees that are still alive. The rapid recovery of the crown foliage, and the increase in sprouting intensity and the production of young leaves may all have benefited from the reduction in competition for space and light resulting from the loss of foliage (Miranda et al. 2002, Hoffmann & Solbrig 2003). In addition, fire enhances mineralization and availability of nutrients (i.e., Ca, K, Mg, and N) in the superficial layers of the soil (Coutinho 1982, Mistry 1998), enabling the rapid recovery of leaf production. In fact, a number of studies have recorded a post-fire increase in the nutrient concentrations of the leaves of woody species (Batmanian & Haridasan 1985, Nardoto et al. 2006), indicating that the phenological behavior of the plants following a fire may be related to alterations in environmental conditions and the availability of nutrients.

Our results confirm the prediction that fire causes immediate negative effects on the vegetative phenophases of the woody cerrado species (Hoffmann 1998, Felfili et al. 1999, Fernandes-Bulhão & Figueiredo 2002). However, these effects were short-lived, due to the marked and rapid increase in sprouting and the production of leaves following the fire. This suggests compensatory behavior in the vegetative phenophases in response to burning. The woody stratum may respond positively to the addition of nutrients, increasing in biomass, litter production, and shading (Haridasan 2008), so the short-term effects of fire on the phenology of surviving individuals and the increase in the nutrient concentrations of the leaves (Nardoto et al. 2006) may reflect the more efficient uptake of the nutrients made available by the fire (Coutinho 1982, Mistry 1998). The deep roots of the woody species and their capacity to redistribute the humidity available in the soil even during the dry season (Scholz et al. 2002) further support this conclusion. However, it is important to note that the recent increase in the frequency of burning, compared to the natural occurrence of wildfires, may have significant negative effects on the vegetation of the cerrado. The long-term benefits of more open savanna habitats, differential mortality of the woody species with low fire tolerance, and the reduction in the nutrient pool due to runoff and discharge into the atmosphere, may all be important factors in this process (Moreira 2000, Miranda et al. 2002, Roitman et al. 2007).

The results presented here show that fire has immediate negative effects on the vegetative phenophases of the woody plants of the Brazilian savanna, and that these effects are greater in evergreen species in comparison with deciduous ones. However, the rapid recovery of the crown foliage through the increased production of shoots and young leaves meant that the negative effects persisted for a short period of time. These characteristics combine to enhance the capacity of the woody species, and the community as a whole, to recover from wildfires. Despite this, the human occupation of the Brazilian Cerrado over the past few decades has changed the natural fire regime, and further studies will be required in order to evaluate the capacity of evergreen and deciduous plants to respond to consecutive fires or events occurring at different times of the year. Among other things, this will allow us to understand whether the increased investment of resources in leaf production will influence future reproductive events and the overall dynamics of the woody community.

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References

BATMANIAN, G.J. & HARIDASAN, M. 1985. Primary production and accumulation of nutrients by the ground layer community of *cerrado* vegetation of central Brazil. Plant and Soil 88(3): 437-440, http://dx.doi.org/10.1007/BF02197500

BURNHAM, K.P. & ANDERSON, D.R. 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach. Springer-Verlag, New York.

CARVALHO-JÚNIOR, O.A., SAMPAIO, C.S., SILVA, N.C., COUTO-JÚNIOR, A.F., GOMES, R.A.T., CARVALHO, A.P.F. & SHIMABUKURO, Y.E. 2008. Classificação de padrões de savana usando assinaturas temporais NDVI do sensor MODLS no Parque Nacional Chapada dos Veadeiros. Rev. Bras. Geof. 26(4): 505-517, http://dx.doi.org/10.1590/S0102-261X2008000400010

COUTINHO, L.M. 1982. Ecological effects of fire in Brazilian Cerrado. In Ecology of tropical savannas (B.J. Huntley & B.H. Walker, eds). Springer, Berlin, p.273-290, http://dx.doi.org/10.1007/978-3-642-68786-0

de Assis, A.C.C, Coelho, R.M., da Silva Pinheiro, E, Durigan, G., 2011. Water availability determines physiognomic gradient in an area of low-fertility soils under Cerrado vegetation. Plant Ecol. 212: 1135–1147, http://dx.doi.org/10.1007/s11258-010-9893-8

FELFILI, J.M., SILVA-JUNIOR, M.C., DIAS, B.J. & REZENDE, A.V. 1999. Estudo fenológico de *Stryphnodendron adstringens* (Mart.) Coville no cerrado *sensu stricto* da Fazenda Água Limpa no Distrito Federal, Brasil. Rev. Brasil. Bot. 22(1): 83-90, http://dx.doi.org/10.1590/S0100-84041999000100011

FERNANDES-BULHÃO, C. & FIGUEIREDO, P.S. 2002. Fenologia de leguminosas arbóreas em uma área de cerrado marginal no nordeste do Maranhão. Rev. Brasil. Bot. 25(3): 361-369, http://dx.doi.org/10.1590/S0100-84042002000300012

FOURNIER, L.A. 1974.Un método cuantitativo para la medición de características fenológicas en árboles. Turrialba 24(4):422-423.

FRANCO, A.C., BUSTAMANTE, M., CALDAS, L.S., GOLDSTEIN, G., MEINZER, F.C., KOZOVITS, A.R, RUNDEL, P. &

CORADIN, V.T.R. 2005. Leaf functional traits of Neotropical savanna trees in relation to seasonal water deficit. Trees 19(3): 326-335, http://dx.doi.org/10.1007/s00468-004-0394-z

FROST, P.G.H. & ROBERTSON F. 1987. The ecological effects of fire in savannas. In Determinants of Tropical Savannas (B.J. Walker, ed.) IUBS Special, Paris, p. 93-140.

GOMES, L., LENZA, E., MARACAHIPES, L., MARIMON, B.S. & OLIVEIRA, E.A. 2011. Comparações florísticas e estruturais entre duas comunidades lenhosas de cerrado típico e cerrado rupestre, Mato Grosso, Brasil. Acta bot. bras. 25(4): 865-875, http://dx.doi.org/10.1590/S0102-33062011000400013

HARIDASAN, M. 2008. Nutritional adaptations of native plants of the cerrado biome in acid soils. Brazilian J. Plant Physiol. 20(3): 183-195, http://dx.doi.org/10.1590/S1677-04202008000300003

HOFFMANN, W.A. & MOREIRA, A.G. 2002. The Role of Fire in Population Dynamics of Woody Plants. In The Cerrados of Brazil: ecology and natural history of a neotropical savanna (R.S. Oliveira & P.S. Marquis, eds). The University of Columbia Press, New York, p. 159-177.

HOFFMANN, W.A. & SOLBRIG, O.T.2003. The role of topkill in the differential response of savanna woody species to fire. For. Ecol. Manag. 180(1-3): 273–286, http://dx.doi.org/10.1016/S0378-1127(02)00566-2

HOFFMANN, W.A, SILVA Jr, E.R, MACHADO, G.C, BUCCI, S.J, SCHOLZ, F.G, GOLDSTEIN, G, MEINZER, F.C. 2005. Seasonal leaf dynamics across a tree density gradient in a Brazilian savanna. Oecologia 145: 307–316, http://dx.doi.org/10.1007/s00442-005-0129-x

HOFFMANN, W.A., ADASME, R., HARIDASAN, M., CARVALHO, M.T., GEIGER, E.L., PEREIRA, M.A., GOTSCH, S. & FRANCO, A.C. 2009. Tree topkill, not mortality, governs the dynamics of savanna-forest boundaries under frequent fire in central Brazil. Ecology 90(5): 1326–1337, http://dx.doi.org/10.1890/08-0741.1

HOFFMANN, W.A. 1998. Post-burn reproduction of woody plants in a neotropical savanna: the relative importance of sexual and vegetative reproduction. J. Appl. Ecol. 35(3): 422-433, http://dx.doi.org/10.1046/j.1365-2664.1998.00321.x

HOFFMANN, W.A. 1999. Fire and population dynamics of woody plants in a neotropical savanna: matrix model projections. Ecology 80(4): 1354-1369, http://dx.doi.org/10.1890/0012-9658(1999)080[1354:FAPDOW]2.0.CO;2

HUDSON, I.L., KIM, S.W. & KEATLEY, M.R. 2010. Climatic Influences on the Flowering Phenology of Four Eucalypts: A GAMLSS Approach. In Phenological Research - Methods for Environmental and Climate Change Analysis. (I.L. Hudson & M.R. Keatley, eds). Springer: Netherlands, p. 209-228.

INMET. 2012. Monitoramento das Estações Convencionais. Instituto Nacional de Meteorologia, http://www.inmet.gov.br/html/rede_obs.php (last access in 12/12/2012).

KLINK, C.A. & MACHADO, R.B. 2005. Conservation of the Brazilian Cerrado. Conserv. Biol 19(3): 707-713, http://dx.doi.org/10.1111/j.1523-1739.2005.00702.x

LANDIM, M. & HAY, J. 1996. Impacto do Fogo sobre alguns aspectos da biologia reprodutiva de *Kielmeyera coriacea* Mart. Rev. Brasil. Biol. 56(1): 127-134.

LENZA, E & KLINK, C.A. 2006. Comportamento fenológico de espécies lenhosas em um cerrado sentido restrito de Brasília, DF. Rev. Brasil. Bot. 29(4): 627-638, http://dx.doi.org/10.1590/S0100-84042006000400013

MARIMON-JUNIOR, B.H. & HARIDASAN, M. 2005. Comparação da vegetação arbórea e características edáficas de um cerradão e um cerrado sensu stricto em áreas adjacentes sobre solo distrófico no leste de Mato Grosso, Brasil. Acta bot. bras. 19(4): 913-926, http://dx.doi.org/10.1590/S0102-33062005000400026

MEDEIROS, M.B. & FIEDLER, N.C. 2004. Incêndios florestais no Parque Nacional da Serra da Canastra: desafios para a conservação da biodiversidade. Ciên. Florest. 14(2): 157-168.

MEWS H.A., SILVÉRIO D.V., LENZA E. & MARIMON B.S. 2013. Influência de agrupamentos de bambu na dinâmica pós-fogo da vegetação lenhosa de um cerrado típico, Mato Grosso, Brasil. Rodriguésia 64(2): 211-221, http://dx.doi.org/10.1590/S2175-78602013000200002

MIRANDA, H.S. & SATO, M.N. 2004. Efeitos do fogo na vegetação lenhosa do Cerrado. In Cerrado: Ecologia e Caracterização (L.M.S. Aguiar & A.J.A Camargo, eds). Embrapa Cerrados: Planaltina, p. 66-123.

MIRANDA, H.S., SATO, M.N., NETO, W.N. & AIRES, F.S. 2009. Fires in the cerrado, the Brazilian savanna, in: Cochrane, M.A. (Ed.), Tropical Fire Ecology. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 427–450.

MIRANDA, H.S., BUSTAMANTE, M.M.C. & MIRANDA, A.C. 2002. The Fire Factor. In The Cerrados of Brazil: Ecology and Natural History of a Neotropical Savanna (R.S. Oliveira & P.S. Marquis, eds.). The University of Columbia Press: New York, p. 51-68.

MISTRY, J., BERARDI, A., ANDRADE, V., KRAHÔ, T., KRAHÔ, P. & LEONARDOS, O. 2005. Indigenous Fire Management in the cerrado of Brazil: The Case of the Krahô of Tocantíns. Hum. Ecol. 33(3): 365-386, http://dx.doi.org/10.1007/s10745-005-4143-8

MISTRY, J. 1998. Fire in the cerrado (savannas) of Brazil: an ecological review. Prog. Phys. Geogr. 22(4): 425-448, http://dx.doi.org/10.1177/030913339802200401

MOREIRA, A.G. 2000. Effects of fire protection on savanna structure in Central Brazil. J. Biog. 27(4): 1021-1029, http://dx.doi.org/10.1046/j.1365-2699.2000.00422.x

NARDOTO, G.B., BUSTAMANTE, M.M.C., PINTO, A.S. & KLINK, C.A. 2006. Nutrient use efficiency at ecosystem and species level in savanna areas of Central Brazil and impacts of fire. J. Trop. Ecol. 22(2): 191-201, http://dx.doi.org/10.1017/S0266467405002865

NASA. 2012. The Moderate Resolution Imaging Spectroradiometer (MODIS), http://modis.gsfc.nasa.gov/ (last access in 12/12/2013).

OLIVEIRA-FILHO, A.T. & RATTER, J.A. 2002. Vegetation Physiognomies and Woody Flora of the Cerrado Biome. In The Cerrados of Brazil: ecology and natural history of a neotropical savanna (P.S. Oliveira & R.J. Marquis, eds.). Columbia University Press: New York, p.91-120.

OLIVEIRA, P.E. 2008. Fenologia e biologia reprodutiva das espécies de Cerrado. In Cerrado: ecologia e flora (S.M. Sano, S.P. Almeida. & J.F. Ribeiro, eds.). Embrapa Cerrados: Planaltina, p.169-188.

PINHEIRO, J.C. & BATES, D.M. 2000. Mixed Effects Models in S and S-Plus. Springer, Berlin.

POLANSKY, L. & ROBBINS, M.M. 2013. Generalized additive mixed models for disentangling long-term trends, local anomalies, and seasonality in fruit tree phenology. Ecol. Evol. 3(9): 3141-3151, http://dx.doi.org/10.1002/ece3.707

R CORE TEAM. 2012. R: A language and environment for statistical computing. Vienna: R Foundation for Statistical Computing, http://www.R-project.org (last access in 12/12/2013).

RABASA, S.G., GRANDA, E., BENAVIDES, R., KUNSTLER, G., ESPELTA, J.M., OGAYA, R., PEÑUELAS, J., SCHERER-LORENZEN, M., GIL, W., GRODZKI, W., AMBROZY, S., BERGH, J., HÓDAR, J.A., ZAMORA, R. & VALLADARES, F. 2013. Disparity in elevational shifts of European trees in response to recent climate warming. Glob. Chang. Biol. 19(8): 2490-2499, http://dx.doi.org/10.1111/gcb.12220

ROITMAN, I., FELFILI, J.M. & REZENDE, A.V. 2007. Tree dynamics of a fire-protected cerrado sensu stricto surrounded by forest plantations, over a 13-year period (1991-2004) in Bahia, Brazil. Plant Ecol. 197(2): 255-267, http://dx.doi.org/10.1007/s11258-007-9375-9

SCHOLZ, F.G., BUCCI, S.J., GOLDSTEIN, G., MAINZER, F.C. & FRANCO, A.C. 2002. Hydraulic redistribution of soil water by neotropical savanna trees. Tree Physiol. 22(9): 603-612, http://dx.doi.org/10.1093/treephys/22.9.603

SILVA, F.A.M., ASSAD, E.D. & EVANGELISTA, B.A. 2008. Caracterização climática do Bioma Cerrado. In Cerrado: ecologia e flora (S.M. Sano, S.P. Almeida & J.F. Ribeiro, eds). Embrapa Cerrados, Planaltina, p.69-88.

SILVÉRIO, D.V. & LENZA, E. 2010. Fenologia de espécies lenhosas em um cerrado típico no Parque Municipal do Bacaba, Nova Xavantina, Mato Grosso, Brasil. Biota Neotrop. 10(3): 205-216, http://dx.doi.org/10.1590/S1676-06032010000300024

WOOD, S.N. 2006. Generalized Additive Models: an introduction with R. Chapman and Hall/CRC, Florida.

ZAR, J.H. 1999. Biostatistical Analysis. 4th ed. Prentice Hall, New Jersey.

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inventory

Flora of inland Atlantic riparian forests in southwestern Brazil

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FAXINA, C., FISCHER, E., POTT, A. **Flora of inland Atlantic riparian forests in southwestern Brazil** Biota Neotropica. 15(3): e20130083. http://dx.doi.org/10.1590/1676-06032015008313

Abstract: The flora of the Atlantic Rainforest of Mato Grosso do Sul, southwestern Brazil, has not been inventoried in spite of being the westernmost inland region of this domain. We present an inventory of the riparian flora of inland Atlantic Forest in Mato Grosso do Sul. We describe the species distribution along three habitats with contrasting flood conditions: non-flooded, seasonally flooded, and swampy forests. The inventory consisted of sampling every reproductive individual, during 12 months on 1.12 ha of plots inside a 24 ha study area. We recorded 1967 individuals of 253 species and 72 families. The most representative families in number of species were Asteraceae (27), Fabaceae (19), Myrtaceae (17), Cyperaceae (12), Rubiaceae, Solanaceae and Orchidaceae (10 each). The most abundant reproductive species were *Guarea macrophylla* (169 individuals), *Miconia chamissois* (85) and *Conyza bonariensis* (80). Eleven species of six families were recorded for the first time in Mato Grosso do Sul, two of them endemic to the Atlantic Forest – *Passiflora jilekii* and *Capanema micromera*. We found 119 species exclusively in non-flooded habitat, 19 in seasonally flooded habitat, and 31 in swampy forest. *Guarea macrophylla* was the most frequent species in swampy forest, and *Gochnatia polymorpha* in non-flooded. The riparian forest flora at the study site resembles the Atlantic Forest and includes wide distribution riparian species; the variation of flood conditions among habitats favors its richness. Our records add new occurrences for Mato Grosso do Sul and new distribution ranges for some plant species, what arises concern upon the local biodiversity conservation.

Keywords: *flood gradient, plant distribution, plant richness, riparian forest, semideciduous forest.*

FAXINA, C., FISCHER, E., POTT, A. **Flora de florestas ripárias da Mata Atlântica de interior no sudoeste do Brasil.** Biota Neotropica. 15(3): e20130083. http://dx.doi.org/10.1590/1676-06032015008313

Resumo: Vegetação ripária de Floresta Atlântica de interior no sudoeste do Brasil. A flora da Mata Atlântica de Mato Grosso do Sul, sudoeste do Brasil, tem sido muito pouco estudada, embora represente a porção mais oeste e continental deste domínio. Descrevemos aqui a flora de matas ciliares na região de Mata Atlântica de Mato Grosso do Sul, e a distribuição das espécies em três habitas classificados segundo a ocorrência de inundação como: floresta não inundável, floresta sazonalmente inundável, e floresta inundada. O inventário consistiu de um ano de amostragens mensais de todos os indivíduos reprodutivos em 1,12 ha de parcelas em 24 ha. Encontramos 1967 indivíduos de 253 espécies e 72 famílias. As famílias mais representativas foram Asteraceae (27), Fabaceae (19), Myrtaceae (17), Cyperaceae (12), Rubiaceae, Solanaceae e Orchidaceae (10 espécies cada). As espécies reprodutivas mais abundantes foram *Guarea macrophylla* (169), *Miconia chamissois* (85) e *Conyza bonariensis* (80). Onze espécies de seis famílias foram registradas pela primeira vez em Mato Grosso do Sul, duas delas endêmicas da Mata Atlântica – *Passiflora jilekii* e *Capanema micromera*. Encontramos 119 espécies apenas na floresta não inundável, 19 na floresta sazonalmente inundável, e 31 na floresta inundada. *Guarea macrophylla* foi a espécie mais comum na floresta inundada e *Gochnatia polymorpha*, na floresta não inundável. A flora das matas ciliares estudadas assemelha-se à da Mata Atlântica e apresenta espécies ripárias de ampla distribuição; a variação do regime de inundação entre os habitats favorece sua riqueza. Nossos registros adicionam novas ocorrências para Mato Grosso do Sul e novos limites de distribuição para algumas espécies, fatos que trazem preocupação quanto à conservação da biodiversidade local.

Palavras-chave: *distribuição de plantas, gradiente de inundação, floresta ripária, floresta semidecídua, riqueza de espécies.*

Introduction

Floristic inventories are important to know plant species distribution and diversity, and to subsidize conservation initiatives. The southeastern Mato Grosso do Sul's territory has been considered part of the Atlantic Forest domain, indeed its westernmost inland limit (Rizzini 1979). However, this region is widely uncovered regarding plant surveys. Most inventory efforts in the state of Mato Grosso do Sul have focused on the Pantanal and its surrounding Cerrado floras (Pott & Pott 1994, 2000; 2003, Salis et al. 2004, Pott et al. 2006, Lehn et al. 2008, Damasceno-Junior et al. 2009, Noguchi et al. 2009). Additional plant surveys are available for the northeastern and southwestern Cerrado regions of the state (Pott et al. 2006, Arruda & Daniel 2007, Baptista-Maria et al. 2009). This situation occurs, in part, because the Atlantic Forest domain in Mato Grosso do Sul was largely modified for agriculture, and the remaining natural vegetation became limited to riparian forests.

Riparian forests are highly diverse, often presenting low similarity of flora even between adjacent portions (Rodrigues & Nave 2004). Variation of flood conditions is largely associated with heterogeneity in floristic composition and life forms along riparian forests (Fischer & Araujo 1995, Rodrigues & Shepherd 2004). The importance of abiotic and biotic pressures appears to vary along the gradient of flooding. Increased flood depth and duration can select plant taxa whose traits allow escaping from waterlogging, whereas competitive ability is expected to determine plant occurrences in non-flooded forest patches (Fischer & Santos 2001, Rodrigues & Shepherd 2004). Here, we describe the flora of riparian forests along Touro and Tarumã streams in the Mato Grosso do Sul's Atlantic Forest domain, and address species distribution among three contiguous habitats with contrasting flood conditions.

Methods

Study site

The study was carried out in five plots within 24 ha of the Touro and Tarumã riparian vegetation in the Paraná river basin, municipality of Naviraí, Mato Grosso do Sul (Figure 1). The climate is seasonal characterized by rainy summers and dry winters (Cfa of Köppen); mean annual temperature varies from 12 to 28 °C and mean annual rainfall is 1600 mm (IBGE 1984). The region belongs to the Caiuá geological formation, from upper Cretaceous, with 360 m average altitude and fertile soils, mainly Red Latosol and small patches of Red Spodosol (IBGE 1984), and hydromorphic soils on floodable or swampy areas. The study site is located in the western portion of the major continental phytogeographic domain of Atlantic Rainforest (Ab'Saber 2000). Remaining vegetation comprises mainly alluvial or submontane semideciduous forests (Veloso et al. 1991). Hereafter we refer to the study alluvial semideciduous forests simply as 'riparian forests'.

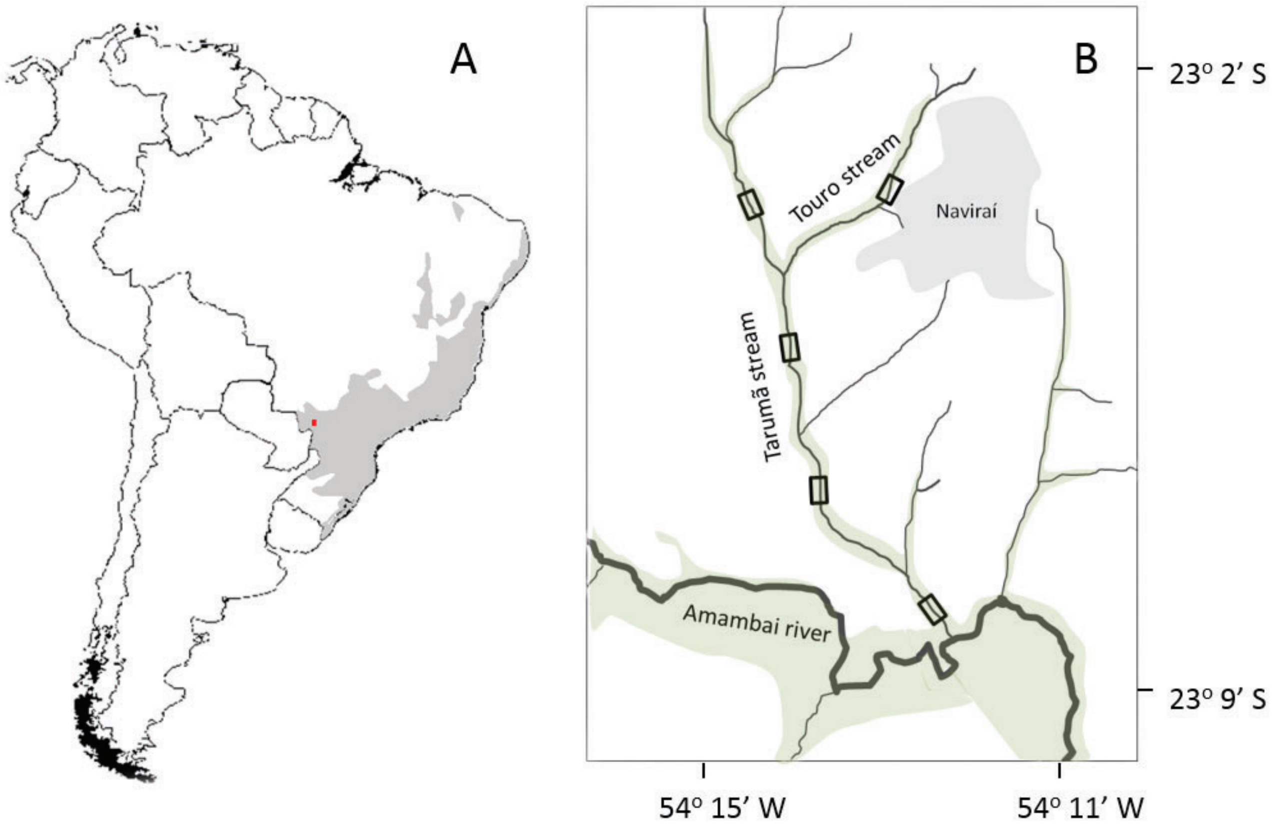

Figure 1. (A) Atlantic Forest domain (gray) and the study site (red dot). (B) Location of plant surveys (rectangles) in the Touro and Tarumã riparian forests (greenish); gray indicates the urban area of Naviraí, and white does pastures and cultivated areas.

Figura 1. (A) Domínio da Mata Atlântica (cinza) e local de estudo (ponto vermelho). (B) Localização das amostragens de plantas (retângulos) nas florestas ripárias (esverdeado) do Touro e Tarumã; cinza indica a área urbana de Naviraí, e branco indica pastagens e áreas cultivadas.

Data collection and analysis

From July 2009 to June 2010 we monthly surveyed all reproductive plant individuals in six meters wide plots perpendicular to the streams, to include the flood gradient from the river margin to the higher ground of the riparian forest. Plots were placed at least 30 m apart, and their lengths varied from 40 to 180 m according to the riparian forest width at each stretch. The total sampled area was 1.12 ha. To control previously sampled individuals, we marked them with numbered aluminum tags. Samples included all angiosperms of different habits (Guedes-Bruni et al. 2002): ground herbs (without woody stems above ground), shrubs (multiple woody stems), climbers (woody or non-woody with climbing structures), trees (one woody stem; palms included), epiphytes, and parasites. For some species of shrubs and herbs in tussocks or multi-stemmed clumps, each bunch was counted as one individual. We also recorded monthly the flood condition (flooded or not flooded) where individuals, or their hosts if epiphyte or parasite, were rooted. After one year of records of flood conditions we assumed three habitat categories: (1) soil not flooded (non-flooded habitat, hereafter), (2) soil flooded during the rainy season (seasonally flooded habitat), and (3) soil persistently flooded (swampy habitat). We then determined limits of habitats within the plots and estimated the area covered by them with help of field GPS readings checked on Google Earth images, where we measured distances between zones. The altimetric difference between the lowest and the upper sampled areas was ca 43 m. Based on the surveyed area for each habitat (non-flooded = 0.64 ha, seasonally flooded = 0.22 ha, and swampy = 0.26 ha) we calculated density of reproductive individuals per species ($N.ha^{-1}$) per habitat. We then used values of density per habitat as a proxy for number of individuals after controlling for equal size of areas (1 ha) among habitats. Considering the total of individuals estimated for one hectare of each habitat, we calculated the proportion (%) of individuals per habitat for each species separately. Finally we entered the values of proportion of individuals in a species x habitat matrix to ordinate plant species in relation to habitats, in the R program (R Development Core Team 2010); epiphytes and species with less than 10 individuals were not included. Number of surveyed species relative to sample size was evaluated through rarefaction curves; in the Past program (Hammer et al. 2001). Identifications were based on comparisons with herbarium materials, and help of literature and specialists. Taxonomy follows the Angiosperm Phylogeny Group (APG III 2009). Voucher material was included in the Herbarium CGMS, Universidade Federal de Mato Grosso do Sul. Finally, we obtained from literature and herbarium sites (www.tropicos.org; www.floradobrasil.jbrj.gov.br) the occurrences of species throughout the phytogeographical domains. Each species was assigned to a domain when its previous known occurrence was restricted, or assigned as "wide distribution" when its occurrence included more domains, considered as Amazonia, Atlantic Forest, Caatinga, Cerrado, Chaco, Pampas or Pantanal. Species that are not South American natives were assigned as exotic.

Results

Surveyed flora and new occurrences in Mato Grosso do Sul

We recorded 1967 reproductive individuals of 253 species, 193 genera and 72 families (Table 1). The eight richest families included 46% of all surveyed species – Asteraceae (27 species), Fabaceae (19), Myrtaceae (17), Cyperaceae (12), Malvaceae, Orchidaceae, Rubiaceae and Solanaceae (10). Thirty-three families presented two to nine species, and the remaining families presented a single one. The most abundant reproductive species were *Guarea macrophylla* (Meliaceae; 169 individuals), *Miconia chamissois* (Melastomataceae; 85), *Conyza bonariensis* (Asteraceae; 80), *Ocotea lancifolia* (Lauraceae; 65) and *Cecropia pachystachya* (Urticaceae; 57). Eleven species were recorded for the first time in Mato Grosso do Sul – *Campylocentrum grisebachii*, *Capanemia micromera*, *Cohniella jonesiana*, *Microlaelia lundii*, *Rodriguezia decora*, *Sauroglossum nitidum* (all Orchidaceae), *Passiflora jilekii* (Passifloraceae), *Persea willdenovii* (Lauraceae), *Merremia macrocalyx* (Convolvulaceae), *Qualea cordata* (Vochysiaceae), and the saprophyte *Apteria aphylla* (Burmanniaceae). We additionally recorded the parasite *Phoradendron piperoides* (Viscaceae) and four invader species – *Leucaena leucocephala* (Fabaceae), *Tecoma stans* (Bignoniaceae), *Cordia myxa* (Cordiaceae), and *Hedychium coronarium* (Zingiberaceae). Most species were herbs (99; 39%) or trees (72; 28%). Climbers and shrubs included 39 (15%) and 33 (13%) species, respectively, and epiphytes, nine species (4%).

Species distribution among habitats

Floras of swampy and seasonally flooded forests showed less species and so tended to be fully surveyed, but flora of non-flooded forest was richer and less completely surveyed despite its larger area sampled (Figure 2). In general, most species (169 out of 253) were sampled only in one habitat, mainly in non-flooded (119) than in swampy (31) or seasonally flooded (19) (Table 1). On the other hand, considering only those species with 10 or more individuals recorded (n = 49 species), 63% were found in the three habitats, 20% in two habitats, 13% exclusively in non-flooded, 4% in swampy, and none was found solely in seasonally flooded habitat. In overall, densities of the most abundant herbs and shrubs species in swampy and seasonally flooded habitats were one order of magnitude above non-flooded habitat. Among tree species, densities in swampy were one order of magnitude above the other habitats.

Among herbaceous plants, *Conyza bonariensis* (62.5 $N.ha^{-1}$), *Geophila repens* (57.8) and *Triumfetta bartramia* (45.3) were the species with highest densities in non-flooded habitats; *G. repens*, *Elephantopus mollis* (32.8) and *Rhynchospora mariscul*us (23.4) occurred in this habitat only (Table 1). The commonest species in swampy habitat were *Coccocypselum lanceolatum* (153.9) and *Calyptrocarya glomerulata* (119.2), whereas *Conyza bonariensis* (182.6) and *Canna indica* (160.0) were the most common in seasonally flooded habitat. Among shrubs, highest densities in non-flooded habitat were found for *Piper aduncum* (32.8), *Psychotria carthagenensis* (31.3) and *Ludwigia sericea* (23.4), and in swampy for *Miconia chamissois* (28.8), *M. theizans* (13.9) and *Gaylussacia brasiliensis* (61.5) (Table 1). Density of *Piper aduncum* (122.7) was one order of magnitude higher than the subsequent most abundant species in seasonally flooded habitat, *M. chamissois* (45.5), *Lantana camara* (31.8) and *Ludwigia sericea* (22.7). The commonest tree species in non-flooded habitat were *Gochnatia polymorpha* (34.4), *Allophylus edulis* (31.25) and *Helietta apiculata* (28.1); *G. polymorpha* and *H. apiculata* were exclusively found in this habitat (Table 1). *Guarea macrophylla* (557.7), *Ocotea lancifolia* (188.5) and *Styrax*

Table 1. Families, species, habits (TRE = trees; SHR = shrubs; EPI = epiphytes; HER = herbs; CLI = climbers; PAR = parasites), number of individuals (n), and density (N.ha^{-1}) in three soil moisture types (NF = non flooded; SF = seasonally flooded; SW = swampy) in the riparian forests along Touro and Tarumã streams, Paraná river basin, Mato Grosso do Sul. Collection number: CF = Claudenice Faxina; Phytogeography: AF = Atlantic Forest, CE = Cerrado, CH = Chaco, WD = wide distribution, EX = exotic.

Tabela 1. Famílias, espécies, hábitos (TRE = árvores; SHR = arbustos; EPI=epífitas; HER = herbáceas; CLI = climbers; PAR= parasita), número de indivíduos (n) e densidade (N.ha-1) em três tipos umidade de solo (NF = não inundado; SF = sazonalmente inundado; SW = permanentemente inundado) ao longo da floresta ripária dos córregos Touro e Tarumã, bacia do rio Paraná, Mato Grosso do Sul. Número de coleta: CF = Claudenice Faxina; Fitogeografia: AF = Mata Atlântica, CE = Cerrado, CH = Chaco, WD = ampla distribuição, EX = exótica.

Family	Species	Habit	n	NF	SF	SW	Phytogeography	Collection number
Acanthaceae	*Hygrophila costata* Nees	HER	1	1.6			WD	
	Ruellia cf. *brevifolia* (Pohl) C. Ezcurra	SHR	1	1.6			WD	CF 075
Alismataceae	*Echinodorus longipetalus* Micheli	HER	4			15.4	WD	CF 229
	Sagittaria rhombifolia Cham.	HER	1			3.9	WD	
Anacardiaceae	*Schinus terebenthifolia* Raddi	TRE	3	4.7			WD	CF 042
	Tapirira guianensis Aubl.	TRE	32	7.8	36.4	73.8	WD	
Apocynaceae	*Condylocarpon isthmicum* (Vell.) A. DC.	CLI	7	3.2	4.6	15.4	AF	CF 238
	Mesechites sp.	CLI	1	1.6			WD	CF 217
	Tabernaemontana catharinensis A. DC.	SHR	1	1.6			AF	
Aquifoliaceae	*Ilex brasiliensis* Loes.	TRE	13	1.6	9.1	38.5	AF	CF 228
	Ilex affinis Gardner	TRE	2			7.7	WD	CF 174
Araliaceae	*Hydrocotyle leucocephala* Cham. & Schltdl.	HER	9	1.6	4.6	27.9	WD	
	Hydrocotyle verticillata Thunb.	HER	1		4.6		WD	
Arecaceae	*Acrocomia aculeata* (Jacq.) Lodd. ex Mart.	TRE	5	7.8			WD	
	Geonoma brevispatha Barb. Rodr.	TRE	12			46.2	AF	CF 011
	Syagrus romanzoffiana (Cham.) Glassman	TRE	14	9.4	18.2	15.4	AF	
Aristolochiaceae	*Aristolochia triangularis* Cham.	CLI	3	4.7			AF	CF 081
Asteraceae	*Achyrocline satureioides* (Lam.) DC.	HER	5	7.8			WD	
	Aspilia latissima Malme	HER	2	1.6	3.9		WD	
	Baccharis sp.	HER	1	1.6				CF 302
	Barrosoa candolleana (Hook. & Arn.) R. M. King & H. Rob.	HER	1			3.9	WD	CF 274
	Conyza bonariensis (L.) Cronquist	HER	80	62.5	182.6		WD	CF 262
	Chromolaena odorata (L.) R. M. King & H. Rob.	HER	11	9.4	18.2	3.9	WD	CF 063
	Eclipta prostrata (L.) L.	HER	2			7.7	WD	CF 337
	Elephantopus mollis Kunth	HER	21	32.8			WD	CF 125
	Elephantopus palustris Gardner	HER	2	1.6	3.9		WD	CF 112
	Emilia fosbergii Nicolson	HER	2	3.1			WD	CF 141
	Erechtites hieraciifolius (L.) Raf. ex DC.	HER	2		10.0		WD	CF 183
	Gnaphalium pensylvanicum Willd.	HER	1		4.6		WD	CF 143
	Gochnatia polymorpha (Less.) Cabrera	SHR	22	34.4			WD	CF 044
	Gymnocoronis spilanthoides (D. Don ex Hook. & Arn.) DC.	HER	1			3.9	WD	CF 118
	Mikania cordifolia (L. f.) Willd.	CLI	2	1.6	4.6		WD	CF 041
	Mikania micrantha Kunth	CLI	6	9.4			WD	CF 335
	Porophyllum ruderale (Jacq.) Cass.	HER	3	4.7			WD	CF 209
	Sonchus oleraceus L.	HER	2	3.1			EX	CF 128
	Trichogonia crenulata (Gardner) D. J. N. Hind	SHR	2			7.7	WD	CF 108
	Trixis antimenorrhoea (Schrank) Kuntze	CLI	3	4.7			WD	CF 155
	Vernonanthura cuneifolia (Gardner) H. Rob.	HER	6				WD	CF 139
	Vernonia cf. *grandiflora* Less.	HER	2	3.1			WD	CF 297
	Vernonia remotiflora Rich.	HER	4	4.7	4.6		WD	CF 207
	Vernonia sp.1	HER	1	1.6				CF 345
	Vernonia sp.2	SHR	5	6.3	4.6			CF 065
	Indet. 1	HER	1	1.6				CF 263
	Indet. 2	SHR	1	1.6				CF 338
Begoniaceae	*Begonia cucullata* Willd.	HER	22	1.6	18.2	65.4	WD	CF 216

Continued on next page

Table 1. Continued.

Family	Species	Habit	n	NF	SF	SW	Phyto-geography	Collection number
Bignoniaceae	*Anemopaegma chamberlaynii* (Sims) Bureau & K. Schum.	CLI	1	1.6			WD	CF 184
	Fridericia florida (DC.) L.G. Lohmann	CLI	3	4.7			WD	CF 085
	Fridericia sp.	CLI	1	1.6				CF 145
	Pyrostegia venusta (Ker Gawl.) Miers	CLI	2		9.1		AF	CF 043
	Tecoma stans (L.) Juss. ex Kunth	SHR	3	4.7			EX	CF 181
Bromeliaceae	*Aechmea bromeliifolia* (Rudge) Baker	EPI	2	1.6		3.9	WD	
	Bromelia balansae Mez	HER	7	4.7	13.6	3.9	WD	
Burmaniaceae	*Apteria aphylla* (Nutt.) Barnhart ex Small	HER	4			15.4	WD	CF 199
Boraginaceae	*Cordia myxa* L.	TRE	2	1.6	4.6		EX	CF 233
	Cordia polycephala (Lam.) I. M. Johnst.	SHR	5	3.1	9.1	3.9	WD	CF 248
Cactaceae	*Epiphyllum phyllanthus* (L.) Haw.	EPI	1	1.6			WD	
Campanulaceae	*Pratia* cf. *hederacea* (Cham.) G. Don	HER	2				WD	
Cannaceae	*Canna indica* L.	HER	37	1.6	160.0	3.9	WD	CF 048
Cannabaceae	*Trema micrantha* (L.) Blume	TRE	3	4.7			WD	CF 130
Cardiopteridaceae	*Citronella gongonha* (Mart.) R. A. Howard	TRE	5	1.6		15.4	WD	CF 023
Commelinaceae	*Commelina erecta* L.	HER	2		10.0		WD	CF 121
	Floscopa glabrata (Kunth) Hassk.	HER	2	1.6	4.6		WD	CF 313
Convolvulaceae	*Ipomoea* sp.	CLI	1	1.6				CF 298
	Jacquemontia sp.	CLI	1	1.6				CF 187
	Merremia macrocalyx (Ruiz & Pav.) O'Donell	CLI	1	1.6			WD	CF 336
Costaceae	*Costus arabicus* L.	HER	11		45.5	3.8	WD	
Cucurbitaceae	*Melothria* cf. *pendula* L.	CLI	1	1.6			WD	CF 235
Cyperaceae	*Calyptrocarya glomerulata* (Brongn.) Urb.	HER	37	3.1	18.2	119.2	WD	CF 324
	Cyperus haspan L.	HER	20		10.0	69.2	WD	CF 311
	Cyperus luzulae (L.) Rottb. ex Retz.	HER	9		27.3	11.5	WD	CF 260
	Cyperus odoratus L.	HER	5			19.2	WD	CF 256
	Diplacrum longifolium (Griseb.) C. B. Clarke	HER	6		10.0	15.4	WD	CF 325
	Fimbristylis complanata (Retz.) Link	HER	3		13.6		WD	CF 258
	Fuirena umbellata Rottb.	HER	4		13.6	3.8	WD	CF 294
	Pycreus lanceolatus (Poir.) C. B. Clarke	HER	8	3.1	10.0	15.4	WD	CF 242
	Rhynchospora corymbosa (L.) Britton	HER	8	1.6	13.6	15.4	WD	CF 210
	Rhynchospora marisculus Nees	HER	15	23.4			WD	CF 244
	Scleria cf. *bancana* Miq.	HER	21	7.8	22.7	42.4	WD	CF 124
	Scleria melaleuca Rchb.	HER	26	3.1	18.2	76.9	WD	
Dioscoreaceae	*Dioscorea altissima* Lam.	CLI	4	6.3			WD	CF 347
	Dioscorea cf. *trifida* L. f.	CLI	1		4.6		WD	CF 291
	Dioscorea sp.1	CLI	5	1.6		15.4		CF 096
	Dioscorea sp.2	CLI	4	1.6		11.5		CF 259
Ebenaceae	*Diospyros inconstans* Jacq.	TRE	1	1.6			WD	CF 059
Ericaceae	*Gaylussacia brasiliensis* (Spreng.) Meisn.	SHR	16			61.5	WD	CF 107
Eriocaulaceae	*Syngonanthus caulescens* (Poir.) Ruhland	HER	4		4.6	11.5	WD	CF 243
Euphorbiaceae	*Acalypha* sp.	HER	1			3.9		
	Croton lobatus L.	HER	1	1.6			WD	CF 226
	Croton urucurana Baill.	TRE	6	9.4			WD	CF 060
	Euphorbia heterophylla L.	HER	1	1.6			WD	CF 142
	Ricinus communis L.	TRE	5	7.8			EX	
	Sapium haematospermum Müll. Arg.	TRE	8	4.7	18.2	3.9	WD	CF 208
	Sebastiania brasiliensis Spreng.	TRE	18	18.8	18.2	7.7	WD	CF 055
	Tragia sp.	CLI	1	1.6				CF 158
Fabaceae	*Canavalia mattogrossensis* (Barb. Rodr.) Malme	CLI	3	4.7			WD	CF 319
	Centrosema sagittatum (Humb. & Bonpl. ex Willd.) Brandegee	CLI	2	3.1			WD	CF 320
	Chamaecrista nictitans (L.) Moench	HER	1	1.6			WD	CF 343
	Copaifera langsdorffii Desf.	TRE	2	3.1			WD	CF 193
	Crotalaria pallida Aiton	HER	5	7.8			WD	CF 342

Continued on next page

Table 1. Continued.

Family	Species	Habit	n	NF	SF	SW	Phyto-geography	Collection number
	Desmodium cajanifolium (Kunth) DC.	HER	1		4.6		WD	
	Desmodium incanum DC.	HER	3	4.7			WD	CF 299
	Galactia striata (Jacq.) Urb.	HER	1	1,6			WD	CF 300
	Inga vera Willd.	TRE	1	1.6			WD	CF 266
	Leucaena leucocephala (Lam.) de Wit	TRE	1	1.6			EX	CF 071
	Macroptilium lathyroides (L.) Urb.	HER	1			3.9	WD	CF 326
	Mimosa debilis Humb. & Bonpl. ex Willd.	HER	1	1.6			WD	CF 270
	Parapiptadenia rigida (Benth.) Brenan	TRE	2	3.1			AF	
	Rhynchosia edulis Griseb.	CLI	1	1.6			WD	CF 153
	Rhynchosia melanocarpa Grear	CLI	1			3.9	WD	CF 283
	Senegalia riparia (Kunth) Britton & Rose ex Britton & Killip	TRE	3	4.7			WD	
	Senna pendula (Humb. & Bonpl. ex Willd.) H.S. Irwin & Barneby	SHR	1		4.6		WD	CF 070
	Sesbania virgata (Cav.) Pers.	TRE	1	1.6			WD	CF 052
	Vigna caracalla (L.) Verdc.	CLI	1	1.6			WD	CF 305
Gentianaceae	*Irlbachia alata* (Aubl.) Maas	HER	7		22.7	7.7	WD	CF 284
Lamiaceae	*Aegiphila sellowiana* Cham.	TRE	3	4.7			AF	CF 271
	Hyptis althaeifolia Pohl ex Benth.	HER	1	1.6			WD	CF 331
	Peltodon tomentosus Pohl	HER	2	3.1			WD	CF 064
	Vitex montevidensis Cham.	TRE	1		4.6		AF	
Lauraceae	*Endlicheria paniculata* (Spreng.) J. F. Macbr.	TRE	23	28.1	13.6	7.7	WD	CF 078
	Nectandra megapotamica (Spreng.) Mez	TRE	3	4.7			AF	
	Nectandra warmingii Meisn.	TRE	2	3.1			CE	CF 148
	Ocotea lancifolia (Schott) Mez	TRE	65	9.4	45.5	188.5	AF	CF 340
	Ocotea minarum (Nees & C. Mart.) Mez	TRE	2	3.1			WD	
	Persea willdenovii Kosterm.	TRE	2			7.7	AF	CF 349
Lentibulariaceae	*Utricularia gibba* L.	HER	2			7.7	WD	
Lythraceae	*Cuphea* cf. *sessiliflora* A. St.-Hil.	HER	1	1.6			WD	CF 332
	Cuphea melvilla Lindl.	HER	1			3.9	WD	CF 329
	Cuphea retrorsicapilla Koehne	HER	1	1.6			WD	
	Heimia myrtifolia Cham. & Schltdl.	HER	1	1.6			AF	CF 330
Malpighiaceae	*Banisteriopsis pubipetala* (A. Juss.) Cuatrec.	CLI	1			3.9	WD	CF 190
	Heteropterys sp.	CLI	1			3.9		CF 293
	Janusia guaranitica (A. St.-Hil.) A. Juss.	CLI	1	1.6			WD	CF 247
Malvaceae	*Ayenia tomentosa* L.	HER	1	1.6			CH	CF 166
	Luehea candicans Mart.	TRE	8	10.9	4.6		WD	CF 038
	Luehea divaricata Mart.	TRE	13	9.4	31.8		AF	CF 047
	Sida cordifolia L.	SHR	1		4.6		WD	CF 264
	Sida linifolia Cav.	HER	1		4.6		WD	CF 309
	Sidastrum paniculatum (L.) Fryxell	HER	1				WD	CF 287
	Triumfetta bartramia L.	HER	35	45.3	27.3		EX	CF 068
	Urena lobata L.	SHR	1	1.6			EX	CF 103
	Wissadula subpeltata (Kuntze) R. E. Fr.	SHR	1	1.6			WD	CF 312
Marantaceae	*Calathea grandiflora* K. Schum.	HER	2	3.1			WD	CF 215
	Maranta divaricata Roscoe	HER	7	10.9			WD	CF 211
Mayacaceae	*Mayaca sellowiana* Kunth	HER	2			7.7	WD	CF 280
Melastomataceae	*Clidemia* cf. *urceolata* DC.	HER	12	1.6	27.3	19.2	WD	CF 101
	Clidemia hirta (L.) D. Don	HER	1		4.6		WD	CF 140
	Clidemia sp.	HER	1	1.6				CF 225
	Miconia chamissois Naudin	SHR	85	3.1	45.5	280.8	WD	CF 098
	Miconia theizans (Bonpl.) Cogn.	SHR	32	3.1	13.6	103.8	WD	CF 087
	Rhynchanthera verbenoides Cham.	HER	1				WD	CF 246
	Rhynchanthera sp.	HER	7		22.7	7.7		CF 286
Meliaceae	*Guarea macrophylla* Vahl	TRE	169	14.6	68.2	557.7	WD	CF 012
	Trichilia elegans A. Juss.	TRE	10	15.6			WD	CF 076

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Table 1. Continued.

Family	Species	Habit	n	NF	SF	SW	Phyto-geography	Collection number
	Trichilia pallida Sw.	TRE	1	1.6			WD	CF 310
Moraceae	*Ficus* cf. *luschnathiana* (Miq.) Miq.	TRE	1	1.6			AF	
	Ficus sp.	TRE	1			3.9		
Myrsinaceae	*Rapanea gardneriana* (A. DC.) Mez	TRE	30	6.3	27.3	76.9	WD	CF 092
Myrtaceae	*Calyptranthes clusiifolia* (Miq.) O. Berg	SHR	1		4.6		CE	
	Calyptranthes lucida Mart. ex DC.	SHR	16	4.7		50.0	WD	CF 332
	Calyptranthes concinna DC.	SHR					WD	CF 322
	Calyptranthes sp.	SHR	8	1.6		26.9		CF 288
	*Campomanesia guazumifolia (*Cambess.) O. Berg	TRE	1	1.6			AF	CF 191
	Eugenia hiemalis Cambess.	TRE	1	1.6			AF	CF 150
	Eugenia involucrata DC.	TRE	1	1.6			WD	CF 200
	Eugenia pyriformis Cambess.	TRE	1	1.6			WD	CF 220
	Eugenia speciosa Cambess.	TRE	1	1.6			WD	CF 205
	Eugenia sp.1	TRE	1		4.6			
	Eugenia sp.2	TRE	1	1.6				
	Eugenia sp.3	TRE	1	1.6				
	Myrcia guianensis (Aubl.) DC.	TRE	4	6.3			WD	CF 231
	Myrcia splendens (Sw.) DC.	TRE	3	4.7			WD	CF 224
	Myrcia sp.	TRE						CF 255
	Psidium guajava L.	TRE	2	3.1			EX	CF 180
	Indet	TRE	1	1.6				CF 202
Nyctaginaceae	cf. *Guapira*	TRE	1	1.6				CF 176
Ochnaceae	*Ouratea* cf. *cuspidata* Tiegh.	TRE	2	3.1			AF	CF 253
	Sauvagesia racemosa A. St.-Hil.	HER	1	1.6			WD	CF 106
Onagraceae	*Ludwigia decurrens* Walter	HER	2	3.1			WD	CF 268
	Ludwigia sericea (Cambess.) H. Hara	SHR	21	23.4	22.7	3.9	WD	CF 093
	Ludwigia tomentosa (Cambess.) H. Hara	SHR	12	1.6	18.2	26.9	WD	CF 030
Orchidaceae	*Campylocentrum aromaticum* Barb. Rodr.	EPI	1			3.9	AF, CE	
	Campylocentrum grisebachii Cogn.	EPI	1			3.9	WD	CF 123
	Capanemia micromera Barb. Rodr.	EPI	1			3.9	AF	
	Catasetum sp.	EPI	1	1.6				
	Cochniella jonesiana (Rchb. F). Christenson	EPI	1			3.9	WD	
	Habenaria sp.	HER	1			3.9		CF 353
	Microlaelia lundii (Rchb. f.) Chiron & V. P. Castro	EPI	10			38.5	AF, CE	CF 021
	Oeceoclades maculata (Lindl.) Lindl.	HER	14	17.2	4.6	7.7	WD	CF 051
	Rodriguezia decora (Lem.) Rchb. f.	EPI	5			19.2	AF, CE	CF 113
	Sauroglossum nitidum (Vell.) Schltr.	HER	1			3.9	WD	
Oxalidaceae	*Oxalis corymbosa* DC.	HER	1	1.6			EX	
	Oxalis latifolia Kunth	HER	1	1.6			EX	CF 056
Passifloraceae	*Passiflora alata* Curtis	CLI	6	6.3		7.7	WD	CF 074
	Passiflora jilekii Wawra	CLI	1	1.6			AF	CF 201
	Passiflora misera Kunth	CLI	1	1.6			WD	CF 251
	Passiflora speciosa Gardner	CLI	1	1.6			AF	CF 133
Piperaceae	*Piper aduncum* L.	TRE	52	32.8	122.7	15.4	WD	CF 029
	Piper amalago L.	TRE	3	3.1		3.9	WD	CF 273
	Piper arboreum Aubl.	TRE	2	3.1			WD	CF 058
	Piper umbellatum L.	SHR	8	4.7	4.6	15.4	WD	CF 122
Poaceae	*Merostachys* sp.	SHR	1	1.6			AF	CF 111
	Oplismenus hirtellus (L.) P. Beauv.	HER	4	3.1		7.7	AF, CE	
	Panicum cyanescens Nees ex Trin.	HER	1			3.9	WD	CF 290
	Panicum sp.	HER	3	4.7				CF 245
	Pharus lappulaceus Aubl.	HER	14	18.8		7.7	AF	CF 135
	Setaria parviflora (Poir.) Kerguélen	HER	1	7.8			WD	CF 272

Continued on next page

Table 1. Continued.

Family	Species	Habit	n	NF	SF	SW	Phyto-geography	Collection number
Rhamnaceae	*Gouania mollis* Reissek	CLI	8	9.4	4.6	3.9	WD	CF 045
Rosaceae	*Prunus myrtifolia* (L.) Urb.	TRE	17	4.7	9.1	46.2	WD	CF 306
Rubiaceae	*Chomelia obtusa* Cham. & Schltdl.	TRE	8	12.5			WD	CF 304
	Coccocypselum lanceolatum (Ruiz & Pav.) Pers.	HER	45	7.8		153.9	WD	CF 083
	Emmeorhiza umbellata (Spreng.) K. Schum.	HER	1	1.6			WD	CF 115
	Geophila repens (L.) I. M. Johnst.	HER	37	57.8			WD	CF 062
	Manettia cordifolia Mart.	CLI	1	1.6			WD	CF 315
	Palicourea marcgravii A. St.-Hil.	SHR	17	10.9	13.6	26.9	AF	CF 218
	Psychotria carthagenensis Jacq.	SHR	31	31.3		42.4	AF	CF 234
	Psychotria racemosa Rich.	SHR	18	3.1	9.1	53.9	WD	CF 079
	Randia nitida (Kunth) DC.	TRE	1	1.6			WD	CF 237
	Indet.	TRE	18	25.0	9.1			CF 253
Rutaceae	*Esenbeckia febrifuga* (A. St.-Hil.) A. Juss. ex Mart.	TRE	7	10.9			AF, CE	CF 061
	Helietta apiculata Benth.	TRE	18	28.1			AF, CE	CF 213
	Zanthoxylum rhoifolium Lam.	TRE	1	1.6			WD	CF 223
Salicaceae	*Casearia decandra* Jacq.	TRE	1	1.6			WD	CF 221
Santalaceae	*Phoradendron piperoides* (Kunth) Trel.	PAR	1			3.9	WD	CF 230
Sapindaceae	*Allophylus edulis* (A. St.-Hil., Cambess. & A. Juss.) Radlk.	TRE	22	31.3	9.1		WD	CF 165
	Cupania vernalis Cambess.	TRE	6	9.4			AF, CE	CF 160
	Matayba elaeagnoides Radlk.	TRE	9	14.6			AF, CE	CF 194
	Paullinia pinnata L.	CLI	2	1.6		3.9	WD	CF 069
	Serjania caracasana (Jacq.) Willd.	CLI	4	1.6		11.5	WD	CF 131
	Urvillea ulmacea Kunth	CLI	1	1.6			WD	CF 163
Sapotaceae	*Chrysophyllum marginatum* (Hook. & Arn.) Radlk.	TRE	18	21.9	4.6	11.5	AF, CE	CF 100
Smilacaceae	*Smilax campestris* Griseb.	CLI	16	6.3	45.5	7.7	WD	CF 084
	Smilax fluminensis Steud.	CLI	25	21.9	31.8	15.4	WD	CF 035
Solanaceae	*Capsicum baccatum* L.	HER	1		4.6		WD	CF 269
	Capsicum chinense Jacq.	HER	1	1.6			EX	
	Cestrum axillare Vell.	SHR	9	12.5	4.6		WD	CF 135
	Cestrum mariquitense Kunth	TRE	1	1.6			WD	
	Cestrum schlechtendalii G. Don	SHR	1	1.6			WD	
	Cestrum strigilatum Ruiz & Pav.	SHR	5	3.1	13.6		WD	CF 120
	Physalis angulata L.	HER	1		4.6		WD	CF 189
	Solanum americanum Mill.	HER	3	4.7			WD	CF 053
	Solanum mauritianum Scop.	TRE	3	4.7			AF	CF 040
	Solanum paniculatum L.	SHR	1	1.6			WD	CF 227
Styracaceae	*Styrax pohlii* A. DC.	TRE	47	3.1	36.4	142.4	WD	CF 239
Theophrastaceae	*Clavija nutans* (Vell.) B. Stahl	SHR	7		4.6	23.8	AF, CE	CF 162
Thymelaeaceae	*Daphnopsis racemosa* Griseb.	SHR	3	4.7			AF	CF 161
Urticaceae	*Cecropia pachystachya* Trécul	TRE	57	15.6	95.5	100.0	WD	
	Boehmeria sp.	HER	1		4.6			CF 265
Verbenaceae	*Lantana camara* L.	SHR	10	1.6	31.8	7.7	WD	CF 046
Violaceae	*Hybanthus communis* (A. St.-Hil.) Taub.	HER	1	1.6			WD	
Vitaceae	*Cissus* sp.	CLI	1	1.6				CF 333
Vochysiaceae	*Qualea cordata* (Mart.) Spreng.	TRE	1		4.6		AF, CE	
Xyridaceae	*Xyris laxifolia* Mart.	HER	15		22.7	38.5	WD	
Zingiberaceae	*Hedychium coronarium* J. König	HER	1	1.6			EX	

pohlii (142.4) presented the highest densities among trees in swampy, and *Cecropia pachystachya* (95.5) and *Guarea macrophylla* (68.2) in seasonally flooded habitat.

Density of epiphytes was very low, but they tended to occur in swampy rather than in the other habitats. Six orchid species (*Campylocentrum aromaticum*, *C. grisebachii, Capanemia micromera*, *Microlaelia lundii*, *Cohniella jonesiana* and *Rodriguezia decora*) included 19 individuals exclusively in swampy, and one orchid species (*Catasetum* sp.) presented one individual in non-flooded habitat (Table 1). The bromeliad

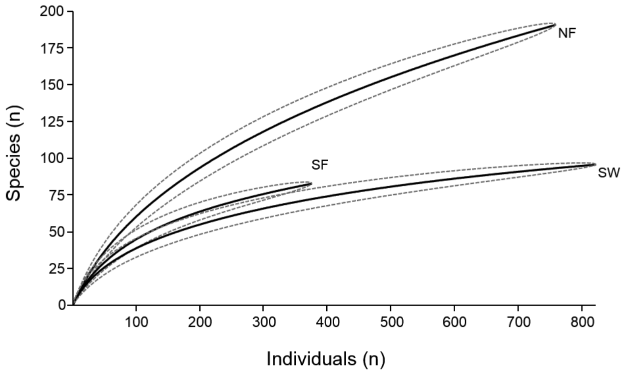

Figure 2. Rarefaction curves for cumulative species according to number of reproductive individuals sampled in non-flooded (NF), seasonally flooded (SF) and swampy (SW) habitats in the riparian forests of Touro and Tarumã streams, southwestern Brazil. Dotted lines show 95% Confidence Intervals.
Figura 2. Curvas de rarefação de espécies com base na quantidade de indivíduos reprodutivos amostrados em habitat não inundável (NF), sazonalmente inundável (SF) e permanentemente inundado (SW) nas florestas ripárias dos rios Touro e Tarumã, sudoeste do Brasil. Linhas pontilhadas mostram Intervalos de Confiança de 95%

Aechmea bromeliifolia showed one individual in swampy and another in non-flooded habitat, where also one individual of the epiphytic cactus *Epiphyllum phyllanthus* occurred.

Based on proportional distribution of species with sample size ≥ 10 individuals, most of them presented higher abundance in swampy (25) than in seasonally (10) or non-flooded habitats (14). This pattern was also consistent within habits – herbs, shrubs or trees (Figure 3). The most frequent species in swampy were *Coccocypselum lanceolatum*, *Cyperus haspan*, *Calyptrocarya glomerulata*, *Scleria melaleuca*, *Begonia cucullata*, *Xyris laxifolia*, *Scleria bancana*, *Smilax campestris* (herbs), *Gaylussacia brasiliensis*, *Miconia chamissois*, *M. theizans*, *Psychotria racemosa*, *Ludwigia tomentosa* (shrubs), *Geonoma brevispatha*, *Calyptranthes lucida*, *Guarea macrophylla*, *Styrax pohlii*, *Ocotea lancifolia*, *Ilex brasiliensis*, *Prunus myrtifolia*, *Rapanea gardneriana*, *Tapirira guianensis*, *Cecropia pachystachya* (trees). On the other hand, in non-flooded habitat were *Geophila repens*, *Rhynchospora marisculus*, *Elephantopus mollis*, *Triumfetta bartramia*, *Pharus lappulaceus*, *Oeceoclades maculata* (herbs), *Ludwigia sericea*, *Chrysophyllum marginatum* (shrubs), *Helietta apiculata*, *Trichilia elegans*, *Gochnatia polymorpha*, *Allophylus edulis*, *Endlicheria paniculata*, and *Sebastiania brasiliensis* (trees). Common species in seasonally flooded habitat were *Costus arabicus*, *Canna indica*, *Smilax fluminensis*, *Chromolaena maximilianii*, *Conyza bonariensis* (herbs), *Piper aduncum*, *Lantana camara*, *Clidemia* cf. *urceolata* (shrubs), *Luehea divaricata* and *Syagrus romanzoffiana* (trees). The pioneer tree *Cecropia pachystachya* was equally abundant in swampy and seasonally flooded habitats (Figure 3).

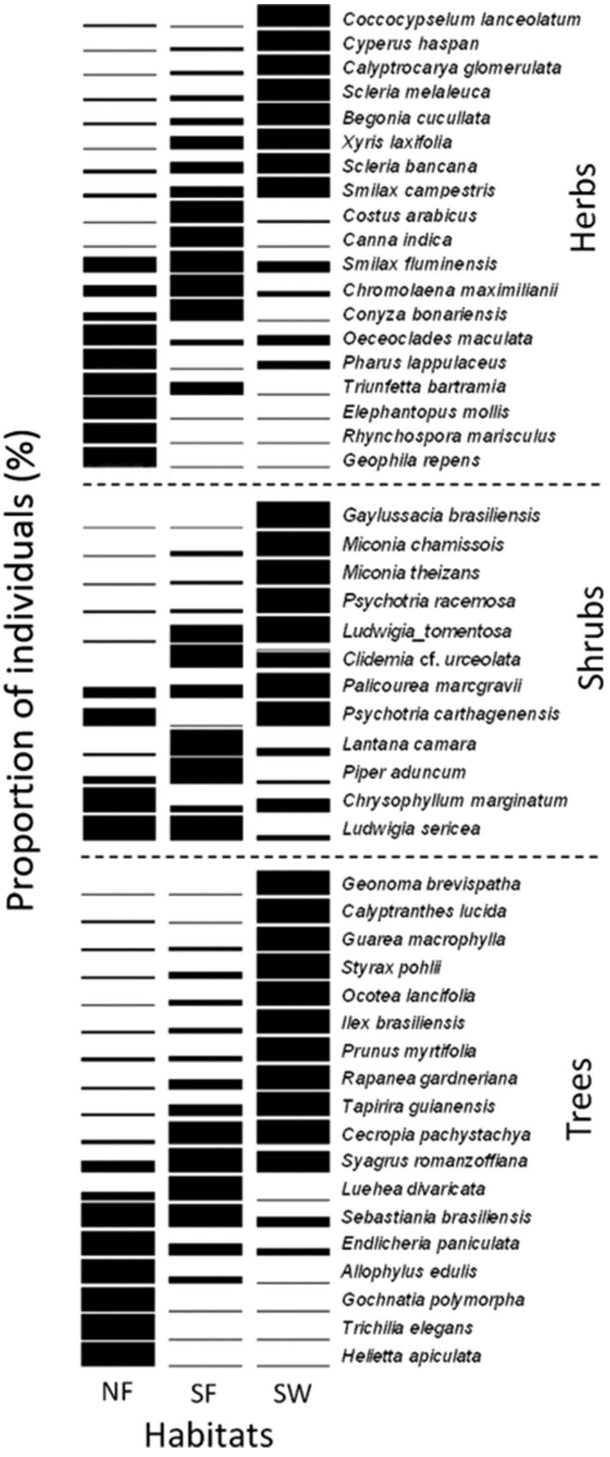

Figure 3. Commonest herbaceous, shrub and tree species (≥ 10 individuals) ordinated according to non-flooded (NF), seasonally flooded (SF) and swampy (SW) habitats along Touro and Tarumã riparian forests, Mato Grosso do Sul. Black bars indicate the proportion (%) of reproductive individuals per habitat for each species, estimated for areas of equal sizes among habitats.
Figura 3. Espécies herbáceas, arbustivas e arbóreas mais comuns (> 10 indivíduos) ordenadas conforme os tipos de habitats, não inundável (NF), sazonalmente inundável (SF) e permanentemente inundado (SW), ao longo da floresta ripária do Touro e Tarumã, Mato Grosso do Sul. Barras pretas indicam a proporção (%) de indivíduos reprodutivos por habitat para cada espécie, estimada para áreas de tamanhos iguais entre os habitats.

Discussion

The flora we inventoried seems to be markedly similar to other Atlantic Forest floras elsewhere, as all recorded species indeed occur throughout this domain (sensu Ab'Saber 2000), including two regarded as endemic, *Capanemia micromera* (Orchidaceae) and *Passiflora jilekii* (Passifloraceae) (Cervi 1997, Stehmann et al. 2009, Buzatto & Machado 2011). The richest families in our study site (Asteraceae, Fabaceae, Myrtaceae, Cyperaceae, Malvaceae, Orchidaceae, Rubiaceae and Solanaceae) also show high number of species in other Atlantic Forest sites (Romagnolo & Souza 2000, Rodrigues & Nave 2004, Stehmann et al. 2009). Furthermore, the local high representativeness of Orchidaceae and low richness of some families, such as Moraceae, differ from the expected for riparian forests in the state's Cerrado domain (Pott et al. 2006, Lehn et al. 2008, Baptista-Maria et al. 2009). Therefore, flora of Touro and Tarumã riparian forests add support to sustain the southeastern Mato Grosso do Sul as an inland region of the Atlantic Forest domain, as formerly suggested by Rizzini (1979).

We found several species that have not been reported in the Mato Grosso do Sul regions of Cerrado or Pantanal, which reinforces the influence of the Atlantic Forest domain on our study site. The orchid *Campylocentrum grisebachii* is known to occur in the Atlantic Forest and Amazon, and our record increases its known distribution (Johnson 2001, Barros et al. 2010) towards the center of South America. In addition, the distribution of *Capanemia micromera* is known along Atlantic Forest in Brazil, and in Paraguay, Uruguay and Argentina (Johnson 2001, Barros et al. 2010, Buzatto & Singer 2010, Buzatto et al. 2011), thus our record enlarges its distribution to 290 km northward and 150 km eastward. Our record of *Microlaelia lundii* (Orchidaceae), distributed in the Atlantic Forest and Cerrado domains (Barros et al. 2010), increases the species' distribution to 290 km north, 650 km south (Dubs 1998), and 300 km westward (Barros et al. 2010). Other orchid species recorded here for the first time in Mato Grosso do Sul have been found 100 and 300 km apart, respectively *Rodriguezia decora* in Atlantic Forest and Cerrado (Johnson 2001, Souza et al, 2009, Barros et al. 2010) and *Sauroglossum nitidum* in Atlantic Forest, Cerrado and Caatinga (Barros et al. 2010). The occurrence of *Passiflora jilekii* in the Touro and Tarumã riparian forests increases its distribution 1100 km westward (Forzza et al. 2010, Cervi et al. 2010). For *Persea willdenovii* (Lauraceae), our record is 600 km northwestern from its previous known distribution (Quinet et al. 2010, Forzza et al. 2010). Additional species recorded for the first time in Mato Grosso do Sul – *Merremia macrocalyx* (Convolvulaceae), *Apteria aphylla* (Burmanniaceae) and *Qualea cordata* (Vochysiaceae) – might be expected since they are widely distributed throughout different domains (Dubs 1998, Bianchini & Ferreira 2010, Forzza et al. 2010, França 2010, Maas & Maas 2010). *Ilex brasiliensis* (Aquifoliaceae), *Gaylussacia brasiliensis* (Ericaceae), *Daphnopsis racemosa* (Thymelaeaceae), *Condylocarpon isthmicum* (Apocynaceae) and *Citronella gongonha* (Cardiopteridaceae) were previously recorded in mid-east regions of Cerrado in Mato Grosso do Sul only (Pott et al. 2006).

In general, the studied flora is highly composed of herbs and contains few tree species, compared to other riparian forests in the Atlantic Forest domain or even elsewhere in Brazil (Oliveira-Filho & Ratter 1995, Metzger et al. 1997, Oliveira-Filho & Fontes 2000, Felfili et al. 2001, Souza et al. 2009). The extension of wetter soils – swampy and seasonally flooded – could partially explain such differences, as they are highly occupied by herbs at the study site. Tree richness is otherwise expected to be favored in non-flooded habitats, where we recorded several species with low abundances. On the other hand, the most abundant species within any habit are the flood-tolerant ones, which occur in the habitats with reduced number of species. This pattern agrees with the expectation that non-flooded sites allow occurrence of most plant species, whose abundances are mainly regulated by interspecific competition, whereas environmental filter determines plant species under flood conditions (Ivanauskas et al. 1997, Fischer & Santos 2001, Marques et al. 2003, Lobo & Joly 2004).

Richness of epiphytes in Touro and Tarumã forests is lower than that in other Atlantic Forest regions with less seasonality and higher annual rainfall than in our study site (1600 mm), as indeed expected since humidity has been regarded as a main factor affecting epiphytic growth (Fischer & Araujo 1995, Rogalski & Zanin 2003, Bataghin et al. 2012; Forzza et al. 2014). Likewise, epiphytes were richer and more abundant in swampy than in non-flooded habitat at the study site probably due to higher humidity in the former. However, additional factors are likely contributing to low richness of epiphytes at the study site, since other Atlantic Forest sites with similar annual rainfall can present remarkably more epiphytic species (Forzza et al. 2014). The narrow forest remnants along Touro and Tarumã streams are enclosed in pasture and cultivated landscapes, thus different sources of disturbance can contribute to the low richness of epiphytes at the study site (Wolf 1994, Pinto et al. 1995, Barthlot et al. 2001, Rogalski & Zanin 2003).

Overall, flora of Touro and Tarumã riparian forests contains several components expected for the Atlantic Forest, although it predominantly included species widespread in different domains. The local flood gradient may favor plant richness. A certain level of disturbance is indeed apparent at the study site due to the relatively high abundance of herbs, the lack of epiphytes in some suitable sites, the conspicuous presence of weedy pioneers, and the occurrence of exotic invaders. The new occurrences for Mato Grosso do Sul and the new limits of distribution for plant species surveyed here highlight the importance of conservation of the remaining forests in the westernmost Atlantic Forest.

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References

AB'SABER, A.N. 2000. The natural organization of Brazilian inter- and subtropical landscapes. Revista do Instituto Geológico 21: 57-70.

APG III. 2009. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. Bot. J. Linn. Soc. 161:105-121, http://dx.doi.org/10.1111/(ISSN)1095-8339

ARRUDA, L. & DANIEL, O. 2007. Florística e diversidade em um fragmento de floresta estacional semidecidual aluvial em Dourados-MS. Floresta 37(2):189-199.

BAPTISTA-MARIA, V.R., RODRIGUES, R.R., DAMASCENO-JUNIOR, G.A., SOUZA MARIA, F. & SOUZA, V.C. 2009. Composição florística de florestas estacionais ribeirinhas no estado de Mato Grosso do Sul, Brasil. Acta Bot. Bras. 23:535-548, http://dx.doi.org/10.1590/S0102-33062009000200025

BARTHLOT, W., SCHMIT-NEUERBURG, V., NIEDER, J. & ENGWALD, S. 2001. Diversity and abundance of vascular epiphytes: a composition of secondary vegetation and primary montane rain forest in the Venezuelan Andes. Plant Ecol. 152:145-156, http://dx.doi.org/10.1023/A:1011483901452

BARROS, F.D.E., VINHOS, F., RODRIGUES, V.T., BARBERENA, F.F.V.A. & FRAGA, C.N. 2010. Orchidaceae In Lista de espécies da flora do Brasil. Jardim Botânico do Rio de Janeiro. (http://floradobrasil.jbrj.gov.br/2010/FB011274).

BATAGHIN, F.A., MULLER, A., PIRES, J.S.R., BARROS, F., FUSHITA, A.T. & SCARIOT, E.C. 2012. Riqueza e estratificação vertical de epífitas vasculares na Estação Ecológica de Jataí - área de Cerrado no sudeste do Brasil. Hoehnea 39(4):615-626.

BIANCHINI, R.S. & FERREIRA, P.P.A.2010. Convolvulaceae In Lista de espécies da flora do Brasil. Jardim Botânico do Rio de Janeiro. (http://floradobrasil.jbrj.gov.br/2010/FB007100).

BUZATTO, C R. & SINGER, R B. 2010. O gênero *Capanemia* Barb. Rodr. (Oncidiinae: Orchidaceae). Rev. Bras. Biociênc. 8:309-323.

BUZATTO, C R. & MACHADO, M C. 2011. *Capanemia* Barb. Rodr. (Orchidaceae: Oncidiinae), a new record from Bahia state, Brazil. Acta Bot. Bras. 25:249-251.

BUZATTO, C R., SINGER, R B. & ROMERO-GONZALEZ, G A. 2011. Typifications and new synonymies in *Capanemia* (Orchidaceae, Oncidiinae). Novon 21:28-33.

CERVI, A.C. 1997. Passifloraceae do Brasil: estudo do gênero *Passiflora* L. subgênero *Passiflora.* Fontqueria 45:1-92.

CERVI, A.C., MILWARD-DE-AZEVEDO, M.A. & BERNACCI, L. C. 2010. Passifloraceae In Lista de espécies da flora do Brasil. Jardim Botânico do Rio de Janeiro. (http://floradobrasil.jbrj.gov.br/2010/FB012537).

DAMASCENO-JUNIOR, G.A., POTT, A., POTT, V.J. & SILVA, J. S.V. 2009. Florestas estacionais no Pantanal, considerações florísticas e subsídios para conservação. Geografia 34: 697-707.

DUBS, B. 1998. Prodromus florae matogrossensis. Küssnacht, Betrona Verlag.

FELFILI, J.M., MENDONÇA, R.C., WALTER, B.M.T., SILVA JUNIOR, M.C., NÓBREGA, M.G.G., FAGG, C.W., SEVILHA, A.C. & SILVA, M.A. 2001. Flora fanerogâmica das matas de galeria e ciliares do Brasil Central. In Cerrado caracterização e recuperação de matas de galeria (J. F. Ribeiro, C. E. L. da Fonseca & J. C. Sousa-Silva, eds.). Embrapa Cerrados, Planaltina, DF, Brasil. p.195-263.

FISCHER, E.A. & ARAUJO, A.C. 1995. Spatial organization of a bromeliad community in the Atlantic rainforest, south-eastern Brazil. J. Trop. Ecol. 11: 559-567, http://dx.doi.org/10.1017/S0266467400009123

FISCHER, E. & SANTOS, F.A.M. 2001. Demography, phenology and sex of Calophyllum brasiliense (Clusiaceae) trees in the Atlantic Forest. J. Trop. Ecol. 17: 903-909, http://dx.doi.org/10.1017/S0266467401001675

FORZZA, R.C., LEITMAN, P.M., COSTA, A.F., CARVALHO JR., A.A, PEIXOTO, A.L, WALTER, B.M.T, BICUDO, C, ZAPPI, D, COSTA, D.P, LLERAS, E, MARTINELLI, G, LIMA, H.C, PRADO, J, STEHMANN, J.R, BAUMGRATZ, J.F.A, PIRANI, J.R, SYLVESTRE, L, MAIA, L.C, LOHMANN, L.G, QUEIROZ, L.P, SILVEIRA, M, COELHO, M.N, MAMEDE, M.C, BASTOS, M.N.C, MORIM, M.P, BARBOSA, M.R, MENEZES, M, HOPKINS, M, SECCO, R, CAVALCANTI, T.B & SOUZA, V.C. 2010. Catálogo de plantas e fungos do Brasil. Andréa Jakobsson Estúdio, Jardim Botânico do Rio de Janeiro, Rio de Janeiro, v.2.

FORZZA, R.C., PIFANO, D.S., OLIVEIRA-FILHO, A.T., MEIRELES, L.D., FARIA, P.L., SALIMENA, F.R., MYNSSEN, C.M. & PRADO, J. 2014. Flora vascular da Reserva Biológica da Represa do Grama, Minas Gerais, e sua relação florística com outras florestas do sudeste brasileiro. Rodriguésia 65: 275-292.

FRANÇA, F. 2010. Vochysiaceae In Lista de espécies da flora do Brasil. Jardim Botânico do Rio de Janeiro. (http://floradobrasil.jbrj.gov.br/2010/FB015282).

GUEDES-BRUNI, R.R., MORIM, M.P.M., LIMA, H.C. & SYLVESTRE, L.S., 2002. Inventário florístico. In Manual metodológico para estudos botânicos na Mata Atlântica (L.S., Sylvestre & M.M.T., Rosa, eds.). Rio de Janeiro. p.24-49.

HAMMER, Ø., HARPER, D.A.T. & RYAN, P.D. 2001. PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1): 9pp. http://palaeo-electronica.org/2001_1/past/issue1_01.htm

IBGE. 1984. Naviraí - Centro-Oeste - Mato Grosso do Sul. Coleção de monografias municipais. N. 101, Rio de Janeiro-RJ.

IVANAUSKAS, N.M., RODRIGUES, R.R. & NAVE, A G. 1997. Aspectos ecológicos de um trecho de floresta de brejo em Itatinga, SP: florística, fitossociologia e seletividade de espécies. Rev. Bras. Bot. 20:139-153, http://dx.doi.org/10.1590/S0100-84041997000200005

JOHNSON, A.E. 2001. Las Orquídeas del Parque Nacional Iguazú. LOLA, Buenos Aires, Argentina.

LEHN, C.R., ALVES, F.M. & DAMASCENO-JUNIOR, G.A. 2008. Fitossociologia de um cerrado sensu-stricto na região da borda oeste do Pantanal, Corumbá, MS. Pesquisa Botânica 59: 129-142.

LOBO, P.C. & JOLY, C.A. 2004. Aspectos ecofisiológicos da vegetação de mata ciliar de mata ciliar do sudeste do Brasil. In Matas ciliares: conservação e recuperação (R. R. Rodrigues & H. F. Leitão-Filho,eds.). São Paulo. Edusp/Fapesp, p.143-157.

MAAS, P. & MAAS, H. 2010. Burmanniaceae In Lista de espécies da flora do Brasil. Jardim Botânico do Rio de Janeiro. (http://floradobrasil.jbrj.gov.br/2010/FB110590).

MARQUES, M.C.M., SILVA, S.M. & SALINO, A. 2003. Florística e estrutura do componente arbustivo-arbóreo de uma floresta higrófila da bacia do rio Jacaré-Pepira, SP, Brasil. Acta Bot. Bras. 17:495-506, http://dx.doi.org/10.1590/S0102-33062003000400002

METZGER, J.P., BERNACCI, L.C. & GOLDENBERG, R. 1997. Pattern of tree species diversity in riparian forest fragments with different widths (SE Brazil). Plant Ecol. 133:135-152, http://dx.doi.org/10.1023/A:1009791831294

NOGUCHI, D.K., PETINE, G.N. & SARTORI, A.L.B. 2009. Florística e síndromes de dispersão de espécies arbóreas em remanescentes de Chaco de Porto Murtinho, Mato Grosso do Sul. Rodriguésia 60:353-365.

OLIVEIRA-FILHO, A.T. & RATTER, J.A. 1995. A study of the origin of central Brazilian forests by the analysis of plant species distribution patterns. Edinburgh J. Bot. 52:141-194, http://dx.doi.org/10.1017/S0960428600000949

OLIVEIRA-FILHO, A.T. & FONTES, M.A.L. 2000. Patterns of floristic differentiation among Atlantic forests in southeastern Brazil and the influence of climate. Biotropica 32:793-810.

PINTO, A.C.R., DEMATTÊ, M.E.S.P. & PAVANI, M.C.M.D. 1995. Composição florística de epífitas (Magnoliophyta) em fragmento de floresta no município de Jaboticabal, SP, Brasil. Científica 23: 283-289.

POTT, A. & POTT, V.J. 1994. Plantas do Pantanal. Embrapa, Brasília.

POTT, V.J. & POTT, A. 2000. Plantas aquáticas do Pantanal. Embrapa, Brasília.

POTT, A. & POTT, V.J. 2003. Espécies de fragmentos florestais em Mato Grosso do Sul. In Fragmentação florestal e alternativas de desenvolvimento rural na região Centro-Oeste (Costa, R. B., ed.). UCDB. Campo Grande, p.26-52.

POTT, A., POTT, V.J., SCIAMARELLI, A., SARTORI Â.L.B., SCREMIN-DIAS, E., JACQUES, E. de L., ARAGAKI, S., NAKAJIMA, J.N., ROMERO R., CRISTALDO, A.C. de M. & DAMASCENO-JUNIOR, G.A. 2006. Flora - Inventário das Angiospermas no Complexo Aporé-Sucuriu In Biodiversidade do Complexo Aporé-Sucuriu – Subsídios à conservação e manejo do cerrado – Área prioritária 316 (Pagotto, T. C. S. & Souza, P. R. de, eds.).UFMS, Campo Grande, p. 45-66.

QUINET, A., BAITELLO, J.B. & MORAES, P.L.R DE 2010. Lauraceae In Lista de espécies da flora do Brasil. Jardim Botânico do Rio de Janeiro. (http://floradobrasil.jbrj.gov.br/2010/FB008523).

R DEVELOPMENT CORE TEAM 2010. R: A language and environment for statistical computing. Vienna: R Foundation for Statistical Computing (http://www.R-project.org).

RIZZINI, C T. 1979. Tratado de fitogeografia do Brasil. v.2. Aspectos ecológicos. Hucitec-Edusp, São Paulo.

RODRIGUES, R.R., NAVE A.G., 2004. Heterogeneidade florística das matas ciliares In Matas ciliares: conservação e recuperação (R. R. Rodrigues & H. F. Leitão-Filho, eds.). São Paulo. Edusp/Fapesp, p.45-71.

RODRIGUES, R.R. & SHEPHERD, G.J. 2004. Fatores condicionantes da vegetação ciliar In Matas ciliares: conservação e recuperação (R. R. Rodrigues & H. F. Leitão-Filho, eds.). São Paulo. Edusp/Fapesp, p.101-107.

ROGALSKI, J.M. & ZANIN, E.M. 2003. Composição florística de epífitos vasculares no estreito de Augusto César, floresta estacional decidual do alto Uruguai, RS, Brasil. Rev. Bras. Bot. 26:551-556, http://dx.doi.org/10.1590/S0100-84042003000400014

ROMAGNOLO, M.B. & SOUZA, M.C. 2000. Analise florística e estrutural de florestas ripárias do alto rio Paraná, Taquaruçu, MS. Acta Bot. Bras. 14:163-174.

SALIS, S.M., SILVA, M.P., MATTOS, P.P., SILVA, J.S.V., POTT, V. J. & POTT, A. 2004. Fitossociologia de remanescentes de floresta estacional decidual em Corumbá, estado de Mato Grosso do Sul, Brasil. Rev. Bras. Bot. 27: 671-684, http://dx.doi.org/10.1590/S0100-84042004000400008

SOUZA, M.C., KAWAKITA, K., SLUSARSKI, S.R. & PEREIRA, G.F. 2009. Vascular flora of the Upper Paraná River floodplain. Braz. J. Biol. 69: 735-745, http://dx.doi.org/10.1590/S1519-69842009000300027

STEHMANN, J.R., FORZZA, R.C., SALINO, A., SOBRAL, M., COSTA, D.P. & KAMINO, L.H.Y. 2009. Plantas da Floresta Atlântica. Jardim Botânico do Rio de Janeiro, Rio de Janeiro.

VELOSO, H.P., RANGEL FILHO, A.L. & LIMA, J.C.A. 1991. Classificação da vegetação brasileira, adaptada a um sistema universal. IBGE, Rio de Janeiro.

WOLF, J.H.D. 1994. Factors controlling the distribution of vascular and nonvascular epiphytes in the northern Andes. Vegetatio 112:15-28.

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Foraging, oviposition sites and notes on the natural history of the harvestman *Heteromitobates discolor* (Opiliones, Gonyleptidae)

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Abstract: The lack of data on the natural history often hampers phylogenetic studies on the evolution of behavior. Herein we provide quantitative field data on foraging and oviposition sites of a Neotropical harvestman belonging to a subfamily with a published phylogeny, Goniosomatinae. *Heteromitobates discolor* rests during the day on granitic boulders on rivers, laying eggs in sheltered and darker areas. The female guard the eggs and aggressively respond to approaching conspecific females. In the absence of the female, ants, conspecifics and reduviids may predate the eggs. Egg-guarding females are known not to leave the clutch, but males and non-guarding females may leave the granitic boulders and forage on the vegetation at night, close to the river margins and with no difference in the sites explored between males and females. The general features described in *H. discolor* are similar to what has been reported for other species in this subfamily, suggesting an evolutionary conservatism within the group.

Keywords: *Parental care, maternal care, microhabitat choice, substrate choice, Laniatores, Goniosomatinae.*

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Resumo: A falta de dados de história natural por vezes dificulta estudos filogenéticos sobre a evolução do comportamento. Nesse estudo nós fornecemos dados quantitativos de campo sobre forrageamento e sítios de oviposição de um opilião Neotropical pertencente a uma subfamília com uma filogenia publicada, Goniosomatinae. *Heteromitobates discolor* passa o dia em rochedos graníticos em rios, onde deposita os ovos em áreas abrigadas e escuras. A fêmea cuida dos ovos e responde agressivamente a fêmeas co-específicas que se aproximam. Na ausência de fêmeas, formigas, co-específicos e percevejos reduvídeos podem predar os ovos. Fêmeas que guardam ovos não deixam as desovas, mas machos e fêmeas sem ovos deixam os rochedos graníticos e forrageiam sobre a vegetação à noite, próximos à margem do rio e sem diferença nos sítios explorados entre os machos e as fêmeas. As características gerais descritas em *H. discolor* são similares ao que tem sido reportado para outras espécies nesta subfamília, sugerindo um conservadorismo evolutivo dentro do grupo.

Palavras-chave: *Cuidado parental, cuidado maternal, escolha de micro-habitat, escolha de substrato, Laniatores, Goniosomatinae.*

Introduction

Harvestmen are often nocturnal animals that shelter during the day under rocks or tree trunks, on leaf litter, on trees, shrubs and in caves. Their foraging site is often different, and distinct species may descend from the vegetation to forage on leaf litter, or leave caves or the underside of rocks to forage on the vegetation. The different types of substrates used when foraging have recently been used as characters for phylogenies, but data are scarce due to the low number of studies (Curtis & Machado 2007; Caetano & Machado 2013). Harvestmen feed on a number of items, including small invertebrates, dead animals, plant material and even fungi (Acosta & Machado 2007).

The oviposition site may also be slightly different from the foraging and resting areas because most harvestmen species search for humid and protected sites to lay eggs (Curtis & Machado 2007; Machado & Macías-Ordóñez 2007). In the subfamily Goniosomatinae (Laniatores, Gonyleptidae), females of all the species studied take care of the eggs and of first instar immature (Machado 2002; Machado & Macías-Ordóñez 2007), and males of at least some species patrol the females with which they have copulated. Males may also take care of the eggs if females are experimentally removed from the batch (Machado & Oliveira 1998; Buzatto & Machado 2009).

Although Goniosomatinae is the laniatorid group of species with most published behavioral studies, only four of the 36 species

(DaSilva & Gnaspini 2009) have been studied behaviorally in detail (e.g. *Serracutisoma spelaeum* (Mello-Leitão 1933); *Heteromitobates albiscriptus* (Mello-Leitão 1932); *Acutisoma longipes* (Roewer 1913); *Serracutisoma proximum* (Mello-Leitão 1922) - Gnaspini 1996; Machado & Oliveira 1998; Willemart & Gnaspini 2004a; Buzatto et al. 2011). Because there is a published phylogeny of the subfamily (DaSilva & Gnaspini 2009), this group is excellent to study the evolution of behavior when using data from several papers. However studies on the natural history of more species are necessary because we often generalize data obtained for a few species for the entire subfamily, which is not necessarily accurate.

Herein we provide field data about foraging and oviposition sites of the Neotropical harvestman *Heteromitobates discolor* Soerensen 1884 (Gonyleptidae, Goniosomatinae), asking what are the exact sites that this species use for both these activities.

Material and Methods

We conducted this study in an Atlantic rainforest in the city of Ubatuba (723,883 Km^2), State of São Paulo, Southeast of Brazil. We used four rivers: Marimbondo (Km 75), and Cachoeira da Bacia (Km 69), both close to Rodovia SP-55; Camburi (Km 1) and Corisco (Km 11), both close to Rodovia SP-101, the latter two belonging to the Parque Estadual Serra do Mar. Data on foraging were collected in April 2014, which is the end of the warm and rainy season, in three different populations by the rivers Marimbondo, Camburi and Corisco. We used two transects per river, both parallel to the river, 25 m long, 4 m wide and 4 m high, one in the right margin and the other in the left margin of each river (Fig. 1). Because the animals are large (~10-15 cm leg spam), they could easily be seen up to four meters high. The rivers typically have an area with no trees at their margins (~1.5 m from the river margin towards the forest). Beginning from where the vegetation starts, we counted 2 m perpendicularly away from the river throughout the 25 m of the transect, and this was called Zone 1. Zone 2 was parallel to Zone 1 but from 2 m to 4 m away the region where vegetation starts (Fig. 1). Two researchers monitored each 1 m^2 of the transect for two minutes in each of the zones. Because studies with other Gonosomatinae species are known to forage on vegetation (e.g. Santos & Gnaspini 2002), we did not search for animals on boulders on the river. Because this species was known to be nocturnal based on preliminary observations by the authors, we have collected data from 21h to 3h AM during one night. For every animal found, we measured the distance in a straight line of the animal to the forest floor and the distance in a straight line to the river margin. We also took note of the type of substrate (rocks or vegetation) and the posture of each individual.

For oviposition sites, we studied three populations by the margins of the rivers Marimbondo, Cachoeira da Bacia and Camburi. We defined a 100 m transect by the margins of each river. We looked for females and their egg batches in open and exposed areas of large boulders on rivers (Figs. 2A, B). The rivers width varied between 3 m to 15 m. For every animal found, we measured the distance of the animal to the river and the distance of the female to the margin of the egg batch. We also measured the distance of nearby females and of males within 1 m to the focal egg batch. Males in this subfamily typically have distinguishable two morphs, which we will call major (larger) and minor (smaller) males (Buzatto & Machado 2014). These were considered separately for data related to reproduction (oviposition sites) but not for foraging, since, for other species in the subfamily, there is evidence for distinct behaviors in the former (Buzatto et al. 2011, 2014) but not in the latter context. We classified the clutches to be either on exposed (walls directly exposed to sunlight) or non-exposed rocks (see Chelini et al. 2012). Clutches found on rocks were separated in either naked rock or rock with vegetation. A luximeter application for Android was used to classify the luminance in one of these seven categories: 5, 22, 75, 220, 800, 2800 and 6000 lux, with the probe 2 cm over from the eggs and always between 11AM-13h. We also registered the presence of fungi infecting eggs. We made all these observations on oviposition sites in May 2013, which is the transition to the cold and drier season. We took pictures of the egg-batches to count the number of eggs. These pictures were taken from March to June 2013 and from January to April 2014. We made the opportunistic observations described herein between March and July 2013 and in March 2014.

Results

1. Foraging

We found 24 males and 17 females foraging in Zone 1 (0-2 m), five males and two females foraging in Zone 2 (2-4 m). Pooling

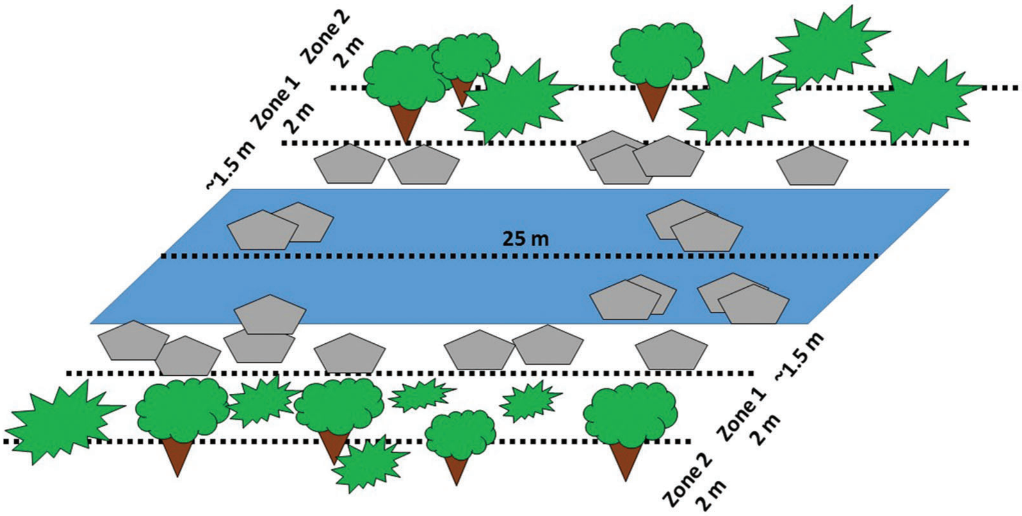

Figure 1. The transect used for studying foraging in the harvestman *Heteromitobates discolor* (not to scale), showing the river (blue), boulders (grey) and the vegetation (green). See text for further explanation.

data from the two Zones, males were 123 cm (mean; SD = 82.62; min = 20; max = 310 cm; n = 29) and females 80 cm (mean; SD = 81.83; min = 45; max = 300 cm; n = 19) from the floor. Males were 255 cm (mean; SD = 147.83; min = 100; max = 610 cm; n = 29) from the river water and females were 300 cm (mean; SD = 69.0; min = 100; max = 350 cm; n = 19). Males and females did not differ in the distance to the river or to the forest floor, both considering the two zones separately or with data from the two zones pooled (data pooled, distance to river: Mann-Whitney test, U = 479.5; n = 19 females, 29 males; p = 0.779; data pooled, distance to floor: U = 421; n = 19 females, 29 males; p = 0.354).

In Zone 1, nine of the 24 males were on rocks and 15 on vegetation, the latter including leaves, bromeliads, plant stems and tree trunks. Among females, four were on rocks and 13 on vegetation. In Zone 2, two males were on rocks and three on vegetation, one female on rock and one on vegetation. Pooling the results from both Zones, we found no differences in the substrate use between the sexes (Fisher exact test: p = 0.306; n = 19 females and 29 males).

Out of the 48 animals observed foraging, 30 had their body parallel to the forest floor. Of these 30, 23 had the ventral region facing the canopy and seven had the ventral region facing the floor. Eighteen animals had their body perpendicular to the forest floor, with 14 individuals facing the floor and four facing the canopy. Legs II were extended sideways with no contact with the substrate in 47 of the 48 animals.

2. *Oviposition sites*

Females of *H. discolor* oviposit mainly on substrates above the river (Fig. 2A and B), with 98 clutches found on granitic boulders and seven on a human made bridge. Among the boulders chosen for oviposition, 78 had moss, roots or small plants less than 3 cm from the eggs and 20 had no vegetation. Eighty five clutches were in non-exposed areas and 20 were in exposed areas. As for luminance, 46 clutches had values closer to 5 lux, 27 closer to 22 lux, 19 to 75 lux and 13 to 220 lux (n = 105). The clutches were 132.32 ± 110.38 cm (mean ± SD; n = 105) far from the water. In some cases the clutches were close enough that water would regularly spill on the eggs. All the 200 females were in resting posture (Fig. 3: body close to the substrate and legs flexed close to the body). Groups of clutches were often found: 80 clutches were less than a meter close to another clutch. We found 27 major and 20 minor males less than 1 m to a clutch (n = 47; only males that were less than a meter from the batches were counted). The mean number of eggs was 99 (SD = 33; min = 4; Max = 150; n = 105). Twelve out of 210 clutches observed were infected with fungi, with a mean of 7.3% of the eggs infected (SD = 9.1; min = 7.5; max = 26.4%; n = 8, the remaining four could not be counted).

3. *Opportunistic observations*

We observed *H. discolor* females (n = 5), ants (one observation, 13 ants: Myrmicinae, possibly *Crematogaster* sp.) and a reduviid heteropteran (n = 1, *Zelurus* sp., probably *Z. travassosi*, Fig. 4) feeding on unprotected eggs. We observed five egg-guarding females behaving aggressively towards conspecific females and two egg-guarding females mating with major males. We observed two males face-to-face fighting each other and after some seconds both fell in the river. A male was observed eating a cockroach and it is unknown if it was captured alive.

Discussion

Males and females were found foraging at similar distances from the river and the forest floor, which is consistent with the idea that they feed on similar food items. Both sexes were found more often in Zone 1, which may be related to the higher humidity in this area that is closer to the river (Machado et al. 2000; Santos 2007). Because the individuals rest on boulders that lay on rivers during the day, the fact that they were found more often in Zone 1 may also due to the fact that the individuals do not move a lot from their resting to foraging places.

No individual was seen foraging on leaf litter, unlike several harvestmen (Curtis & Machado 2007) but similar to other species in the subfamily Goniosomatinae (Machado et al. 2000; Willemart & Gnaspini 2004b; Caetano & Machado 2013), which may climb higher than 20 m to forage (Santos & Gnaspini 2002). The foraging site – vegetation, is clearly different from the resting and ovipositing sites - granitic

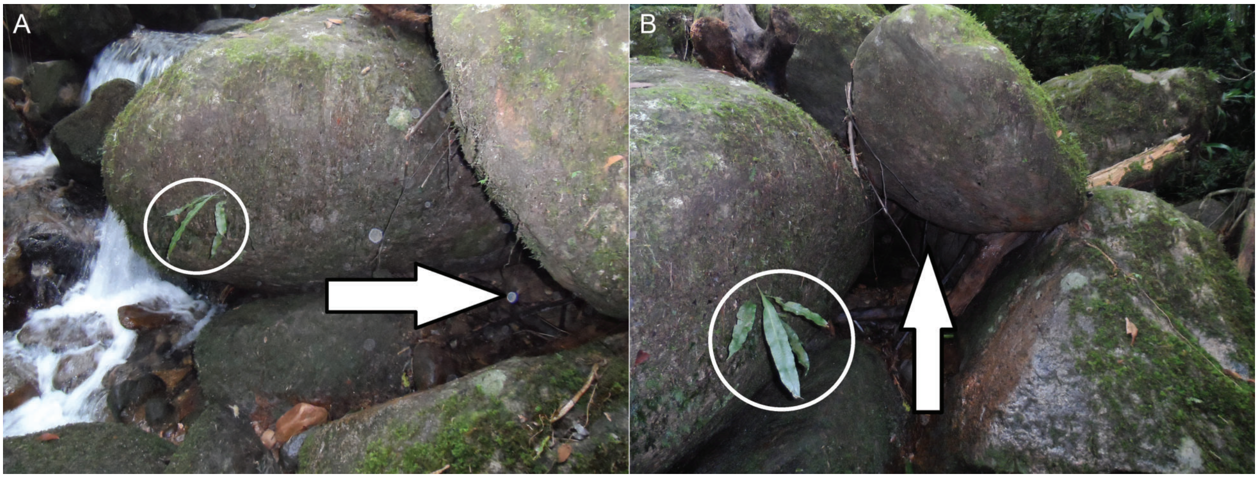

Figure 2 A and B. A typical shelter where the harvestman Heteromitobates discolor is found during the day. The same area is shown from different angles, with arrows showing the approximate region of an oviposition site. The circle indicates the same landmark in the two pictures.

Figure 3. A female *Heteromitobates discolor* (body size ~7 mm) guarding eggs.

boulders. The latter are probably more humid because they are by the river and also probably less visited by predators than the vegetation. Although larger trechaleid spiders are also found on such boulders, harvestmen might be chemically and mechanically protected from their attacks (Machado et al. 2005; Souza & Willemart 2011; Dias & Willemart 2013; Segovia et al. 2015a, b). It is still not clear why some harvestmen forage on the vegetation and others on the floor. Although there seem to be a relation between leg length and resting area (leaf litter vs vegetation), with long-legged species being found on the vegetation and short-legged ones on the floor, leg length per se may not be an explanation for the foraging sites since several long-legged species in the suborder Eupnoi forage on the floor (Curtis & Machado 2007; Donaldson & Grether 2007).

All the individuals found at night were in a typical active posture in the subfamily Goniosomatinae, with the body away from the substrate and legs II extended sideways (Machado et al. 2000; Santos & Gnaspini 2002; Willemart & Gnaspini 2004b). Extending the legs probably increases the chances of detecting food mechanically by contact or chemically (Willemart et al. 2009; Willemart & Chelini 2007; Costa & Willemart 2013).

Egg batches were laid mainly in non-exposed and dark areas, contrasting with *Heteromitobates albiscriptus* (Gonyleptidae) (Willemart & Gnaspini 2004a) that often lay eggs in exposed areas but similarly to two other species in other genera within Goniosomatinae (Gnaspini 1995; Machado & Oliveira 1998), where eggs are laid by rivers or other sources of humidity. The number of eggs was similar to other species in Goniosomatinae (see Machado 2002). Almost 80% of the clutches on boulders were within or less than 3 cm close to wet vegetation, which could be either to camouflage, to provide humidity for the eggs or even water for the females during the long period of egg guarding. Females may stay for more than a month and sometimes up to two months without leaving the clutch in closely related species (Gnaspini 1995; Machado & Oliveira 1998; Willemart & Gnaspini 2004a; Buzatto et al. 2007).

Figure 4. A heteropteran, *Zelurus* sp. (probably *travassosi*), on an egg batch of *Heteromitobates discolor*. Egg diameter ~1.9 mm.

Active major males near egg guarding females during the day in this nocturnal species suggest male patrolling females as observed in other species of the subfamily (Machado & Oliveira 1998; Buzatto & Machado 2009). It is worth mentioning that only major males (no minor males) were observed within 10 cm of egg guarding females or mating with the egg guarding females. Females of Goniosomatinae do not remove fungi from the eggs and this represent a cost of laying eggs in such humid environments (Machado & Oliveira 1998).

The predators of eggs observed in this study are common predators of eggs in large laniatorids of the Atlantic forest (Gnaspini 1996; Machado & Oliveira 1998; Buzatto et al. 2007; Chelini & Machado 2012). We added two taxa to the list of egg-predators for *H. discolor* provided in Machado (2002), namely ants (Myrmicinae, probably *Crematogaster*) and the reduviid (*Zelurus* sp.). Just as has been observed in other Goniosomatinae (e.g. Willemart & Gnaspini, 2004b), females actively repel potential predators approaching their batches.

We have provided additional field data on a Goniosomatinae, complementing previous behavioral studies on closely related species. Our results matched what was considered to be typical of Goniosomatinae in Caetano & Machado (2013) considering foraging and oviposition sites and presence of maternal care. Nocturnal observations on the foraging behavior in harvestmen are particularly scarce in the literature, with few data on the foraging sites and foraging posture. There are 30-40 species described in the subfamily (DaSilva & Gnaspini 2009), of which 4 have been studied in details and 7 have been the target of some field observations (e.g. Gnaspini 1996; Machado 2002; Willemart & Gnaspini 2004a; Buzatto & Machado 2014). So far, following what we have discussed above, the behaviors reported here are similar to what is commonly observed in different genera of the subfamily, but more species should be studied to test this apparent high conservatism in Goniosomatinae.

References

ACOSTA, L.E. & MACHADO, G. 2007. Diet and foraging. In Harvestmen: The Biology of Opiliones. (R. Pinto-da-Rocha, G. Machado & G. Gibiret, eds.). Harvard University Press, Cambridge, Massachusetts, p.309-338.

BUZATTO, B.A. & MACHADO, G. 2009. Amphisexual care in *Acutisoma proximum* (Arachnida, Opiliones), a neotropical harvestman with exclusive maternal care. Insectes Soc. 56:106-108, http://dx.doi.org/10.1007/s00040-008-1044-z

BUZATTO, B.A., REQUENA, G.S., LOURENÇO, R.S., MUNGUÍA-STEYER, R. & MACHADO, G. 2011. Conditional male dimorphism and alternative reproductive tactics in a

Neotropical arachnid (Opiliones). Evol. Ecol. 25:331-349, http://dx.doi.org/10.1007/s10682-010-9431-0

BUZATTO, B.A., REQUENA, G.S., MARTINS, E.G. & MACHADO, G. 2007. Effects of maternal care on the lifetime reproductive success of females in a Neotropical harvestman. J. Anim. Ecol. 76:937–945, http://dx.doi.org/10.1111/jae.2007.76.issue-5

BUZATTO, B.A. & MACHADO, G. 2014. Male dimorphism and alternative reproductive tactics in harvestmen (Arachnida: Opiliones). Behav. Process. 109:2-13, http://dx.doi.org/10.1016/j.beproc.2014.06.008

BUZATTO, B.A., TOMKINS, J.L., SIMMONS, L.W. & MACHADO, G. 2014. Correlated evolution of sexual dimorphism and male dimorphism in a clade of Neotropical harvestmen. Evolution 68:1671-1686.

CAETANO, D.S. & MACHADO, G. 2013. The ecological tale of Gonyleptidae (Arachnida, Opiliones) evolution: phylogeny of a Neotropical lineage of armoured harvestmen using ecological, behavioural and chemical character. Cladistics 29:589-609.

CHELINI, M.C. & MACHADO, G. 2012. Costs and benefits of temporary brood desertion in a Neotropical harvestman (Arachnida: Opiliones). Behav. Ecol. Sociobiol. 66:1619–1627, http://dx.doi.org/10.1007/s00265-012-1417-1

COSTA, T.M. & WILLEMART, R.H. 2013. First experimental evidence that a harvestman (Arachnida: Opiliones) detects odors of non-rotten dead prey by olfaction. Zoologia 30:359-361.

CURTIS, D.J. & MACHADO, G. 2007. Ecology. In Harvestmen: The Biology of Opiliones. (R. Pinto-da-Rocha, G. Machado & G. Giribet, eds.). Harvard University Press, Cambridge, Massachusetts, p.280-308.

DASILVA, M.B. & GNASPINI, P. 2009. A systematic revision of Goniosomatinae (Arachnida: Opiliones: Gonyleptidae), with a cladistic analysis and biogeographical notes. Invertebr. Syst. 23:530-624, http://dx.doi.org/10.1071/IS09022

DIAS, B.C. & WILLEMART, R.H. 2013. The effectiveness of post-contact defenses in a prey with no pre-contact detection. Zoology 116:168–174.

DONALDSON, Z.R. & GRETHER, G.F. 2007. Tradition without social learning: scentmark-based communal roost formation in a Neotropical harvestman (*Prionostemma* sp.). Behav. Ecol. Sociobiol. 61:801-809, http://dx.doi.org/10.1007/s00265-006-0311-0

GNASPINI, P. 1995. Reproduction and postembryonic development of *Goniosoma spelaeum*, a cavernicolous harvestman from southeastern Brazil (Arachnida: Opiliones: Gonyleptidae). Invert. Reprod. & Dev. 28:137-151.

GNASPINI, P. 1996. Population ecology of *Goniosoma spelaeum*, a cavernicolous harvestman from south-eastern Brazil (Arachnida: Opiliones: Gonyleptidae). J. Zool. 239:417-435, http://dx.doi.org/10.1111/jzo.1996.239.issue-3

MACHADO, G. 2002. Maternal care, defensive behavior, and sociality in Neotropical Goniosoma harvestmen (Arachnida, Opiliones). Insectes Soc. 49:388–393, http://dx.doi.org/10.1007/PL00012663

MACHADO, G., CARRERA, P.C., POMINI, A.M. & MARSAIOLI, A.J. 2005. Chemical defense in harvestmen (Arachnida: Opiliones): do benzoquinones deter invertebrate and vertebrate predators? J. Chem. Ecol. 31:2519–2539, http://dx.doi.org/10.1007/s10886-005-7611-0

MACHADO, G. & MACÍAS-ORDÓÑEZ, R. 2007. Reproduction. In Harvestmen: The Biology of Opiliones. (R. Pinto-da-Rocha, G. Machado & G. Giribet, eds.). Harvard University Press, Cambridge, Massachusetts, p.414-454.

MACHADO, G. & OLIVEIRA, P.S. 1998. Reproductive biology of the neotropical harvestman (*Goniosoma longipes*) (Arachnida, Opiliones: Gonyleptidae): mating and oviposition behavior, brood mortality, and parental care. J. Zool. 246:359-367, http://dx.doi.org/10.1111/jzo.1998.246.issue-3

MACHADO, G., RAIMUNDO, R.L.G. & OLIVEIRA, P.S. 2000. Daily activity schedule, gregariousness, and defensive behaviour in the Neotropical harvestman Goniosoma Gonyleptidae). J. Nat. Hist. 34:587–596, http://dx.doi.org/10.1080/002229300299453

SANTOS, F.H. 2007. Ecology. In Harvestmen: The Biology of Opiliones. (R. Pinto-da-Rocha, G. Machado & G. Giribet, eds.). Harvard University Press, Cambridge, Massachusetts, p.473-488.

SANTOS, F.H. & GNASPINI, P. 2002. Notes on the foraging behavior of the Brazilian cave harvestman *Goniosoma spelaeum* (Opiliones, Gonyleptidae). J. Arachnol. 30:177-180, http://dx.doi.org/10.1636/0161-8202(2002)030[0177:NOTFBO]2.0.CO;2

SEGOVIA, J.M.G., DEL-CLARO, K. & WILLEMART, R.H. 2015. Defences of a Neotropical harvestman against different levels of threat by the recluse spider. Behaviour 152: 757-773.

SEGOVIA, J.M.G., DEL-CLARO, K. & WILLEMART, R.H. 2015. Delicate fangs, smart killing: the predation strategy of the recluse spider. Anim. Behav. 101:169-177, http://dx.doi.org/10.1016/j.anbehav.2014.12.025

SOUZA, E.D.S. & WILLEMART, R.H. 2011. Harvest-ironman: heavy armature, and not its defensive secretions, protects a harvestman against a spider. Anim. Behav. 81:127-133, http://dx.doi.org/10.1016/j.anbehav.2010.09.023

WILLEMART, R.H. & CHELINI, M.C. 2007. Experimental demonstration of close-range olfaction and contact chemoreception in the Brazilian harvestman *Iporangaia pustulosa*. Entomol. Exp. Appl. 123:73-79, http://dx.doi.org/10.1111/eea.2007.123.issue-1

WILLEMART, R.H., FARINE, J.P. & GNASPINI, P. 2009. Sensory biology of Phalangida harvestmen (Arachnida, Opiliones): a review, with new morphological data on 18 species. Acta Zool. 90:209-227, http://dx.doi.org/10.1111/azo.2009.90.issue-3

WILLEMART, R. H. & GNASPINI, P. 2004a. Breeding Biology of the cavernicolous harvestman *Goniosoma albiscriptum* (Arachnida, Opiliones, Laniatores): sites of oviposition, egg batches characteristics and subsocial behavior. Invert. Rep. Dev. 45:15-28, http://dx.doi.org/10.1080/07924259.2004.9652570

WILLEMART, R. H. & GNASPINI, P. 2004b. Spatial distribution, mobility, gregariousness, and defensive behavior in a Brazilian cave harvestman *Goniosoma albiscriptum* (Arachnida, Opiliones, Gonyleptidae). Anim. Biol. 54:221-235, http://dx.doi.org/10.1163/1570756042484674

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inventory

Mosquito (Diptera: Culicidae) fauna in parks in greater São Paulo, Brazil

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Abstract: Municipal parks in the city of São Paulo, which are used for leisure purposes, contain remnants of the flora of the Atlantic Forest, as well as lakes and springs, and are home to mammals, birds and arthropods, some of which can be vectors of disease. The eastern side of the city has the largest population in São Paulo and twenty-four municipal parks. The aim of this study was to investigate Culicidae fauna in two parks on this side of the city and to determine which of the Culicidae species identified have the potential to act as bioindicators and vectors of human pathogens. Culicidae were collected monthly between March 2011 and February 2012 in Carmo Park and Chico Mendes Park with battery-powered aspirators, Shannon traps and CDC traps for adult mosquitoes, and larval dippers and suction samplers for immature mosquitoes. To confirm sample sufficiency, the EstimateS program was used to plot sample-based species accumulation curves and estimate total richness by the Jackknife 1 method. In all, 1,092 culicids from nine genera (*Aedes, Anopheles, Coquillettidia, Culex, Limatus, Mansonia, Trichoprosopon, Toxorhynchites and Uranotaenia*) and nineteen taxonomic units were collected in Carmo Park. *Coquillettidia venezuelensis* (Theobald 1912), *Aedes scapularis* (Rondani 1848) and *Culex (Culex)* spp. Linnaeus 1758 were the most abundant adults, and *Culex (Melanoconion)* spp. Theobald 1903 and *Anopheles strodei* Root 1926 the most abundant immature mosquitoes. In Chico Mendes Park 4,487 mosquitoes in six genera and eighteen taxonomic units were collected. *Culex (Cux.)* spp. and *Ae. scapularis* were the most abundant adults, and *Ae. albopictus* (Skuse 1984) the most abundant immature mosquitoes. The species accumulation curves in both parks were close to the asymptote, and the total richness estimate was close to the observed richness. Some culicid taxons are bioindicators of environmental conditions in the areas they inhabit. It is important to monitor native fauna in municipal parks in São Paulo as various species in this study were found to have vector competence and capacity to transmit pathogens, such as arboviruses.

Keywords: *Diversity, culicids, mosquitoes, municipal parks.*

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Resumo: Em São Paulo os parques municipais preservam resquícios da vegetação de Mata Atlântica, comportam lagos e nascentes, servem de abrigos para mamíferos, aves e artrópodes vetores. São frequentados pela população humana como ambientes de lazer. A zona Leste da cidade possui o maior índice populacional de habitantes e 24 parques municipais. O objetivo deste trabalho foi conhecer a fauna de Culicidae de dois parques da zona Leste da cidade e avaliar a presença de espécies potencialmente bioindicadoras e vetoras de patógenos ao homem. Foram feitas coletas mensais de culicídeos entre março de 2011 a fevereiro de 2012 no Parque do Carmo e no Parque Chico Mendes, com aspiradores elétricos, armadilhas de Shannon e CDC para mosquitos adultos e concha entomológica e bombas manuais de sucção para os imaturos. Para verificar a suficiência amostral foram construídas curvas de acúmulo de espécies por amostragem e a riqueza total foi estimada pelo método Jackknife 1, ambos gerados pelo programa EstimateS. No parque do Carmo foram coletados 1.092 culicídeos, distribuídos em nove gêneros (*Aedes, Anopheles, Coquillettidia, Culex, Limatus, Mansonia, Trichoprosopon, Toxorhynchites* e *Uranotaenia*), distribuídos em 19 unidades taxonômicas. *Coquillettidia venezuelensis*(Theobald 1912), *Aedes scapularis* (Rondani 1848)e *Culex (Culex)* spp. Linnaeus 1758 foram os adultos mais abundantes e *Culex (Melanoconion)* spp. Theobald 1903 e *Anopheles strodei* Root 1926 os imaturos. No Parque Chico Mendes obteve-se 4.487 mosquitos, distribuídos em seis gêneros e 18 unidades taxonômicas. *Culex (Cux.)* spp. e *Ae. scapularis* foram os mais abundantes dos adultos e *Ae. albopictus* (Skuse 1984) dos imaturos. As curvas de acúmulo de espécies por amostragem em ambos os parques chegaram próximas à assíntota e a estimativa de riqueza total mostrou-se próxima à riqueza observada. Alguns táxons de culicídeos são bioindicadores das condições ambientais dos locais onde vivem, portanto é necessário acompanhar a fauna nativa dos parques municipais porque várias espécies encontradas têm mostrado competência e capacidade para veicular patógenos e arbovírus.

Palavras-chave: *Diversidade, mosquitos, culicídeos, Parques municipais.*

Introduction

The city of São Paulo, in the state of São Paulo in the southeast of Brazil, has a population of over 11 million people and is considered the region with the highest population density in South America. If all the adjacent municipalities, which together with the metropolis form an extensive built-up area, are included, the population is around 20.8 million, making it one of the largest megalopolises in the world. The eastern side of the city has the highest population – approximately 3.8 million inhabitants (IBGE 2010).

For a long time the authorities have paid little attention to this area of the city as it was one that saw the proliferation of low-income districts as a result of the disorganized occupation of land (shanty towns) on the outskirts of the city. In recent decades, with urban growth and the increasing expansion of business and commercial centers, the region has become a focus for property development, with the construction of countless business developments and middle-class residential condominiums. More recently, the construction of a large soccer stadium, together with investments in road infrastructure, has transformed this region into a magnet for shops. In addition, the expansion of the subway, investments in new educational and university centers and the growth in the economy are just some of the factors that have completely transformed this part of the city.

All of these factors, together with the demographic pressure exerted by the east side of São Paulo, have contributed to the increase in population density in the neighboring municipality of Guarulhos, making it the second largest built-up area in the state of São Paulo. São Paulo International Airport, which is also known as Governador André Franco Monteiro Airport, is the largest in South America and is located in Guarulhos; around 100,000 employees, passengers and visitors pass through the airport every day (EMPLASA 2011).

Municipal parks in the city of São Paulo contain remnants of the flora of the Atlantic Forest, as well as lakes and springs, and are home to mammals, birds and arthropods, some of which can be vectors of disease. The parks are in continual use for leisure purposes (Medeiros-Sousa et al. 2013). Twenty-four of the more than 100 parks in the city (Moreti & Fungaro 2012) are to be found on the east side, notable among these being Carmo Park and Chico Mendes Park, which are the subject of this study.

Around 3,500 species of Culicidae have been described around the world, some of which are of importance in public health because they are vectors of human and animal pathogens (Stone et al. 1959, Belkin et al. 1966, Harbach 2013). Various culicid species can be found in the habitats in these urban parks, where their populations are protected and can be maintained (Medeiros-Sousa et al. 2013). The proximity of these hematophagous insects to the human population allows contact between humans and mosquitoes, increasing the risk of the emergence of infectious diseases, particularly those caused by arboviruses. In light of this emerging epidemiological picture, it is important to identify mosquito species in these locations and to determine their potential as vectors. Furthermore, carrying out an entomological investigation into the species composition of Culicidae mosquitoes in urban parks helps to underline the importance of keeping these areas in anthropic environments by showing the biological richness of these enclaves. A knowledge of the culicid population in these environments helps to identify bioindicator species that can be useful when assessing the quality of the environment (Montes 2005; Anjos & Navarro-Silva 2008). The aim of this study was therefore to investigate Culicidae fauna in two parks on the east side of São Paulo and to determine which of the Culicidae species identified have the potential to act as bioindicators and vectors of human pathogens.

Materials and Methods

Collection Areas and Methods

The areas used for collections in this study consisted of forest fragments and the surrounding areas inside two municipal parks in the east of the city of São Paulo. These two environments are described in more detail below.

Carmo Park (23°33’59” S, 46°28’04” W) and Chico Mendes Park (23°30’24” S, 46°25’45” W), the areas chosen for the study are notable for the large number of visitors they receive every month and for their size (Figure 1).

Carmo Park (Olavo Egydio Setúbal Park) was inaugurated on September 19th, 1976, and is considered the second largest municipal park in the city. It has an area of 2,388,930 m^2 with various lakes and is home to mammals, amphibious animals, reptiles and wild and domesticated birds. An area of 839,300 m^2

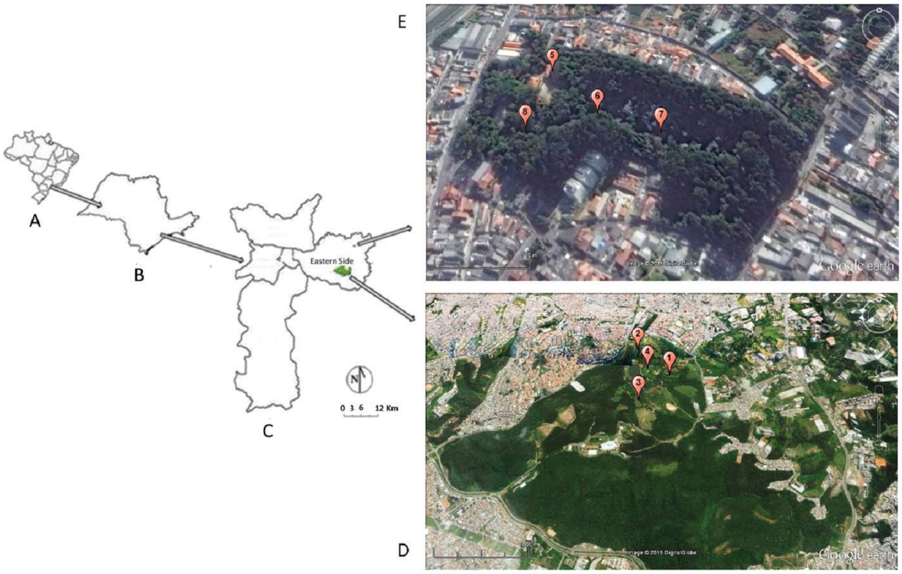

Figure 1. Location of Carmo Park (D) and Chico Mendes Park (E) in the east side of the municipality of São Paulo (C) in the state of São Paulo (B) in Brazil (A). Geographic coordinates of each collection point of **Carmo Park**: **1-** Wooded area close to the administration buildings (23°34'388"S, 46°28'109'W); **2-** Wooded area between the parking lot and the nursery (23°34'058"S, 46°27'786"W); **3-** Area with a large number of ducks beside a lake (23°34'366"S, 46°28'026"W); **4-** Lake close to the cherry tree wood (23°34'523"S, 46°28'049"W). **Chico Mendes Park**: **5-** Close to the administration buildings (23°30'353"S, 46°25'681"W); **6-** Trail leading to the lake (23°30'410"S, 46°25'599"W); **7-** Trail used by walkers (23°30'375"S, 46°25'590"W); **8-** Wood along the edge of the lake (23°30'430"S, 46°25'681"W).

where the São Mateus sanitary landfill used to operate was recently added to the park. The flora consists mainly of remnants of the Atlantic Forest with riparian forest, anthropic vegetation, marshes, lawns, eucalyptus groves, an orchard, a coffee grove, an Okinawa cherry tree wood and a nursery for different species of bushes. In the surrounding area there are houses occupied by low-income families. Between 5,000 and 50,000 people visit the park every month.

Chico Mendes Ecological Park was inaugurated on June 4th, 1989. It extends over an area of 61,600 m^2 and has streams, lakes and springs. The fauna consists mainly of mammals and wild and domesticated birds. The flora is made up of remnants of the Atlantic Forest, a eucalyptus grove, an orchard and areas that have been turned into gardens. The area surrounding the park consists of houses occupied by low-income families. Around 22,500 people visit the park every month.

Field visits were made monthly between March 2011 and February 2012, totalizing twelve samplings in each park. Specimens were collected using four different techniques as follows: (i) Shannon traps, from which specimens were collected for two hours starting at evening twilight by two individuals wearing personal protective equipment; (ii) CDC light traps with 200 g of dry ice placed 1 m above the ground (two traps) and in the canopy 5 m above the ground (two traps) for three hours; (iii) three 12V battery-powered aspirators used in a standardized 20 minute collection effort (Nasci 1981); and (iv) an active search for immature specimens in breeding sites with a 400 mL larval dipper or suction samplers depending on where the collection was being carried out. Throughout the study period it was performed about 240 hours of sampling effort in each park, divided as follows: 12 hours of aspiration, 24 hours of Shannon trap, 144 hours of CDC traps and 60 hours of active search for immature forms.

In **Carmo Park** the collections were performed in the following areas: **1-** a wooded area close to the administration buildings; **2-** a wooded area between the parking lot and the nursery; **3-** an area with a large number of ducks beside a lake; and **4-** a lake close to the cherry tree wood. In **Chico Mendes** Park the areas selected were: **5-** close to the administration buildings; **6-** on a trail leading to the lake; **7-** on a trail used by walkers; and **8-** in a wood along the edge of the lake (Figure 1).

Species identification

After they had been collected, the adult culicids were sacrificed using chloroform and stored in plastic pots, labeled and prepared for dehydration with silica gel. Immature specimens were transported in labeled 200 mL plastic pots containing water from the breeding site and kept in a styrofoam box. All the material collected was transported to the Laboratory for Research into and Identification of Synanthropic Fauna at the Zoonosis Control Center, in the city of São Paulo, then to the Entomology Laboratory at the Faculty of Public Health, University of São Paulo, where the specimens were identified. Immature individuals were kept until they reached the adult stage. Morphological identification was based on Lane (1953), Consoli & Lourenço-de-Oliveira (1994) and Forattini (2002), as well as on comparison with standard specimens in the collection at the Faculty of Public Health, University of São Paulo. The abbreviations for genera and subgenera used here follow the standardization proposed by Reinert (2001).

To confirm sample sufficiency, the EstimateS program was used to plot sample-based species accumulation curves and estimate total richness by the Jackknife 1 method (Burnham & Overton 1979); 1000 randomizations without replacement and a 95% confidence interval were used (Colwell et al., 2004).

Results

In all, 5,579 specimens of Culicidae were captured (Tables 1 and 2). Collections in **Carmo Park** yielded 837 adult mosquitoes

Table 1. Distribution of adult and immature culicids collected in **Carmo Park** in the city of São Paulo between March 2011 and February 2012 by collection technique and gender.

Taxon	**Adults**										**Immature Individuals**			**Total**
	Aspiration		**CDC canopy**		**CDC ground**		**Shannon**		**Subtotal**		**Dipping**	**Suction**	**Subtotal**	
	Female	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**				
# ° *Ae. (Och.) fluviatilis*	2		10	1	14	1	43		**69**	**2**		5	**5**	**76**
° * *Ae. (Och.) scapularis*	16	6	74		10		126		**226**	**6**				**232**
# ° * *Ae. (Ste.) albopictus*		2	1				1		**2**	**2**				**4**
° * *An. (Nys.) strodei*							12	1	**12**	**1**	47		**47**	**60**
° * *Cq. (Rhy.) nigricans*							6		**6**	**0**				**6**
° * *Cq. (Rhy.) venezuelensis*			3				277		**280**	**0**				**280**
° * *Cx. (Cux.) chidesteri*	1	1	7		4		2		**14**	**1**				**15**
° * *Cx. (Cux.) declarator*		3							**0**	**3**				**3**
° * *Cx. (Cux.) dolosus*									**0**	**0**	7	1	**8**	**8**
# ° * *Cx. (Cux.) nigripalpus*		1							**0**	**1**	2	9	**11**	**12**
# ° *Cx. (Cux.) quinquefasciatus*	1	13	3		7				**11**	**13**	1		**1**	**25**
# ° * *Cx. (Cux.) spp.*	7		104		45		15		**171**	**0**				**171**
° * *Cx. (Mcx.) imitator imitator*									**0**	**0**		2	**2**	**2**
° * *Cx. (Mel.) spp.*	3		6						**9**	**0**	117	16	**133**	**142**
# ° * *Li. durhamii*	2		2		1				**5**	**0**		36	**36**	**41**
° * *Ma. (Man.) titillans*	1						1		**2**	**0**				**2**
° * *Tr. sp.*							1		**1**	**0**				**1**
# ° * *Tx. spp.*									**0**	**0**		8	**8**	**8**
° * *Ur. (Ura.) lowii*									**0**	**0**	4		**4**	**4**
Subtotal	**33**	**26**	**210**	**1**	**81**	**1**	**484**	**1**	**808**	**29**				
TOTAL	**59**		**211**		**82**		**485**		**837**		**178**	**77**	**255**	**1092**

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[808 (96.5 %) - ♀, 29 (3.5 %) - ♂] and 255 immature individuals, giving a total of 1,092 mosquitoes distributed in nine genera (*Aedes* Meigen 1818, *Anopheles* Meigen 1818, *Coquillettidia* Dyar 1905, *Culex* Linnaeus 1758, *Limatus* Theobald 1901, *Mansonia* Blanchard 1901, *Trichoprosopon* Theobald 1901, *Toxorhynchites* Theobald 1901 and *Uranotaenia* Lynch Arribálzaga 1891) and nineteen taxonomic units.

Of the four techniques used, the Shannon trap was the most effective in terms of the number of adult mosquitoes collected, accounting for 58.0 % (485) of the total, followed by the CDC light traps in the canopy with 25.2 % (211); CDC light traps on the ground and the battery-powered aspirator, which accounted for 9.8% and 7.0% (82 and 59), respectively. *Coquillettidia* (*Rhynchotaenia*) *venezuelensis* (Theobald 1912), (33.4 %), *Aedes* (*Ochlerotatus*) *scapularis* (Rondani 1848) (27.7 %) and *Culex* (*Culex*) spp. Linnaeus 1758 (20.4 %) were the most abundant adult culicids (Table 1).

Collections of immature mosquitoes made using a dipper and a suction sampler resulted in 178 and 77 specimens (69.8 % and 30.2 %), respectively. *Culex (Melanoconion)* spp. Theobald 1903 (52.2 %) and *Anopheles (Nyssorhynchus) strodei* Root 1926 (18.4%) were the most abundant taxonomic units (Table 1).

Collections in **Chico Mendes Park** yielded 4,416 adult mosquitoes [3,894 (88.2 %) - ♀, 522 (11.8 %) ♂] and 71 immature individuals, giving a total of 4,487 mosquitoes distributed in six genera (*Aedes*, *Anopheles*, *Culex*, *Limatus*, *Mansonia* and *Trichoprosopon*) and eighteen taxonomic units.

The CDC light traps in the canopy had the highest yield of adult mosquitoes and accounted for 42.0 % of the total (1,856 specimens), followed by the Shannon traps, with 21.6 % of the total (955 specimens), the aspirators, with 21.4 % of the total (947 specimens), and the CDC light traps on the ground with 14.9 % of the total (658 specimens). The taxonomic units *Culex (Cux.)* spp. (56.7 %) and *Ae.* (*Och.*) *scapularis* (25.1 %) were the most abundant adult culicids (Table 2).

When immature mosquitoes were collected using only the suction technique, *Ae. (Ste.) albopictus* (Skuse 1894) (73.2 %) was the predominant species, with 52 specimens collected (Table 2).

The sample-based species accumulation curves in both parks were close to the asymptote, and the total richness estimate was close to the observed richness, with a good degree of overlapping of confidence intervals (Figure 2).

Discussion

One of the aims of the inventory of Culicidae species in Carmo Park and Chico Mendes Park was to identify species that are important for public health; in other words, those that are potential vectors of pathogens or cause discomfort. The characterization of hematophagous mosquitoes found in parks located in urban environments produces data that can be used to support possible monitoring or control efforts by the public authorities responsible for these areas. According to Mascara et al. (2012), the use of a variety of traps and collection points in different locations and a search for breeding sites over a greater areas of the parks requires a greater collection effort but is necessary to ensure more representative sampling of the fauna. This strategy was adopted in the present study.

Although various studies have already been carried out in fragments of green areas inside urban São Paulo, the data accumulated from these studies are not comprehensive enough to allow us to claim that all the Culicidae fauna in these areas are known (Urbinatti et al. 2001, Taipe-Lagos & Natal 2003, Montes 2005). Comparison of the findings of a preliminary study (Medeiros-Sousa et al. 2013) of Carmo Park and Chico Mendes Park with the data from the present study, which found nineteen taxons in Carmo Park, shows that eleven of these taxons had already been recorded and that eight were found here for the first time. The same comparison for Chico Mendes Park revealed that of the eighteen taxons identified, only six had also been found by Medeiros-Sousa et al. 2013. These results show that our study has helped provide a greater understanding of culicid fauna in these green areas. While the number of samplings was sufficient to obtain an inventory of culicids in the whole of Chico Mendes Park, based on the species accumulation curves the number of samplings for Carmo Park was considered satisfactory in the study area but inadequate for the park as a whole as its size made it unfeasible to explore areas farther from the defined collection points.

Culicids are of interest not only from an epidemiological perspective, an aspect that has been amply discussed, but also because some taxons can be used as bioindicators of environmental conditions in the areas they inhabit. The usefulness of mosquitoes as bioindicators is readily apparent if one assesses the extent of the changes that have occurred in a particular region and at the same time observes the increase or decrease in frequency of a particular taxon or whether the taxon has disappeared. Forattini et al. (1978) and Teodoro et al. (1994) defined *Ae. scapularis* as an abundant species in environments that have undergone change and a rare species in native forests. *Ae. scapularis* and mosquitoes in tribe Mansoniini are examples of culicids that are indicative of environments that have undergone major changes antropic, oscillating between presence or absence (Dorvillé 1995, Paula et al. 2012)

Although the parks studied here contain fragments of native forests, their location within built-up areas, the changes made to accommodate the parks and their users and the presence of humans in large numbers in and around them mean that these areas are under environmental stress. We found that *Ae. scapularis* is one of the most abundant species in the study area. The presence of *Ae. scapularis* in transformed environments may be related to the hematophagous habits of the females, which feed mainly on mammals, particularly humans and domestic animals (Forattini et al. 1986, 1989, Teodoro et al. 1994, Almiron & Brewer 1996). It is well known that this species has a competitive advantage over other species in transformed environments as it lives in small temporary breeding sites in soil and its larval development cycle is considered fast compared with those of other culicids. Furthermore, its synanthropy and anthropophily are well-documented characteristics. This species through experimental infection presented vectorial epidemiological capacity in transmit the virus Rocio in the Vale do Ribeira, Estado de São Paulo and of *Dirofilaria immitis* in coastal areas of the State of Rio de Janeiro, Brazil (Forattini 2002).

In Carmo Park the tribe Masoniini was represented by *Cq. venezuelensis* in high frequencies and *Cq. nigricans* (Coquillett 1904) and *Ma. titillans* (Walker 1848) but few in numbers while in the Chico Mendes park only this last species was found. In the immature stage, these culicids live in association with macrophytes that colonize lakes and act as indicators for the presence of these plants and in both parks was noted the presence of *Typha domingensis* Pers. (Typhaceae).

Table 2. Distribution of adult and immature culicids collected in **Chico Mendes Park** in the city of São Paulo between March 2011 and February 2012 by collection technique and gender.

Taxon	Adults										Immature Individuals	Total
	Aspiration		CDC canopy		CDC ground		Shannon		Subtotal		Suction	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male		
# ° *Ae. (Och.) fluviatilis*	5	7	15	3	17	5	92	7	**129**	**22**		**151**
° * *Ae. (Och.) scapularis*	181	58	153	2	189	1	523	3	**1046**	**64**		**1110**
# *Ae. (Ste.) aegypti*	1	1			1				**2**	**1**	11	**14**
# ° * *Ae. (Ste.) albopictus*	5	4	2		2		1	1	**10**	**5**	52	**67**
° * *An. (Nys.) strodei*							1		**1**	**0**		**1**
° * *Cx. (Cux.) acharistus*		1							**0**	**1**		**1**
° * *Cx. (Cux.) bidens*		2							**0**	**2**		**2**
° * *Cx. (Cux.) chidesteri*	10	34	79		44	1	7	6	**140**	**41**		**181**
° * *Cx. (Cux.) declarator*		328		2		3		5	**0**	**338**		**338**
° * *Cx. (Cux.) dolosus/eduardoi*		2		2		8			**0**	**12**		**12**
° * *Cx. (Cux.) lygrus*		6				1		2	**0**	**9**		**9**
# ° * *Cx. (Cux.) nigripalpus*		11				1			**0**	**12**		**12**
# ° *Cx. (Cux.) quinquefasciatus*	2	14	2		1	1	1		**6**	**15**		**21**
# ° * *Cx. (Cux.)* spp.	275		1591		382		256		**2504**	**0**		**2504**
° * *Cx. (Mel.)* sp.			1						**1**	**0**		**1**
° * *Li. durhamii*									**0**	**0**	8	**8**
° * *Ma. (Man.) titillans*			3		1		50		**54**	**0**		**54**
° * *Tr.* sp.			1						**1**	**0**		**1**
Subtotal	**479**	**468**	**1847**	**9**	**637**	**21**	**931**	**24**	**3894**	**522**		
TOTAL	**947**		**1856**		**658**		**955**		**4416**		**71**	**4487**

Urban Environment, ° Modified Environment, *Preserved Environment

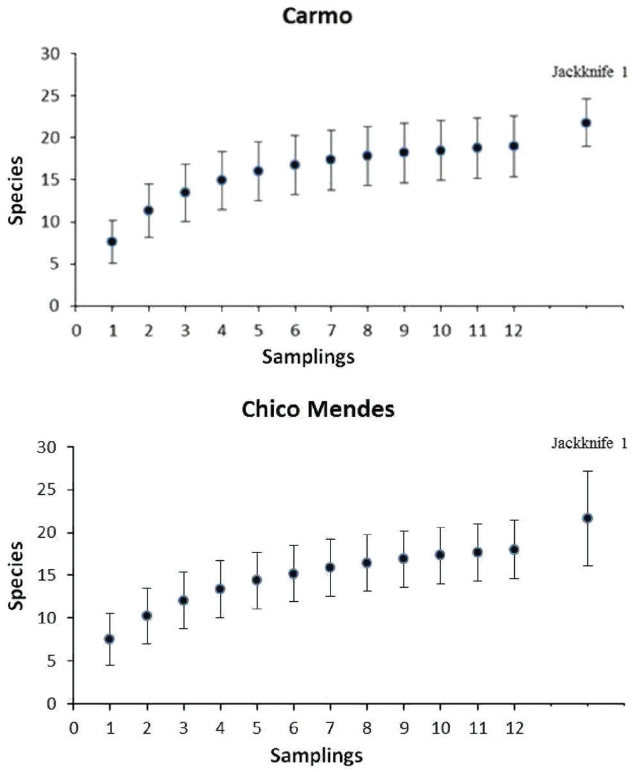

Figure 2. Sample-based species accumulation curves (jackknife 1) with a 95% confidence interval for Carmo Park and Chico Mendes Park based on collections between March 2011 and February 2012.

Representatives of tribe Sabethini and *Culex* (*Microculex*) Theobald 1907 grow in treeholes, bromeliads and palm axils. They are frequently found in wild places and are considered indicators for such places. The fact that we found only a small number of sabethines (*Limatus* and *Trichoprosopon* and the absence of anophelines from subgenus *Kerteszia* Theobald 1905 may indicate marked anthropic environmental changes or environmental degradation in both parks, at least in the areas studied, making it difficult or impossible for these populations to survive there.

In Brazil, anophelines are generally common in rural or wild environments and rare in urban areas because their habitats require special environmental conditions (Forattini 2002). They are common on the outskirts of Manaus and other cities in the north of Brazil, and can cause outbreaks of malaria (Souza & Castellón 2012). Our finding of *An. strodei* in both parks indicates that this species is not so selective in its choice of breeding sites, possibly tolerating polluted water, and that adults of this species may seek shelter in forest fragments in these parks. Although it exhibits exophilic and zoophilic behavior, this species is considered a secondary or potential vector of human malaria (Consoli and Lourenço de Oliveira 1994). The relationship between anophelines and the presence of favorable man-made habitats can be considered to contribute to the maintenance of the population of these species in the parks (Gomes et al. 2008). However, because of their low frequency, the risk of these anophelines acting as vectors of *Plasmodium* spp. in the urban environment can be considered remote.

The taxon *Cx. (Cux.)* spp. includes a range of species whose females are not morphologically distinct except for a few species. Our finding of these mosquitoes in both parks and the fact that they were among the most abundant species suggest that these environments, which include preserved forest fragments and at the same time suffer the impact of humans, are suitable for this taxon. We found males of the following species in areas frequented by humans: *Cx. (Cux.) acharistus* Root 1927, *Cx. (Cux.) bidens* Dyar 1922, *Cx. (Cux.) chidesteri* Dyar 1921, *Cx. (Cux.) declarator* Dyar & Knab 1906, *Cx. (Cux.) dolosus* Lynch Arribálzaga 1891/ *Cx. (Cux.) eduardoi* Casal & Garcia 1968, *Cx. (Cux.) lygrus* Root 1927, *Cx. (Cux.) nigripalpus* Theobald 1901 and *Cx. (Cux.) quinquefasciatus* Say 1823. These mosquitoes are adapted to a wide range of different breeding grounds and shelters. Because of their eclectic feeding habits, they are considered potential vectors of arboviruses, which can cause infections in humans and domestic animals, and also a source of discomfort among people who frequent these parks and the surrounding areas (Urbinatti et al. 2001, Medeiros-Sousa et al. 2013). An epidemiologically important species is the common urban mosquito *Cx. quinquefasciatus*, as it is known to be the main vector of filaria *Wuchereria bancrofti* and secondary vector of Oropouche virus in Brazil. It also has very anthropophilyc behavior and causes discomfort among residents of cities with untreated sewage. Another important mosquito found in the study is *Cx. (Cux.) nigripalpus* a species with marked ornithophily and a known vector of St. Louis encephalitis virus (Forattini 2002).

Species in the genus *Culex* and subgenus *Melanoconion* can be found in natural or artificial environments and include eclectic species that can use humans and wild and domestic animals as sources of blood meals. They have the potential to become part of the natural cycle of some arboviruses, such as Venezuelan equine encephalitis virus (Forattini 2002, Montes 2005).

Exotic species such as *Aedes (Ste.) aegypti* (Linnaeus 1762) and *Aedes (Ste.) albopictus*, which were found in our study, are common in Brazilian cities and were expected to be found in both parks. In various situations these species can be found sharing the environment with a series of autochthonous mosquitoes from various genera, such as *Anopheles*, *Coquillettidia*, *Culex*, *Mansonia*, *Limatus*, *Trichoprosopon*, *Toxorhynchites* and *Uranotaenia*, as occurred here. In Brazil, *Ae. aegypti*, the vector of dengue and urban yellow fever, is highly adapted to the urban environment, where it reproduces in countless different types of artificial and natural receptacles. *Ae. albopictus* has the ability to spread rapidly, to occupy different environments and to take blood meals off various mammal species, leading to the hypothesis that it may be a potential vector of yellow fever and dengue in the Americas and potentially changing the epidemiology of the transmission of these diseases (Johnson et al. 2002).

In Brazil, the presence of various "autochthonous" species has been recorded on the outskirts and in more central areas of cities. Although exotic species have been considered important for public health, the importance of native fauna that has become established in densely inhabited areas should not be underestimated. Various such species have been found to have both the competence and capacity to transmit important pathogens and some have shown a progressive tendency to become domiciliated, increasing contact with humans and the risk of emerging infections by arboviruses (Dorvillé 1995, Smith et al. 2004, Guedes 2012). This adaptation is facilitated by the existence of environmental reserves in urban centers, such as the parks studied here.

Attention should be paid to these areas as they are true green enclaves within cities and combine epidemiological conditions that favor the vector-borne transmission of disease (Lufchitz & Marcondes 2011). It is important to include such areas in official entomological surveillance programs and to carry out regular investigations to determine whether arboviruses, particularly flaviviruses, may be circulating in these areas.

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References

ALMIRÓN, W.R. & BREWER, M.E. 1996. Classification of immature stage habitats of Culicidae (Diptera) collected in Córdoba, Argentina. Mem. Inst. Oswaldo Cruz. 91(1):1-9, http://dx.doi.org/10.1590/S0074-02761996000100001.

ANJOS, A.F. & NAVARRO-SILVA, M.A. 2008. Culicidae (Insecta: Diptera) em área de Floresta Atlântica, no Estado do Paraná, Brasil. Acta Sci. Biol. Sci. 30(1):23-27, http://dx.doi.org/10.4025/actascibiolsci.v30i1.1411.

BELKIN, J.N., SCHICK, R.X. & HEINEMANN, S.J. 1966. Mosquito studies (Diptera: Culicidae). V. Mosquitoes originally described from Middle America. Cont. Am. Entomol. Inst. 1(6): 1-95.

BURNHAM, K.P. & OVERTON, W.S. 1979. Robust estimation of population size when capture probabilities vary among animals. Ecology. 60(5): 927-936, http://dx.doi.org/10.2307/1936861.

COLWELL, R.K., MAO, C.X. & CHANG, J. 2004. Interpolating, extrapolating, and comparing incidence-based species accumulation curves. Ecology. 85(10): 2717-2727, http://dx.doi.org/10.1890/03-0557.

CONSOLI, R.A.G.B. & LOURENÇO-DE-OLIVEIRA, R. 1994. Principais mosquitos de importância sanitária do Brasil. Editora FIOCRUZ, Rio de Janeiro.

DORVILLÉ, L.F.M. 1995. Composição e aspectos da biologia da fauna de mosquitos (Diptera, Culicidae) da restinga de Barra de Maricá (RJ). Rev. Bras. Entomol. 39(1): 203-219.

EMPLASA. Empresa Paulista de Planejamento Metropolitano SA. 2011. Governo do Estado de São Paulo. Secretaria de Estado de Desenvolvimento Metropolitano. http://www.emplasa.sp.gov.br-atendimento@ emplasa.sp.gov.br. (accessed on January 18th, 2014).

FORATTINI, O.P., GOMES, A.C., GALATI, E.A.B., RABELLO, E.X. & IVERSON, L.B. 1978. Estudos ecológicos sobre mosquitos Culicidae no sistema Serra do Mar, Brasil. 1 - Observações no ambiente extradomiciliar. Rev. Saúde Pública. 12(4): 297-325.

FORATTINI, O.P, GOMES, A.C., NATAL, D. & SANTOS, J.L.F. 1986. Observações sobre atividade de mosquitos Culicidae em matas primitivas da planície e perfis epidemiológicos de vários ambientes no Vale do Ribeira, São Paulo, Brasil. Rev. Saúde Pública. 20(3): 178-203.

FORATTINI, O.P., GOMES, A.C., NATAL, D.,KAKITANI, I. & MARUCCI, D. 1989. Preferências alimentares e domiciliação de mosquitos Culicidae no Vale do Ribeira, São Paulo, Brasil, com especial referência a *Aedes scapularis* e a *Culex* (*Melanoconion*). Rev. Saúde Pública. 23(1): 9-19.

FORATTINI, O.P. 2002. Culicidologia Médica. EDUSP, São Paulo, v.2, p.860

GOMES, E.C.S., ALBUQUERQUE, C.M.R., SOUZA, J.R.B., ARRUDA, M.E. & CONFALONIERI, U.E.C. 2008. Structure of *Anopheles* (Diptera: Culicidae) population in areas with different degrees of human settlement: Cantá - Roraima – Brazil. Acta Amaz. 38(2): 321-329, http://dx.doi.org/10.1590/S0044-59672008000200016.

GUEDES, M.L.P. 2012. Culicidae (Diptera) no Brasil: Relações entre Diversidade, Distribuição e Enfermidades. Oecologia Australis. 16(2): 283-296, http://dx.doi.org/10.4257/oeco.

HARBACH, R.E. 2013. Mosquito taxonomic inventory. http://mosquito-taxonomic-inventory.info/. (accessed on January 18th, 2014).

IBGE. Instituto Brasileiro de Geografia e Estatística. 2010. IBGE Cidades@ São Paulo. http://www.ibgegov.br/cidadesat/. (accessed on November 28th, 2013).

JOHNSON, B.W., CHAMBERS, T.V., CRABTREE, M.B., FILIPPIS, A.M., VILARINHOS, P.T., RESENDE, M.C., MACORIS, M.L. & MILLER, B.R. 2002. Vector competence of Brazilian *Aedes aegypti* and *Ae. albopictus* for a Brazilian yellow fever virus isolate. Trans. R. Soc. Trop. Med. Hyg. 96(6): 611-613, http://dx.doi.org/10.1016/S0035-9203(02)90326-3.

LANE, J. 1953. Neotropical Culicidae. Ed.Universidade de São Paulo, São Paulo, v.2.

LUFCHITZ A.H.M. & MARCONDES C.B. 2011. Culicidae. In Projeto Parques e Fauna: Plano de Manejo da Área de Proteção Ambiental Municipal da Ponta do Araçá – Diagnóstico de Fauna. Instituição Financiadora Prefeitura Municipal de Porto Belo. p. 48-53.

MASCARA, D., COSTA FILHO, E.S., BATISTA, E. & SILVA, S.P. 2012. Culicídeos da Serra do Itapeti. In Serra do Itapeti: Aspectos Históricos, Sociais e Naturalísticos (M.S.C. Morini & V.F.O. Miranda, orgs). Canal 6 Editora, Bauru, p. 400.

MEDEIROS-SOUSA, A.R., CERETTI J.R., W., URBINATTI, P.R., CARVALHO, G.C., PAULA, M.B., FERNANDES, A., MATOS, J.R., M.O., ORICO, L.D., ARAUJO, A.B., NARDI, M.S., & MARRELLI, M.T. 2013. Mosquito Fauna in Municipal Parks of São Paulo City, Brazil: A Preliminary Survey. J. Am. Mosq. Control Assoc. 29(3): 275-279, http://dx.doi.org/10.2987/12-6304R.1.

MONTES, J. 2005. Fauna de Culicidae da Serra da Cantareira, São Paulo, Brasil. Rev. Saúde Pública. 39(4): 578-584.

MORETI, C. & FUNGARO, M.L. 2012. Guia dos parques municipais de São Paulo. 3 ed., Prefeitura de São Paulo, Secretaria do Verde e do Meio Ambiente. São Paulo. http://www.prefeitura.sp.gov.br/svmaparques.

NASCI, R.S. 1981. A lightweight battery-powered aspirator for collecting resting mosquitoes in the field. Mosq. News, 41(4): 808-811.

PAULA, M.B., GOMES, A.C., NATAL, D., DUARTE, A.M.R.C. & MUCCI, L.F. 2012. Effects of Artificial Flooding for Hydroelectric Development on the Population of *Mansonia humeralis* (Diptera: Culicidae) in the Paraná River, São Paulo, Brazil. J. Trop. Med. ID 598789, 6 pages, http://dx.doi.org/10.1155/2012/598789.

REINERT, JF. 2001. Revised list of abbreviations for genera and subgenera of Culicidae (Diptera) and notes on generic and subgeneric changes. J. Am. Mosq. Control. Assoc. 17: 51-55.

SMITH, D.L., DUSHOFF, J & MCKENZIE, F.E. 2004. The risk of a mosquito-borne infection in a heterogeneous environment. PLoS Biology. 2(11): 368, http://dx.doi.org/10.1371/journal.pbio.0020368.

SOUZA, L.A.G. & CASTELLÓN, E.G. 2012. Desvendando as fronteiras do conhecimento na região amazônica do Alto Rio Negro. http://www.inpa.gov.br/arquivos/livro_fronteiras/02-Livro_Fronteiras.pdf. (último acesso em 27/01/2014).

STONE, A., KNIGHT, K.L. & STARCKE, H. 1959. A synoptic catalog of the mosquitoes of the world (Diptera: Culicidae). Entomological Society of America, Maryland, v. 6, p.1-358.

TAIPE-LAGOS, C.B. & NATAL, D. 2003. Abundância de culicídeos em área metropolitana preservada e suas implicações epidemiológicas. Rev. Saúde Pública 37(3): 275-279.

TEODORO, U., GUILHERME, A.L.F., LOZOVEI, A.L., SALVIA FILHO, V.L, SAMPAIO, A.A, SPINOSA, R.P, FERREIRA,

M.E.M.C., BARBOSA, O.C. & LIMA, E.M. 1994. Mosquitos de ambientes peri e extradomiciliares na região sul do Brasil. Rev. Saúde Pública. 28(2): 107-15.

URBINATTI, P.R., SENDACZ, S. & NATAL, D. 2001. Imaturos de mosquitos (Diptera: Culicidae) em parque de área metropolitana aberto à visitação pública. Rev. Saúde Pública 35(5): 461-466.

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Erratum

No artigo "Mosquito (Diptera: Culicidae) fauna in parks in greater São Paulo, Brazil" publicado do periódico Biota Neotropica, 15(3), na página 1 onde lia-se:

Marcia Bicudo de Paula[1] , Aristides Fernandes[1], Antônio Ralph Medeiros-Sousa[1], Walter Ceretti-Júnior[1], Rafael Christe[1] , Regina Claudia Stroebel[2] , Leila Pedrosa[2] , Rosa Maria Marques de Sá Almeida[1], Uellinton Damasceno Pereira[3], Marcelo Cassiano de Oliveira Jacintho[3], Delsio Natal[1], Mauro Toledo Marrelli[1 4]

Leia-se:

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erratum

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Vascular flora of the *cerrado* of Bauru-SP

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CAVASSAN, O., WEISER, V. de L. **Vascular flora of the *cerrado* of Bauru-SP.** Biota Neotropica. 15(3): e20140093. http://dx.doi.org/10.1590/1676-0611-BN-2014-0093

Abstract: Information on the cerrado vascular flora of the municipality of Bauru has been provided in lists of floristic surveys carried out in fragments of this vegetation type at different times, applying different criteria, and conforming to current taxonomic classifications. We organized this information according to APG III and revised synonymies, aiming at producing a single floristic list of species occurring in *cerrado sensu lato* or ecotonal areas (transitions between *cerrado* and seasonal forest) in municipality of Bauru to inform conservation proposals. For this purpose, we referred to all floristic lists of vascular plants found in *cerrado* fragments in Bauru and to botanic material collected and deposited in the herbaria of the Department of Biological Sciences, School of Sciences, Bauru Campus, UNESP (UNBA), and of the Bauru Botanical Garden (JBMB). We recorded 371 species from 78 families. Fabaceae was the richest in species. We also indicated each mentioned species' habit and the vegetation types where plants occur in the municipality.

Keywords: *floristics, savanna, plant survey.*

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Resumo: Informações relativas à flora vascular do cerrado do município de Bauru foram divulgadas em listas de levantamentos florísticos obtidas em fragmentos dessa vegetação em diferentes épocas, critérios e obedecendo às classificações taxonômicas vigentes. Organizamos tais informações, adotando o sistema APG III e revendo as sinonímias, com o objetivo de produzir uma lista florística única, com espécies que ocorrem no cerrado sentido amplo ou áreas ecotonais (transições entre cerrado e floresta estacional) do município de Bauru, para subsidiar propostas de conservação. Para isso, consultamos todas as listas florísticas conhecidas de plantas vasculares em fragmentos de cerrado do município de Bauru e material botânico coletado e depositado nos herbários do Departamento de Ciências Biológicas, Faculdade de Ciências, Câmpus de Bauru, UNESP (UNBA) e do Jardim Botânico Municipal de Bauru (JBMB). Registramos 371 espécies, pertencentes a 78 famílias. Fabaceae foi a mais rica em espécie. Indicamos o hábito de cada espécie e os tipos de vegetação em que ela ocorre no município.

Palavras-chave: *florística, savana, inventário de plantas.*

Introduction

The *Cerrado* has a highly diverse flora, estimated at ten thousand species of higher plants (Ratter 2004), hosting also a high diversity of other organisms from different taxa. This ecosystem shows a high diversity of relationships among organisms and between organisms and the abiotic environment where they occur. According to Coutinho (2002), only the Amazon and Atlantic forests exceed the Brazilian *Cerrado* in species richness.

The importance of Cerrado in Brazil lies unquestionably on its high biodiversity (Bitencourt 2004). The municipality of Bauru is located in a climatic zone intermediate between tropical and southern temperate, which gives its ecosystems a different feature from that of the Cerrado core area regarding adaptation (Cavassan et al. 2006), especially because of occasional frosts, which do not occur in the central-north part of this biome (Cavassan 2002, Durigan et al. 2004).

At present, *cerrado* remnants in the state of São Paulo are disjunct fragments. Few of these fragments are protected within state conservation units (Cavassan 2002). In the state of São Paulo, the *cerrado* is distributed mainly in the Peripheral Depression, from north to south, along the line of the Basaltic Cuestas, expanding to some regions of the Western Plateau (Durigan et al. 2004), where it is distributed in mosaics between seasonal forest and riparian formations in the valleys. In this paper, we consider as riparian formations those adjacent to bodies of water (Rodrigues 2000). The same distribution is observed in the Bauru region (Cavassan 2013). Durigan et al. (2003) discussed cerrado phytogeographical patterns in São Paulo from a regional perspective and demonstrated the existence of two floristic groups: eastern *cerrados*, together with open physiognomies in the states of Mato Grosso do Sul and Goiás and the Triângulo Mineiro; and western *cerradões* (woodland savannas), located basically in the state of São

Paulo. According to Durigan et al. (2003), the *cerrado* of the municipality of Bauru belongs to the latter group.

The transition between different *cerrado* physiognomies and seasonal forests in the state of São Paulo occurs, in general, in a gradient of different extensions (Durigan et al. 2012), not always clearly limited. This often hinders the identification and delimitation of *cerrado* areas, especially during supervision or vegetation management processes. According to Durigan et al. (2012), the vegetation floristic structure is important in its classification.

Just as it is difficult to establish the limits between *cerrado* vegetations and seasonal forests in Bauru, it is not safe to define which plant species are typical of each of these plant formations. For this reason, this article aims at building a single table of tracheophyte plant species based on species occurrence in fragments considered *cerrado sensu lato* or in ecotonal areas (transitions between *cerrado* and seasonal forest), in addition to recording the existence of these species in other vegetation types in the municipality of Bauru.

Material and Methods

Bauru is located in the central-west region of the state of São Paulo, in southeastern Brazil. The climate is highland tropical, type Cwa, according to Koeppen (1948), with an average yearly rainfall of 1262.9 mm between 2001 and 2014 (Emídio 2014), featuring dry and mild winters – minimum average temperature of 13.6 °C and maximum average temperature of 25.7 °C (Emídio 2014) – and rainy summers with moderately high temperatures, with the maximum average temperature occurring after the summer solstice (Cavassan et al. 1984) – minimum average temperature of 19.8 °C and maximum average temperature of 30.4 °C (Emídio 2014). In this region, soil types are Dark Red Latosol, sandy phase, and Red Yellow Acrisol, generally found in steeper hillsides, both with medium to sandy texture, probably derived from the Bauru sandstone (Cavassan et al. 1984).

Bauru has a vegetation complex composed of *cerrado*, mostly represented by *cerradão* (woodland savanna). This vegetation type prevails in southeastern interfluvial areas. In the valleys, the vegetation types are swamp grasslands of *cerrado* and permanently flooded riparian forests (Rodrigues 2000), popularly known as swamp forests. In the northwest, fragments of montane semideciduous seasonal forest (IBGE 2012) prevail. Between fragments of *cerradão* and montane seasonal semideciduous forest, we usually find transition areas (Cavassan 2013).

To prepare a floristic list of the vascular species that occur in the *cerrado* of Bauru (Table 1), we systematized all other lists found in surveys carried out in areas of *cerrado* (Ferracini et al. 1983, Cavassan 1990, Koch 1994, Christianini & Cavassan 1998, Koch & Kinoshita 1999, Pinheiro 2000, Pinheiro & Monteiro 2006, Genovez 2007, Faraco 2007, Weiser 2007, Nóbrega & Prado 2008, Pinheiro & Monteiro 2008, Rissi 2011, and Joanitti 2013), within the following limits: 22°14’46.35”-22°21’58.63” South, 48°54’13.40”-49°02’42.09” West. These limits represent the estimated area covered by *cerrado* within the municipality. We included all exsiccates mentioned in the references above and also all botanic material collected in Bauru and deposited in the herbaria of the Department of Biological Sciences, School of Sciences, Bauru Campus, UNESP (UNBA), and of the Bauru Botanical Garden (JBMB). Moreover, we occasionally searched for vouchers from species collected in Bauru on the Specieslink (2014) database to supplement information recorded in some exsiccates.

These studies, published at different times, comply with spelling and taxonomic classifications effective at the time they were written. To prepare a single list, we updated the nomenclature according to the database Tropicos (Tropicos.org. Missouri Botanical Garden 2013) and the abbreviations of authors’ names according to The International Plant Names Index (2012). Only taxa identified and confirmed to the species level were included. The classification system employed was the Angiosperm Phylogeny Group (APG III 2009), with recent updates from the Angiosperm Phylogeny Website (Stevens 2001 onwards) and Souza & Lorenzi (2012). We have verified valid scientific names in the databases The Plant List (2010) and Lista de Espécies da Flora do Brasil (2013) and checked them against synonyms often cited in our references and in the exsiccates from the UNBA and JBMB herbaria.

The occurrence of some species in the *cerrado* does not necessarily demonstrate that they are endemic to this vegetation type. For this reason, the nature of these species was searched in Lista de Espécies da Flora do Brasil (2013), as suggested by Moro et al. (2012).

Plant habits were indicated as follows: Climber (Climber) – vascular, autotrophic plants that germinate in the ground, with which they are in contact for their entire life cycle, and that need a support (phorophyte) to develop branches; Epiphyte (Epi.) – vascular plants that need a support to grow, without parasitizing it, and have no contact with the ground; Hemiepiphyte (Hemiepi.) – vascular, autotrophic plants that germinate on others and later send and establish roots in the ground (primary) or that germinate in the ground, grow on other plants, and later break their link or connection to the ground (secondary); Herb (Herb) – sub-woody plants or plants with stalk or rhizome, with terminal gemmae above the ground, not more than one meter high; Palm (Palm) – all plants of the Arecaceae family; Shrub or tree (St) – vascular plants with woody, aerial, erect stems at least 50 centimeters high; Vascular saprophyte (Vs) – vascular, saprophytic, heterotrophic plants; Vascular hemiparasite (Vh) – autotrophic plants that grow on other plants and extract their raw sap.

We showed other vegetation types of the municipality of Bauru where the species occur besides the *cerrado*, according to the following criterion: montane semideciduous seasonal forest (mssf) (IBGE 2012), permanently flooded riparian forest (pfrf), and non-flooded riparian forest (nfrf) (Rodrigues 2000). Species from swamp grasslands formations occurring in the transition between the *cerrado* and the permanently flooded riparian forests were not included in Table 1, although Nóbrega & Prado (2008) included in their list the Pteridophyte species sampled in that environment.

Results and Discussion

We observed and recorded 371 tracheophyte species from 78 families in the *cerrado* fragments of the municipality of Bauru, SP (Table 1).

The most species-rich family is Fabaceae (10.2%), followed by Asteraceae (8.6%), Bignoniaceae (6.2%), Malpighiaceae (5.1%), Myrtaceae (4.6%), Rubiaceae (4.6%), Apocynaceae (3.8%), and Melastomataceae (3.2%). The family ranked first in

Table 1. List of vascular species found in the *cerrado* fragments of the municipality of Bauru, indicating family, species, synonyms, habit, other vegetation types of the municipality where the plants occur, voucher number at herbaria UNBA or JBMB, and collector number. Asterisks indicate the naturalized species. Key to habit: Climber = Climber, Epi. = Epiphyte, Hemiepi. = Hemiepiphyte, Herb = Herb, Palm = Palm, St = Shrub or tree, Vs = Vascular saprophyte, and Vh = Vascular hemiparasite. Key to other vegetation types: mssf = montane semideciduous seasonal forest, pfrf = permanently flooded riparian forest, and nfrf = non-flooded riparian forest.

FAMILY / SPECIES/ [SYNONIMS]	HABIT	OTHER VEGETATION TYPE	VOUCHER NUMBER	COLLECTOR NUMBER
ANACARDIACEAE				
Anacardium humile A.St.-Hil.	Herb		UNBA 5935	A.L. Giles 62
Lithraea molleoides (Vell.) Engl.	St	mssf	UNBA 5911	V. de L. Weiser 866
Tapirira guianensis Aubl.	St	mssf, pfrf, nfrf	UNBA 3900	O. Cavassan 390
ANEMIACEAE				
Anemia phyllitidis (L.) Sw.	Herb	mssf	UNBA 5962	A.G. Faraco s/n
Anemia villosa Humb. & Bonpl. ex Willd.	Herb	mssf	UNBA 3486	G.A. Nóbrega 65
ANNONACEAE				
Annona cacans Warm.	St	mssf	UNBA 5912	V. de L. Weiser 867
Annona coriacea Mart.	St	mssf	UNBA 4072	M.N. Rissi 89
Annona crassiflora Mart.	St		UNBA 5212	M.N. Rissi 152
Annona dioica A.St.-Hil.	St		UNBA 5936	A.L. Giles 63
Duguetia furfuracea (A.St.-Hil.) Saff.	St		UNBA 5862	A.L. Giles 26
Xylopia aromatica (Lam.) Mart.	St	mssf	JBMB 0209	V. de L. Weiser 291
APOCYNACEAE				
Aspidosperma cylindrocarpon Müll.Arg.	St	mssf	UNBA 5913	V. de L. Weiser 868
Aspidosperma tomentosum Mart.	St		UNBA 3909	O. Cavassan 342
Forsteronia glabrescens Müll.Arg.	Climber	mssf, nfrf	UNBA 5897	V. de L. Weiser 852
Forsteronia velloziana (A.DC.) Woodson	Climber		JBMB 0664	V. de L. Weiser 553
Himatanthus obovatus (Müll.Arg.) Woodson	St		JBMB 0483	V. de L. Weiser 382
Macroditassa adnata (E.Fourn.) Malme	Climber		JBMB 0709	V. de L. Weiser 600
Odontadenia lutea (Vell.) Markgr.	Climber		JBMB 0717	V. de L. Weiser 607
Oxypetalum appendiculatum Mart.	Climber	mssf	UNBA 0305	O. Cavassan 284
Peltastes peltatus (Vell.) Woodson (*)	Climber		UNBA 0389	O. Cavassan 389
Prestonia coalita (Vell.) Woodson	Climber	mssf, nfrf	JBMB 0811	V. de L. Weiser 680
Prestonia erecta (Malme) J.F.Morales [*Rhodocalyx rotundifolius* Müll.Arg.]	St		UNBA 3361	A.G. Faraco 38
Secondatia densiflora A.DC.	Climber	nfrf	UNBA 5346	B.M. Palma 84
Tabernaemontana catharinensis A.DC. [*Peschiera australis* (Müll.Arg.) Miers]	St	mssf, nfrf	UNBA 0509	M.H.O. Pinheiro 379
Temnadenia violacea (Vell.) Miers	Climber		JBMB 0478	V. de L. Weiser 377
ARALIACEAE				
Dendropanax cuneatus (DC.) Decne. & Planch.	St	mssf, pfrf	UNBA 3041	M.H.O. Pinheiro 361
Schefflera vinosa (Cham. & Schltdl.) Frodin & Fiaschi [*Didymopanax vinosus* (Cham. & Schltdl.) Marchal]	St	mssf	UNBA 3906	O. Cavassan 131
ARECACEAE				
Acrocomia aculeata (Jacq.) Lodd. ex Mart.	Palm	mssf, pfrf, nfrf	UNBA 3416	P.R. Genovez 21
Acrocomia hassleri (Barb.Rodr.) W.J.Hahn	Palm		UNBA 3419	P.R. Genovez 40
Allagoptera campestris (Mart.) Kuntze	Palm		UNBA 5875	A.L. Giles 39
Butia paraguayensis (Barb.Rodr.) L.H.Bailey	Palm		UNBA 3437	P.R. Genovez 10
Syagrus flexuosa (Mart.) Becc.	Palm	mssf	UNBA 3436	P.R. Genovez 16
Syagrus romanzoffiana (Cham.) Glassman	Palm	mssf, nfrf	UNBA 5927	V. de L. Weiser 882
ARISTOLOCHIACEAE				
Aristolochia esperanzae Kuntze	Climber		JBMB 0087	V. de L. Weiser 135
Aristolochia melastoma Silva Manso ex Duch.	Climber	mssf	JBMB 0465	V. de L. Weiser 364
ASTERACEAE				
Achyrocline satureioides (Lam.) DC.	St		UNBA 5800	A.L. Giles 1
Acilepidopsis echitifolia (Mart. ex DC.) H.Rob. [*Vernonia echitifolia* Mart. ex DC.]	St		UNBA 5802	A.L. Giles 3
Austroeupatorium inulifolium (Kunth) R.M.King & H.Rob. [*Eupatorium inulifolium* Kunth]	St		UNBA 5801	A.L. Giles 2
Baccharis caprariifolia DC.	St		UNBA 0279	M.H.O Pinheiro 821

Table 1. Continued.

FAMILY / SPECIES/ [SYNONIMS]	HABIT	OTHER VEGETATION TYPE	VOUCHER NUMBER	COLLECTOR NUMBER
Baccharis dracunculifolia DC.	St	mssf	UNBA 5881	A.L. Giles 45
Baccharis pseudotenuifolia Malag.	St		UNBA 4012	M.N. Rissi 56
Bidens segetum Mart. ex Colla	Herb	pfrf	UNBA 3891	M. Carboni 210
Chaptalia integerrima (Vell.) Burkart	Herb		UNBA 5809	A.L. Giles 10
Chromolaena cylindrocephala (Sch.Bip. ex Baker) R.M.King & H.Rob. [*Eupatorium cylindrocephalum* Sch.Bip. ex Baker]	St		UNBA 5891	A.L. Giles 55
Chromolaena squalida (DC.) R.M.King & H.Rob. [*Eupatorium squalidum* DC.]	St		UNBA 5804	A.L. Giles 5
Chromolaena laevigata (Lam.) R.M.King & H.Rob. [*Eupatorium laevigatum* Lam.]	St		UNBA 5890	A.L. Giles 54
Clibadium armanii (Balb.) Sch.Bip. ex O.E.Schulz (*)	St		UNBA 5892	A.L. Giles 56
Elephantopus micropappus Less.	St		UNBA 5811	A.L. Giles 12
Elephantopus mollis Kunth	Herb	pfrf	UNBA 5810	A.L. Giles 11
Gochnatia barrosii Cabrera	St		UNBA 1563	O. Cavassan 338
Gochnatia polymorpha (Less.) Cabrera	St	mssf	UNBA 5805	A.L. Giles 6
Gochnatia pulchra Cabrera	St		UNBA 1573	O. Cavassan 229
Lepidaploa acutiangula (Gardner) H.Rob. [*Vernonia acutangula* Gardner]	St		UNBA 5812	A.L. Giles 15
Lepidaploa cotoneaster (Willd. ex Spreng.) H.Rob.	St		UNBA 5893	A.L. Giles 57
Lepidaploa rufogrisea (A.St.-Hil.) H.Rob. [*Vernonia tricephala* Gardner]	St		UNBA 5807	A.L. Giles 8
Lepidaploa salzmannii (DC.) H.Rob. [*Vernonia salzmannii* DC.]	St		UNBA 5803	A.L. Giles 4
Lessingianthus bardanoides (Less.) H.Rob. [*Vernonia bardanoides* Less.]	St		UNBA 5889	A.L. Giles 53
Mikania campanulata Gardner	Climber	pfrf	JBMB 0628	V. de L. Weiser 597
Mikania cordifolia (L.f.) Willd.	Climber		JBMB 0037	V. de L. Weiser 85
Mikania hirsutissima DC.	Climber		UNBA 5898	V. de L. Weiser 853
Piptocarpha rotundifolia (Less.) Baker	St	mssf	UNBA 1498	O. Cavassan 537
Porophyllum ruderale (Jacq.) Cass.	St		UNBA 5808	A.L. Giles 9
Pterocaulon lanatum Kuntze	St		UNBA 5806	A.L. Giles 7
Tilesia baccata (L.) Pruski (*)	Herb		UNBA 5955	A.L. Giles 82
Vernonanthura brasiliana (L.) H.Rob.	St		UNBA 0263	M.H.O. Pinheiro 378
Vernonanthura membranacea (Gardner) H.Rob. [*Vernonia membranacea* Gardner]	St		UNBA 5887	A.L. Giles 51
Vernonia rubriramea Mart. ex DC.	St		UNBA 1106	M.H.O. Pinheiro 285
BIGNONIACEAE				
Adenocalymma peregrinum (Miers) L.G.Lohmann [*Memora peregrina* (Miers) Sandwith]	Climber		JBMB 0782	V. de L. Weiser 651
Amphilophium elongatum (Vahl) L.G.Lohmann [*Distictella elongata* (Vahl) Urb.]	Climber	mssf	JBMB 0475	V. de L. Weiser 374
Anemopaegma arvense (Vell.) Stellfeld ex de Souza	St		UNBA 5937	A.L. Giles 64
Cuspidaria floribunda (DC.) A.H.Gentry [*Adenocalymma floribundum* A.DC.]	Climber	mssf	JBMB 0076	V. de L. Weiser 124
Cuspidaria pulchra (Cham.) L.G.Lohmann [*Arrabidaea pulchra* (Cham.) Sandwith]	Climber	mssf	JBMB 0491	V. de L. Weiser 390
Cybistax antisyphilitica (Mart.) Mart.	St		UNBA 4043	M.N. Rissi 81
Dolichandra unguis-cati (L.) L.G.Lohmann [*Macfadyena unguis-cati* (L.) A.H.Gentry]	Climber	mssf	UNBA 5899	V. de L. Weiser 854
Fridericia chica (Bonpl.) L.G.Lohmann [*Arrabidaea chica* (Bonpl.) Verl.]	Climber		JBMB 0781	V. de L. Weiser 650
Fridericia craterophora (DC.) L.G.Lohmann [*Arrabidaea craterophora* (DC.) Bureau]	Climber	mssf	JBMB 0451	V. de L. Weiser 350
Fridericia platyphylla (Cham.) L.G.Lohmann [*Arrabidaea brachypoda* (DC.) Bureau]	St		JBMB 0454	V. de L. Weiser 353

Table 1. Continued.

FAMILY / SPECIES/ [SYNONIMS]	HABIT	OTHER VEGETATION TYPE	VOUCHER NUMBER	COLLECTOR NUMBER
Fridericia pulchella (Cham.) L.G.Lohmann [*Arrabidaea pulchella* (Cham.) Bureau]	Climber	mssf	UNBA 5900	V. de L. Weiser 855
Fridericia speciosa Mart.	Climber		UNBA 5932	V. de L. Weiser 887
Fridericia triplinervia (Mart. ex DC.) L.G.Lohmann [*Arrabidaea triplinervia* (Mart. ex DC.) Baill. ex Bureau]	Climber	mssf	JBMB 0453	V. de L. Weiser 352
Handroanthus ochraceus (Cham.) Mattos [*Tabebuia ochracea* (Cham.) Standl.]	St	mssf	UNBA 5938	A.L. Giles 65
Jacaranda decurrens Cham.	St		UNBA 5939	A.L. Giles 66
Jacaranda rufa Silva Manso	St		JBMB 0057	V. de L. Weiser 105
Mansoa difficilis (Cham.) Bureau & K.Schum.	Climber	mssf	UNBA 5901	V. de L. Weiser 856
Pyrostegia venusta (Ker Gawl.) Miers	Climber	mssf	JBMB 0014	V. de L. Weiser 62
Stizophyllum perforatum (Cham.) Miers	Climber		UNBA 5257	A.G. Faraco 161
Stizophyllum riparium (Kunth) Sandwith	Climber		JBMB 0071	V. de L. Weiser 119
Tabebuia aurea (Silva Manso) Benth. & Hook.f. ex S.Moore [*Tabebuia caraiba* (Mart.) Bureau]	St		UNBA 5940	A.L. Giles 67
Zeyheria montana Mart.	St		JBMB 0178	V. de L. Weiser 240
Zeyheria tuberculosa (Vell.) Bureau ex Verl.	St	mssf	UNBA 5914	V. de L. Weiser 869
BIXACEAE				
Cochlospermum regium (Schrank) Pilg.	St		UNBA 5240	J.A. Ribeiro 16
BORAGINACEAE				
Heliotropium transalpinum Vell.	Herb		UNBA 3040	M.H.O. Pinheiro 298
BROMELIACEAE				
Acanthostachys strobilacea (Schult. & Schult.f.) Klotzsch	Epi.	pfrf	UNBA 5356	S.A. Joanitti 2
Ananas ananassoides (Baker) L.B.Sm.	Herb		UNBA 5941	A.L. Giles 68
Billbergia zebrina (Herb.) Lindl.	Epi.		UNBA 5367	S.A. Joanitti 13
Bromelia antiacantha Bertol.	Herb		UNBA 5506	A.G. Faraco 370
Bromelia balansae Mez	Herb		UNBA 5942	A.L. Giles 69
Tillandsia loliacea Mart. ex Schult. & Schult.f.	Epi.		UNBA 5386	S.A. Joanitti 32
Tillandsia pohliana Mez	Epi.		UNBA 5370	S.A. Joanitti 16
Tillandsia recurvata (L.) L.	Epi.		UNBA 5360	S.A. Joanitti 6
Tillandsia tenuifolia L.	Epi.	pfrf	UNBA 5797	S.A. Joanitti 37
Tillandsia tricholepis Baker	Epi.		UNBA 5394	S.A. Joanitti 40
Tillandsia usneoides (L.) L.	Epi.	mssf, pfrf	UNBA 5933	V. de L. Weiser 888
BURSERACEAE				
Protium heptaphyllum (Aubl.) Marchand	St	mssf	UNBA 1568	O. Cavassan 325
CACTACEAE				
Cereus hildmannianus K.Schum.	St		UNBA 5943	A.L. Giles 70
Epiphyllum phyllanthus (L.) Haw.	Epi.		UNBA 5375	S.A. Joanitti 21
CALOPHYLLACEAE				
Kielmeyera coriacea Mart. & Zucc.	St	mssf	UNBA 5490	A.G. Faraco 312
Kielmeyera rubriflora Cambess.	St		UNBA 5001	M.N. Rissi 139
Kielmeyera variabilis Mart. & Zucc.	St		JBMB 0777	V. de L. Weiser 646
CANNABACEAE				
Celtis spinosa Spreng. [*Celtis pubescens* (Kunth) Spreng.]	St	mssf	UNBA 2231	M.H.O. Pinheiro 627
Trema micrantha (L.) Blume	St	mssf	UNBA 5958	A.L. Giles 85
CARYOCARACEAE				
Caryocar brasiliense Cambess.	St		UNBA 5657	M.N. Rissi 410
CELASTRACEAE				
Peritassa campestris (Cambess.) A.C.Sm.	Herb		UNBA 0083	O. Cavassan s/n
Plenckia populnea Reissek [*Austroplenckia populnea* (Reissek) Lundell]	St		UNBA 3600	M.N. Rissi 4
CHRYSOBALANACEAE				
Couepia grandiflora (Mart. & Zucc.) Benth. ex Hook.f.	St		UNBA 1565	O. Cavassan 309

Table 1. Continued.

FAMILY / SPECIES/ [SYNONIMS]	HABIT	OTHER VEGETATION TYPE	VOUCHER NUMBER	COLLECTOR NUMBER
Licania humilis Cham. & Schltdl.	St		UNBA 1285	O. Cavassan 500
COMBRETACEAE				
Terminalia argentea Mart.	St	mssf	JBMB 0774	V. de L. Weiser 643
Terminalia glabrescens Mart.	St	mssf	UNBA 1564	O. Cavassan 329
[*Terminalia brasiliensis* (Cambess. ex A.St.-Hil.) Eichler]				
COMMELINACEAE				
Tradescantia zebrina Heynh. (*)	Hemiepi.		UNBA 5359	S.A. Joanitti 5
CONNARACEAE				
Connarus suberosus Planch.	St	mssf	UNBA 1456	O. Cavassan 506
Rourea induta Planch. var. *induta*	St		UNBA 5883	A.L. Giles 47
CONVOLVULACEAE				
Ipomoea virgata Meisn.	Herb		JBMB 0812	V. de L. Weiser 681
Merremia dissecta (Jacq.) Hallier f.	Climber	mssf	JBMB 0458	V. de L. Weiser 357
CUNONIACEAE				
Lamanonia ternata Vell.	St	mssf	JBMB 0666	V. de L. Weiser 555
CYPERACEAE				
Rhynchospora exaltata Kunth	Herb		UNBA 5481	A.G. Faraco 374
DENNSTAEDTIACEAE				
Pteridium arachnoideum (Kaulf.) Maxon	Herb		UNBA 5944	A.L. Giles 71
[*Pteris arachnoidea* Kaulf.]				
DILLENIACEAE				
Curatella americana L.	St		UNBA 5492	A.G. Faraco 326
Davilla elliptica A.St.-Hil.	St		UNBA 5879	A.L. Giles 43
Davilla rugosa Poir.	Climber		JBMB 0012	V. de L. Weiser 60
Doliocarpus dentatus (Aubl.) Standl.	Climber	mssf, pfrf	JBMB 0041	V. de L. Weiser 89
EBENACEAE				
Diospyros hispida A.DC.	St		UNBA 5945	A.L. Giles 72
ERYTHROXYLACEAE				
Erythroxylum campestre A.St.-Hil.	St		UNBA 5495	A.G. Faraco 340
Erythroxylum cuneifolium (Mart.) O.E.Schulz	St		UNBA 0269	M.H.O. Pinheiro 543
Erythroxylum deciduum A.St.-Hil.	St		UNBA 5421	A.G. Faraco 101
Erythroxylum pelleterianum A.St.-Hil.	St	mssf	UNBA 3588	S.R. Christianini 18
Erythroxylum suberosum A.St.-Hil.	St		UNBA 0266	M.H.O. Pinheiro 463
Erythroxylum subracemosum Turcz.	St	mssf, pfrf	JBMB 0641	V. de L. Weiser 530
Erythroxylum tortuosum Mart.	St		UNBA 1455	O. Cavassan 507
EUPHORBIACEAE				
Actinostemon klotzschii (Didr.) Pax	St	mssf	JBMB 0217	V. de L. Weiser 302
[*Actinostemon concepcionis* (Chodat & Hassl.) Hochr.]				
Croton floribundus Spreng.	St	mssf	UNBA 5946	A.L. Giles 73
Manihot tripartita (Spreng.) Müll.Arg.	St		UNBA 5934	V. de L. Weiser 889
Sapium glandulosum (L.) Morong	St		UNBA 2250	M.H.O. Pinheiro 538
[*Sapium glandulatum* (Vell.) Pax]				
Sapium obovatum Klotzsch ex Müll.Arg.	St		UNBA 5915	V. de L. Weiser 870
FABACEAE				
Acosmium subelegans (Mohlenbr.) Yakovlev	St		UNBA 1310	O. Cavassan 400
Anadenanthera peregrina var. *falcata* (Benth.) Altschul	St		JBMB 0613	V. de L. Weiser 502
[*Anadenanthera falcata* (Benth.) Speg.]				
Andira humilis Mart. ex Benth.	St		UNBA 5947	A.L. Giles 74
Andira vermifuga Mart. ex Benth.	St		UNBA 5916	V. de L. Weiser 871
Bauhinia forficata Link	St	mssf	UNBA 2172	M. Carboni s/n
Bauhinia holophylla (Bong.) Steud.	St	mssf	JBMB 0611	V. de L. Weiser 500
Bauhinia ungulata L.	St		JBMB 0128	V. de L. Weiser 203
Bowdichia virgilioides Kunth	St		UNBA 1308	O. Cavassan 499
Camptosema ellipticum (Desv.) Burkart	St		JBMB 0036	V. de L. Weiser 84
Canavalia grandiflora Benth.	Climber	mssf	JBMB 0174	V. de L. Weiser 232

Table 1. Continued.

FAMILY / SPECIES/ [SYNONIMS]	HABIT	OTHER VEGETATION TYPE	VOUCHER NUMBER	COLLECTOR NUMBER
Clitoria falcata Lam.	Climber	mssf	UNBA 5903	V. de L. Weiser 858
Copaifera langsdorffii Desf.	St	mssf, nfrf	UNBA 1933	O. Cavassan 438
Crotalaria martiana subsp. *mohlenbrockii* (Windler & S. G.Skinner) Planchuelo	Herb		UNBA 5886	A.L. Giles 50
Dalbergia miscolobium Benth. [*Dalbergia violacea* (Vogel) Malme]	St	mssf	JBMB 0459	V. de L. Weiser 358
Dimorphandra mollis Benth.	St		UNBA 3609	M.N. Rissi 15
Diptychandra aurantiaca Tul.	St		UNBA 5219	M.N. Rissi 154
Enterolobium contortisiliquum (Vell.) Morong	St	mssf	UNBA 0966	O. Cavassan 2054
Enterolobium gummiferum (Mart.) J.F.Macbr.	St		JBMB 0633	V. de L. Weiser 522
Eriosema crinitum (Kunth) G.Don	Herb	mssf	UNBA 5502	A.G. Faraco 361
Hymenaea stigonocarpa Mart. ex Hayne	St		UNBA 5931	V. de L. Weiser 886
Inga affinis DC.	St	mssf	UNBA 5957	A.L. Giles 84
Inga marginata Willd.	St	mssf	UNBA 1116	M.H.O. Pinheiro 241
Machaerium acutifolium Vogel	St	mssf	UNBA 1311	O. Cavassan 419
Machaerium brasiliense Vogel	St	mssf	UNBA 5917	V. de L. Weiser 872
Macroptilium atropurpureum (Moc. & Sessé ex DC.) Urb. (*)	Climber		UNBA 5470	A.G. Faraco 87
Mimosa dolens Vell.	Herb		UNBA 5884	A.L. Giles 48
Plathymenia reticulata Benth.	St	mssf	UNBA 1307	O. Cavassan 216
Platypodium elegans Vogel	St	mssf	JBMB 0235	V. de L. Weiser 321
Pterodon emarginatus Vogel	St		UNBA 1470	O. Cavassan 532
Rhynchosia phaseoloides (Sw.) DC.	Climber	mssf, pfrf	UNBA 5904	V. de L. Weiser 859
Sclerolobium aureum (Tul.) Baill.	St		UNBA 3585	G.M. Marconato 3
Senna rugosa (G.Don) H.S.Irwin & Barneby	St		UNBA 5867	A.L. Giles 31
Senna silvestris (Vell.) H.S.Irwin & Barneby	St	mssf	JBMB 0098	V. de L. Weiser 146
Stryphnodendron adstringens (Mart.) Coville	St		UNBA 2240	M.H.O. Pinheiro 803
Stryphnodendron rotundifolium Mart.	St	mssf	JBMB 0467	V. de L. Weiser 366
Stylosanthes guianensis (Aubl.) Sw.	St	pfrf	UNBA 5880	A.L. Giles 44
Teramnus uncinatus (L.) Sw.	Climber	mssf	UNBA 5905	V. de L. Weiser 860
Vatairea macrocarpa (Benth.) Ducke	St		UNBA 5918	V. de L. Weiser 873
GENTIANACEAE				
Voyria aphylla (Jacq.) Pers.	Vs		UNBA 5443	A.G. Faraco 168
LACISTEMATACEAE				
Lacistema hasslerianum Chodat	St	mssf	UNBA 3678	S.R. Christianini 37
LAMIACEAE				
Aegiphila lhotskiana Cham.	St		UNBA 4055	M.N. Rissi 84
Aegiphila sellowiana Cham.	St	mssf	UNBA 0506	M.H.O. Pinheiro 329
Eriope crassipes Benth.	Herb		UNBA 5500	A.G. Faraco 358
LAURACEAE				
Ocotea corymbosa (Meisn.) Mez	St	mssf	UNBA 1400	O. Cavassan 429
Ocotea diospyrifolia (Meisn.) Mez	St		UNBA 3919	O. Cavassan 512
Ocotea minarum (Nees & Mart.) Mez	St	mssf	UNBA 0257	M.H.O. Pinheiro 297
Ocotea puberula (Rich.) Nees	St	mssf	JBMB 0701	V. de L. Weiser 591
Ocotea pulchella (Nees & Mart.) Mez	St	mssf	UNBA 3920	O. Cavassan 514
Ocotea velloziana (Meisn.) Mez	St	mssf	UNBA 5948	A.L. Giles 75
LOGANIACEAE				
Strychnos bicolor Progel	Climber		UNBA 5906	V. de L. Weiser 861
Strychnos pseudoquina A.St.-Hil.	St		JBMB 0052	V. de L. Weiser 100
LYTHRACEAE				
Lafoensia pacari A.St.-Hil.	St	mssf	UNBA 0252	M.H.O. Pinheiro 221
MALPIGHIACEAE				
Banisteriopsis anisandra (A.Juss.) B.Gates	Climber	mssf, nfrf	JBMB 0077	V. de L. Weiser 125
Banisteriopsis argyrophylla (A.Juss.) B.Gates	Climber	mssf	JBMB 0472	V. de L. Weiser 371
Banisteriopsis oxyclada (A.Juss.) B.Gates	Climber		JBMB 0119	V. de L. Weiser 175
Banisteriopsis stellaris (Griseb.) B.Gates	Climber		JBMB 0045	V. de L. Weiser 93

Table 1. Continued.

FAMILY / SPECIES/ [SYNONIMS]	HABIT	OTHER VEGETATION TYPE	VOUCHER NUMBER	COLLECTOR NUMBER
Banisteriopsis variabilis B.Gates	Climber		JBMB 0113	V. de L. Weiser 163
Byrsonima coccolobifolia Kunth	St	pfrf	UNBA 1287	O. Cavassan 549
Byrsonima crassa Nied.	St		UNBA 5949	A.L. Giles 76
Byrsonima crassifolia (L.) Kunth	St		UNBA 5929	V. de L. Weiser 884
Byrsonima intermedia A.Juss.	St		UNBA 1277	O. Cavassan 423
Byrsonima laxiflora Griseb.	St		JBMB 0438	V. de L. Weiser 337
Byrsonima pachyphylla A.Juss.	St		UNBA 1290	O. Cavassan 447
Byrsonima verbascifolia (L.) DC.	St		UNBA 1289	O. Cavassan 519
Diplopterys pubipetala (A.Juss.) W.R.Anderson & C.Davis	Climber	mssf	JBMB 0246	V. de L. Weiser 336
[*Banisteriopsis pubipetala* (A.Juss.) Cuatrec.]				
Heteropterys byrsonimifolia A.Juss.	St		UNBA 5661	M.N. Rissi 497
Heteropterys cochleosperma A.Juss.	Climber		UNBA 5255	A.G. Faraco 64
Heteropterys pteropetala A.Juss.	Climber		JBMB 0011	V. de L. Weiser 59
Heteropterys syringifolia Griseb.	Climber		UNBA 5907	V. de L. Weiser 862
Heteropterys umbellata A.Juss.	Climber		UNBA 5120	A.G. Guimarães 7
Mascagnia cordifolia (A.Juss.) Griseb.	Climber	mssf	JBMB 00751	V. de L. Weiser 621
MALVACEAE				
Eriotheca gracilipes (K.Schum.) A.Robyns	St	mssf	UNBA 1457	O. Cavassan 263
Guazuma ulmifolia Lam.	St	mssf	JBMB 0124	V. de L. Weiser 194
Helicteres brevispira A.St.-Hil.	St		UNBA 5453	A.G. Faraco 61
Helicteres sacarolha A.St.-Hil., A.Juss. & Cambess.	St		UNBA 5873	A.L. Giles 37
Luehea grandiflora Mart.	St	mssf	JBMB 0062	V. de L. Weiser 110
Pavonia biflora Fryxell	St		JBMB 0797	V. de L. Weiser 666
Pavonia garckeana Gürke	St		UNBA 5450	A.G. Faraco 58
Pavonia hexaphylla (S.Moore) Krapov.	St		JBMB 0038	V. de L. Weiser 86
Pavonia malacophylla (Link & Otto) Garcke	St	mssf	JBMB 0001	V. de L. Weiser 49
Pseudobombax longiflorum (Mart. & Zucc.) A.Robyns	St		JBMB 0188	V. de L. Weiser 256
MELASTOMATACEAE				
Acisanthera alsinaefolia (DC.) Triana	Herb		JBMB 0031	V. de L. Weiser 79
Leandra lacunosa Cogn.	St		UNBA 0261	M.H.O. Pinheiro 367
Miconia albicans (Sw.) Steud.	St	mssf	UNBA 1281	O. Cavassan 320
Miconia chamissois Naudin	St	mssf, pfrf	UNBA 0503	M.H.O. Pinheiro 268
Miconia fallax DC.	St		UNBA 4050	M.N. Rissi 77
Miconia langsdorffii Cogn.	St	mssf	UNBA 3911	M. Kubo 1
Miconia ligustroides (DC.) Naudin	St		UNBA 1279	O. Cavassan 324
Miconia rubiginosa (Bonpl.) DC.	St		UNBA 5045	M.N. Rissi 137
Miconia stenostachya DC.	St	mssf	UNBA 1280	O. Cavassan 331
Rhynchanthera dichotoma (Desr.) DC.	St	mssf	JBMB 0029	V. de L. Weiser 77
Tibouchina cerastifolia Cogn.	St		JBMB 0028	V. de L. Weiser 76
Tibouchina stenocarpa (DC.) Cogn.	St		JBMB 0486	V. de L. Weiser 385
MELIACEAE				
Cedrela fissilis Vell.	St	mssf	UNBA 5930	V. de L. Weiser 885
Trichilia pallida Sw.	St	mssf	JBMB 0626	V. de L. Weiser 515
MORACEAE				
Brosimum gaudichaudii Trécul	St	mssf	JBMB 0091	V. de L. Weiser 139
Brosimum guianense (Aubl.) Huber ex Ducke	St		UNBA 5919	V. de L. Weiser 874
Ficus citrifolia Mill.	St	mssf	JBMB 0650	V. de L. Weiser 539
[*Ficus guaranitica* Chodat]				
Ficus obtusifolia Kunth	St		UNBA 5424	A.G. Faraco 108
MYRTACEAE				
Calyptranthes concinna DC.	St	mssf	UNBA 5920	V. de L. Weiser 875
Campomanesia adamantium (Cambess.) O.Berg	St		UNBA 4025	L. Baggio 104
Campomanesia pubescens (Mart. ex DC.) O.Berg	St		UNBA 5215	J.A. Ribeiro 12
Eugenia aurata O.Berg	St	mssf	UNBA 1955	O. Cavassan 418

Table 1. Continued.

FAMILY / SPECIES/ [SYNONIMS]	HABIT	OTHER VEGETATION TYPE	VOUCHER NUMBER	COLLECTOR NUMBER
Eugenia bimarginata DC.	St		UNBA 5632	M.N. Rissi 209
Eugenia florida DC.	St	pfrf	UNBA 4053	M.N. Rissi 83
Eugenia hiemalis Cambess.	St		JBMB 0694	V. de L. Weiser 583
Eugenia punicifolia (Kunth) DC.	St		UNBA 5921	V. de L. Weiser 876
Eugenia uniflora L.	St		UNBA 5477	A.G. Faraco 99
Myrcia bella Cambess.	St		UNBA 3912	O. Cavassan 518
Myrcia guianensis (Aubl.) DC.	St		UNBA 1294	O. Cavassan 384
[*Myrcia lingua* (O.Berg) Mattos]				
Myrcia multiflora (Lam.) DC.	St	mssf	UNBA 5922	V. de L. Weiser 877
Myrcia tomentosa (Aubl.) DC.	St	mssf	JBMB 0079	V. de L. Weiser 127
Myrcia uberavensis O.Berg	St		JBMB 0585	V. de L. Weiser 474
Myrcia venulosa DC.	St	mssf	UNBA 5950	A.L. Giles 77
Psidium guajava L. (*)	St	mssf	UNBA 5959	A.L. Giles 86
Psidium guineense Sw.	St		JBMB 0768	V. de L. Weiser 637
NYCTAGINACEAE				
Guapira areolata (Heimerl) Lundell	St		UNBA 5923	V. de L. Weiser 878
Guapira graciliflora (Mart. ex J.A.Schmidt) Lundell	St		JBMB 0773	V. de L. Weiser 642
Guapira hirsuta (Choisy) Lundell	St	mssf	UNBA 2241	M.H.O. Pinheiro 209
Guapira noxia (Netto) Lundell	St		UNBA 3620	A.G. Guimarães 3
Guapira opposita (Vell.) Reitz	St	mssf	UNBA 4051	M.N. Rissi 79
OCHNACEAE				
Ouratea spectabilis (Mart. ex Engl.) Engl.	St		UNBA 1468	O. Cavassan 334
ONAGRACEAE				
Ludwigia elegans (Cambess.) H.Hara	St	nfrf	JBMB 0030	V. de L. Weiser 78
OPILIACEAE				
Agonandra excelsa Griseb.	St		UNBA 5928	V. de L. Weiser 883
ORCHIDACEAE				
Catasetum fimbriatum (C.Morren) Lindl.	Epi.		UNBA 5584	S.A. Joanitti 69
Epidendrum denticulatum Barb.Rodr.	Epi.		UNBA 5586	S.A. Joanitti 71
Oeceoclades maculata (Lindl.) Lindl. (*)	Herb	mssf	UNBA 5429	A.G. Faraco 113
Polystachya concreta (Jacq.) Garay & H.R.Sweet	Epi.		UNBA 5583	S.A. Joanitti 68
Prescottia stachyodes (Sw.) Lindl.	Herb		UNBA 5491	A.G. Faraco 315
Rodriguezia decora (Lem.) Rchb.f.	Epi.		UNBA 5585	S.A. Joanitti 70
PASSIFLORACEAE				
Passiflora alata Curtis	Climber		UNBA 5908	V. de L. Weiser 863
Passiflora cincinnata Mast.	Climber		JBMB 0470	V. de L. Weiser 369
Passiflora edulis Sims	Climber		UNBA 5902	V. de L. Weiser 857
Passiflora foetida L.	Climber		UNBA 5513	M.N. Rissi 160
Passiflora miersii Mast.	Climber	mssf	JBMB 0227	V. de L. Weiser 312
Passiflora pohlii Mast.	Climber		JBMB 0086	V. de L. Weiser 134
Passiflora suberosa L.	Climber	mssf	UNBA 5909	V. de L. Weiser 864
PERACEAE				
Pera glabrata (Schott) Poepp. ex Baill.	St		UNBA 1286	O. Cavassan 314
[*Pera obovata* (Klotzsch) Baill.]				
PIPERACEAE				
Piper cuyabanum C.DC.	St	mssf	UNBA 2271	M.H.O. Pinheiro 640
POACEAE				
Brachiaria decumbens Stapf (*)	Herb		UNBA 5951	A.L. Giles 78
Ichnanthus pallens (Sw.) Munro ex Benth.	Herb		UNBA 5482	A.G. Faraco 213
Imperata brasiliensis Trin.	Herb		UNBA 5960	A.L. Giles 87
POLYGALACEAE				
Bredemeyera floribunda Willd.	St	mssf	UNBA 5924	V. de L. Weiser 879
Securidaca divaricata Nees & Mart.	Climber		JBMB 0638	V. de L. Weiser 527
[*Securidaca rivinifolia* A.St.-Hil.]				
POLYGONACEAE				
Coccoloba mollis Casar.	St	mssf	UNBA 4021	M.N. Rissi 61

Table 1. Continued.

FAMILY / SPECIES/ [SYNONIMS]	HABIT	OTHER VEGETATION TYPE	VOUCHER NUMBER	COLLECTOR NUMBER
POLYPODIACEAE				
Microgramma lindbergii (Mett. ex Kuhn) de la Sota [*Polypodium lindbergii* Mett. ex Kuhn]	Epi.		UNBA 5798	S.A. Joanitti 1
Microgramma squamulosa (Kaulf.) de la Sota [*Polypodium squamulosum* Kaulf.]	Epi.	mssf, pfrf	UNBA 5580	S.A. Joanitti 65
Pleopeltis hirsutissima (Raddi) de la Sota [*Polypodium hirsutissimum* Raddi]	Epi.		UNBA 5963	A.G. Faraco 189
Pleopeltis pleopeltifolia (Raddi) Alston [*Polypodium pleopeltifolium* Raddi]	Epi.	mssf, pfrf	UNBA 5363	S.A. Joanitti 9
Pleopeltis polypodioides (L.) E.G.Andrews & Windham	Epi.	pfrf	UNBA 5418	S.A. Joanitti 64
Polypodium chnoophorum Kunze	Epi.		UNBA 5582	S.A. Joanitti 67
Serpocaulon catharinae (Langsd. & Fisch.) A.R.Sm. [*Polypodium catharinae* Langsd. & Fisch.]	Epi.		UNBA 5581	S.A. Joanitti 66
Serpocaulon latipes (Langsd. & L.Fisch.) A.R.Sm. [*Polypodium latipes* Langsd. & L.Fisch.]	Epi.		UNBA 3490	G.A. Nóbrega 43
Serpocaulon vacillans (Link) A.R.Sm. [*Polypodium vacillans* Link]	Herb		UNBA 3392	G.A. Nóbrega 4
PRIMULACEAE				
Ardisia ambigua Mart.	St	mssf, pfrf	UNBA 3782	M. Carboni 233
Myrsine guianensis (Aubl.) Kuntze [*Rapanea guianensis* Aubl.]	St	pfrf	UNBA 5227	B.M. Palma 27
Myrsine umbellata Mart. [*Rapanea umbellata* (Mart.) Mez]	St	mssf	UNBA 1283	O. Cavassan 211
PROTEACEAE				
Roupala montana Aubl.	St	mssf	UNBA 2230	M.H.O. Pinheiro 487
Roupala montana var. *paraensis* (Huber) K.S.Edwards [*Roupala brasiliensis* Klotzsch]	St	mssf	JBMB 0123	V. de L. Weiser 191
PTERIDACEAE				
Adiantum serratodentatum Humb. & Bonpl. ex Willd.	Herb	mssf	UNBA 3484	G.A. Nóbrega 19
RHAMNACEAE				
Gouania latifolia Reissek	Climber	mssf	JBMB 0469	V. de L. Weiser 368
Rhamnidium elaeocarpum Reissek	St	mssf	UNBA 5952	A.L. Giles 79
ROSACEAE				
Prunus sellowii Koehne	St		UNBA 5047	J.C. Peres 4
RUBIACEAE				
Amaioua intermedia Mart. ex Schult. & Schult.f.	St	mssf	UNBA 1305	O. Cavassan 517
Chiococca alba (L.) Hitchc.	Climber	mssf	JBMB 0094	V. de L. Weiser 142
Chomelia pohliana Müll.Arg.	St	mssf	UNBA 5961	A.L. Giles 88
Coccocypselum lanceolatum (Ruiz & Pav.) Pers.	Herb	pfrf	UNBA 5435	A.G. Faraco 142
Cordiera sessilis (Vell.) Kuntze [*Alibertia sessilis* (Vell.) K.Schum.]	St	mssf	UNBA 3918	O. Cavassan 330
Coussarea hydrangeifolia (Benth.) Benth. & Hook.f. ex Müll.Arg.	St	mssf	UNBA 1302	O. Cavassan 544
Faramea montevidensis (Cham. & Schltdl.) DC.	St	mssf	JBMB 0643	V. de L. Weiser 532
Guettarda viburnoides Cham. & Schltdl.	St	mssf	UNBA 0415	O. Cavassan 415
Ixora gardneriana Benth.	St	mssf	JBMB 0445	V. de L. Weiser 344
Manettia cordifolia Mart.	St	mssf	JBMB 0460	V. de L. Weiser 359
Palicourea rigida Kunth	St		UNBA 5425	A.G. Faraco 109
Psychotria capitata Ruiz & Pav.	St	mssf	UNBA 5163	S.R. Christianini 30
Psychotria carthagenensis Jacq.	St	mssf, pfrf	JBMB 0622	V. de L. Weiser 511
Psychotria hoffmannseggiana (Willd. & Schult.) Müll.Arg.	St	mssf	UNBA 5426	A.G. Faraco 111
Rudgea jasminoides (Cham.) Müll.Arg.	St	mssf	UNBA 5925	V. de L. Weiser 880
Rudgea viburnoides (Cham.) Benth.	St	mssf	JBMB 0207	V. de L. Weiser 288
Tocoyena formosa (Cham. & Schltdl.) K.Schum.	St	mssf	JBMB 0471	V. de L. Weiser 370

Table 1. Continued.

FAMILY / SPECIES/ [SYNONIMS]	HABIT	OTHER VEGETATION TYPE	VOUCHER NUMBER	COLLECTOR NUMBER
RUTACEAE				
Zanthoxylum rhoifolium Lam.	St	mssf	JBMB 0746	V. de L. Weiser 616
Zanthoxylum riedelianum Engl.	St	mssf	UNBA 5953	A.L. Giles 80
SALICACEAE				
Casearia sylvestris Sw.	St	mssf	UNBA 5871	A.L. Giles 35
SANTALACEAE				
Phoradendron crassifolium (Pohl ex DC.) Eichler	Vh		UNBA 5964	A.G. Faraco s/n
Phoradendron piperoides (Kunth) Trel.	Vh	pfrf	UNBA 3740	M. Carboni 221
SAPINDACEAE				
Matayba elaeagnoides Radlk.	St	mssf	UNBA 5538	M.N. Rissi 334
Serjania caracasana (Jacq.) Willd.	Climber		UNBA 5271	A.G. Faraco 331
Serjania erecta Radlk.	St		UNBA 5178	L. Baggio 96
Serjania gracilis Radlk.	Climber		UNBA 5910	V. de L. Weiser 865
Serjania lethalis A.St.-Hil.	Climber	mssf	JBMB 0053	V. de L. Weiser 101
Serjania reticulata Cambess.	Climber	mssf	JBMB 0479	V. de L. Weiser 378
SAPOTACEAE				
Chrysophyllum marginatum (Hook. & Arn.) Radlk.	St	mssf	UNBA 5926	V. de L. Weiser 881
Pouteria ramiflora (Mart.) Radlk.	St		UNBA 1301	O. Cavassan 313
SIPARUNACEAE				
Siparuna guianensis Aubl.	St	mssf, pfrf	UNBA 1282	O. Cavassan 535
SMILACACEAE				
Smilax campestris Griseb.	Climber	mssf	JBMB 0743	V. de L. Weiser 613
Smilax fluminensis Steud.	Climber	mssf	JBMB 0750	V. de L. Weiser 620
Smilax polyantha Griseb.	Climber	mssf	JBMB 0749	V. de L. Weiser 619
SOLANACEAE				
Cestrum mariquitense Kunth	St	mssf	UNBA 2252	M.H.O. Pinheiro 136
Cestrum pedicellatum Sendtn.	St		UNBA 5454	A.G. Faraco 66
Solanum erianthum D.Don	St		UNBA 5046	J.C. Peres 3
Solanum hazenii Britton	St	mssf	UNBA 3031	M.H.O. Pinheiro 229
Solanum lycocarpum A.St.-Hil.	St	mssf	UNBA 5956	A.L. Giles 83
Solanum paniculatum L.	St	mssf	UNBA 4045	M.N. Rissi 82
Solanum variabile Mart.	St		UNBA 5452	A.G. Faraco 60
STYRACACEAE				
Styrax camporum Pohl	St	mssf	UNBA 5877	A.L. Giles 41
Styrax ferrugineus Nees & Mart.	St		UNBA 1299	O. Cavassan 475
SYMPLOCACEAE				
Symplocos nitens (Pohl) Benth.var. *nitens*	St	pfrf	UNBA 0793	V. de L. Weiser 662
Symplocos pubescens Klotzsch ex Benth.	St	mssf	JBMB 0657	V. de L. Weiser 546
THELYPTERIDACEAE				
Thelypteris hispidula (Decne.) C.F.Reed	Herb	mssf, pfrf, nfrf	UNBA 3386	G.A. Nóbrega 60
Thelypteris serrata (Cav.) Alston	Climber	mssf, pfrf	UNBA 3389	G.A. Nóbrega 30
THYMELAEACEAE				
Daphnopsis utilis Warm.	St		UNBA 5444	A.G. Faraco 169
URTICACEAE				
Cecropia pachystachya Trécul	St	mssf, pfrf	UNBA 5479	A.G. Faraco 172
VERBENACEAE				
Aloysia virgata (Ruiz & Pav.) Juss.	St	mssf	UNBA 5954	A.L. Giles 81
Lantana camara L.	St	mssf	UNBA 5896	A.L. Giles 60
Lantana fucata Lindl.	Herb		UNBA 5894	A.L. Giles 58
Lantana hypoleuca Briq.	St	mssf	UNBA 2278	M.H.O. Pinheiro 119
Lippia lasiocalycina Cham.	St		UNBA 5813	A.L. Giles 21
Lippia lupulina Cham.	St		UNBA 5499	A.G. Faraco 356
Lippia origanoides Kunth	Herb		UNBA 5895	A.L. Giles 59
Stachytarpheta cayennensis (Rich.) Vahl	Herb		UNBA 5427	A.G. Faraco 112
VIOLACEAE				
Anchietea pyrifolia (Mart.) G.Don var. *pyrifolia*	Climber	mssf	JBMB 0742	V. de L. Weiser 612

Table 1. Continued.

FAMILY / SPECIES/ [SYNONIMS]	HABIT	OTHER VEGETATION TYPE	VOUCHER NUMBER	COLLECTOR NUMBER
VITACEAE				
Cissus erosa Rich.	Climber	mssf	JBMB 0241	V. de L. Weiser 331
VOCHYSIACEAE				
Qualea cordata Spreng.	St	mssf	UNBA 1119	M.H.O. Pinheiro 186
Qualea grandiflora Mart.	St	mssf	JBMB 0100	V. de L. Weiser 148
Qualea multiflora Mart.	St	mssf	UNBA 1296	O. Cavassan 415
Qualea parviflora Mart.	St		JBMB 0084	V. de L. Weiser 132
Vochysia cinnamomea Pohl	St		UNBA 1295	O. Cavassan 449
Vochysia tucanorum Mart.	St	mssf	UNBA 1937	O. Cavassan 533

our table agrees with Brasil et al.'s research (2010) on the *cerrado* flora of São Paulo. Fabaceae and Asteraceae have also been recognized by Warming (1908) as the most species-rich in the *cerrado* in Lagoa Santa. Warming recorded the highest number of species in Asteraceae, taking into account that the formation studied was predominantly of grasslands, with forest formations located in valleys. Considering the Brazilian flora as a whole, Fabaceae is also the richest, represented by 3,200 species (Giulietti et al. 2005). Bromeliaceae, the ninth in the list, with 11 species (3.0%), is the only new item in our list when compared to other studies. Its inclusion is justified by the addition of epiphytes, rarely sampled in other floristic surveys.

Considering Bauru's geographic position, in the intermediate zone between tropical and southern temperate climates, the comparison carried out shows that, regarding species number per family, there are no differences between this vegetation and the *cerrado* of the core area.

Concerning their inclusion in the "Official list of plant species of the state of São Paulo threatened with extinction", published in Resolution 48 of the State Environment Department on September 21, 2004 (São Paulo 2004), two species (*Acrocomia hassleri* (Barb.Rodr.) W.J.Hahn and *Psychotria capitata* Ruiz & Pav.) are classified as "endangered", three (*Bowdichia virgilioides* Kunth, *Pavonia biflora* Fryxell, and *Pavonia hexaphylla* (S.Moore) Krapov.) as "vulnerable", and one (*Strychnos bicolor* Progel) as "critically endangered". According to the Red Book of the Brazilian Flora (Martinelli & Moraes 2013), one species (*Anemopaegma arvense* (Vell.) Stellfeld ex de Souza) is endangered and two species (*Zeyheria tuberculosa* (Vell.) Bureau ex Verl. and *Cedrela fissilis* Vell.) are vulnerable. In addition, four non-threatened species (*Caryocar brasiliense* Cambess., *Bowdichia virgilioides* Kunth, *Plathymenia reticulata* Benth. and *Voyria aphylla* (Jacq.) Pers.) were considered to be of concern to research and conservation for their economic value and for being in actual or expected decline (Martinelli & Moraes 2013).

Concerning habit, shrub or tree species were the most sampled (64.7%), followed by climbers (18.3%) and herbs (8.6%). This result demonstrates that, although shrub or tree species are better represented in number, plants with other habits investigated contribute significantly to determine diversity in that vegetation.

We can see that 363 species were considered as native and eight as naturalized (Table 1). These species occur naturally in *cerrado* environments and reproduce without human intervention. However, their aggressiveness in the occupation of new areas was not assessed. Based on our fieldwork experience, we observed that *Brachiaria decumbens* Stapf has a high invasive potential, both vegetatively and by seeds, as long as the environment is sunny. In this case, we might as well consider it an invasive species that competes fiercely with native species in the sub-shrub herbaceous stratum (Pivello et al. 1999) and alters the dynamics of *cerrado* ecosystems.

On the other hand, the terrestrial orchid *Oeceoclades maculata* (Lindl.) Lindl. is frequent in the litter of *cerradões*, always in shaded environments. This species has also been observed in the same environment in montane semideciduous seasonal forests of Bauru and does not seem to show the same invasive signs as the species mentioned above.

We observed that 53.6% species were seen only in the *cerrado*, which suggests they are exclusive of this vegetation type in the Bauru region. Therefore, these species are good indicators of the typical *cerrado* vegetation described by Durigan et al. (2012), who considered their survival limited in shaded environments. The others were also observed in other vegetation formations of the municipality, of which 36.4% occurred in montane semideciduous seasonal forests as well. According to the authors, this vegetation type is formed predominantly by generalist species with high ecological plasticity, able to survive in both sunny and shaded environments. However, we should consider that other factors, such as water deficit (Durigan et al. 2003, Siqueira & Durigan 2007), soil characteristics (Coutinho 1978, Ruggiero et al. 2002, Durigan et al. 2003, Siqueira & Durigan 2007, Pinheiro & Durigan 2009), and seral stages (Pinheiro & Durigan 2009) can interfere in their occurrence.

Therefore, this is an unprecedented list of tracheophyte species recorded in *cerrado* fragments in the municipality of Bauru, which we believe can be used as a reference in every effort to protect, modify, suppress, or restore that vegetation type. We observed the *cerrado* fragments under study host species that are also part of other *cerrado* communities in Brazil and are home to at least six species threatened with extinction in the state of São Paulo and three in the country as a whole.

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References

APG III. 2009. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. Bot. J. Linn. Soc. 161(2):105-121, http://dx.doi.org/10.1111/j.1095-8339.2009.00996.x.

BITENCOURT, M.D. 2004. Diagnóstico cartográfico dos remanescentes de cerrado em São Paulo. In Viabilidade de conservação dos remanescentes de cerrado no Estado de São Paulo (M.D. Bitencourt & R.R. Mendonça, orgs.). Annablume and Fapesp, São Paulo, p.17-28.

BRASIL, A.O., SOUZA, S.C.P.M. & CIELO-FILHO, R. 2010. Nomes populares da flora do cerrado paulista e a sua relação com família, hábito e fitofisionomia. IF Sér. Reg. 42:159-164.

CAVASSAN, O. 1990. Florística e fitossociologia da vegetação lenhosa de um hectare de cerrado do Parque Ecológico Municipal de Bauru (SP). Doctoral Dissertation, Universidade Estadual de Campinas, Campinas.

CAVASSAN, O. 2002. O cerrado do Estado de São Paulo. In Eugen Warming e o cerrado brasileiro: um século depois (A.L. Klein, org.). Editora da UNESP and Imprensa Oficial do Estado, São Paulo, p.93-106.

CAVASSAN, O. 2013. Bauru: terra de cerrado ou floresta? Ciênc. Geogr. 17(1): 45-53.

CAVASSAN, O., CESAR, O. & MARTINS, F.R. 1984. Fitossociologia da vegetação arbórea da reserva estadual de Bauru, Estado de São Paulo. Rev. Bras. Bot. 7(1):91-106.

CAVASSAN, O., PINHEIRO da SILVA, P.G & SENICIATO, T. 2006. O ensino de Ciências, a biodiversidade e o cerrado. In Divulgação científica e ensino de Ciências: estudos e experiências. (E.S.N.N. Araújo, J.J. Caluzi & A.M.A. Caldeira, orgs.). Escrituras Editora, São Paulo, p. 190-219. (Educação para Ciência, v. 7).

CHRISTIANINI, S.R. & CAVASSAN, O. 1998. O estrato herbáceo-subarbustivo de um fragmento de cerradão em Bauru - SP. Salusvita 17(1):9-16.

COUTINHO, L.M. 1978. O conceito de cerrado. Rev. Bras. Bot. 1(1):17-23.

COUTINHO, L.M. 2002. O bioma do cerrado. In Eugen Warming e o cerrado brasileiro: um século depois (A.L. Klein, org.). Editora da UNESP and Imprensa Oficial do Estado, São Paulo, p.77-91.

DURIGAN, G., FRANCO, G.A.D.C. & SIQUEIRA, M.F. 2004. A vegetação dos remanescentes de cerrado no Estado de São Paulo. In Viabilidade de conservação dos remanescentes de cerrado no Estado de São Paulo (M.D. Bitencourt & R.R. Mendonça, orgs.). Annablume and Fapesp, São Paulo, p.29-56.

DURIGAN, G., RAMOS, V.S., IVANAUSKAS, N.M. & FRANCO, G.A.D.C. 2012. Espécies indicadoras de fitofisionomias na transição Cerrado-Mata Atlântica no estado de São Paulo. SMA and CBRN, São Paulo.

DURIGAN, G., RATTER, J.A., BRIDGEWATER, S., SIQUEIRA, M.F. & FRANCO, G.A.D.C. 2003. Padrões fitogeográficos do cerrado paulista sob uma nova perspectiva regional. Hoehnea 30 (1):39-51.

EMÍDIO, C.P.O. 2014. Estações do ano. IPMet, Bauru. http://www.ipmet.unesp.br/4estacoes/ (last access on May 6, 2015).

FARACO, A.G. 2007. Composição florística e estrutura fitossociológica de uma área de cerrado pertencente ao Campus de Bauru da Universidade Estadual Paulista – UNESP, SP. Master's Thesis, Universidade Estadual Paulista, Botucatu.

FERRACINI, M.C., CAVASSAN, O. & FERLINI, R.F. 1983. Composição florística de uma área de cerrado no município de Bauru, SP. Salusvita 2(1):1-9.

GENOVEZ, P.R. 2007. Palmeiras ocorrentes em fragmentos remanescentes de vegetação nativa de Bauru e municípios vizinhos - São Paulo. Master's Thesis, Universidade Estadual Paulista, Botucatu.

GIULIETTI, A.M., HARLEY, R.M., QUEIROZ, L.P., WANDERLEY, M. das G.L. & VAN DEN BERG, C. 2005. Biodiversidade e conservação das plantas no Brasil. Megadiversidade 1(1):52-61.

IBGE – INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. 2012. Manual Técnico da Vegetação Brasileira. 2 ed. rev. e ampl. IBGE, Rio de Janeiro. (Manuais Técnicos em Geociências, v. 1).

JOANITTI, S.A. 2013. Epifitismo vascular em três formações vegetais distintas: mata de brejo, floresta estacional semidecidual e cerradão, pertencentes ao município de Bauru, Estado de São Paulo. Master's Thesis, Universidade Estadual Paulista, Botucatu.

KOCH, I. 1994. Caracterização taxonômica dos representantes da família Apocynaceae na região de Bauru - SP. Master's Thesis, Universidade Estadual de Campinas, Campinas.

KOCH, I. & KINOSHITA, L.S. 1999. As Apocynaceae *s. str*. da região de Bauru, São Paulo, Brasil. Acta Bot. Bras. 13(1):61-86.

KOEPPEN, W. 1948. Climatología. Fondo de Cult. Economica, Mexico.

LISTA DE ESPÉCIES DA FLORA DO BRASIL 2013. Jardim Botânico do Rio de Janeiro. http://floradobrasil.jbrj.gov.br (last access on December 18, 2014).

MARTINELLI, G. & MORAES, M.A. 2013. Livro vermelho da flora do Brasil. Andrea Jakobsson/Instituto de Pesquisas Jardim Botânico do Rio de Janeiro, Rio de Janeiro.

MORO, M.F., SOUZA, V.C., OLIVEIRA-FILHO, A.T., QUEIROZ, L.P., FRAGA, C.N., RODAL, M.J.N., ARAÚJO, F.S. & MARTINS, F.R. 2012. Alienígenas na sala: o que fazer com espécies exóticas em trabalhos de taxonomia, florística e fitossociologia? Acta Bot. Bras. 26(4):991-999, http://dx.doi.org/10.1590/S0102-33062012000400029.

NÓBREGA, G.A. & PRADO, J. 2008. Pteridófitas da vegetação nativa do Jardim Botânico Municipal de Bauru, Estado de São Paulo, Brasil. Hoehnea 35(1):7-55, http://dx.doi.org/10.1590/S2236-89062008000100001.

PINHEIRO, E.S. & DURIGAN, G. 2009. Dinâmica espaço-temporal (1962-2006) das fitofisionomias em unidade de conservação do Cerrado no sudeste do Brasil. Rev. Bras. Bot. 32(3):441-454, http://dx.doi.org/10.1590/S0100-84042009000300005.

PINHEIRO, M.H.O. 2000. Levantamento florístico e fitossociológico da floresta estacional semidecídua do Jardim Botânico Municipal de Bauru, São Paulo. Master's Thesis, Universidade Estadual de Campinas, Campinas.

PINHEIRO, M.H.O. & MONTEIRO, R. 2006. Contribution of forest species to the floristic composition of a forested savanna in southeastern Brazil. Braz. Arch. Biol. Techn. 49(5):763-774.

PINHEIRO, M.H.O. & MONTEIRO, R. 2008. Florística de uma floresta estacional semidecidual, localizada em ecótono savânico-florestal, no município de Bauru, SP, Brasil. Acta Bot. Bras. 22(4): 1085-1094, http://dx.doi.org/10.1590/S0102-33062008000400019.

PIVELLO, V.R., SHIDA, C.N. & MEIRELLES, S.T. 1999. Alien grasses in Brazilian savannas: a threat to the biodiversity. Biodivers. Conserv. 8(9):1281-1294, http://dx.doi.org/10.1023/A:1008933305857.

RATTER, J.A. 2004. Prefácio. In Plantas do cerrado paulista: imagens de uma paisagem ameaçada (G. Durigan, J.B. Baitello, G.A.D.C. Franco & M.F. Siqueira, aut.). Páginas & Letras Editora e Gráfica, São Paulo, p.vii-viii.

RISSI, M.N. 2011. Regeneração natural de um fragmento de cerrado degradado com a formação de pastagens de braquiária (*Urochloa decumbens* (Stapf) R.D.Webster). Master's Thesis, Universidade Estadual Paulista, Botucatu.

RODRIGUES, R.R. 2000. Uma discussão nomenclatural das formações ciliares. In Matas ciliares: conservação e recuperação. (R.R. Rodrigues & H.F. Leitão-Filho, eds.). Editora da Universidade de São Paulo/Fapesp, São Paulo, p. 91-99.

RUGGIERO, P.G.C., BATALHA, M.A., PIVELLO, V.R. & MEIRELLES, S.T. 2002. Soil-vegetation relationships in cerrado (Brazilian savanna) and semideciduous forest, Southeastern Brazil. Plant. Ecol. 160(1):1-16, doi: http://dx.doi.org/10.1023/A:1015819219386.

SÃO PAULO (ESTADO). SECRETARIA DO MEIO AMBIENTE. 2004. Resolução SMA n° 48, de 21 de setembro de 2004. http:\\www.cetesb.sp.gov.br/licenciamento/legislaçao/resoluções/2004_Res_SMA_48.pdf (last access on August 23, 2013).

SIQUEIRA, M.F. & DURIGAN, G. 2007. Modelagem da distribuição geográfica de espécies lenhosas de cerrado no Estado de São Paulo. Rev. Bras. Bot. 30(2): 233-243, http://dx.doi.org/10.1590/S0100-84042007000200008.

SOUZA, V.C. & LORENZI, H. 2012. Botânica Sistemática: guia ilustrado para identificação das famílias de fanerógamas nativas e exóticas no Brasil, baseado em APG III. 3 ed. Instituto Plantarum, Nova Odessa.

SPECIESLINK 2014. http://www.splink.org.br (last access on December 18, 2014).

STEVENS, P.F. 2001 onwards. Angiosperm Phylogeny Website. Version 12. http://www.mobot.org/MOBOT/research/APweb/ (last access on August 23, 2013).

THE INTERNATIONAL PLANT NAMES INDEX 2012. Search Authors. Version 1. http://www.ipni.org (last access on August 23, 2013).

THE PLANT LIST 2010. Version 1. http://www.theplantlist.org (last access on August 23, 2013).

TROPICOS.ORG. MISSOURI BOTANICAL GARDEN 2013. http://www.tropicos.org (last access on August 23, 2013).

WARMING, E. 1908. Lagoa Santa: contribuição para a Geographia Phytobiologica. Imprensa Oficial do Estado de Minas Gerais, Belo Horizonte.

WEISER, V. de L. 2007. Árvores, arbustos e trepadeiras do cerradão do Jardim Botânico Municipal de Bauru, SP. Doctoral Dissertation, Universidade Estadual de Campinas, Campinas.

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inventory

Anurans from the Middle Jaguaribe River Region, Ceará State, Northeastern Brazil

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Abstract: The Middle Jaguaribe River region is a poorly sampled area in the Caatingas domain, located in the eastern Ceará State, northeastern Brazil. The Brazilian government agencies considered this region as a priority area for conservation and inventories. In order to fill this biodiversity knowledge gap, we conducted a ten-day rapid inventory of the anuran fauna from April 11 to 20, 2014, surveying different physiognomies of the region. We recorded 19 anuran species belonging to five families: Bufonidae (2), Hylidae (5), Leptodactylidae (9), Microhylidae (2) and Odontophrynidae (1). Most inventories of Caatinga amphibians published to date have been conducted inside protected areas and/or of high altitude (mesic areas known as "brejos de altitude"). The list we present herein contributes to the knowledge of lowland Caatinga sites outside protected areas. We discuss our results in light of taxonomic and geographic features of the anurans sampled.

Keywords: *Amphibians, Caatinga, semiarid, species list, biodiversity.*

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Resumo: A Região do Médio Rio Jaguaribe é uma área pobremente amostrada no domínio das Caatingas, localizada no leste do Estado do Ceará, Nordeste do Brasil. O Ministério do Meio Ambiente considera esta região como uma área prioritária para conservação e realização de inventários. Com o objetivo de preencher esta lacuna do conhecimento sobre a biodiversidade, nós conduzimos um inventário rápido da anurofauna de dez dias de 11 a 20 de Abril de 2014, amostrando diferentes fisionomias da região. Nós registramos 19 espécies de anfíbios anuros pertencentes a cinco famílias: Bufonidae (2), Hylidae (5), Leptodactylidae (9), Microhylidae (2) e Odontophrynidae (1). A maioria dos inventários de anfíbios na Caatinga publicados até o presente momento foram conduzidos em áreas de proteção e/ou de áreas de altitude (áreas mésicas conhecidas como “Brejos de Altitude”). A presente lista contribui para o conhecimento de áreas de baixada da Caatinga fora das áreas protegidas. Nós discutimos os resultados à luz de características taxonômicas e biogeográficas dos anuros amostrados.

Palavras-chave: *Anfíbios, Caatinga, semiárido, lista de espécies, biodiversidade.*

Introduction

The Caatingas morphoclimatic domain (Ab’Sáber 1977), despite being considered for a long time a low diversity region (Leal et al. 2003), has a high number of species for a semiarid region, and several endemic taxa (Albuquerque et al. 2012). This domain only occurs in the Brazilian territory, it is highly threatened by habitat loss and desertification (Tabarelli et al. 2003), and only 1% of its area is inside conservation units of integral protection (Leal et al. 2003). Furthermore, many places have been considered important for conservation based on meetings of scientists and policy makers, making such areas crucial for faunal inventories and future conservation efforts in the domain (e.g., MMA 2007, Melo et al. 2014). Some of these priority areas lie outside protected areas, and were selected based on several individual or combined parameters, such as the presence of endemic/endangered species, unique vegetation types or geomorphological formations, lack of biological knowledge, areas of endemism, and areas of high species richness (Tabarelli et al. 2003, Camardelli & Napoli 2012). Such areas that are under agriculture and deforestation pressure may serve as connecting corridors between protected areas, and may harbor undescribed, endemic and/or rare species.

Data on the distribution, taxonomy, and natural history of amphibians of the Caatingas domain are incipient, and a large subset of the domain is still subsampled (Camardelli & Napoli 2012, Borges-Leite et al. 2014). In addition, the effort for research in non-protected areas within the domain is quite inexpressive (e.g. Azarbe 1999, Vieira et al. 2007, Protázio et al. 2014). Only seven areas of the State of Ceará have published data on amphibian inventories (Borges-Nojosa & Cascon 2005, Borges-Nojosa 2007, Borges-Nojosa et al. 2010, Loebmann & Haddad 2010, Ribeiro et al. 2012, Borges-Leite et al. 2014), and most of these areas, despite being included within the Caatingas domain, do not harbour Caatinga vegetation sensu stricto (Ab'Sáber 2003), being in fact areas that are better characterized as Rain Forest and/or Cerrado enclaves, Coastal areas, or a mosaic of these.

Herein, we present the results of an amphibian survey conducted during the peak of the reproductive season in a Caatinga area in the Ceará State, northeastern Brazil. Our aim was to provide a list of amphibian species occurring in the area, making data available for conservation planning at the State and National levels.

Material and Methods

We conducted the fieldwork at the Middle Jaguaribe River region, Jaguaribe Municipality, eastern Ceará State (Figure 1). The Jaguaribe River Basin covers 72.440 Km^2 along 610 Km in the Ceará State, with its head at the Serra da Joaninha (Tauá Municipality) and its mouth at the coast of Aracati Municipality (Souza & Silva 2013). The study area is within the Caatingas morphoclimatic domain and it is characterized by typical Caatinga vegetation (Ab'Sáber 2003), containing physiognomies ranging from arboreal areas to open grass fields and rocky outcrops (Figure 2). Altitude ranged from 150 to 650 m above sea level, and local climate is Equatorial Savanna with dry winter (Aw) according Köppen-Geiger classification (Kottek et al. 2006). Mean annual temperature is 26.5°C, while mean annual precipitation is 905 mm with most rainfall concentrated from February to May (INMET).

Animals were registered during diurnal and nocturnal visual surveys at four localities in the municipality region, from April 11th to April 20th, 2014. We surveyed a wide variety of environments, including ponds, brooks, forest interior, temporary puddles, and other water bodies. These environments were sampled in four mainly sites in the Jaguaribe region: 1 = Mr. Alzir farm (shrubby Caatinga in a sloped area near to the Serra dos Bastiões with presence of temporary streams, temporary ponds and a small dam), 2 = Pond near to Santana's dam (permanent water body near to big dam within pastures and Caatinga fragments), 3 = Serra do Barro Vermelho (hill with temporary streams and temporary ponds within a forested Caatinga), 4 = Mr. Nogueirinha farm (a grassland area with shrubs spread in a Caatinga formation,

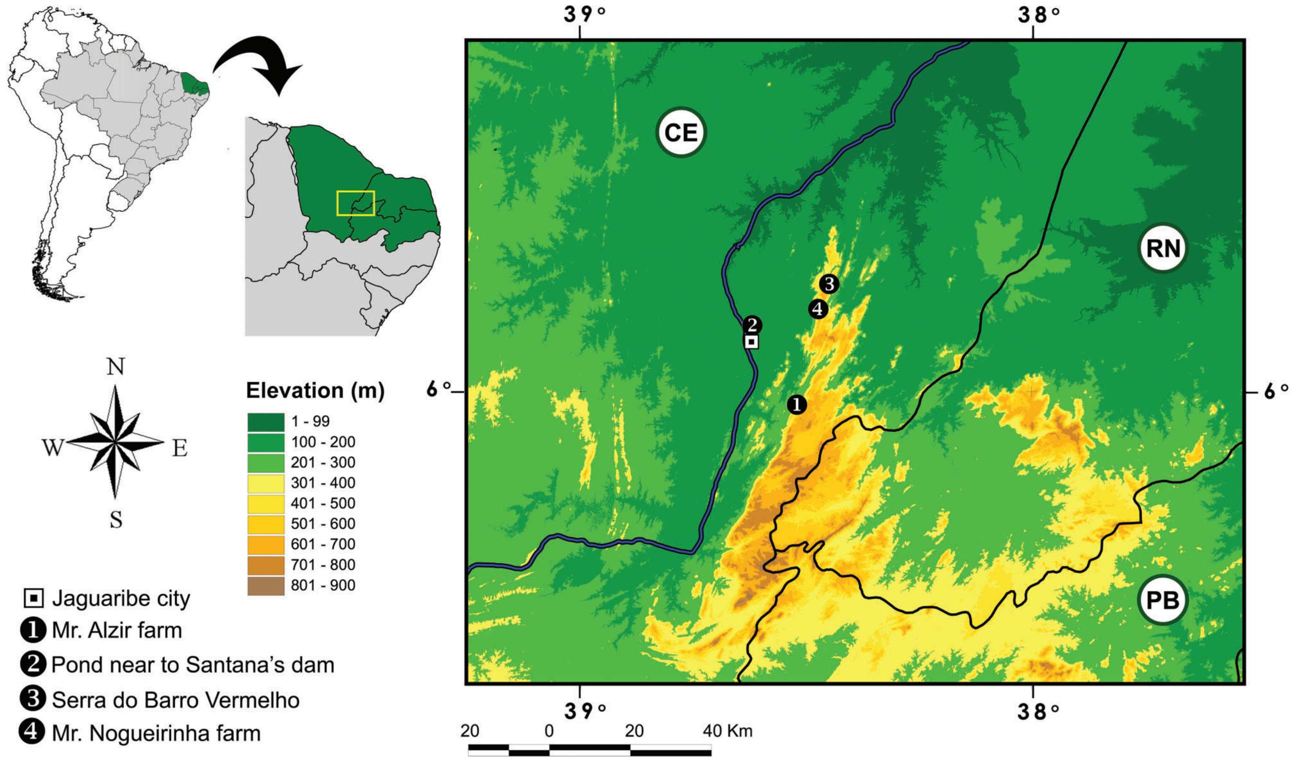

Figure 1. Map of the Region of the Middle Jaguaribe River. Survey sites: 1 = Mr. Alzir Farm; 2 = Pond Near to Santana Dam; 3 = Serra do Barro Vermelho; 4 = Mr. Nogueirinha Farm; square = City of Jaguaribe (CE = State of Ceará; PB = State of Paraíba; RN = State of Rio Grande do Norte).

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Figure 2. Landscapes in the Middle Jaguaribe River region, State of Ceará, northeastern Brazil, and some examples of sampled habitats: A = permanent pond in Serra do Barro Vermelho; B = Santana Dam near the survey site 2; C = temporary stream in a Caatinga area at Mr. Alzir Farm.

and with small temporary ponds). Each study site was surveyed by at least five researches simultaneously. Our field inventory methods followed the "Complete Species Inventories", "Visual Encounter Surveys", and "Audio Strip Transects" guidelines of Heyer et al. (1994).

Voucher specimens are deposited in the herpetological collection of "Laboratório de Anfíbios e Répteis" at "Universidade Federal do Rio Grande do Norte" (AAGARDA), and "Museu de Zoologia" at "Universidade Estadual de Feira de Santana" (MZFS) (Appendix 1). Collected license was issued by Instituto Chico Mendes de Conservação da Biodiversidade - ICMBio (license number 19828).

We perform an accumulation curve by using the individual-based (Gotelli & Colwell 2001), through 1000 randomizations of an abundance matrix where each column represents a species and each row represents one sampling site. We used species richness estimator Jacknife1 to determine the expected richness of amphibians (Colwell & Coddington 1994, Colwell 2009). This analysis was performed using EstimateS v.9.0.0 (Gotelli & Colwell 2001). We build graphs using Stata v.11 for Mac (©Stata Corp).

Results and discussion

We recorded nineteen anuran species in five families (Table 1, Figure 3) at the Middle Jaguaribe River region: Bufonidae (2), Hylidae (5), Leptodactylidae (9), Microhylidae (2) and Odontophrynidae (1). None of the recorded species is listed in the Brazilian list of endangered species or in IUCN red list (Brasil, 2014, 101 IUCN, 2014). In fact, most of them show wide geographic distributions and occur in two or more biomes (Ribeiro et al. 2012, Teixeira-Jr. et al. 2012, Magalhães et al. 2013, Magalhães et al. 2014, Cavalcanti et al. 2014, Silva et al. 2014).

Regarding the sampling effort, the accumulation curve tends to an asymptote after 267 individual sampled (Figure 4), with richness estimator Jacknife1 recovering 20 species. Despite the estimated richness based on the estimators suggesting one more species for the region, the sampling seems looks enough, reaching close its asymptote. Nevertheless, it is important to underscore that accumulation curves rarely stabilize, mainly in

Table 1. Anurans recorded at the Middle Jaguaribe River region, Ceará State, northeastern Brazil (period of sampling from April 11th to April 20th, 2014).

Family	Species
Bufonidae	*Rhinella granulosa* (Spix, 1824)
	Rhinella jimi (Stevaux, 2002)
Hylidae	*Corythomantis greeningi* (Boulenger, 1896)
	Dendropsophus nanus (Boulenger, 1889)
	Hypsiboas raniceps Cope, 1862
	Phyllomedusa nordestina Caramaschi, 2006
	Scinax x-signatus (Spix, 1824)
Leptodactylidae	*Leptodactylus fuscus* (Schneider, 1799)
	Leptodactylus macrosternum Miranda-Ribeiro, 1926
	Leptodactylus troglodytes Lutz, 1926
	Leptodactylus vastus Lutz, 1930
	Physalaemus albifrons (Spix, 1824)
	Physalaemus cicada Bokermann, 1966
	Physalaemus cuvieri Fitzinger, 1826
	Pleurodema diplolister (Peters, 1870)
	Pseudopaludicola pocoto Magalhães, Loebmann, Kokubum, Haddad, and Garda, 2014
Microhylidae	*Dermatonotus muelleri* (Boettger, 1885)
	Elachistocleis piauiensis Caramaschi & Jim, 1983
Odontophrynidae	*Proceratophrys cristiceps* (Müller, 1883)

Figure 3. Anurans registered at the Middle Jaguaribe River region, Ceará State, northeastern Brazil: A = R*hinella granulosa* (AAGARDA 10216); B = *Rhinella jimi* (AAGARDA 10292); C = *Corythomantis greening* (AAGARDA 10391); D = *Dendropsophus nanus* (AAGARDA 10276); E = *Hypsiboas raniceps* (AAGARDA 10404); F = *Phyllomedusa nordestina* (individual not collected).

tropical environments (Santos 2003). Although we carried our survey in the rainy season, some species of the Caatinga biome present explosive breeding behavior, coming out to breed few nights in a year (Duellman & Trueb 1986, Wells 1977), and these species (e.g. *Dermatonotus muelleri*, *Physalaemus cicada*, *Pleurodema diplolister* and *Proceratophrys cristiceps*) depend of specific rainy events. Nevertheless, we have recorded such species considered explosive breeding or opportunistic (Protázio et al. 2014).

Literature data on frog assemblages in Caatinga are scarce, and most of the studies conducted inside protected areas and/or at high altitude areas (Camardelli & Napoli 2012). In the state of Ceará, only seven amphibian species lists have been published (Borges-Leite et al. 2014). Four studies in high altitude areas: Chapada do Araripe Bioregion (Ribeiro et al. 2012), the Ibiapaba plateau, (Loebmann & Haddad 2010), Serra das Almas reserve (Borges-Nojosa & Cascon 2005) which also sampled areas of the reserve located in the "depressão sertaneja" with Caatinga vegetation *strictu sensu*, and Serra do Baturité (Borges-Nojosa 2007). Three studies were conducted in the lowland coastal region of the Ceará State: one in São Gonçalo do Amarante Municipality (Borges-Leite et al. 2014), and one was simultaneously carried in two sites in Caucaia and Pacajus municipalities (Borges-Nojosa et al. 2010). However,

Figure 3 (continued). Anurans registered at the Middle Jaguaribe River region, Ceará State, northeastern Brazil: G = *Scinax x-signatus* (AAGARDA 10241); H = *Leptodactylus fuscus* (AAGARDA 10336); I = *Leptodactylus macrosternum* (AAGARDA 10188); J = *Leptodactylus troglodytes* (AAGARDA 10282); K = *Leptodactylus vastus* (AAGARDA 10339); L = *Physalaemus albifrons* (AAGARDA 10254).

these spots are located in the northeastern region of the Ceará State – the most impacted area in the state by human activities – and also in close contact with coastal lowland regions.

Our inventory is the first study evaluating a nuclear area of the Caatingas domain in the Ceará State outside protected areas. All species sampled are present at least in one of the other seven species lists published for the state (Borges-Nojosa & Cascon 2005, Borges-Nojosa 2007, Borges-Nojosa et al. 2010, Loebmann & Haddad 2010, Ribeiro et al. 2012, Borges-Leite et al. 2014).

The species richness at the Jaguaribe Region (19 species) can be considered high for a semiarid *sensu stricto* Caatinga site. Betânia and Floresta sites in Pernambuco is the only another within Caatingas domain which have 19 species (Borges-Nojosa & Santos 2005). The other studies performed in the Caatingas domain have 18 or less: Boa Vista (9), Cabaceiras (18), São João do Cariri (16) and São José do Bonfim (16) municipalities in state of Paraíba, and municipality of Jacobina (17) in state of Bahia (Arzabe 1999, Protázio et al. 2014, Vieira et al. 2007, Xavier and Napoli 2011). Considering this high richness and lack of protected areas in eastern Ceará State, the region is considered important for the conservation of Caatinga anuran species.

Figure 3 (continued). Anurans registered at the Middle Jaguaribe River Region, Ceará State, northeastern Brazil: M = couple of *Physalaemus cicada* (AAGARDA); N = *Physalaemus cicada* (AAGARDA 10329); O = *Physalaemus cuvieri* (AAGARDA 10394); P = *Pleurodema diplolister* (AAGARDA 10349); Q = *Pseudopaludicola pocoto* (AAGARDA 10335); R = *Dermatonotus muelleri* (AAGARDA 10209). Anurans registered at the Middle Jaguaribe River region, Ceará State, northeastern Brazil: S = *Elachistocleis piauiensis* (AAGARDA 10251); T = *Proceratophrys cristiceps* (AAGARDA 10401).

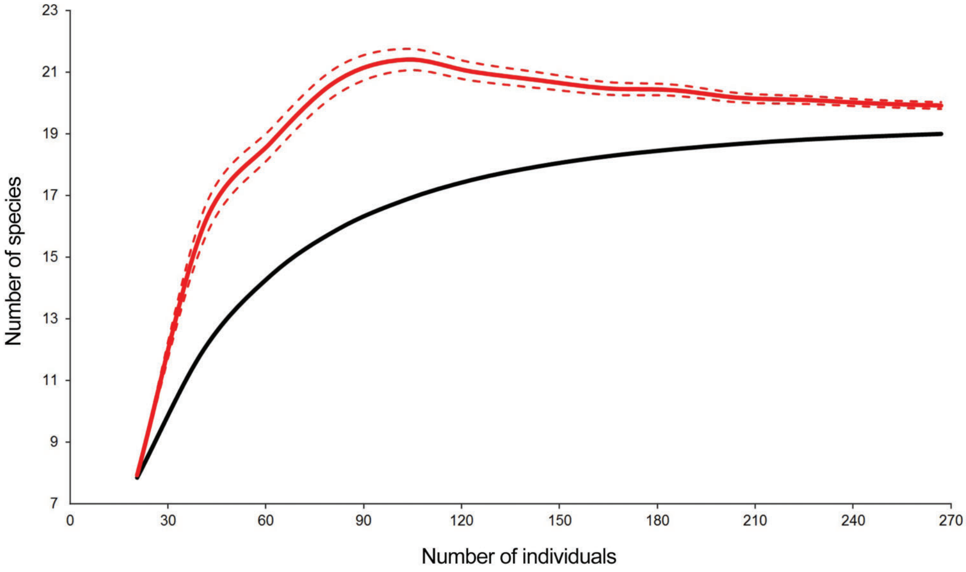

Figure 4. Accumulation curve for anurans sampled at the Middle Jaguaribe River region, Ceará State, northeastern Brazil (period of sampling from April 11th to April 20th, 2014). Black line represents the accumulation curves, red line represents species estimates based on Jacknife1 and red dashed lines represents its interval of confidence.

Appendix 1. Voucher specimens of amphibians collected at Middle Jaguaribe River Region, Ceará State, Northeastern Brazil.

Corythomantis greeningi – MZFS 4818-4822, AAGARDA 10174, AAGARDA 10289, AAGARDA 10391-10395; *Dendropsophus nanus* – MZFS 4806-4879, AAGARDA 10259-10262, AAGARDA 10264, AAGARDA 10266, AAGARDA 10276, AAGARDA 10280, AAGARDA 10296; *Dermatonotus muelleri* – MZFS 4849, AAGARDA 10209; *Elachistocleis piauienses* – AAGARDA 10251; *Hypsiboas raniceps* – AAGARDA 10269, AAGARDA 10404; *Leptodactylus fuscus* – MZFS 4823, AAGARDA 10336; *Leptodactylus macrosternum* – MZFS 4809-4817, MZFS 4851, AAGARDA 10180, AAGARDA 10182-10183, AAGARDA 10186-10189, AAGARDA 10320, AAGARDA 10372-10374, AAGARDA 10403; *Leptodactylus troglodytes* – MZFS 4824-4825, AAGARDA 10282-10283; *Leptodactylus vastus* – AAGARDA 10270, AAGARDA 10319, AAGARDA 10339, AAGARDA 10347; *Phyllomedusa nordestina* – MZFS 4782-4801, AAGARDA 10210-10212, AAGARDA 10252, AAGARDA 10272-10275, AAGARDA 10298-10299, AAGARDA 10302, AAGARDA 10304-10306, AAGARDA 10308, AAGARDA 10310-10311, AAGARDA 10314, AAGARDA 10316-10317, AAGARDA 10345; *Physalaemus albrifrons* – MZFS 4845-4853, AAGARDA 10190-10191, AAGARDA 10255, AAGARDA 10258, AAGARDA 10405; *Physalaemus cicada* – MZFS 4855-4864, AAGARDA 10332-10334, AAGARDA 10348, AAGARDA 10375, AAGARDA 10377-10381, AAGARDA 10397, AAGARDA 10406-10407; *Physalaemus cuvieri* – MZFS 4854, AAGARDA 10295; *Pleurodema diplolister* – MZFS 4892-4905, AAGARDA 10234-10238, AAGARDA 10349-10353, AAGARDA 10358-10359, AAGARDA 10362-10363; *Pseudopaludicola pocoto* – MZFS 4847-4848, MZFS 4865-4878, AAGARDA 10192-10197, AAGARDA 10199, AAGARDA 10201-10202, AAGARDA 10205-10207, AAGARDA 10385-10386, AAGARDA 10388-10389; *Proceratophrys cristiceps* – AAGARDA 10219, AAGARDA 10291, AAGARDA 10396, AAGARDA 10398-10402; *Rhinella granulosa* – MZFS 4826-4840, AAGARDA 10214-10215, AAGARDA 10220-10221, AAGARDA 10223, AAGARDA 10225-10229, AAGARDA 10231-10233, AAGARDA 10337, AAGARDA 10366, AAGARDA 10410-10411; *Rhinella jimi* – AAGARDA 10249, AAGARDA 10408-10409; *Scinax x-signatus* – MZFS 4802-4805, MZFS 4880-4891, AAGARDA 10239, AAGARDA 10241, AAGARDA 10243, AAGARDA 10245, AAGARDA 10247-10248, AAGARDA 10279, AAGARDA 10324-10326, AAGARDA 10338, AAGARDA 10346, AAGARDA 10367-10371

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References

AB'SÁBNER, A.N. 1977. Os domínios morfoclimáticos na América do Sul. Geomorfologia. 52:1-23.

AB'SÁBER, A.N. 2003. Os Domínios de Natureza no Brasil – Potencialidades Paisagísticas. Ateliê Editorial, São Paulo.

ALBUQUERQUE U.P., ARAÚJO, E.L., EL-DEIR, A.C.A., LIMA, A.L.A., SOUTO, A., BEZERRA, B.M., FERRAZ, E.M.N., FREIRE, E.M.X., SAMPAIO, E.V.S.B., LAS-CASAS, F.M.G., MOURA, G.J.B., PEREIRA, G.A., MELO, J.G., RAMOS, M.A., RODAL, M.J.N., SCHIEL, N., LYRA-NEVES, R.M., ALVES, R.R.N., AZEVEDO-JÚNIOR, S.M., TELINO JÚNIOR, W.R & SEVERI, W. 2012. Caatinga revisited: ecology and conser vation of an important seasonal dry forest. Sci. World J. 2012:1-18. http://dx.doi.org/10.1100/2012/205182

ARZABE, C. 1999. Reproductive activity patterns of anurans in two different altitudinal sites within the Brazilian Caatinga. Rev. Bras. Zool. 16(3):851-864. http://www.scielo.br/scielo.php?pid = S010181751999000300022&script = sci_arttext, http://dx.doi.org/10.1590/S0101-81751999000300022

BORGES-LEITE, M.J., RODRIGUES, J.F.M. & BORGES-NOJOSA, D.M. 2014. Herpetofauna of a coastal region of northeastern Brazil. Herpetol. Notes. 7:405-413. http://www.herpetologynotes.seh-herpetology.org/Volume7_PDFs/Borges_HerpetologyNotes_volume7_pp405-413.pdf

BORGES-NOJOSA, D.M. 2007. Diversidade de Anfíbios e Répteis da Serra de Baturité, Ceará. In: Diversidade e Conservação da Biota na Serra de Baturité, Ceará (Oliveira, T.S & Araújo, F.S., eds.). Edições UFC, Fortaleza, p.225-247.

BORGES-NOJOSA, D.M. & CASCON, P. 2005. Herpetofauna da Área Reserva da Serra das Almas, Ceará. In Análise das Variações da Biodiversidade do Bioma Caatinga. (Araújo, F.S., Rodal, M.J.N., & Barbosa, M.R.V., eds.). Ministério do Meio Ambiente, Brasília, p. 243-258.

BORGES-NOJOSA, D.M., PRADO, F.M.V., BORGES-LEITE, M.J., GURGEL-FILHO, N.M. & BACALINI, P. 2010. Avaliação do impacto do manejo florestal sustentável na herpetofauna de duas áreas de caatinga nos municípios de Caucaia e pacajus no Estado do Ceará. (Gariglio, M.A., Sampaio, E.V.S.B., Cestaro, L.A. & Kageyama, P.Y. eds.). Serviço Florestal Brasileiro, Brasília, p. 315-330.

BORGES-NOJOSA, D. M. & SANTOS, E M. 2005. Herpetofauna da Área de Betânia e Floresta, Pernambuco. In Análise das Variações da Biodiversidade do Bioma Caatinga. (Araújo, F.S., Rodal, M.J.N., & Barbosa, M.R.V., eds.). Ministério do Meio Ambiente, Brasília, p. 277-291.

BRASIL. MINISTÉRIO DO MEIO AMBIENTE. INSTITUTO CHICO MENDES DE CONSERVAÇÃO DA BIODIVERSIDADE. 2014. Lista nacional oficial de espécies da fauna ameaçadas de extinção. Diário Oficial da união. 245:121-126.

CAMARDELLI, M. & NAPOLI, M.F. 2012. Amphibian Conservation in the Caatinga Biome and Semiarid Region of Brazil. Herpetologica. 68:31-47. http://dx.doi.org/10.1655/HERPETOLOGICA-D-10-00033.1

CAVALCANTI, L.B.Q., COSTA, T.B., COLLI, G.R., COSTA, G.C., FRANÇA, F.G.R., MESQUITA, D.O., PALMEIRA, C.N.S., PELEGRIN, N., SOARES, A.H.B.S., TUCKER, D.B. & GARDA, A.A. 2014. Herpetofauna of protected areas in the Caatinga II: Serra da Capivara National Park, Piauí, Brazil. Check List 10(1):18-27. http://www.checklist.org.br/getpdf?SL042-13, http://dx.doi.org/10.15560/10.1.18

GOTELLI, N.J. & COLWELL, R.K. 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecol. Lett. 4:379-391. http://dx.doi.org/10.1046/j.1461-0248.2001.00230.x

HEYER, W.R., DONNELLY, M.A., MCDIARMID, R.W., HAYEK, L.A.C. & FOSTER, M.S. 1994. Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Biological Diversity Handbook Series. Stmithsonian Intitution Press. Washington.

INMET. Instituto Nacional de Meteorologia. www.inmet.gov.br (último acesso em 10/12/2014)

IUCN. The IUCN Red List of Threatened Species. Version 2014.3. www.iucnredlist.org. (último acesso em 10/12/2014)

KOTTEK, M., GRIESER, J., BECK, C., RUDOLF, B. & RUBEL, F. 2006. World map of the Köppen-Geiger climate classification updated. Meteorol. Z. 15:259-263. http://dx.doi.org/10.1127/0941-2948/2006/0130

LEAL, I.R., TABARELLI, M. & DA SILVA, J.M.C. 2003. Ecologia e conservação da Caatinga. Editora Universitária UFPE. Recife. http://www.mma.gov.br/estruturas/203/_arquivos/5_livro_ecologia_e_conservao_da_caatinga_203.pdf

LOEBMANN, D. & HADDAD, C.F.B. 2010. Amphibians and reptiles from a highly diverse area of the Caatinga domain: composition and conservation implications. Biota Neotropica. 10:227-256. http://dx.doi.org/10.1590/S1676-06032010000300026

MAGALHÃES, F.M., DANTAS, A.K.B.P., BRITO, M.R.M., MEDEIROS, P.H.S., OLIVEIRA, A.F., PEREIRA, T.C.S.O., QUEIROZ, M.H.C., SANTANA, D.J., SILVA, W.P. & GARDA, A.A. 2013. Anurans from an Atlantic Forest-Caatinga ecotone in Rio Grande do Norte State, Brazil. Herpetol. Notes 6:1-10. http://www.herpetologynotes.seh-herpetology.org/Volume6_PDFs/Magalhaes_Herpetology_Notes_Volume6_page1-10.pdf

MAGALHÃES, F.M., LOEBMANN, D., KOKUBUM, M.N.C., HADDAD, C.F.B. & GARDA, A.A. 2014. A New Species of *Pseudopaludicola* (Anura: Leptodactylidae: Leiuperinae) from Northeastern Brazil. Herpetologica 70:77-88. http://dx.doi.org/10.1655/HERPETOLOGICA-D-13-00054

MELO, F.P., SIQUEIRA, J.A., SANTOS, B.A., ÁLVARES-DA-SILVA, O., CEBALLOS, G. & BERNARD, E. 2014. Football and Biodiversity Conservation: FIFA and Brazil Can Still Hit a Green Goal. Biotropica. 46(3):257-259. http://dx.doi.org/10.1111/btp.12114

MMA - Ministério do Meio Ambiente. 2007. Áreas prioritárias para conservação, uso sustentável e repartição de benefícios da biodiversidade brasileira. Ministério do Meio Ambiente, Secretaria de Biodiversidade e Florestas, Distrito Federal.

PROTÁZIO, A.S., ALBUQUERQUE, R.L., FALKENBERG, L.M. & MESQUITA, D.O. 2014. Acoustic ecology of an anuran assemblage in the arid Caatinga of northeastern Brazil. J. Nat. Hist. 1-20. http://dx.doi.org/10.1080/00222933.2014.931482

RIBEIRO, S.C., ROBERTO, I.J., SALES, D.L., ÁVILA, R.W. & ALMEIDA, W.O. 2012. Amphibians and reptiles from the Araripe bioregion, northeastern Brazil. Salamandra. 48(3):133-146. http://www.salamandra-journal.com/index.php?option = com_docman&task = doc_download&gid = 292&Itemid = 74

SANTOS, A.J. 2003. Estimativa de riqueza em espécies (Cullen-Jr, L., Rudran, R. & Valladares-Padua, C. eds.). Editora da Univeraidade Federal do Paraná, Curitiba, p. 19-41.

SILVA, L.A., HOFFMANN, M.C. & SANTANA, D.J. 2014. New record of *Corythomantis greeningi* Boulenger, 1896 (Amphibia, Hylidae) in the Cerrado domain, state of Tocantins, Central Brazil. Herpetol. Notes. 7:717-720. http://biotaxa.org/hn/article/view/7932

SOUSA, A.B. & DA SILVA, D.F. 2013. Avaliação climática e dos recursos hídricos da bacia hidrográfica do Rio Jaguaribe. Rev. Bras. Geo. Fís. 6:1115-1140. http://www.revista.ufpe.br/rbgfe/index.php/revista/article/viewArticle/749

TABARELLI, M., SILVA, J.M.C. & LEAL, I.R. 2003. Áreas e ações prioritárias para a conservação da biodiversidade da Caatinga (Leal, I.R., Silva J.M.C. & Tabarelli, M. eds.). Editora Universitária UFPE. Recife, p. 777-796.

TEIXEIRA-JR, M., AMARO, R.C., RECODER, R.S., DAL VECHIO, F & RODRIGUES, M.T. 2012. A new dwarf species of *Proceratophrys* Miranda-Ribeiro, 1920 (Anura, Cycloramphidae) from the highlands of Chapada Diamantina, Bahia, Brazil. Zootaxa. 3551:25-42. http://www.mapress.com/zootaxa/2012/f/z03551p042f.pdf

VIEIRA, W.L.S., ARZABE, C. & SANTANA, G.G. 2007. Composição e distribuição espaço-temporal de anuros no Cariri paraibano, Nordeste do Brasil. Oecol. Brasil. 11(3): 383-396. http://www.oecologiaaustralis.org/ojs/index.php/oa/article/viewFile/198/125, http://dx.doi.org/10.4257/oeco

WELLS, K.D. 1977. The social behaviour of anuran amphibians. Anim. Behav. 25:666-693. http://dx.doi.org/10.1016/0003-3472(77)90118-X

XAVIER, A.L., NAPOLI, M.F. 2011. Contribution of environmental variables to anuran community structure in the Caatinga Domain of Brazil. Phyllomedusa. 10(1): 45-64. http://dx.doi.org/10.11606/issn.2316-9079.v10i1p45-64

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short communication

The current distribution pattern of *Biomphalaria tenagophila* and *Biomphalaria straminea* in the northern and southern regions of the coastal fluvial plain in the state of São Paulo

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Abstract: We analyze the current distribution of snails from genus *Biomphalaria* in the north and south of the coastal fluvial plain in the state of São Paulo, which is part of a large coastal floodplain. Data from twenty-nine collection sites confirmed that the freshwater body in both regions is colonized by *Biomphalaria tenagophila* and *Biomphalaria straminea*, which are natural intermediate hosts of *Schistosoma mansoni*. The abundance of *B. straminea* in collection sites where only *B. tenagophila* had previously been recorded indicates the potential for *B. straminea* to expand in the region. While quantitative analysis of the number of specimens per species showed that local growth of *B. tenagophila* populations occurs during periods with little rainfall, there is a greater risk of *B. tenagophila* populations spreading between different water bodies during rainy periods, when heavy rainfall results in water levels rising in the main rivers and flooding caused by water flowing from the *Serra do Mar* mountain range to the coastal plain. The temperature increase caused by global climate changes and the consequent increasing frequency of high-water levels and floods can be expected to affect the distribution of these snails on the coastal fluvial plain, leading to the risk of a change in the autochthonous transmission pattern of schistosomiasis in the region.

Keywords: *B. tenagophila, B. straminea, schistosomiasis, climate change*
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PALASIO, R.G.S., CASOTTI, M.O., RODRIGUES, T.C., MENEZES, R.M.T., ZANOTTI-MAGALHAES, E.M., TUAN, R. **Padrão atual de distribuição de *Biomphalaria tenagophila* e *Biomphalaria straminea* nos setores norte e sul da planície fluvial costeira do Estado de São Paulo, Brasil.** Biota Neotropica. 15(3): e20140153. http://dx.doi.org/10.1590/1676-06032015015314

Resumo: Neste trabalho analisamos a distribuição atual de caramujos do gênero *Biomphalaria* nos setores norte e sul da planície fluvial da costa litorânea de São Paulo. A região está inserida numa extensa planície costeira inundável. Os dados de 29 sítios de coletas confirmam que a coleção de água doce em ambos os setores é colonizada por *Biomphalaria tenagophila* e *Biompalaria straminea*. Ambas as espécies são hospedeiras intermediárias naturais do *Schistosoma mansoni*. A abundânciade *B. straminea* em sítios de coleta em que foram registrados recentemente apenas *B. tenagophila*, indica o potencial de expansão de *B. straminea* na região. A análise quantitativa de espécimes/espécie demonstra que o crescimento local das populações de *B. tenagophila* ocorre em períodos de baixa pluviosidade. Há maior risco de dispersão das populações de *B. tenagophila* entre diferentes coleções de água em períodos úmidos, quando a alta pluviosidade promove a cheia dos principais rios e inundações decorrentes do escoamento de água da Serra do Mar para a planície costeira. O aumento da temperatura causada por alterações climáticas globais, e consequentemente o aumento de cheias e inundações, deve interferir na distribuição dos caramujos na planície fluvial do litoral, com risco de alteração na transmissão autóctone da esquistossomose nesta região.

Palavras-chave: *B. tenagophila, B. straminea, esquistossomose, alteracoes climaticas*
Apoio Financeiro: CAPES, FAPESP 07/03458-7, SUCEN.

Introduction

This study investigates the distribution of species of the genus *Biomphalaria* Preston 1910 in the coastal region of the state of São Paulo, which is characterized by rocky coastlines and lower-lying areas consisting of plains cut by small rivers (Souza 2005) and valleys that are prone to flooding (Diegues et al. 2001). The region includes diversity hotspots, such as the Atlantic Forest (Carnaval 2009, Viadana & Cavalcanti 2006), intermingled with areas where the rural and urban landscape has undergone significant transformation as a result of the continual changes wrought by human activity (Souza & Souza 2004, Borelli 2008). It is an important and extensive distribution area for *Biomphalaria tenagophila* (d'Orbigny 1835) in the Neotropical region. This species continually colonizes freshwater bodies on the coastal plain, particularly in the valley of the Ribeira do Iguape river, along the northern coast and in the Santos lowlands (Piza 1972, Teles 1989). According to Vaz (1989), the coastal region is an important ancestral distribution area and dispersal center from which the species disperses to the São Paulo plateau and to valleys associated with the Paraíba do Sul river. In addition to *B. tenagophila*, *B. straminea* (Dunker 1848) colonizes isolated areas in the southern part of the coastal strip (Teles 2005). Both species are intermediate hosts of *Schistosoma mansoni*, the parasite responsible for transmitting schistosomiasis in Brazil.

Increasing temperatures, changes in rainfall patterns and extreme environmental perturbations caused by man-made climate changes (Parmesan 2006, Rockstrom et al. 2009, Rosenzweig et al. 2008) can affect the biodiversity of freshwater ecosystems directly (Heino et al. 2009) and have an impact on the distribution and dispersion of countless animal species (Nooten et al. 2014), including intermediate hosts associated with the transmission of schistosomiasis (McCreesh & Booth 2014). The success of public campaigns to promote the control of vectors and intermediate hosts of schistosomiasis will therefore depend in future on combining a knowledge of the biology of these snails with advance mapping of areas from which there is a potential risk of diseases being transmitted.

In the case of planorbid snails from the genus *Biomphalaria*, temperature, type of freshwater habitat (DE Kock et al. 2004) and mode of reproduction determine the geographic distribution of the species. As with other Basommatophora (Escobar 2011), *Biomphalaria* reproduces by a combination of self-fertilization and cross-fertilization, increasing its ability to colonize new habitats. *B. tenagophila* and *B. straminea* are also resistant to drought and can survive desiccation during periods without any water, when their metabolic activity is reduced to basal levels (Tuan & Simões 1989, Teles, & Marques 1989, Barbosa et al. 1985, Barbosa et al. 2014).

Modifications caused by climate change and anthropic activity, together with the colonization potential of *B. tenagophila* and *B. straminea*, may directly affect transmission of human schistosomiasis (Silva 1985, Borelli 2008). In the epidemiologic context, the results of the present study highlight the fundamental importance of malacological and

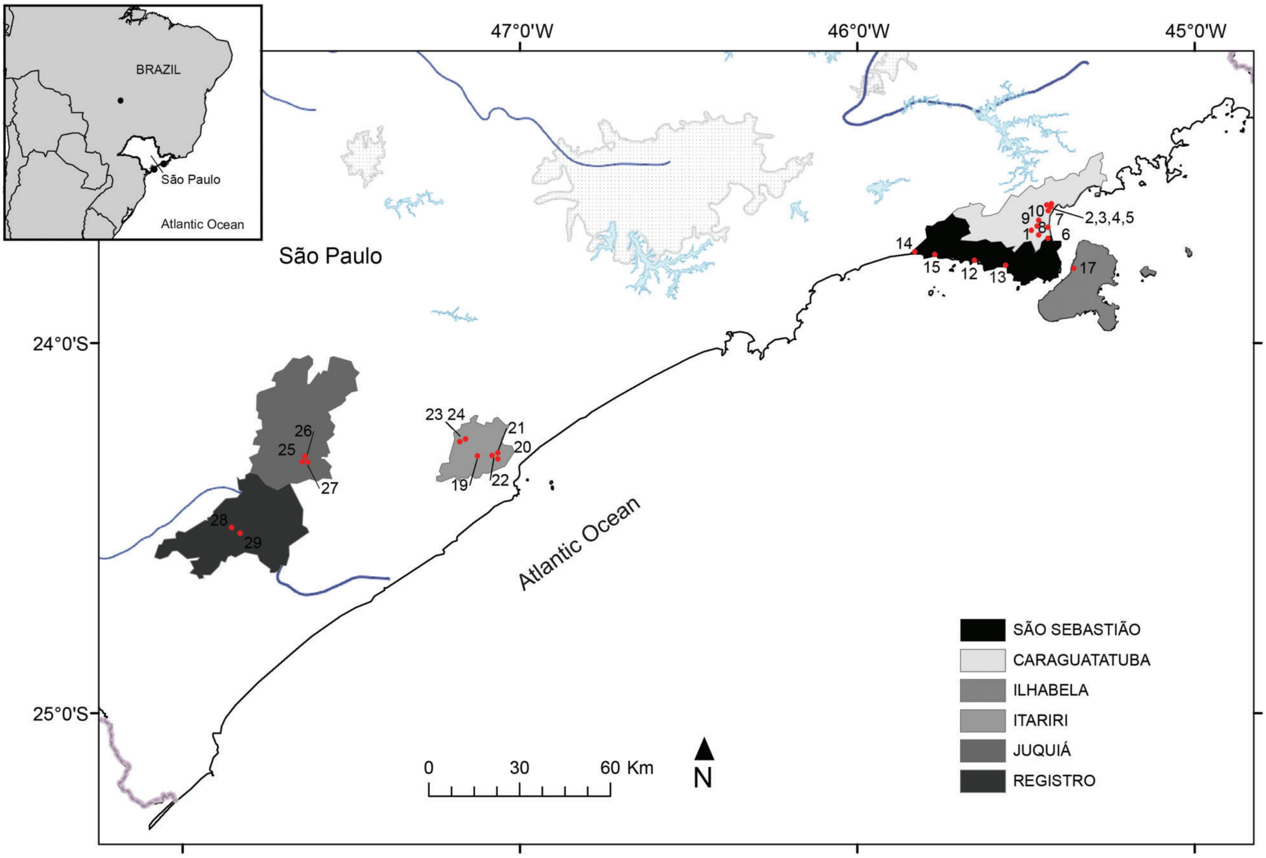

Figure 1. Map of the collection points (●) (North Coast and South Coast/Ribeira do Iguape River) showing the municipalities, (-) rivers/tributaries. (1-10 Caraguatatuba, 11-15 São Sebastião, 16-17 Ilhabela, 18 Ubatuba, 19-24 Itariri, 25-27 Juquiá, 28-29 Registro).

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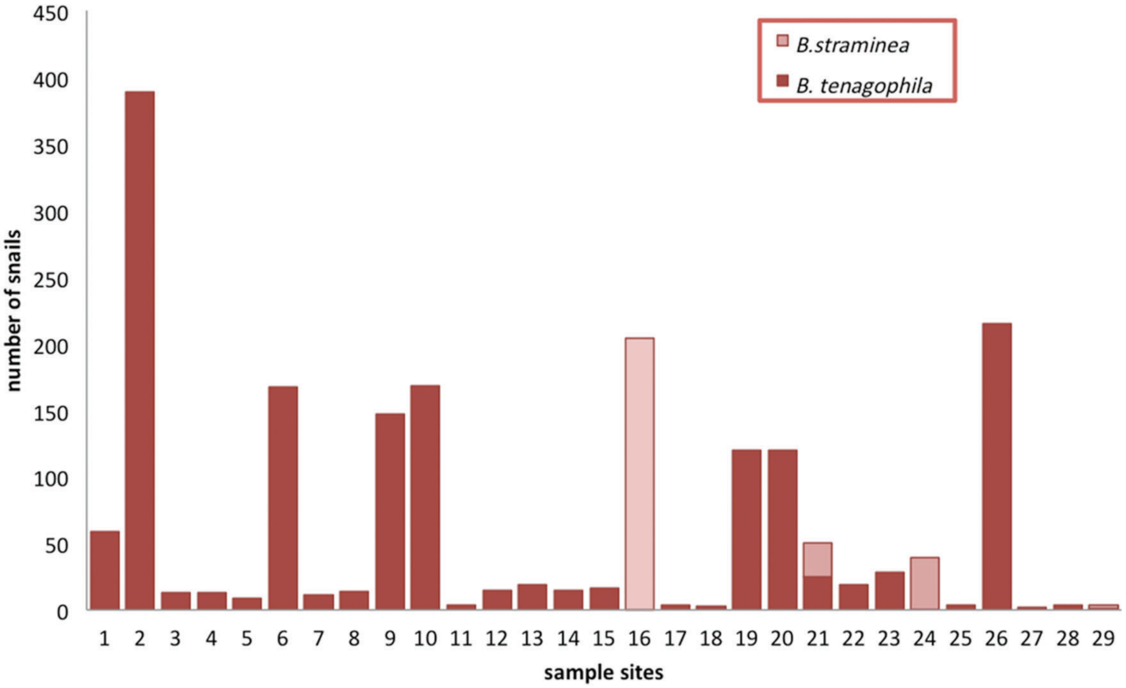

Figure 2. Number of specimens of *B. tenagophila* and *B. straminea* collected at the 29 collection points in the drainage basin on the north and south coast of São Paulo. (1-10 Caraguatatuba, 11-15 São Sebastião, 16-17 Ilhabela, 18 Ubatuba, 19-24 Itariri, 25-27 Juquiá, 28-29 Registro).

Table 1. Geographic details of the areas where the snails were collected in the state of São Paulo.

Municipality	Ref. No.	Neighborhood	Coordinates (Lat. S, Long. W)	
Caraguatatuba	1	Rio Claro	23°41’46”	45°28’57”
	2-5	Indaiá-1,2,3,4	23°38’42”	45°25’14”
			23°37’59”	45°25’11”
			23°38’25”	45°25’14”
			23°37’55”	45°25’08”
	6	Travessão	23°41’49”	45°26’30”
	7-8	Porto Novo-1,2	23°41’24”	45°26’41”
			23°41’34”	45°26’58”
	9-10	Morro do Algodão-1,2	23°40’42”	45°27’18”
			23°40’26”	45°26’54”
São Sebastião	11	Canto do Mar	23°42’58”	45°25’53”
	12	Camburi	23°46’20”	45°38’50”
	13	Maresias	23°47’15”	45°33’24”
	14	Boracéia	23°45’12”	45°49’31”
	15	Barra do Una	23°45’25”	45°46’07”
Ilhabela	16	Barra Velha	23°49’17”	45°22’01”
	17	Itaquanduba	23°47’56”	45°21’44”
Ubatuba	18	Sesmaria	23°27’22”	45°05’06”
Itariri	19	Palmito	24°18’39”	47°07’31”
	20	Alumínio	24°18’26”	47°03’58”
	21	Clay	24°18’11”	47°04’04”
	22	Aviação	24°18’13”	47°04’31”
	23	Raposo Tavares	24°17’55”	47°08’06”
	24		24°17’53”	47°08’55”
Juquiá	25	Estação	24°19’33”	47°37’53”
	26	Parque Nacional	24°18’56”	47°38’03”
	27	Vila Florida	24°19’19”	47°38’22”
Registro	28	Vila São Francisco	24°29’20”	47°51’06”
	29	Nosso Teto	24°30’37”	47°50’ 07”

Table 2. Number of snails collected on the north and south coast of São Paulo.

	Municipality	*B. tenagophila*	*B. straminea*
North	Caraguatatuba	990	0
	São Sebastião	69	0
	Ilhabela	4	204
	Ubatuba	3	0
South	Itariri	312	64
	Juquiá	221	0
	Registro	5	3
	Total	1604	271

environmental surveillance for estimating risks and predicting the spread of schistosomiasis to new geographic regions.

Material and Methods

Snails were collected on the edges of water bodies and in the bottom of breeding sites in municipalities near the south coast of the state of São Paulo (Juquiá, Registro and Itariri) and on the north coast (São Sebastião, Caraguatatuba, Ubatuba and Ilhabela (Figure 1, Table 1). The municipality of Ilhabela is located on São Sebastião Island, which is 1.76 km from the mainland and the third largest island in Brazil (Cantarelli et al. 2014).

Collections were made between 2008 and 2013 and complied with Ministry of Health standards (Ministério da Saúde 2008) and the methodology standardized by the Superintendency for the Control of Endemics (SUCEN) for the Schistosomiasis Control Program in the State of São Paulo.

Once they had been collected, the snails were wrapped in dry gauze and sent to the laboratory for identification, which was based on the morphological characteristics of the genital system, as described in Paraense (1975, 1981). To ensure standard relaxation the snails were anesthetized with sodium pentobarbital (Deslandes 1959).

To analyze the relative frequency distribution of *B. tenagophila* specimens collected in four different locations (Travessão, Porto Novo, Morro do Algodão and Indaiá, in the municipality of Caraguatatuba); the chi-square test was used in a 4 x 2 table, as specified in Pereira (2001). The analysis took into account the different frequencies in October 2010 and June 2012. The Rio Claro site was not included in the analysis as there was no collection there in October 2010. Analysis of residuals (Zres) was carried out to determine which frequency was responsible for the significant result in the chi-square test. For a 5% significance level, residuals greater than 1.96 correspond to a greater number of occurrences than expected, and residuals less than -1.96 to a smaller number of occurrences than expected.

Results and Discussion

Of the 1875 planorbid snails from the genus *Biomphalaria* collected at the 29 collection points shown in Table 1, 85.5% were identified as *B. tenagophila* and only 14.5% as *B. straminea* (Table 2). This finding confirms the predominance of *B. tenagophila* in the region, corroborating malacological surveys previously carried out in the same municipalities (Contino 2004, Teles et al. 2003, SUCEN 2005).

The snails were found in ditches, streams and flooded urban areas with aquatic plants and grasses on the edges.

B. tenagophila specimens collected in Morro de Algodão in Caraguatatuba form a distinct group from the other specimens because of the large absolute frequency of snails collected in the month of June. In this community, pathogens that cause severe diarrhea have historically affected a large section of the population (Asmus et al. 2013). The vulnerability of this area to floods, together with the high risk of disease transmission, makes constant malacological and environmental surveillance of Morro do Algodão essential.

In the comparison of relative frequencies of *B. tenagophila* for the four collection sites in the municipality of Caraguatatuba (Table 3), the chi-square test with three degrees of freedom showed that there was a statistically highly significant difference ($X^2 = 61.425$; $p<0.001$) at the 5% level ($p=0.05$) between October 2010 and June 2012, indicating that the variation in the abundance of snails in the collection points is related to the collection period. The exception was Porto Novo, where the number of *B. tenagophila* specimens was expected to be higher in June. Analysis of residuals showed that the much smaller number than expected ($Zres=-29.347$) of *B. tenagophila* specimens in Porto Novo in June was probably responsible for the significant value observed in the chi-square test.

We believe that the low frequency of snails in Porto Novo may be related to treatment of the breeding site with insecticides or *Baccilus thuringiensis*, which are used in the area to control the *Culex quinquefasciatus* mosquito. It may also be related to mechanical control, including the cleaning and removal of waste from streams and their banks. Both types of control would prevent *Culex* breeding and indirectly increase the mortality rate of *Biomphalaria*.

The greatest number of snails was collected in June, when there is less rain and the smallest number in a period when rainfall increases. Our findings agree with previous filed studies that showed the impact of wet/dry seasons on planorbid populations (Barbosa & Barbosa 1994, Camara et al. 2012, Fernandez et al. 2014).

Table 4 suggests that rainfall rather than temperature is a determining factor in the colonization of *B. tenagophila*. In months with little rainfall, such as June, freshwater habitats remain lentic for longer, allowing the snail population to grow and reproduce. In contrast, during periods of high rainfall and floods, when water levels rise and rivers burst their banks (all of which are common events on the north and south coast, according Pezzoli et al. 2013), growth of the *Biomphalaria* population is inhibited. It is probably during these months that the snail population disperses to new environments.

Table 3. Distribution of number of *B. tenagophila* specimens surveyed among the four sites at Caraguatatuba.

Year/month	Travessão	Porto Novo	Morro do Algodão	Indaiá	Total	%
10/10	7	11	18	26	62	6.3%
06/12	160	14	297	389	919	93.7

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Table 4. Mean temperature (°C) and rainfall (mm) in the municipality of Caraguatatuba. (Source: CEPAGRI. Center for Meteorological and Climatic Research Applied to Agriculture. UNICAMP).

	Mean air temperature (°C)			**Rainfall (mm)**
Month	Minimum	Maximum	Mean	
June	14.3	27.9	21.1	64.3
October	18.4	31.9	25.2	160.0

In this study we identified 204 specimens of *B. straminea* in the Barra Velha stream in Ilhabela (Figure 2), where previous malacological surveys had identified *B. tenagophila* and *B. straminea* living in sympatry (Teles et al. 2003). Our results corroborate the finding that *B. straminea* has a high potential for invading and rapidly colonizing new habitats, as described in studies carried out in Asia (Yipp 1990, Atwood et al. 2014) and on islands in the Caribbean (Pointier 1993). In some cases the competitive ability of *B. straminea* was sufficient to completely replace native species (Barboza et al. 2012, Barbosa et al. 2014). Based on the habitats in which the species in Ilhabela were collected, however, it is reasonable to suppose that *B. straminea* has a preference for freshwater bodies with abundant floating vegetation and that *B. tenagophila* prefers water collection with little vegetation like the drainage culvert in which the few specimens of this species collected in this study were found.

Notable in the southern region of the São Paulo coast was the finding of *B. straminea* in the Ana Dias district in the municipality of Itariri (Figure 2), where Muniz (2007) found only *B. tenagophila*. In 1980, Santos et al. reported finding *B. straminea* naturally infected with *S. mansoni* in the São Paulo municipality of Cruzeiro, in the valley of the Paraíba do Sul river. Dias et al. (1987) subsequently found that this population was susceptible to human and wild lineages of this trematode.

Global climate changes are expected to lead to higher rainfall, increasing water volumes in all Brazilian basins, including the Paraná river basin in the southeast of Brazil (Souza 2010, Valverde & Marengo 2014). As a result, *Biomphalaria* species may be able to cross the natural limits to their geographic distribution and expand to new areas, increasing the risk of transmission of schistosomiasis (Coma et al. 2008, Githeko et al. 2010).

Our findings indicate that *B. tenagophila* is currently the predominant species of *Biomphalaria* on the São Paulo coastal fluvial plain. However, specimens of *B. straminea* were found in regions where *B. tenagophila* had previously predominated. This shows that there is a risk of the distribution patterns of *S. mansoni int*ermediate host species changing as a result of the potential expansion of *B. straminea* into habitats naturally colonized by *B. tenagophila*. Such a change could represent an additional risk of infection for the human population, as *B. straminea* has been shown to be an important vector in areas where schistosomiasis is endemic, such as the northeast of Brazil.

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References

ASMUS, G.F., MELLO, A.Y.I., SEIXAS, S.R.C & BATISTELLA, M. 2013. Análise sociodemográfica da distribuição espacial de ocorrências de diarréias agudas em áreas de risco de inundação. Caraguatatuba, SP. Revista Vitas: visões transdisciplinares sobre ambiente e sociedade 3 (6): 1-26.

ATTWOOD, S.W., HUO, G.N. & QIU, J.W. 2014. Update on the distribution and phylogenetics of *Biomphalaria (Gastropoda:* Planorbidae) populations in Guangdong Province, China. Acta Trop. 1(14):S0001-706X.

BARBOSA, F.S., PEREIRA, C.D.P. & ARRUDA, F. 1985. Competive interactions between species of freshwater snails .I. Laboratory studies: IC. Comparative survival of *Biomphalaria glabrata and B.straminea* kept out of water. Mem. Inst. Oswaldo Cruz 80(2): 155-157.

BARBOSA, C.S., BARBOSA, V.S., NASCIMENTO, W,C., PIERI, O.S. & ARAUJO, K.C.G.M. 2014. Study of the snail intermediate hosts for Schistosoma mansoni on Itamaracá island on northeast Brazil: spacial displacement of *Biomphalaria glabrata* by *Biomphalaria straminea*. Geospatial Health 8(2): 345-351.

BARBOSA, F.S. & BARBOSA, C.S. 1994.The bioecology of snail vectors for Schitosomiasis in Brazil. Cad. Saúde Pública (10)2: 200-209.

BARBOZA, D.M., ZHANG, C., SANTOS, N.C., SILVA, M.M., ROLLEMBERG, C.V., AMORIM, F.J., UETA, M.T., MELO, C.M., ALMEIDA, J.A., JERALDO, V. L. & JESUS, A. R. 2012. *Biomphalaria* species distribution and its effect on human *Schistosoma mansoni* infection in an irrigated area used for rice cultivation in northeast Brazil. Geospatial Health 6(3): S103-S109.

BORELLI, E. 2008. Urbanização e qualidade ambiental: o processo de produção do espaço da costa brasileira. INTERthesis 4(1): 1-27.

CAMARA, I.A., BONY, Y.K., DIOMANDÉ, D., EDIA, O.E., KONAN, F.K., KOUASSI, C.N., GOURÈNE, G. & POINTIER, J.P. 2012. Freshwater snail distribution related to environmental factors in Banco Nationmal Park an urban reserve in the Ivory Coast (West Africa). African Zoology 47(1): 160-168.

CANTARELI, C.V., DUTRA, M. & TURAN, J. 2014. Aves ameaçadas da trilha e do entorno da comunidade da Praia do Bonete Ilhabela – SP. BioScience 3(3): 148-153.

CARNAVAL, A.C., MORITZ, C., HICKERSON, M., HADDAD, C. & RODRIGUES, M. 2009. Stability predicts diversity in the Brazilian Atlantic Forest hotspot. Science 323: 785-789.

CEPAGRI. http://www.cpa.unicamp.br/outras-informacoes/clima_muni_269.html (last access: 16/03/2015).

COMA, M.S., VALERO, M.A & BARGUES, M.D. 2008. Effects of climate change on animal and zoonotic helminthiasis. Rev Sci Tech. 27: 443-457.

CONTINO, M.L. 2004. Foco de esquistossomose – Litoral Norte do estado de São Paulo – Novembro 2003.

DE KOCK, K.N., WOLMARANS, C.T. & BORMAN, M. 2004. Distribution and Habitats of *B. pfeifferi* snail intermediate host of *S. mansoni* in South Africa. Water SA. 30: 80-87.

DESLANDES,N. 1959. Técnica de dissecção e exame de planorbídeos. Rev Serv Espec Saúde Publica, 4(2): 371-382.

DIEGUES, A.C., ARRUDA, R.S.V., SILVA, V.C.F., FIGOLS, F.A.B. & ANDRADE, D. 2001. Os Saberes tradicionais e biodiversidade no Brasil. Ministério do Meio Ambiente, Brasília. 211 p.

DIAS, L.C.S., UETA, M.T & GUARALDO, A.M.A. 1987. Suscetibilidade de *Biomphalaria glabrata, B. straminea e B. tenagophila* a diferentes cepas de *Schistosoma mansoni.* Revista do Instituto de Medicina Tropical de São Paulo 29(4): 205-212.

ESCOBAR, J.S., AULD, J.R., CORREA, A.C., ALONSO, J.M., BONY, Y.K., COUTELLEC, M.A., KOENE, J.M., POITIER, J. P., JARNE, P. & VID, P. 2011. Patterns of mating system evolution in hermaphroditic animals: correlations among selfing rate, inbreeding depression, and the timing of reproduction. Evolution 65(5): 1233-1253.

FERNANDEZ, M.A., MATTOS, A.C., SILVA, E.F., SANTOS, S.B. & THIENGO, S.C. 2014. A malacological survey in the Manso Power Plant, State of Mato Grosso, Brazil: new records of freshwater snails, including transmitters of schistosomiasis and exotic species. Rev. Soc. Bras. Med. Trop. 47(4): 498-506.

GITHEKO, A., LINDSAY, S., CONFALONIERI, U. & PATZ, J. 2010.Climate change and vector borne diseases: a regional analysis. Bull. World Health Organization 78: 1136-1147.

HEINO, J., MYKRÃ & MUOTKA, T. 2009. Temporal variability of nestedness and idiosyncratic species in stream insect assemblages. Diversity and Distribuitions 15:198-206.

MCCREESH, N. & BOOTH, M. 2014. The Effect of Increasing Water Temperatures on *Schistosoma mansoni* transmission and *Biomphalaria pfeifferi* population dynamics: An Agent Based Modelling Study. PLoS ONE 9(8): e105917.

MINISTÉRIO DA SAÚDE. 2008. Secretaria de Vigilância em Saúde. Departamento de Vigilância Epidemiológica. Vigilância e Controle de moluscos de importância epidemiológica: diretrizes técnicas: Programa de Vigilância e Controle da Esquistossomose (PCE). 2 ed. Editora MS, Brasília, DF, p. 43-49.

MUNIZ, C. 2007. Levantamento da malacofauna limnica e aspectos ecológicos de focos de esquistossomose em Ana Dias, Vale do Ribeira, SP. Dissertação de Mestrado, Universidade de São Paulo, São Paulo.

NOOTEN, S.S., ANDREW, N.R. & HUGHES, L. 2014. Potential Impacts of Climate Change on Insect Communities: A Transplant Experiment. PLoS ONE 9(1): e85987.

PALASIO, R.G.S. 2013. Polimorfismo dos genes mitocondrial 16S rRNA e nuclear ITS2 em populações de *Biomphalaria tenagophila* da Bacia Litorânea do estado de São Paulo e estudo da suscetibilidade dos caramujos ao *Schistosoma mansoni.* Dissertação de Mestrado, Universidade Estadual de Campinas, Campinas, São Paulo.

PARAENSE, W.L. 1975. Estado atual da sistemática dos planorbídeos brasileiros. Arq. Mus. Nac. 55: 105-128.

PARAENSE, W.L. 1981. *Biomphalaria sp*.n. from South America (Mollusca Basommatophora Pulmonata). Mem. Inst. Oswaldo Cruz 76(2): 199-211.

PARMESAN, C. 2006. Ecological and evolutionary responses to recent climate change. Ann. Rev. Ecol. Evol. Syst. 37: 637-669.

PEREIRA, J.C.R. 2001. Analise de dados qualitativos: Estratégias metodológicas para as ciências da Saúde, humanas e sociais. 3 ed. Editora da Universidade de São Paulo, São Paulo.

PEZZOLI A., ALFREDINI, P., ARASAKI, E., ROSSO, M. &, SOUZA JR,W.C. 2013. Impacts of climate change on management policy of the harbors, land areas and wetlands in the Sao Paolo State Coastline (Brazil). Adv Res Meteorol Sci 1:1-101.

PIZA, J.T. & RAMOS, A.S. 1972. Os focos de esquistossomose no estado de São Paulo. Arquivo de Higiene e Saúde Pública 25(86): 261-271.

POINTIER, J.P. 1993. The introduction of *Melanoides tuberculata (Mollusca: Thiaridae*) to the island of SaintLucia (West Indies) and its role in the decline of *Biomphalaria glabrata,* the snail intermediate host of *Schistosoma mansoni.* Acta Tropica 54: 13-18.

ROCKSTRÖM, J., STEFFEN, W., NOONE, K., PERSSON, Å., CHAPIN, F.S. & LAMBIN, E.F. 2009. A safe operating space for humanity. Nature 461: 472-475.

ROSENZWEIG, C., KAROLY, D., VICARELLI, M., NEOFOTIS, P., WU, Q., CASASSA, G., MENZEL, A., ROOT, T. L., ESTRELLA, N., SEGUIN, B., TRYJANOWSKI, P. & LIU, C. 2008. Attributing physical and biological impacts to anthropogenic climate change. Nature 453: 353-357.

SANTOS, L., COSTA, I.B., FIGUEIREDO, C.C.S.B. & ALTOMANI, M.A.G. 1980. Primeiro encontro de *Biomphalaria straminea* (Dunker, 1848) no município de Cruzeiro, Vale do Paraíba, Estado de São Paulo, naturalmente infectada por cercarias de *Schistosoma mansoni.* Revista do Instituto Adolpho Lutz 40: ;165-166.

SILVA, L.J. 1985. Crescimento urbano e doenças. A esquistossomose no Município de São Paulo (Brasil). Revista Saúde Pública 19(1): 1-7.

SOUZA, C.R.G. 2005. Suscetibilidade morfométrica de bacias de drenagem ao desenvolvimento de inundações em áreas costeiras. Revista Brasileira de Geomorfologia 6(1): 45-61.

SOUZA, C.R.G. 2010. Impactos das mudanças climáticas no litoral do estado de São Paulo (Sudeste do Brasil). In VI Seminário Latino Americano de Geografia Física e II Seminário Ibero Americano de Geografia Física. Universidade de Coimbra, Portugal. p.1-17

SOUZA, C.R.G. & SOUZA, A.P. 2004. Geologia e geomorfologia da área da estação ecológica Jureia-Itatins. In Estação Ecológica Jureia-Itatins. Ambiente Físico, Flora e Fauna (O.A.V. Marques & W. Duleba eds). Holos Editora, cap. 2, p.16-33.

SUCEN. Superintendência de Controle de Endemias. 2005. Fichas de Distribuição de Planorbídeos capturados, examinados e positivos para *Schistosoma mansoni,* segundo localidade, no período de 2001 á 2005. Relatório Técnico do Serviço Regional 03, Taubaté, São Paulo.

TELES, H.M.S. & MARQUES C.C.A. 1989. Estivação de *Biomphalaria tenagophila (Pulmonata, Planorbidae)*. Rev. Saúde Pública 23(1): 76-78.

TELES, H.M.S. 1989. Distribuição de *Biomphalaria tenagophila* e *B. occidentalis* no Estado de São Paulo (Brasil). Rev. Saúde Pública 23(3): 244-253.

TELES, H.M.S., MITSUYOSHI, H.R., OLIVEIRA, J.C.N., & AVEIRO, J.A. 2003. Ocorrência de vetores da esquistossomose mansônica no litoral norte do estado de São Paulo, Brasil. Cad. Saúde Pública 19(6): 1887-1891.

TELES, H.M.S. 2005. Distribuição geográfica das espécies dos caramujos transmissores de *Schistosoma mansoni* no estado de São Paulo. Rev. Soc. Bras. Med. Trop. 38(5): 426-432, http://dx.doi.org/10.1590/S0037-86822005000500013

TUAN, R. & SIMOES, L.C.G. 1989. Spermatogenesis and desiccation in *Biomphalaria tenagophila* (Orbigny, 1835) (*Gastropoda, Planorbidae*). Revista Brasileira de Genética 12 (4): 881-885.

VALVERDE, M.C. & MARENGO, J.A. 2014. Extreme Rainfall Indices in the Hydrographic Basins of Brazil. Open Journal of Modern Hydrology 4(1): 10-26.

VAZ, J.F. 1989. Distribuição de *Biomphalaria tenagophila* (d'Orgigny,1935) (*GastropodaPulmonata*). Ciência e Cultura 41: 14-27.

VIADANA, A.G. & CAVALCANTI, A.P.B. 2006. Teoria dos refúgios florestais aplicadas ao estado de São Paulo. Revista da Casa da Geografia de Sobral 8 (1): 61-80.

YIPP, M.W. 1990. Distribution of the *Schistosome* vector snail, *Biomphalaria straminea* (*Pulmonata: Planorbidae*) in Hong Kong. J. Mollus. Stud. 56 (1): 47-55.

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Fruit-feeding butterflies (Lepidoptera: Nymphalidae) of the Área de Proteção Especial Manancial Mutuca, Nova Lima and Species list for the Region of Belo Horizonte, Minas Gerais, Brazil

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Abstract: A study of the assembly of fruit-feeding butterflies in the Área de Proteção Especial Manancial Mutuca, Nova Lima, MG was conducted with the goal of inventorying the species of the site. Forty-two traps were used to attract fruit-feeding butterflies, divided between Cerrado (rupestrian field) and riparian vegetation, monthly over one year. 2245 butterflies, which belonged to 63 species, were recorded. Of this total, fourty-eight species were collected in the Cerrado, twenty-one exclusively in this environment, forty-two in riparian forest, fifteen being exclusive to this environment, and twenty-seven species were sampled in both environments. From the total of sampled species, thirty-five were considered rare, eight accessory species, and twenty constant species. *Prepona deiphile deiphile* (Charaxine) is classified as vulnerable on the Minas Gerais' list and on the national list of threatened species. The collector curve showed no clear trend to stabilization, suggesting that there are species still not sampled in the study area. Adding the data from field sampling to the information on species occurrence in the literature and in entomological collections, the current number of frugivorous butterflies species for the region of Belo Horizonte is 104. This result foregrounds the importance of APE Mutuca for maintaning a rich fauna of frugivorous butterflies to the area.

Keywords: *Biodiversity, community, conservation, inventory, species richness.*

SILVA, A.R.M., PONTES, D.V., GUIMARÃES, M.P., OLIVEIRA, M.V., ASSIS, L.T.F., UEHARA-PRADO, M. **Borboletas frugívoras (Lepidoptera: Nymphalidae) da Área de Proteção Especial Manancial Mutuca, Nova Lima e lista de espécies da região de Belo Horizonte, Minas Gerais, Brasil.** Biota Neotropica. 15(3): e20140118. http://dx.doi.org/10.1590/1676-06032015011814

Resumo: Foi realizado um estudo da assembléia de borboletas frugívoras da Área de Proteção Especial Manancial Mutuca, Nova Lima-MG, com o objetivo de inventariar as espécies do local. Foram utilizadas 42 armadilhas atrativas para borboletas frugívoras, divididas entre mata ciliar e Cerrado (campo rupestre), mensalmente ao longo de um ano. Foram amostradas 2245 borboletas, pertencentes a 63 espécies. Deste total, 48 espécies foram coletadas no Cerrado, sendo 21 exclusivamente neste ambiente, 42 na Mata Ciliar com 15 exclusivas e 27 espécies foram amostradas nos dois ambientes. Do total de espécies amostradas, 35 foram consideradas raras, oito acessórias e 20 constantes. *Prepona deiphile deiphile* (Charaxine) encontra-se classificada como vulnerável na lista de Minas Gerais e na lista nacional de espécies ameaçadas. A curva do coletor não mostrou tendência nítida à estabilização, o que sugere que ainda existam espécies não amostradas na área de estudo. Somando-se aos dados de amostragem em campo, informações sobre ocorrência de espécies na literatura e em coleções entomológicas, o número atual de espécies de borboletas frugívoras para a região de Belo Horizonte é de 104. Esse resultado ressalta a importância da APE Mutuca na manutenção de uma fauna rica de borboletas frugívoras para a região.

Palavras-chave: *Biodiversidade, comunidade, conservação, inventário, riqueza de espécies.*

Introduction

Biological diversity is being lost at a rapid pace (Wilson 1997) and habitat loss and degradation, especially deforestation, are among the factors that most contribute to species extinction events (Brown & Lomolino 2006, Machado et al. 2005). The Cerrado is no exception to this global trend. Most of the biome has already been cleared out or transformed, by human action, into pastures, annual crops and other types of land use (Klink & Machado 2005). Only in the State of Minas Gerais, approximately 75% of the original area of the Cerrado has been destroyed (Lins & Mendonça 2000).

The transformations which have happened in this biome have brought great environmental damages, such as fragmentation and reduction of habitats, species extinction, invasion of exotic species, soil erosion, pollution of aquifers, changes in fire regime, imbalances in the carbon cycle and possibly changes in regional climate (Klink & Machado 2005). The Cerrado is considered a global hotspot for being an area with high rate of endemism and less than 30% of remnant vegetation (Myers et al. 2000), and the conservation of its biodiversity should be considered a priority in Brazil. Inventories are important for filling gaps in our knowledge of local biodiversity, assisting in the identification of endemism and generating subsidies for conservation (Lewinsohn et al., 2005, Mielke et al., 2010, Ritter et al. 2011).

The Lepidoptera comprise approximately 160,000 species, 20,000 of which are butterflies, and in Brazil there should occur around 26,000 species, including over 3,000 butterflies (Brown 1996, Freitas & Almeida 2012). Among the butterflies, the Nymphalidae family is responsible for a significant portion of the species richness in the Neotropical region (DeVries et al. 1997), representing approximately 30% of this fauna (Lamas 2004). 'Charismatic' insects, such as butterflies, have the potential to become flagship groups in conservation programs (Lewinsohn et al. 2005). Butterflies are also considered good biological indicators as they respond quickly to environmental changes and are easily observed and sampled (Freitas et al., 2003, Freitas 2010).

Butterflies can be separated into two guilds, considering the eating habits of adults: nectarivorous, which feed on nectar; and frugivorous, which feed on fermented fruit, excrements, plants' exudates and decaying animals (Uehara-Prado et al. 2004). All the strict frugivorous belong to the Nymphalidae family, and represent 20% of neotropical butterflies (Lamas 2004). The frugivorous butterflies are divided into four subfamilies and 13 tribes: Satyrinae (Brassolini, Haeterini, Melanitini, Morphini e Satyrini), Charaxinae (Anaeini e Preponini), Biblidinae (Ageroniini, Biblidini, Callicorini, Epicalini e Epiphilini) e Nymphalinae (Coeini) (Marín et al. 2011). For the sampling of those butterflies, traps containing fermented fruit as bait have been vastly used in the tropics (De Vries et al. 1999, Uehara-Prado et al., 2004, Marini-Filho & Martins, 2010, De Vries et al. 2011, Silva et al. 2012).

Only a few studies have been conducted with fruit-feeding butterflies in Cerrado areas, such as Pinheiro & Ortiz (1992) in Brasilia, Fortunato & Ruszczyk (1997) in Uberlândia, Marini-Filho & Martins (2010) in the Parque Nacional da Serra da Canastra and Silva et al. (2012) in Belo Horizonte. In this context, knowing the assemblage of fruit-feeding butterflies in Cerrado areas can generate data for further evaluation of the local biodiversity conservation. In this paper, a inventory of fruit-feeding butterflies from the Área de Proteção Especial (APE) Manancial Mutuca is presented. Moreover, the resulting list was supplemented with data from the occurrence of fruit-feeding butterflies in the region of Belo Horizonte.

Material e Methods

1. The study area

The study was conducted at a Área de Proteção Especial (Special Protection Area) Manancial Mutuca (20°00'3723'' S and 43°58'8,92'' W), a propriety of the Sanitation Company of Minas Gerais (COPASA - MG). The reserve is located in Nova Lima, Minas Gerais State, in the Ferriferous four-side. It is nestled in the Parque Estadual da Serra do Rola Moça, having joint administration with the State Forest Institute (SFI) and it borders the BR-040, two large mining companies and part of the Barreiro district in Belo Horizonte.

The APE Mutuca is 1250 hectares, with transitional vegetation between Cerrado and Atlantic Forest, with 371 hectares of arboreal coverage, including riparian zone of the Mutuca stream (Copasa 2013) (Figure 1). In this stream, there is a dam to capture water, composing, along with Cercadinho and Fechos reserves, the Supply System Morro Redondo, which provides water for a part of Nova Lima and southern area of Belo Horizonte (Copasa 2013).

In this region the climate is high-altitude tropical, characterized by dry winters and rainy summers (Brandão et al. 1997). The annual average temperature varies between 18° and 21° C. The rainfall shows variation between 1300-2100 mm annual rainfall, with the dry season between April and July and the rainy season starting in August (Cetec 1993).

The samplings were held in both of Cerrado phyto-physiognomies present in the area: riparian vegetation and rupestrian field. The rupestrian field is found in areas above a thousand feet high, along the Serra do Espinhaço, in rocky or sandy soils and its vegetation consists of herbs and sparse shrubs (Mendonça & Lins 2000). The riparian forest is a formation located along minor rivers and streams, but it is now reduced to scattered clumps (Mendonça & Lins 2000).

2. Sampling

Samples were collected monthly for one year (from October 2008 to September 2009) during four days per month, the first day being for the installation of traps and placement of bait (banana with sugar cane juice, prepared two days in advance). Van Someren-Rydon traps, consisting of a cylinder of tulle of approximately eighty centimetres high, closed at the top and mounted on a wooden platform where the bait lies (DeVries 1987) were used.

Twenty-one traps were placed in the riparian area and other twenty-one in the Cerrado (rupestrian field), organized into sampling units (UA) with three traps. Within an UA, the traps were set twenty meters apart from each other and each UA was 200 meters away from the other.

When possible, captured specimens were identified in the field, marked and released. The unidentified specimens were collected for later identification. At least two individuals of each species were collected and assembled, and this reference collection is deposited in the Laboratory of Zoology of the

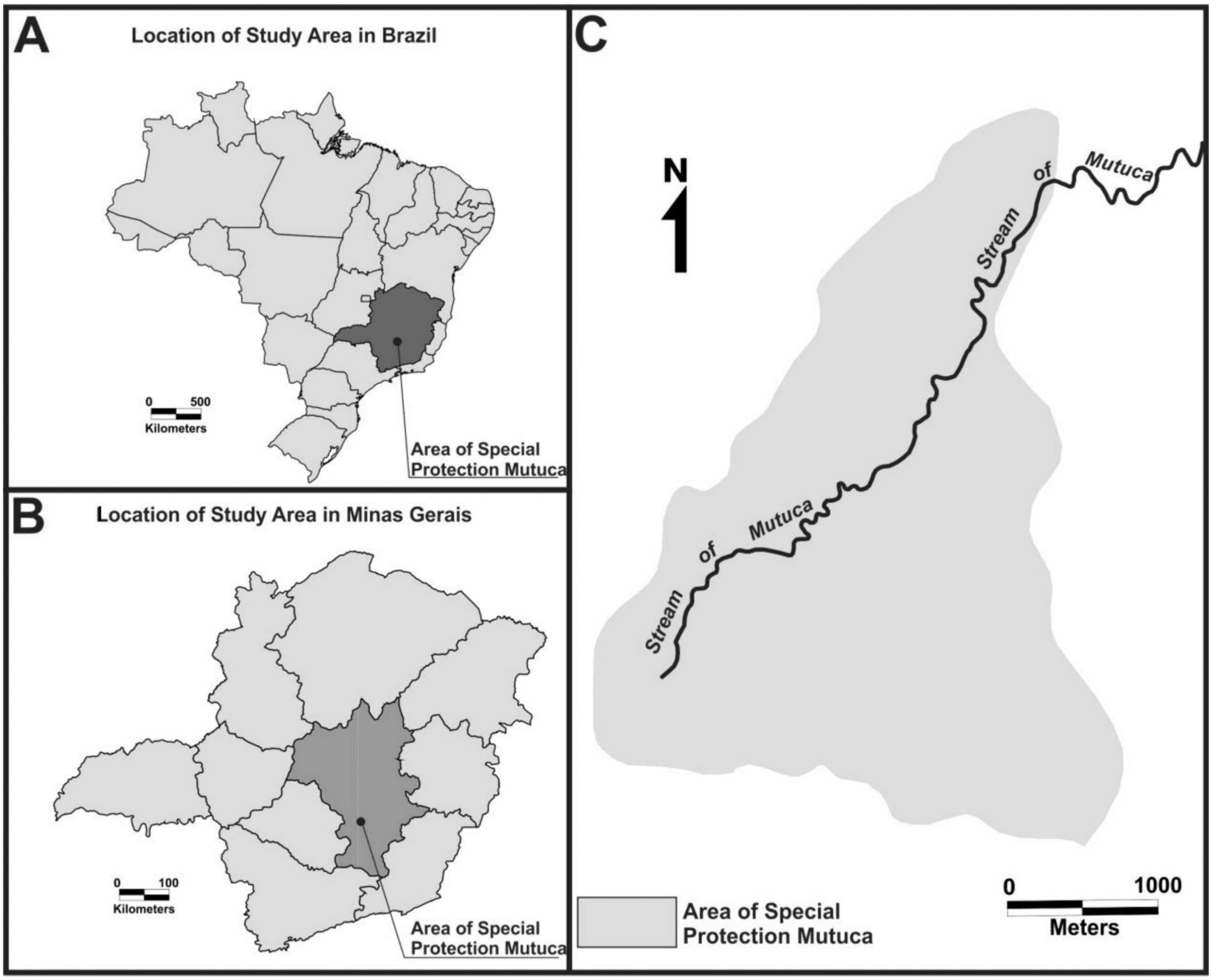

Figure 1. Location of Área de Proteção Especial Manancial Mutuca. A. Location of study area in Brazil, B. Location of study area in Minas Gerais and C. APE Mutuca.

Centro Universitário UNA at Belo Horizonte. The nomenclature used was based on Lamas (2004).

To complement the local species list, three collections containing butterflies from neighbouring cities to Belo Horizonte and Nova Lima and that had similar ecosystems were consulted: Collection of the Museu de História Natural e Jardim Botânico da UFMG (MHNJB-UFMG), the Entomological Collection of the Museu de Ciências Naturais Puc Minas (MCN-PUC-MG) and the Coleção Entomológica das Coleções Taxonômicas da UFMG. Additionally, data from four studies on butterflies of the city of Belo Horizonte were included (Brown & Mielke 1968, Silva et al. 2007, Silva et al. 2012, Soares et al. 2012).

3. Analysis of data

The species accumulation curve (Mau Tau) and three richness estimators (Jackknife 2, Chao 2 and ACE) were calculated using the program EstimateS 8.2 (Cowel 2009). The percentage of the fauna in the field and the list supplemented with information from entomological collections and papers were compared to the estimates obtained. According to Magurran (2011), the nonparametric estimators are the most effective methods to estimate species richness in ecological assemblages.

Species present in over 50% of the sampled months were considered constant, species present between 25 and 50% (present between three and five months) were considered accessory and species present in less than 25% of samples (one or two samples) were considered rare (Dajoz 1983).

Results and Discussion

In all, 2245 specimens belonging to sixty-three species of fruit-feeding butterflies were sampled (Table 1). From the recorded species, one appears on the list of threatened Fauna of Minas Gerais (2006) and on the national list of threatened species (O.J. Marini-Filho, unpublished data): *Prepona deiphile deiphile* (Charaxinae), classified as vulnerable on both lists (Figure 2).

The Satyrinae subfamily was the most abundant with 1637 specimens (73%), followed by the Charaxinae with 348 (15.5%), Biblidinae with 220 (9.8%) and Nymphalinae with forty specimens (1.7%). Regarding the overall richness, Satyrinae had thirty-one species, representing 49.2% of the sample (from Satyrini, there were nineteen species, 80.9%, from Brassolini, nine species, 14.3%, and from Morphini three, 4.8%), followed by Biblidinae with seventeen species (27%), Charaxinae with twelve species (19%) and Nymphalinae with three species (4.8%),

Table 1. Species list, constancy and abundance of fruit-feeding butterflies species (Nymphalidae), in the rupestrian fields and riparian forest from the Área de Proteção Especial Manancial Mutuca, Nova Lima, MG, Brazil, (October 2008 and September 2009) and species found in the region of Belo Horizonte recorded in other studies.

	APE Mutuca			
Subfamilies/Species	**rupestrian field**	**riparian forest**	**constancy**	**Recorded in collections and literature**
Biblidinae				
Biblis hyperia nectanabis (Fruhstorfer, 1909)	1	-	R	a, b, d, e, f
Callicore astarte selima (Guenée1872)				a, b, d, e
Callicore pygas thamyras (Ménétriés, 1857)	1	-	R	b, e, f, g
Callicore sorana sorana (Godart[1824])	128	-	C	a, b, c, d, e, f
Catonephele numilia penthia (Hewitson, 1852)	-	2	R	e
Catonephele sabrina (Hewitson, 1852)				b
Cybdelis phaesyla (Hübner, [1831])				b, d
Diaethria candrena (Godart[1824])	1	-	R	b, d, e, f
Diaethria clymena (Cramer, 1775)	1	-	R	b, d, f
Diaethria eluina eluina (Hewitson, 1855)				b
Ectima thecla (Fabricius, 1796)	-	1	R	g
Epiphile hubneri Hewitson, 1861	6	32	C	b, d, f
Epiphile orea (Hubner[1823])	-	13	A	b, d
Eunica bechina magnipunctata Talbot, 1928				b, f
Eunica cuvierii (Godart, 1819)				f
Eunica eburnea Fruhstorfer, 1907				d
Eunica margarita (Godart, [1824])				b, e
Eunica tatila bellaria Fruhstorfer, 1908	9	-	R	d
Hamadryas amphinome amphinome (Linnaeus, 1767)	1	-	R	a, b, d, e, f, g
Hamadryas chloe rhea (Fruhstorfer, 1907)	-	1	R	d, e
Hamadryas epinome (C. Felder & R. Felder, 1867)				b, c, d, e, f, g
Hamadryas februa februa (Hübner, 1823)	13	-	C	a, b, c, d, e, f, g
Hamadryas feronia feronia (Linnaeus, 1758)	1	1	R	a, b, c, e, f, g
Hamadryas fornax fornax (Hübner, [1823])				e
Hamadryas iphthime iphthime (H. W. Bates, 1864)	-	1	R	g
Hamadryas laodamia laodamia (Cramer, 1777)				a, b, e, g
Myscelia orsis (Drury, 1782)	-	2	R	
Nica flavilla (Godart, [1824])				a
Temenis laothoe meridionalis Ebert, 1965	5	-	R	b, c, d, f
Nymphalinae				
Colobura dirce (Linnaeus, 1758)	1	23	C	a, b, d, e, f, g
Historis odius (Fabricius, 1775)	10	-	A	c, f
Smyrna blomfildia (Fabricius, 1781)	4	2	A	e, f
Charaxinae				
Archaeoprepona amphimachus (Fabricius, 1775)	37	14	C	d, e
Archaeoprepona chalciope (Hubner, [1823])	2	9	R	d, e, f
Archaeoprepona demophon thalpius (Hubner, [1814])	7	6	C	a, b, d, f
Archaeoprepona demophoon (Hubner, [1814])	8	1	A	d
Fountainea ryphea (Cramer, 1775)	22	16	C	b, d, e, f
Hypna clytemnestra (Cramer, 1777)				b, d
Memphis acidalia victoria (H. Druce, 1877)				b
Memphis appias (Hubner, [1825])	75	44	C	b, d, e
Memphis moruus stheno (Prittwitz, 1865)	12	21	C	a, d, e, f
Memphis otrere (Hubner, [1825])	22	28	C	b, d, e
Prepona deiphile deiphile (Godart, [1824])	2	-	R	
Prepona laertes (Hubner, [1811])	1	-	R	
Prepona pylene Hewitson, [1854]	1	-	R	d
Siderone galanthis (Cramer, 1775)				d, e, f
Zaretis isidora (Cramer, 1779)	15	5	C	b, d, e, f

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Table 1. Continued.

	APE Mutuca			
Subfamilies/Species	**rupestrian field**	**riparian forest**	**constancy**	**Recorded in collections and literature**
Satyrinae: Brassolini				
Blepolenis batea batea (Hübner, 1821)	12	-	R	b, c, d, e, f
Brassolis sophorae laurentii Stichel, 1925				b, c, d, e, g
Caligo arisbe Hubner, [1822]	8	80	A	b, d, e, f
Caligo illioneus illioneus (Cramer, 1775)				b, c
Catoblepia amphirhoe (Hubner, [1825])	1	2	R	
Catoblepia berecynthia (Cramer, 1777)				d
Dasyophthalma rusina (Godart, [1824])	-	7	R	d, e
Eryphanis reevesii (Doubleday, [1849])	20	53	C	b, d, e, f
Narope cyllarus Westwood, 1851				b, d
Narope cyllastros Doubleday, [1849]	-	2	R	
Opoptera syme (Hubner, [1821])	3	36	R	d, e, f
Opsiphanes cassiae (Linnaeus, 1758)				a, b, c, e
Opsiphanes invirae (Hubner, [1808])	12	8	C	a, b, c, d, e, f
Opsiphanes quiteria (Stoll, 1780)	-	3	R	b, d, e
Satyrinae: Morphini				
Antirrhea archaea Hubner [1822]	-	11	R	d
Morpho anaxibia (Esper, [1801])				b, d, e
Morpho helenor mielkei (Blandin, 2007)	43	157	C	a, b, c, d, e, f
Morpho menelaus coeruleus (Perry, 1810)	-	5	R	d, e
Satyrinae: Satyrini				
Capronnieria galesus (Godart, [1824])				d
Cissia terrestris (Butler, 1867)				b
Eteona tisiphone (Boisduval, 1836)				g
Euptychoides castrensis (Schaus, 1902)	9	-	R	d, e, f
Forsterinaria quantius (Godart, [1824])	2	70	C	b, d, e
Forsterinaria necys (Godart, [1824])				d, e
Forsterinaria pronophila (Butler, 1867)				d
Godartiana muscosa (Butler, 1870)	84	466	C	b, d, e, f
Hermeuptychia sp.	1	-	R	a, b, d, e
Carminda griseldis (Weymer, 1911)				e
Moneuptychia itapeva Freitas, 2007	129	1	C	d, e, f
Carminda paeon (Godart, [1824])	-	2	R	d, e
Moneuptychia soter (Butler, 1877)				d
Pareuptychia ocirrhoe interjecta (d'Almeida, 1952)	-	1	R	
Pareuptychia ocirrhoe ocirrhoe (Fabricius, 1776)				b, d, e
Pareuptychia summandosa (Gosse, 1880)				d
Paryphthimoides phronius (Godart, [1824])	-	2	R	c, d, e, f, g
Paryphthimoides poltys (Prittwitz, 1865)	-	3	R	a, d, e, f, g
Paryphthimoides sp.	1	-	R	
Paryphthimoides vetigiata (Butler, 1867)				b
Pharneuptychia innocentia (C. Felder & R. Felder, 1867)	189	-	C	b, d, e, f
Pierella nereis (Drury, 1782)				b, d
Taygetis acuta Weymer, 1910	2	12	C	d, e
Taygetis drogoni Siewert, Zacca, Dias & Freitas, 2013	5	23	C	d, e, f
Taygetis laches (Fabricius, 1793)	2	10	A	a, c, d, e, f
Taygetis rufomarginata Staudinger, 1888				d
Taygetis thamyra (Cramer, 1779)				b
Taygetis virgilia (Cramer, 1776)				b, d, e
Taygetomorpha celia (Cramer, 1779)				f
Yphthimoides affinis (Butler, 1867)	8	-	R	d, g

Continued on next page

Table 1. Continued.

Subfamilies/Species	**APE Mutuca** **rupestrian field**	 **riparian forest**	 **constancy**	**Recorded in collections and literature**
Yphthimoides angularis (Butler, 1867)				b, d, e
Yphthimoides celmis (Godart, [1824])	8	-	R	b, d, e, f
Yphthimoides saltuensis	126	1	A	d, e, f
Yphthimoides ochracea (Butler, 1867)	11	5	A	d, e, f
Yphthimoides pacta (Weymer, 1911)	1	-	R	d, e
Yphthimoides renata (Stoll, 1780)				d, e, f, g
Yphthimoides straminea (Butler, 1867)				e
Yphthimoides yphthima (C. Felder & R. Felder, 1867)				d, e
Zischkaia pacarus (Godart, [1824])				d
Total	1063	1182		

C = Constant, A = Accessory and R = Rare; a = Silva et al. (2007); b = Brown & Mielke (1968); c = Collection of the MHNJB-UFMG; d = Entomological Collection of the MCN-PUC-MG; e = Entomological Collection of the Taxonomic Collections of UFMG; f = Silva et al. (2012); g = Soares et al. (2012).

the same sequence mentioned by Lamas (2004) regarding the richness of the butterflies subfamily of Nymphalidae in the Neotropical region.

A study conducted in APE Cercadinho, near APE Mutuca (Silva et al., 2012), found 78% species of Satyrinae in sampling, and in both locations the richness of this subfamily was close to 50% of species in the sample. Indeed, Satyrinae usually occupies a prominent position in number of species in the studies of fruit-feeding butterflies (De Vries et al. 1997, De Vries et al. 1999). Studies in other areas of Cerrado in Minas Gerais also found Satyrinae as the group with the highest number of species (Marini-Filho & Martins, 2010, Silva et al. 2012). This pattern is due to the fact that Satyrinae is the richest subfamily of fruit-feeding butterflies in the Neotropical region with 1235 species, having many more species than the second subfamily, Biblidinae, with 266 species (Lamas 2004).

From the total of sampled species, thirty-five were found to be rare (56%), eight were considered accessory and twenty were considered constant (Table 1). From the thirty-five rare species, fourteen (22%) were singletons and seven (11%) doubletons. In insect assemblies, species represented by a single individual are prevalent (Magurran 2011). Pinheiro & Ortiz (1992), in a study in Jardim Botânico de Brasília, found 26% of singletons and, in an area near APE Mutuca (APE Cercadinho) there were records of 18% of singletons (Silva et al., 2012), similar numbers to the ones in this paper.

According to Magurran (2011), in all environments (either tropical or temperate), most species in an assembly are rare, and a small number of common species will represent 90% of total abundance. As a matter of fact, in this study, ten species accounted for 71% of total abundance. The four most abundant species in the sample belong to the subfamily Satyrinae: *Godartiana muscosa*, with 550 specimens; *Morpho helenor mielkei* (200); *Pharneuptychia innocentia* (189) and *Moneuptychia itapeva*, with 130 specimens. Of these, three are small, being better able to survive in small fragments of habitat because their larvae require a smaller volume of host plants, having large populations (Shahabuddin & Ponte 2005, Marini-Filho & Martins 2010), what could explain the large abundances found. *M. helenor* was one of the most abundant species in riparian forests in the Cerrado in the Parque Nacional da Serra do Canastra MG (Marini-Filho & Martins 2010), showing similar results to the ones in the present study. Species of the genus *Morpho* can fly in the understory or canopy, and *M. helenor* flies to about one meter above ground along streams and forest edges (De Vries et al. 2010), being considered typical of riparian forest (Pinheiro et al. 2008), which may explain the great abundance of this butterfly in APE Mutuca, having 79% of individuals sampled in this environment.

When considering the sampled environments, it was recorded in the rupestrian field 1063 specimens (47.4%) of forty-eight species, twenty-one of which are exclusive to this environment, while in riparian area it was recorded 1182 specimens (52.6%) belonging to forty-two species, fifteen of which were exclusive to this site (Table 1). According to Baz & Boyero (1995), the structural heterogeneity of a place with distinct vegetation types is a favourable factor to increase diversity of butterflies. The various vegetation types recognized in the Cerrado region provide a spatial variation in the distribution of butterfly species, influencing the composition of their communities (Camargo 2001), supported by the large number of species exclusive to each environment in the present study. The establishment and persistence of butterfly populations in riparian forest and rupestrian field are related to the availability of resources for larvae and adults, vegetation type, climate and degree of disturbance, which certainly varies between these two sites in APE Mutuca, in addition to the intrinsic characteristics of the organisms involved, such as population dynamics, mobility and adaptability to disturbed environments (Fortunato & Ruszczyk 1997).

Even when taking into account differences in relation to sampling effort, it is important to observe that the species richness of fruit-feeding butterflies APE Mutuca was similar or greater when compared to other sites in Cerrado. The APE Mutuca showed greater richness other places, such as APE Cercadinho in Belo Horizonte, a very similar and nearby area, where forty-five species (Silva et al. 2012) were recorded; in Uberlandia, where thirty-six species were found in urban and extra urban areas (Fortunato & Ruszczyk 1997); in Jardim Botânico de Brasília, where forty-six species were recorded in

Figure 2. Male *Prepona deiphile deiphile.* Species classified as vulnerable on the list of threatened Fauna of Minas Gerais (2006) and on the national list of threatened species.

riparian forest, Cerrado and transition area (Pinheiro & Ortiz 1992); and in riparian and Cerrado areas of Campus Darcy Ribeiro in Brasília, there were thirty-one species (Pinheiro et al. 2008). The number of species found in the APE Mutuca was similar only to the Parque Nacional da Serra do Canastra (MG), where sixteen fragments of riparian vegetation were sampled, and sixty-seven species were registered (Marini-Filho & Martins 2010).

Regarding the region of Belo Horizonte, Brown & Mielke (1968) registered forty nine species of fruit-feeding butterflies (eight exclusive records this location) and estimated 107 species for the city. Silva et al. (2007) studied an urban area of Belo Horizonte, finding seventeen species of fruit-feeding butterflies, four of which had not been found by Brown & Mielke (1968) and one was not recorded in this study; *Nica flavilla*. Silva et al. (2012) studied an area in Belo Horizonte (APE Cercadinho), registering forty-five species, two exclusive ones. Soares et al. (2012) studied other urban area, in the centre of Belo Horizonte, finding fifteen species, with one exclusive to this area (*Eteona tisiphone*, Satyrinae).

Five of the seven surveys conducted in the region of Belo Horizonte had fourteen species in common: *Biblis hyperia*

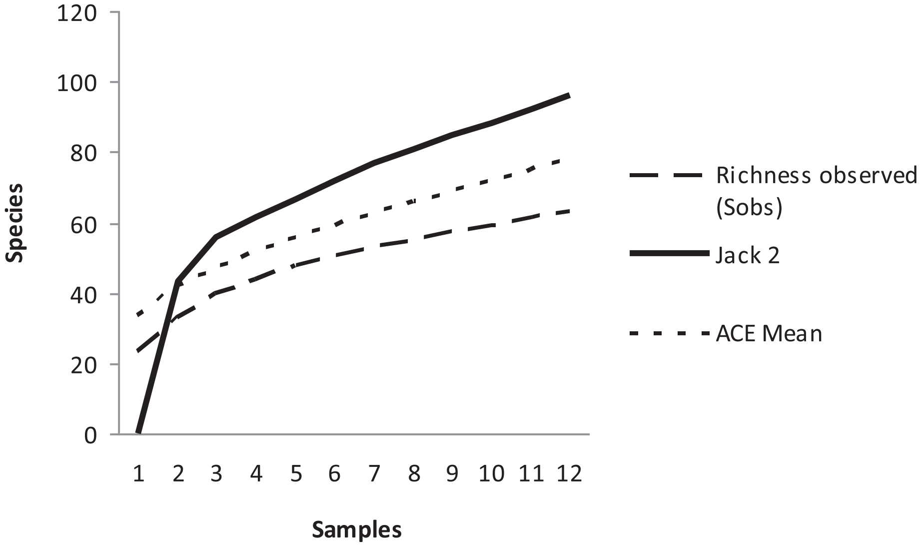

Figure 3. Species accumulation curve of butterflies recorded at the Área de Proteção Especial Manancial Mutuca, Nova Lima, MG, Brazil, between October 2008 and September 2009.

Table 2. Estimators of species richness and proportion of the number of species observed in APE Mutuca and of the compiled species in the region of Belo Horizonte.

Estimators of species richness	Estimated number of species	Proportion of observed species (63)	Proportion of species compiled list for Belo Horizonte (104)
Chao 2	107	59%	97%
Jackknife 2	95	66%	109%
ACE	79	80%	131%

nectanabis, *Callicore sorana sorana*, *Hamadryas amphinome amphinome*, *Hamadryas epinome*, *Hamadryas februa februa*, *Hamadryas feronia feronia* (Biblidinae), *Colobura dirce* (Nymphalinae), *Brassolis sophorae laurentii*, *Blepolenis batea batea*, *Opsiphanes invirae*, *Morpho helenor mielkei*, *Paryphthimoides phronius*, *Paryphthimoides poltys* and *Taygetis laches* (Satyrinae). These species could be the focus of population studies at the regional scale (eg: long-term monitoring), since most of them are easily identified and occur with high abundance in the samples.

From the fruit-feeding butterflies species found in collections, seventy-one were identified in the collection of MCN-PUC-MG, including twelve exclusive species this collection. In the Coleção Entomológica da UFMG sixty species were identified, with three exclusive ones, while in the collection of MHNJB-UFMG fourteen species of fruit-feeding butterflies were recorded, neither exclusive specie.

In APE Mutuca, six species, which were not recorded in any of the studies or collections mentioned above, were sampled, and are new records for the region of Belo Horizonte: *Myscelia orsis, Prepona deiphile deiphile, Prepona laertes, Catoblepia amphirhoe, Narope cyllastros* and *Pareuptychia ocirrhoe interjecta*. Adding the records of the four papers (Brown & Mielke 1968, Silva et al. 2007, Silva et al. 2012, Soares et al. 2012), the three collections and the present study, the total number of fruit-feeding butterflies in the region of Belo Horizonte is of 104 species. Brown & Freitas (2000), referring to articles, collections, an personal communication, recorded eighty species of fruit-feeding butterflies in Belo Horizonte.

The species accumulation curve of APE Mutuca showed no clear stabilization trend (Figura 3), indicating that other species could be recorded with increasing sampling effort, a result corroborated by the richness estimators. The estimated species richness reached 107 species by the Chao 2 estimator, ninety-five species by the Jackknife 2 estimator, and seventy-nine species by ACE estimator (Table 2). Therefore, the complied list in this study, with 104 species in the region of Belo Horizonte, approaches the richness achieved by estimators Chao 2 and Jackknife 2 for SPA Mutuca (Table 2). The Chao 2 estimator was closer to the list of Belo Horizonte (104 species), with an estimate of 107 species, indicating a congruence between the locally estimated and regionally observed values for fruit-feeding butterflies.

The number of fruit-feeding butterflies species recorded in this study (sixty-three) may be considered high, especially if it is taken into account that the APE Mutuca is a relatively small vegetation sample (1250 ha). The present study demonstrates that the APE Mutuca is essential for the maintenance of local diversity of butterflies because, even though the area is subjected to anthropogenic impact, it harbors an important portion of the fruit-feeding butterfly fauna in the region – including thirty-five rare and one endangered species. This study also reinforces the importance of the creation and preservation of protected areas, even near large cities, for the maintenance of biodiversity at the regional scale.

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References

BAZ, A. & BOYERO, A.G. 1995. The effects of forest fragmentation on butterfly communities in central Spain. J. Biogeogr. 22:129-140, http://dx.doi.org/10.2307/2846077

BIODIVERSITAS. 2006. Lista da Fauna Ameaçada de Extinção de Minas Gerais. http://www.biodiversitas.org.br/listas-mg/MG-especies-Fauna-ameacadas.pdf. (último acesso em 30/05/2011).

BRANDÃO, M., FERREIRA, P.B.D. & ARAUJO, M. G. 1997. Mais uma contribuição para o conhecimento da Cadeia do Espinhaço em Minas Gerais – VI: Serra do Rola Moça. Daphne 7(4):50-64.

BROWN, J. & LOMOLINO, M. 2006. Biogeografia. 2 ed. FUNPEC Editora, Ribeirão Preto.

BROWN JR., K.S. 1996. Diversity of Brazilian Lepidoptera: history of study, methods for measurements, and use as indicator for genetic, specific and system richness. In Biodiversity in Brazil: a first approach (C.E.M. Bicudo & N.A. Menezes, eds). Instituto de Botânica, São Paulo, p.121-153.

BROWN JR., K.S & FREITAS, A.V.L. 2000. Atlantic Forest butterflies: indicators for landscape conservation. Biotropica 32(4): 934-956, http://dx.doi.org/10.1111/btp.2000.32.issue-4b

BROWN JR., K.S & MIELKE, O.H.H. 1968. Lepidoptera of the Central Brazil Plateau. III. Partial list for the Belo Horizonte area, showing the character of the southeastern "Blend Zone". J. Lepid. Soc. 22(3):147-157.

CAMARGO, A.J.A., 2001. Importância das Matas de Galeria para a conservação de lepidópteros do Cerrado. In Cerrado: caracterização e recuperação de Matas de Galeria. (J.F. Ribeiro, C.E.L. Fonseca & J.C. Sousa-Silva, eds.) Embrapa, Planaltina, p.607-634.

CETEC. Fundação Centro Tecnológico de Minas Gerais. 1993. Desenvolvimento de metodologia (técnicas) para recuperação do revestimento florístico natural em áreas de proteção das captações de água da COPASA na região da grande Belo Horizonte. Relatório Técnico. CETEC, Belo Horizonte.

COPASA. 2013. Reservas Ambientais. http://www.copasa.com.br/cgi/cgilua.exe/sys/start.htm?sid = 157&infoid = 104&tpl = section.htm (último acesso em 10/06/2013).

COLWELL, R.K. 2009. Estimates Version 8.2: statistical estimation of species richness and shared species from samples. University of Connecticut, Connecticut. http://viceroy.eeb.ucon.edu/estimates.

DAJOZ, R. 1983. Ecologia Geral. 4 ed. Editora Vozes, Petrópolis.

DE VRIES, P. 1987. The butterflies of Costa Rica and their natural history. Papilionidae, Pieridae, Nymphalidae. Princeton University Press, Princeton.

DE VRIES, P.J, MURRAY, D. & LANDE, R. 1997. Species diversity in vertical, horizontal, and temporal dimensions of a fruit-feeding butterfly community in an Ecuadorian rainforest. Biol. J. Linn. Soc. 62:343-364, http://dx.doi.org/10.1111/bij.1997.62.issue-3

DE VRIES, P.J, WALLA, T.R & GREENEY, H.F. 1999. Species diversity in spatial and temporal dimensions of a fruit-feeding butterfly community from two Ecuadorian rainforest. Biol. J. Linn. Soc. 68:333-353, http://dx.doi.org/10.1111/bij.1999.68.issue-3

DE VRIES, P.J, PENS, C.M & HILL, R.I. 2010. Vertical distribution, flight behavior and evolution of wing morphology in Morpho butterflies. J. Anim. Ecol. 79:1077-1085, http://dx.doi.org/10.1111/j.1365-2656.2010.01710.x

DE VRIES, P.J, ALEXANDER, L.G, CHACON, I.A & FORDYCE, J. A. 2011. Similarity and difference among rainforest fruit-feeding butterfly communities in Central and South America. J. Anim. Ecol. 81:472-482, http://dx.doi.org/10.1111/j.1365-2656.2011.01922.x

FORTUNATO, L. & RUSZCZYK, A. 1997. Comunidades de Lepidópteros frugívoros em áreas verdes urbanas e extra-urbanas de Uberlândia, MG. Rev. Brasil. Biol. 57(1):79-87.

FREITAS, A.V.L & ALMEIDA, A.C. 2012. Lepidoptera: borboletas e mariposas do Brasil. 1 ed. Exclusiva Publicações, São Paulo.

FREITAS, A.V.L., FRANCINI, R.B. & BROWN JR., K.S. 2003. Insetos como indicadores ambientais. In Métodos de estudos em biologia e manejo da vida silvestre. (L. Cullen Jr, R. Rudran & C. Valladares-Padua, eds). Curitiba, Editora da UFPR, p.125-151.

FREITAS, A.V.L. 2010. Impactos potenciais das mudanças propostas no Código Florestal Brasileiro sobre as borboletas. Biota Neotrop. 10(4):1-5. http://www.biotaneotropica.org.br/v10n4/pt/fullpaper?bn00810042010 + pt (último acesso em 20/03/2014).

KLINK, C.A. & MACHADO, R.B. 2005. A conservação do cerrado brasileiro. Megadiversidade 1(1):147-155.

LAMAS, G. 2004. Atlas of Neotropical Lepidóptera: Checklist. Part 4A – Hesperioidea e Papilionoidea. Scientific Publishers, Gainesville.

LEWINSOHN, T.M., FREITAS, A.V.L. & PRADO, P.I. 2005. Conservação de Invertebrados terrestres e seus hábitats no Brasil. Megadiversidade 1(1):62-69.

MACHADO, A.B.M., MARTINS, C.S. & DRUMMOND, G.M. 2005. Lista da Fauna Brasileira Ameaçada de Extinção. Fundação Biodiversitas, Belo Horizonte.

MAGURRAN, A.E. & VIANNA, D.M. (Trad.) 2011. Medindo a diversidade biológica. Editora da UFPR, Curitiba.

MARÍN, M.A., PEÑA, C., FREITAS, A.V.L., WAHLBERG, N. & URIBE, S I. 2011. From the Phylogeny of the Satyrinae Butterflies to the Systematics of Euptychiina (Lepidoptera: Nymphalidae): History, Progress and Prospects. Neotrop. Entomol. 40(1):1-13.

MARINI-FILHO, O.J. 2012. Comunicação pessoal.

MARINI-FILHO, O.J. & MARTINS, R.P. 2010. Nymphalid butterfly dispersal among forest fragments at Serra da Canastra National Park, Brazil. J. Insect Conserv. 14:401-411, http://dx.doi.org/10.1007/s10841-010-9271-9

MENDONÇA, M.P. & LINS, L.V. 2000. Lista vermelha das espécies ameaçadas de extinção da flora de Minas Gerais. Belo Horizonte. Fundação Biodiversitas, Fundação Zôo-Botância de Belo Horizonte, Belo Horizonte.

MIELKE, O.H.H., CARNEIRO, E. & CASAGRANDE, M.M. 2010. Lepidopterofauna (Papilionoidea e Hesperioidea) do Parque Estadual do Chandless e arredores, Acre, Brasil. Biota Neotrop. 10(4):285-300. http://www.biotaneotropica.org.br/v10n4/pt/fullpaper?bn03210042010 + pt (último acesso em 16/02/2014).

MYERS, N., MITTERMEIER, R.A., MITTERMEIER, C.G., FONSECA, G.A.B. & KENT, J. 2000. Biodiversity hotspots for conservation priorities. Nature 3:853-858.

PINHEIRO, C.E.G. & ORTIZ, J.V.C. 1992. Communities of Fruit-Feeding Butterflies along a vegetation gradiente in Central Brazil. J. Biogeog. 19:505-511, http://dx.doi.org/10.2307/2845769

PINHEIRO, C.E.G., MALINOV, I.C., ANDRADE, T.O., MARAVALHAS, J.B., ANDRADE, M.B.M., DEUS, L.P.A., PEDROSA, L.G.P. & ZANATTA, G.V. 2008. As borboletas (Lepidoptera: Papilionoidea) do Campus Universitário Darcy Ribeiro (Distrito Federal, Brasil). Biota Neotrop. 8(4):138-144. http://www.biotaneotropica.org.br/v8n4/pt/fullpaper?bn00608042008 + pt (último acesso em 20/02/2013).

RITTER, C.D., LEMES, R., MORAIS, A.B.B. & DAMBROS, C.S. 2011. Borboletas (Lepidoptera: Hesperioidea e Papilionoidea) de fragmentos de Floresta Ombrófila Mista, Rio Grande do Sul, Brasil. Biota Neotrop. 11(1):1-8. http://www.biotaneotropica.org.br/v11n1/pt/fullpaper?bn00511012011 + pt (último acesso em 27/04/2013).

SHAHABUDDIN, G. & PONTE, C.A. 2005. Frugivorous butterfly species in tropical forest fragments: correlates of vulnerability to extinction. Biodiv. Conserv. 14:1137-1152, http://dx.doi.org/10.1007/s10531-004-7842-3

SILVA, A.R.M., LANDA, G.G. & VITALINO, R.F. 2007. Borboletas (Lepidoptera) de um fragmento de mata urbano em Minas Gerais, Brasil. Lundiana 8(2):137-142.

SILVA, A. R. M., CASTRO, C. O., MAFIA, P. O., MENDONÇA, M. O. C., ALVES, T. C. C. & BEIRÃO, M. V. 2012. Borboletas frugívoras (Lepidoptera: Nymphalidae) de uma área urbana (Área de Proteção Especial Manacial Cercadinho) em Belo Horizonte, Minas Gerais, Brasil. Biota Neotrop. 12(3):292-297. http://www.biotaneotropica.org.br/v12n3/pt/abstract?inventory + bn03112032012 (último acesso em 17/09/2013), http://dx.doi.org/10.1590/S1676-06032012000300028

SOARES, G. R., OLIVEIRA, A. A. P. & SILVA, A. R. M. 2012. Borboletas (Lepidoptera: Papilionoidea and Hesperioidea) de um parque urbano em Belo Horizonte, Minas Gerais. Biota Neotrop. 12(4):209-217. http://www.biotaneotropica.org.br/v12n4/pt/fullpaper?bn02612042012 + pt (último acesso em 11/04/2013), http://dx.doi.org/10.1590/S1676-06032012000400022

UEHARA-PRADO, M., FREITAS, A.V.L.; FRANCINI, R.B. & BROWN JR., K.S. 2004. Guia das borboletas frugívoras da Reserva Estadual do Morro Grande e região de Caucaia do Alto, Cotia (São Paulo). Biota Neotrop. 4(1):1-25. http://www.biotaneotropica.org.br/v4n1/pt/download?article + BN00504012004 + abstract (último acesso em 12/10/2012).

WILSON, E.O. 1997. A situação atual da diversidade biológica. In Biodiversidade. (E.O. Wilson & F.M. Peter, eds). Editora Nova Fronteira, Rio de Janeiro, p.3–

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Bionomics of *Melipona mondury* Smith 1863 (Hymenoptera: Apidae, Meliponini) in relation to its nesting behavior

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Abstract: *Melipona mondury* Smith 1863 is an important stingless bee species pollinator and honey/pollen producer, but threatened by fragmentation of habitats throughout its range. This article presents the identification and partial characterization of nesting substrates, bionomic including population features of *M. mondury* by comparing data between nest architecture of natural beehive and boxes colonies. Nineteen colonies (13 in boxes and six in beehives) were analyzed with regards to substrate nesting, nest characteristics (e.g. length and width of the combs, height and diameter of the pollen and honey jar) and bee population. The average volume and diameter of the trunks cavities used for nesting of *M.mondury* were18.4 L and 15.8 cm; the average number of combs was 9.26; the average diameter and height of the honey pots were 2.81 cm and 3.29 cm, and the average volume of honey stored was 15.85 mL; the average height and diameter of pollen pots was 3.21 cm and 2.93 cm, respectively, while the average mass of pollen deposited was equal to 12.56 g. The population ranged from 3537 to 10281 individuals between colonies. The results suggest that the conservation of *M. mondury* should involve reforestation with native species from Atlantic Forest, and the dimensions of boxes should be based on the average size of the nests in the natural environment in order to support strategies of conservation and sustainable management of this species.

Keywords: *Conservation, nest architecture, nesting substrate, rational management, stingless bees.*

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Resumo: *Melipona mondury* Smith 1863 é uma espécie de abelha sem ferrão, importante polinizadora, produtora de mel e de pólen, mas ameaçada pela fragmentação dos habitats ao longo de sua área de ocorrência. Este artigo apresenta a identificação e a caracterização parcial dos substratos de nidificação e as características bionômicas, incluindo as populacionais, de *M. mondury*, comparando os dados de arquitetura do ninho entre colônias de cortiço e caixas rústicas. Dezenove colônias (13 em caixas rústicas e seis em cortiços) foram analisadas em relação aos substratos de nidificação, características do ninho (e.g.: comprimento e largura dos favos de cria, altura e diâmetro dos potes de pólen e mel) e população das abelhas. Foram encontrados volume e diâmetro médios da cavidade dos troncos nidificados por *M. mondury*, de 18,4 L e 15,8 cm; número médio de favos de cria de 9,26; diâmetro e altura médios dos potes de mel de 2,81 cm e 3,29 cm, sendo o volume médio de mel armazenado de 15,85 mL; altura e diâmetro médios dos potes de pólen de 3,21 cm e 2,93 cm, enquanto a massa média de pólen depositado foi de 12,56 g. A população variou de 3 537 a 10 281 indivíduos entre as colônias. Os resultados sugerem que a conservação de *M. mondury* deve envolver o reflorestamento com espécies nativas da Mata Atlântica; e as dimensões das caixas racionais foram definidas com base no tamanho médio dos ninhos no ambiente natural, para subsidiar estratégias conservacionistas e de manejo racional.

Palavras-chave: *Abelhas sem ferrão, arquitetura do ninho, conservação, manejo racional, substrato de nidificação.*

Introduction

The tribe Meliponini, which includes the “indigenous stingless bees” is widespread over tropical regions worldwide and subtropical areas of South hemisphere. Brazil encompasses most of their occurrence, comprising nearly 375 eusocial species distributed into 23 genera (Camargo & Pedro, 2013).

The meliponini species show a large array of nesting and nest thermoregulation strategies. One of these strategies is the nesting within trunk cavities with thick walls and construction of involucrum around broods (Nogueira-Neto 2002, Cortopassi-Laurindo & Nogueira-Neto 2003). The indigenous stingless bees are remarkable pollinators, being responsible for 30% to 40% of pollination rate according to biomes (Kerr 1997). Therefore, they directly improve the production of fruits and seeds that are used as resources for several species (Silveira et al. 2002), including humans.

Independently of the Brazilian region, forests are the most suitable location for meliponins finding food and nesting places. However, these environments have been changing over the years by human action and nowadays are severely fragmented. This process threatens the regional biodiversity because of isolation of remaining populations, leading to losses in genetic variation, one of the main causes of species extinction (Schaffer & Prochnow 2002).

Deforestation reduces the population of stingless bees, particularly in areas used for intensive agriculture and cattle production inasmuch these disturbed areas acts as barriers to fixation and dispersal of species that depend on specific vegetation types (Kerr 1987,Viana & Melo 1987).

Within meliponins, *Melipona* Illiger, 1806 is the most species-rich genus (nearly 70 representatives) with distribution throughout the Neotropical region, from Mexico to Misiones in Argentina, and higher diversification in Amazon basin (Silveira et al. 2002, Camargo & Pedro, 2013). *Melipona mondury* Smith 1863, popularly known as “uruçu amarela” is an efficient producer of honey and pollen, playing a major role in pollination and primary environmental services. It is found in Atlantic Forest fragments from the states of Bahia, Espírito Santo, Rio de Janeiro, Minas Gerais, São Paulo, Paraná and Santa Catarina (Melo 2003), and its rational culture might determine both economic and environmental advantages.

The knowledge about nesting habits of stingless bees such as *M. mondury* allows understanding their adaptation to habitats (Alfaro 2003) and helps the establishment of strategies of forest management to conservation of species. This information is also useful to improve the management practices and increase the productivity of rational colonies, an economic activity with low environmental impacts and related to familiar agriculture.

However, studies about the nest biology of this species are not available. Therefore, the goal of this work was to investigate the nesting substrate and bionomic features including population density of colonies of *Melipona mondury*, through the nest architecture analysis of colonies in nature and in rational boxes, as a support to conservation of the species and the rational creation.

Material and methods

The present study comprised 19 colonies of *M. mondury* in Atlantic Forest, being 13 raised in boxes and six in natural beehives (isolated trunk cavities kept in culture systems), in the municipalities of Jaguaquara (13°43’29.82"S, 39°47’24.72"W), Jequié (13°51’4"S/40°04’52"W) and Tancredo Neves (13°27’14"S/39°25’15"W) (Bahia/Brazil) from December 2009 to August 2011.

The nest description was performed according to the methodology proposed by Camargo (1970) and Wille & Michener (1973). The following indicators were analyzed:

- Substrate used for nesting of colonies in natural beehives – length of trunk cavity, diameter of trunk cavity, wood thickness;
- Nest features – volume of trunk cavity occupied by colony (L) (in beehive), height of brood area (cm), number of brood combs, length and width of brood combs (cm), diameter of entrance hole (mm), height and diameter of brood combs (mm), height of pillars (cm), height and diameter of honey pots (cm), volume of honey pots (ml), height and diameter of pollen pots (cm), mass of pollen in closed pots (g);
- Bee population – number and mass of specimens per colony, number of brood cells per cm^2 of comb.

The external measurements of length and diameter in trunk cavity and wood thickness of substrate used for nesting were obtained by using a tape measure. A pachymeter and a ruler were used to obtain the length, width and diameter of nest features. A disposable 20-mL syringe was used to collect the content of honey pots and measure their volume. The mass of pollen stored in pots was determined by using a digital scale (precision of 0.01 g). The weight of workers and queen bee was obtained in an analytical scale model Denver Instrument APX-200 (precision of 0.001 g).

The mean number of brood cells per cm^2 of comb and the state of colonies were obtained according to Aidar (1995). The total population was estimated as proposed by Ihering (1930) based on the ratio ($x + x/2$), where x is the total number of brood cells in a colony. The vegetal species used as beehives were identified by taxonomists and confirmed by comparing them with exsiccates sent to the herbarium at UESB (Universidade Estadual do Sudoeste da Bahia).

After describing the nest architecture, the colonies were transferred to 20 x 20 x 20 cm boxes model INPA (Oliveira & Kerr 2000) to nest and overnest, adequate to management and artificial development of colonies of *M. mondury*, as previously determined. The temperature inside colonies and involucre in boxes were obtained by using a digital thermo-hygrometer JProlab indoor/outdoor.

The data analysis was carried out using the software BioEstat version 5.0 (Ayres et al. 2007), which as based on the descriptive analysis of variables by estimating mean, standard deviation and variation coefficient. Moreover, the relationship between environmental, colony and involucre temperature around brood areas was evaluated by Pearson’s linear correlation.

Results

Two out of the six colonies of *M. mondury* found nesting in natural substrate used the tree *Pouteria venosa* (Mart.) Baehni (Sapotaceae) while the others nested in different species, identified as *Hirtella hebeclada* Moric. ex DC (Chrysobalanaceae), *Tabebuia serratifolia* (Vahl) Nichols (Bignoniaceae), *Ocotea*

Table 1. Results of measurements recorded in *M. mondury* nesting substrates.
Tabela 1. Resultados das medidas registradas nos substratos de nidificação de *M. mondury.*

Measures	Min	Max	Mean	SD
Cavity length of the tree trunk (cm)	80	110	93	12
Cavity diameter trunk (cm)	11	19	16	3
Wood thickness (cm)	4	12	7	3
Cavity volume of the trunk (L)	10	24	18,4	5

odorifera (Vellozo) Rohwer (Lauraceae) and *Byrsonima stipulacea* A.Juss. (Malpighiaceae). The nests of *M. mondury* were found in relatively preserved Atlantic Forest areas within large fragments and the bees visited vegetal species in advanced successional steps.

The mean volume and diameter of trunk cavities used as nests by *M. mondury* were equal to 18.4 ± 5.34 L and 15.8 ± 2.95 cm, respectively. The wood thickness ranged from 4 to 12 cm, with a mean value of 7.0 ± 3.0 cm (Table 1).The entrance hole in colonies of *M. mondury* presented a mean diameter of 0.96 ± 0.14 cm, and the height in relation to soil ranged from 2.80 to 5.20 m.

In all studied colonies of *M. mondury*, involucres were observed around brood combs, being thicker in less populated colonies. During warmer seasons, the nest of hives transferred to boxes remained without involucrum for longer periods when compared the periods of lower temperatures (around 22°C), when the involucres started being built right after nest transference.

The temperature of brood combs in colonies ranged from 28 to 31°C with a mean value of 29.67 ± 0.33 °C while the environmental temperature during studied period varied from 17 to 30 °C, with a mean value of 22.58 ± 1.16 °C. The temperature range in the environment was equal to 13°C, while that within brood combs was equal to 3°C.

No significant correlation between environmental and involucrum temperature was detected in the most populated colony established in box ($p = 0.1176$, $r = 0.48$ and $r^2 = 23\%$). However, a significant correlation ($p < 0.01$) was observed between environmental and within-colony temperatures ($r = 0.85$ and $r^2 = 72.1\%$).

In less populated colonies, the correlation was positive and significant for both environmental and honey pot temperature and environmental and within-colony temperature ($p < 0.01$), as shown by the high values of correlation (r) and determination (r^2) coefficients.

The number of brood combs in colonies of *M. mondury* ranged from six to 15 (mean = 9.26 ± 2.64). The mean dimensions of brood combs were 12.03 ± 3.89 cm in length, 9.75 ± 3.33 cm in width, 10.03 ± 0.18 mm in height, 0.52 cm of internal diameter and 3.75 ± 0.62 cells/cm^2. The combs were separated from each other by wax pillars of 0.41 ± 0.05 cm in average height, allowing the bees to pass between brood disks. The arrangement of brood combs varied among colonies, being either helicoidal or overlapped. In Table 2, the bionomic measurements reported for *M. mondury* are compared to other *Melipona* species.

The measurements of honey pots of *M. mondury* ranged from 2 to 5 cm in diameter (mean = 2.81 ± 0.54 cm); 2 to 4 cm in height (mean = 3.29 ± 0.54 cm); and 7 to 39 mL of stored honey volume (mean = 15.85 ± 5.30 mL). The dimensions of pollen pots ranged from 2 to 4 cm (mean value of 2.93 ± 0.58 cm) in diameter, and 2 to 7 cm in height (mean of 3.21 ± 0.81 cm). The pollen mass deposited in closed pots varied from 5 to 33 g (mean of 12.56 ± 4.93 g) (Table 3). In Table 2, a comparison of measurements of honey and pollen pots among different *Melipona* species is presented.

The storage capacity of honey and pollen pots among developed colonies in hives and boxes had no significant differences ($p = 0.4716$). Similarly, the volume of honey and pollen mass in pots between hives and boxes were equivalent ($p = 0.4716$).

Taking into account the mean number of brood cells per colony, the population of *M. mondury* varied from 3537 to 10281 individuals, including eggs, larvae, pupae and adults (mean of 5959 ± 1736 individuals). In this work, colonies raised in 16-L boxes had some empty spaces and mean individual number lower than that observed in natural hives. The comparison between mean number of individuals between colonies in hives and boxes revealed significant differences ($p < 0.01$). Table 4 shows the comparative data of number of individuals per colony observed in this study for *M. mondury* and previous reports in other congeners.

The mean number of individuals per colony was higher in hives (7762.83) when compared to boxes (5126.40), with significant differences ($p < 0.01$).

Discussion

1. Nesting substrate

Similarly to the results observed in this work for *M. mondury*, Siqueira et al. (2007) also reported *Melipona rufiventris* Lepeletier, 1836 in trunk holes of trees belonging to genera *Pouteria* (*Pouteria ramiflora* (Mart.) Radlk, Sapotaceae) and *Tabebuia* (*Tabebuia aurea* (Manso) Benth. & Hook.f., Bignoniaceae) along forest fragments in a transition zone

Table 2. Features of nests of *Melipona mondury* in relation to congeneric species.
Tabela 2. Características dos ninhos de *Melipona mondury* em relação aos ninhos de espécies congêneres.

	Brood combs per colony			Brood combs			Pillars	
Species	Number	Length (cm)	Width (cm)	Per cm^2	Height (cm)	Diameter (cm)	Height	Reference
M. mondury	9.26	12.03	9.75	3.75	1.00	0.52	0.41	This study
M. mandacaia	6.13	6.32	5.74	4.23	1.01	0.57	0.7	Alves et al. (2007)
M. alsilvai	5.55	5.44	4.13	5.87	0.76	0.45	0.4	Souza et al. (2008)
M. scutellaris	6.81	9.33	8.63					Alves et al. (2012)
M. quadrifasciata	5.1		5.8					Brito et al. (2013)
M. compressipes	6.6	11.2	7.4					Almendra (2007)

Table 3. Comparison of honey and pollen pots of different *Melipona* species.
Tabela 3. Comparação das medidas dos potes de mel e de pólen entre diferentes espécies do gênero *Melipona*.

	Honey pots			**Pollen pots**			
	Diameter (cm)	**Height (cm)**	**Volume (mL)**	**Diameter (cm)**	**Height (cm)**	**Mass (g)**	**Reference**
M. mondury	2.81	3.29	15.85	2.93	3.21	12.56	This study
M. mandacaia	2.53	2.78	6.47	2.48	3.02	6.66	Alves et al. (2007)
M. alsilvai	2.03	2.4	4.1	2.28	2.67	4.46	Souza et al. (2008)
M. scutellaris			15.71			14.04	Alves et al. (2012)
M. quadrifasciata			5.73				Brito et al. (2013)
M. compressipes	2.9	3.7	15.8	2.8	3.5	14.1	Almendra (2007)

between Brazilian savannah and semi deciduous seasonal forest of Minas Gerais, as well as in species of other genera. *Pouteria* ("abiu") is a fruit plant and *Tabebuia* ("ipê") is used in landscaping and furniture industry.

M. mondury is genetically close to *M. rufiventris* that occurs in Brazilian savannah (cerrado). Moure (1975) was the first to propose that individuals from Atlantic forest were morphologically distinguished from those found in "Cerrado". Therefore, *M. rufiventris* and *M. mondury* were valid species names from populations from Cerrado and Atlantic forest regions, respectively (Obiols 2008, Camargo & Pedro 2013). Molecular studies using PCR-RAPD (Tavares et al. 2008), microsatellite (Lopes 2004, Tavares et al. 2008), PCR-RFLP (Schetino 2005, Barni et al. 2007), isozymes (Tavares et al. 2008) and ISSR (Dias 2008) markers corroborated the differences pointed out by Melo (2003) and Moure (1975).

Souza et al. (2008), analyzing bionomic features of *Melipona asilvai* Moure, 1971 observed individuals of that species nesting in umburana (*Amburana cearenses* Smith, Fabaceae), a species usually regarded as a suitable substratum for stingless bees, particularly *Melipona subnitida* Ducke, 1910 (Bruening 1990). Mesquite (*Prosopis juliflora* (sw.) DC., Fabaceae) was the second species with the highest number of nests.

Alves et al. (2007) reported 15 colonies of *Melipona mandacaia* Smith, 1863 in "umburana-de-cambão" (*Commiphora leptophloeos* (Mart.) Gillett (Burseraceae)), while Oliveira (2002) found *M. mandacaia* nesting in "quixabeira" (*Sideroxylon obtusifolium* Roem. & Schult.). Both botanical species occurring in the "Caatinga" biome. These plant species are of beekeeping and medicinal importance, and are threatened by deforestation.

When compared to *M. mondury*, other intensively studied species of *Melipona* from drier regions, such as *M. mandacaia* Smith, 1863, *M. quadrifasciata* Lepetier, 1836 and *M. subnitida* Ducke, 1910, nested mostly in certain vegetal species like *Centrolobium tomentosum* Guill. ex Benth. (Alves et al. 2007).

The present results in *M. mondury* suggest this species has adapted to different substrata because of the higher floristic diversity within their range and a lower concentration of specific tree species per area, thus differing from the conditions reported by Souza et al. (2008) and Alves et al. (2007) for *M. asilvai* and *M. mandacaia*, respectively. Alves et al. (2009) observed that *M. scutellaris* Latreille, 1811 nests in an array of substrata since 82 nests were observed in 19 vegetal species from 12 families.

According to Araújo et al. (1998), *M. mondury* occurs in moist forests with the presence of tall trees such as *Dalbergia nigra*, *Caesalpinia echinata* and *Cariniana* sp., and the abundance of epiphytes, differing from the area occupied by *M. scutellaris*. *M. mondury* occurs in an environment with greater diversity of plant species and lower concentrations of the same species per area, while *M. scutellaris* is found in domain of lower diversity and higher concentration of the same species, such as *Sclerolobium* sp. and *Tapirira* sp., which are excellent substrates for nesting.

Cortopassi-Laurino et al. (2009), studying neotropical trees used for nesting by stingless bees revealed that Fabaceae and Anacardiaceae were the most observed families with nests of Meliponini, including *Melipona*. Under natural conditions, *M. mondury*, a stingless bee species from Atlantic forest, occupies holes formed by natural accidents in trees in which the poor healing allows the entrance of water into the trunk, thus accelerating the deterioration of lignified parts and forming a favorable place for nesting. Once most species of Meliponini build nests in trunk cavities, strategies to maintain their biodiversity should include vegetal species that usually form trunk holes.

Table 4. Number of individuals per colony of *M. mondury* in relation to other *Melipona* species.
Tabela 4. Número de indivíduos por colônia de *M. mondury* em comparação aos de outras espécies de *Melipona*.

	Number of specimens per colony				
	Min	**Max**	**Mean**	**Deviation**	**Reference**
M. mondury	3537	10281	5959	1736	This study
M. mandacaia	889	1597	1297		Alves et al. (2007)
M. alsilvai		1868	1034		Souza et al. (2008)
M. scutellaris	1315	3945	2485	515.19	Alves et al. (2010)
M. quadrifasciata			1092	338.37	Brito et al. (2013)
M. compressipes			2079		Almendra (2007)

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The mean volume of trunk cavities used as nests by *M. mondury* (Table 1) was higher to the mean volume of nest cavities in *M. mandacaia,* reported by Alves et al. (2007), of 1.59 L; and 2.73 L by *M. asilvai,* according to Souza et al. (2008), what might indicate the potential of this species to the productions of individuals, pollen and honey.

The mean diameter of trunk cavity in nest cavities of *M. mondury* (15.8 ± 2.95 cm) was also higher than that observed in trunks of trees from drier regions inhabited by *M. mandacaia* (mean diameter of 7.15 ± 1.17 cm) (Alves et al. 2007) and *M. asilvai* (mean diameter of 6.77 ± 1.9 cm) (Souza et al. 2008). According to Siqueira et al. (2007), the timber extraction of trees with large diameter might lead to scarcity of nesting substrata.

The mean thickness of wood in nests of *M. mondury* was similar to the mean value of 6.86 cm for trunks with nests of *M. mandacaia* (Alves et al. 2007) and 6.78 cm for *M. asilvai* (Souza et al. 2008). The mean length of trunk cavity in these congeners was also similar: 92.6 ± 12.4 cm for *M. mondury* (this study), 115 ± 20.28 for *M. mandacaia* (Alves et al. 2007) and 96 ± 25 for *M. asilvai* (Souza et al. 2008). Therefore, the conservation of flora visited by *M. mondury* will also contribute to the protection of other species of Melipona that coexist in the same region.

2. Nest architecture

2.1 Colony entrance. The construction of colony entrance to protect against invaders, location and landing by *Melipona mondury* is made of clay, wax, resin and propolis, composing the geopropolis of hard density and red coloration, forming a central orifice surrounded by convergent rays, detached in populated colonies with a coloration that might change according to the pigment of used resin.

The glandular substances applied to the structure of colony entrance serve to guide the foragers because of their high reflectivity to ultraviolet light (Ihering 1930, Roubik 1989). Nonetheless, in the case of *M. mondury*, the entrance of colonies become overcrowded during periods of high foraging since the orifice presents a reduced diameter when compared to body size, allowing the entrance of a single bee each time. It was observed a forager that guards the orifice in structure entrance, aware of any intruder.

Alves et al. (2007) reported a mean diameter of 0.71 cm for the entrance orifice in nests of *M. mandacaia*. In *M. asilvai*, Souza et al. (2008) reported a mean diameter of entrance orifice equal to 0.36 cm. These and other authors (Nogueira Neto 1997, Oliveira 2002, Souza et al. 2008) observed that, in less populated colonies of some *Melipona* species (*M. mandacaia*, *M. quadrifasciata*, *M. subnitida* and *M. asilvai*), the bees close the entrance orifice with clay and/or animal feces during period of low temperature or dry season (Alves et al. 2007, Nogueira Neto 1997, Oliveira 2002, Souza et al. 2008). This behavior was absent in *M. mondury*. The population of *M. mondury* varied between 3537 and 10281 individuals (eggs, larvae, pupae and adults) being the mean value of 5959 ± 1736 individuals.

2.2 Presence of involucre and thermoregulation. The involucres in colonies of *M. mondury* are related to thermoregulation of brood combs. The mode of involucrum production by *M. mondury* is similar to that described by Alves et al. (2007) and Souza et al. (2008) in *M. mandacaia* and *M. asilvai*, respectively. Alves et al. (2007) observed that only few colonies of *M. mandacaia* presented this structure. However, in colder regions, even highly populated colonies of *M. mondury* had involucres. Therefore, the presence of involucrum is more related to environmental temperature than to activity level of colonies.

The results of this study suggest that thermoregulation is more efficient in the presence of wax lamellae in involucres and populations of high density, as observed by Nogueira-Neto (2002); Cortopassi-Laurino (2003). This can be one of the reasons that hinder the survival of less populated colonies during colder seasons, when the temperature in the brood combs remains below the mean value of 29.67°C, verified in dense colonies.

2.3 Brood combs. The measurements of brood combs were remarkably higher in *M. mondury* when compared to other species of *Melipona*. In *M. mandacaia*, Alves et al. (2007) estimated a mean value of 6.13 combs per colony with dimensions of 6.32 cm in length and 5.74 cm in width, slightly shorter than the mean values reported in *M. mondury*. Similarly, Souza et al. (2008), analyzing nests of *M. asilvai*, found on average 5.55 combs per colony being 5.44 cm long and 4.13 cm wide. Studies carried out by Brito et al. (2013) and Almendra (2007), the indicators of brood combs for *M. quadrifasciata* and *M. compressipes* Schwarz, 1932, respectively, were also inferior to those observed in *M. mondury*. The results regarding the brood cells were similar to the reports by Alves et al. (2007) in *M. mandacaia* and Souza et al. (2008) in *M. asilvai* (Table 2).

2.4 Food pots. The pollen and honey pots were overlapped and attached to nest walls by wax pillars similar to those separating

Figure 1. Colony entrance of *Melipona mondury*.
Figura 1. Entrada da colônia de *Melipona mondury*.

Figure 2. Rational box with honey and pollen pots and brood combs of *Melipona mondury*.
Figura 2. Caixas racionais com potes de mel e de polén e discos de cria de *Melipona mondury*.

the combs. Souza et al. (2008) reported the same irregularity in organization of honey and pollen pots in *M. asilvai*. In several meliponins, this irregular shape in both dimensions and organization is influenced by the space to nesting, once workers are likely to occupy most of available space (Camargo 1970). The number of pollen and honey pots were 129 and 82 respectively.

According to Table 3, both diameter and height of honey pots are similar among species, while the honey volume in pots showed a greater variation. The volume of honey in pots of *M. mondury* was similar to that reported in *M. scutellaris* and *M. compressipes*.

3. *Population Estimation*

The variation in the number of individuals per colony in a same species is also reported in other *Melipona* species. Alves et al. (2007) found 1297 individuals on average for *M. mandacaia*, ranging from 889 to 1597. Souza et al. (2008) obtained similar results in *M. asilvai*, with a mean number of 1034 individuals while the most populated colony had 1868 individuals. The most numerous populations of *M. mondury* when compared to other species (Table 4) might represent an advantage for the commercial raising of this species, since a higher number of foragers will determine more efficient foraging and flower visitation. Consequently, this could favor the production of honey, pollen, or even the success of pollination projects.

The higher incidence of empty spaces and the lower mean number of individuals in boxes in relation to natural hives are expected since the food supply for colonies in natural environments is higher. Considering that colonies from each substratum were located close to each other, this difference should not be related to features like differential competition by resources between both nest types but rather to lack of manipulation in hives, thereby avoiding stress caused by management of bees. In hives, the colonies are less susceptible to frequent handling by bee keepers that might damage the nests and demand additional efforts in workers to rebuild them.

The conservation status of *M. mondury* is heterogeneous throughout their natural range and its occurrence is presently limited to forest fragments. The conservation of this species should encompass the reforestation of Atlantic Forest with native and regional species, including those plants used for nesting and resin collection by the colonies investigated in the present work, once *M. mondury* is usually found in large and high-quality fragments. The inclusion of vegetal species pollinated by stingless bees of the genus *Melipona* in reforestation programs is highly recommended. This study suggests that the dimensions of boxes in *M. mondury* should be defined based on the mean size of nests found in natural habitat, as well as the food availability (pollen and nectar) around the location of meliponaries. In this context, studies about bionomics are particularly relevant, once these data might be useful to the rationale management and species conservation, like *M. mondury*, that might serve as income sources for local farmers throughout their range.

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References

AIDAR, D.S. 1995. Multiplicação artificial e manejo de colônias de *Melipona quadrifascia* Lep. (Hymenoptera, Apidae, Meliponinae). Tese de Doutorado. Universidade Federal de Viçosa. 85 p.

ALFARO, M.Y.C. 2003. Comparacion de nidos de abejasinaguijón em três regiones de Guatemala. Available in http://www.monografias.com/trabajos7/abag/abag.shtml?relacionados Assessed in March 23rd 2014.

ALMENDRA, E. C. A. 2007. Aspectos da bionomia da abelha tiúba (*Melipona compressipes*) / Eline Chaves de Abreu Almendra, Teresina, 2007. 53 f. Dissertação (Mestrado em Ciência Animal) – Universidade Federal do Piauí. 2007.

ALVES, R.M.O., SOUZA, B.A. & CARVALHO, C.A.L. 2007. Nota sobre a Bionomia de *Melipona mandacaia* (APIDAE: MELIPONINA). Magistra, 19 (3) 204-212.

ALVES, R.M.O., SOUZA, B.A., CARVALHO, C.A.L., SOUZA, L.S.S. & ANDRADE, J.P. 2009. Substratos vegetais utilizados para nidificação pela Abelha uruçu (*Melipona scutellaris*) no litoral norte do Estado da Bahia. Mensagem doce n° 100. Março de 2009. Available in http://www.apacame.org.br/mensagemdoce/100/msg100.htm. Assessed in March 23rd 2014.

ALVES, R.M. de O.; CARVALHO, C. A. L. de; FAQUINELLO, P.; LÊDO, C.A. da S.; FIGUEREDO, L. 2012. Parâmetros biométricos e produtivos de colônias de *Melipona scutellaris* Latreille, 1811 (Hymenoptera: Apidae) em diferentes gerações. Magistra 24: 105-111.

AYRES, M., AYRES Jr, M., AYRES, D.L. & SANTOS, A.A. 2007. BioEstat: aplicações estatísticas nas áreas das ciências biológicas e médicas. Belém; Sociedade Civil Mamirauá: MCT-CNPq, 2007.

BARNI, G. S., STRAPAZZON, R., GERRA, J.V.C. & MORETTO, G. 2007. Mitochondrial genome diferences between the stingless bees *Melipona rufiventris* and *Melipona mondury* (Apidae: Meliponini). Genetics and Molecular Research 6 (1): 8-14.

BRITO, B.B.P., FAQUINELLO, P., PAULA-LEITE, M.C. & CARVALHO, C.A.L. 2013. Parâmetros biométricos e produtivos de colônias em gerações de *Melipona quadrifasciata anthidioides.* Archivos de Zootecnia 62 (238): 265-273. 2013, http://dx.doi.org/10.4321/S0004-05922013000200012.

BRUENING, H. 1990. Abelha jandaíra. Coleção Mossoroense, série C, volume 557. 181 p.

CAMARGO, J.M.F. 1970. Ninhos e biologias de algumas espécies de Meliponideos (Hymenoptera: Apidae) da região de Porto Velho, Território de Rondônia, Brasil. Revista de Biologia Tropical 16: 207-239.

CAMARGO J. M F. & PEDRO, S. R M. 2013. Meliponini Lepeletier, 1836. In Moure, J. S., Urban, D. & Melo, G. A. R. (Orgs). **Catalogue of Bees (Hymenoptera, Apoidea) in the Neotropical Region - online version.** Available at http://www.moure.cria.org.br/catalogue. Accessed Sep/25/2014

CORTOPASSI-LAURINO, M. & NOGUEIRA-NETO P. 2003. Notas sobre bionomia de *Tetragonisca weyrauchi* Schwwarz, 1943 (Apidae, Meliponini). Acta Amazonica 33: 643-650.

CORTOPASSI-LAURINO, M., ALVEZ, D.A. & IMPERATRIZ-FONSECA, V.L. 2009. Árvores neotropicais, recursos importantes para a nidificação de abelhas sem ferrão (Apidae, Meliponini). Mensagem Doce n° 100. Março de 2009. Available in http://www.apacame.org.br/mensagemdoce/100/artigo9.htm. Assessed in March 23rd 2014.

DIAS, F. G. 2008. Diferenciação genética entre *Melipona mondury*, Smith, 1863, *Melipona rufiventris*, Lepeletier, 1836 e *Melipona* sp. (Hymenoptera, Apidae) no Estado de Minas Gerais, Brasil, utilizando marcadores moleculares ISSR. Dissertação de Mestrado – Universidade Federal de Viçosa. Viçosa, 2008.

IHERING, H. 1930. Biologia das abelhas melíferas do Brasil. Publicado em 1930, como tradução do original alemão impresso em 1903. Tradutores: R.vonIhering e B. Correia de Sampaio. Boletim de Agricultura da Secretaria de Agricultura do Estado de São Paulo. 31 (5-8): 435-506, 649-714.

KERR, W.E. 1987. Biologia, manejo e genética de Melipona *compressipes fasciculata*Smith (Hymenoptera, Apoidea). Tese de Professor Titular. UFMA – Universidade Federal do Maranhão. São Luis, Brasil, 141p.

KERR, W.E. 1997. Importância da meliponicultura para o país. Biotecnologia Ciência e Desenvolvimento, 1 (3):42-44.

LOPES, D. M. 2004. Diversidade e estrutura genética em populações de *Melipona rufiventris*e *Melipona mondury* (Hymenoptera: Apidae) por análise de microssatélites. Dissertação de Mestrado – Universidade Federal de Viçosa. Viçosa.

MELO, C.A.R. 2003. Notas sobre meliponíneos neotropicais (Hymenoptera, Apoidae). Com a descrição de três novas espécies. In: Apoidea Neotropical. Homenagem aos 90 anos de Jesus Santiago Moure. UNESC. Santa Catarina, Brasil. p.85-92.

MICHENER, C. D. 2000. The Bees of the World.Baltimore. Johns Hopkins. Nature - 953p.

NOGUEIRA-NETO, P. 1997. Vida e criação de abelhas indígenas sem ferrão. Editora Nogueirapis. São Paulo. 445p.

NOGUEIRA-NETO, P. 2002. Management of Plants to Maintain and Study Pollinating Bee Species, and Also to Protect Vertebrate Frugivorous Fauna. IN: Kevan P & Imperatriz Fonseca VL (eds) - Pollinating Bees - The Conservation Link Between Agriculture and Nature - Ministry of Environment / Brasília. p.21-28.

OBIOLS, C. L.Y. 2008. O gênero *Melipona* Illiger, 1806 em Minas Gerais - identificação, distribuição e estado atual de conservação. Dissertação de Mestrado. PPG em Ecologia, Conservação e Manejo da Vida Silvestre. UFMG. 2008. 108 p.

OLIVEIRA, F. & KERR, W.E. 2000. Divisão de uma colônia de jupará (*Melipona compressipes manaosensis*) usando-se a colméia e o método de Fernando Oliveira. INPA/MCT. Manaus. 10 p.

OLIVEIRA, C.M. 2002. Hábitos de nidificação de abelhas sem ferrão do gênero *Melipona* ILLIGER, 1806 (Hymenoptera; Apidae; Meliponinae) em áreas de caatinga do baixo-médio São Francisco. Universidade Estadual de Feira de Santana. Monografia. 32 p.

ROUBIK, D.W. 1989. Ecology and natural history of tropical bees. Cambridge Tropical Biology Series, 514 p.

SCHAFFER, W.B. & PROCHNOW, M. 2002. A Mata Atlântica e você: como preservar, recuperar e se beneficiar da mais ameaçada floresta brasileira. Brasília: APREMAVI. 156p.

SCHETINO, M.A.A. 2005. Filogeografia de *Melipona rufiventris*e *Melipona mondury*: Contribuição para a elucidação do padrão de distribuição geográfico, inferências taxonômicas e preservação. Viçosa, MG: UFV. Monografia (Curso de Biologia) – Universidade Federal de Viçosa, Viçosa.

SILVEIRA, F.A., MELO, G.A.R. & ALMEIDA, E.A.B. 2002. Abelhas brasileiras: sistemática e identificação. Belo Horizonte. 253p.

SIQUEIRA, E.L., MARTINES, R.B. & NOGUEIRA-FERREIRA, F.H. 2007. Ninhos de abelhas sem ferrão (Hymenoptera, Meliponina) em uma Região do rio Araguari, Araguari-MG. Bioscience Journal, Uberlândia, 23, Supplement 1, 38-44.

SOUZA, B.A., ALVES, R.M.O. & CARVALHO, C.A.L. 2008 Nota sobre a Bionomia de *Melipona asilvai* (Apidae: Meliponini) como subsídio à sua criação racional. Archivos de Zootecnia 57 (217): 53-62.

TAVARES, M.G., SALOMÃO, T.M.F., BORGES A.A. & CAMPOS L.A.O. 2008. Uso de biologia molecular como subsídio para a preservação de abelhas: espécie do grupo rufiventris (Meliponini) em Minas Gerais. In: Vilela EF., Santos I A., Schoereder J H., Serrão J E., Campos L. A O. eds. Insetos Sociais: da biologia a aplicação. p128-141.

VIANA, L.S. & MELO, G.A. 1987. Conservação de abelhas. Informe Agropecuário, Belo Horizonte, v. 13, n.149, p. 23-26.

WILLE, A. & MICHENER, C.D. 1973. The nest architecture of stingless bees with special reference to those of Costa Rica (Hymenoptera: Apidae). Revista de Biologia Tropical 21: 1-278.

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Widening the geographical distribution of *Pimelodus mysteriosus* Azpelicueta 1998 (Siluriformes: Pimelodidae) to the upper Paraná River, with diagnosis for syntopic congeners

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Abstract: *Pimelodus mysteriosus* Azpelicueta 1998, previously known only from the lower Paraná and Paraguay River basins, has been also recorded in the upper Paraná River floodplain. The only congeners occurring in syntopy with *P. mysteriosus* in the upper Paraná River basin are *P. maculatus* and *P. ornatus*. New diagnostic characters between *P. mysteriosus* and *P. maculatus* are provided.

Keywords: *Canal da piracema, Invasive species, Itaipu, Non-native species, Taxonomy.*

DEPRÁ, G.C., OTA, R.R., SOUZA, F., GRAÇA, W.J., PAVANELLI, C.S. **Ampliando a distribuição geográfica de *Pimelodus mysteriosus* Azpelicueta 1998 (Siluriformes: Pimelodidae) para a bacia do alto rio Paraná, com diagnose para congêneres sintópicas.** Biota Neotropica. 15(3): e20140124. http://dx.doi.org/10.1590/1676-06032015012414

Resumo: *Pimelodus mysteriosus* Azpelicueta 1998, previamente conhecida apenas das bacias do baixo rio Paraná e do rio Paraguai, foi também registrada na planície de inundação do alto rio Paraná. As únicas congêneres que ocorrem em sintopia com *P. mysteriosus* na bacia do alto rio Paraná são *P. maculatus* e *P. ornatus*. Novos caracteres diagnósticos entre *P. mysteriosus* e *P. maculatus* são fornecidos.

Palavras-chave: *Canal da piracema, Espécies invasoras, Espécies não nativas, Itaipu, Taxonomia.*

Introduction

Pimelodus mysteriosus Azpelicueta 1998 was described, based on 179 specimens (mostly below 100.0 mm SL, maximum 143.2 mm SL), from the stretch of the lower Paraná River basin comprised between the mouth of the Iguaçu River and little downstream of the mouth of the Paraguay River. In the original description, two specimens from the upper Paraguay River basin (MZUSP 44403, 76.2 and 111.0 mm SL, not examined here), in the municipality of Cáceres, Mato Grosso State, were also assigned to that species. Azpelicueta (1998) did not mention any other specimen from the Paraguay River basin, leaving a geographic gap between the aforementioned specimens and the specimens from the lower Paraná River basin. Additional records of the species in the Paraguay River basin were made by Souza-Filho & Shibatta (2007) who reported *P. mysteriosus* from the Cuiabá and Miranda River basins, Mato Grosso and Mato Grosso do Sul States, respectively. Meanwhile, no records have been made of this species in the Paraná River basin, upstream of the mouth of the Iguaçu River, meaning that it has been considered absent in the upper Paraná River basin.

In the main channel of the Paraná River, upstream of the mouth of the Iguaçu River is the Itaipu Dam. Between 1982, when its dam was concluded, and December 2002, when the Canal da Piracema was opened, it would be considered as the inferior boundary of the upper Paraná River basin, working as a barrier avoiding fish dispersion between the lower and the upper portions of the basin. Before 1982, the lower limit of the upper Paraná River basin was the Sete Quedas, a complex of falls that also worked as an effective barrier to fish dispersion until it was submersed by the Itaipu Reservoir. Initially, therefore, the dam caused the mixture of the upper and lower Paraná River basin fish faunas, because the filling of the reservoir worked as a lift, allowing some species to overcome the Sete Quedas falls barrier and to establish themselves in the upper Paraná River basin (Petry et al. 2003, Agostinho et al. 2007, Langeani et al. 2007, Júlio Jr. et al. 2009). Since 2002, the Canal da Piracema, a fish pass system, has allowed the dispersion of even more fish species (Makrakis et al. 2007), both upwards and downwards.

The stretch between the Itaipu Reservoir and the dam of the hydroelectric power plant Engenheiro Sérgio Motta (also called Porto Primavera) upstream is the last lotic stretch of the Paraná River in Brazilian territory (Agostinho et al. 2004). The right bank of that stretch is bordered by the upper Paraná River floodplain, characterized by possessing many biotopes (backwaters, canals, rivers and lagoons with or without permanent connection to a river, among others). The Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura (Nupélia), of the Universidade Estadual de Maringá, has been collecting in the upper Paraná River floodplain since 1986. Since then, mainly after year 2000, Nupélia staff has captured many specimens of *Pimelodus,* some of which housed in the Coleção Ictiológica do Nupélia, that do not belong to any of the species previously reported in the upper Paraná River basin (see Langeani et al. 2007). They have been identified as *P. mysteriosus* based on the following characters pointed out by Azpelicueta (1998): (1) three or four rows of spots along the sides of the body; (2) long maxillary barbel frequently reaching beyond the caudal-fin base; (3) exposed surface of supraneural and 1st and 2nd dorsal pterygiophores broad; (4) anterior margin of pectoral spines with well-developed serration; (5) teeth present on vomer and metapterygoid in most individuals.

Thereby, the scope of this study was to extend the current geographic distribution of *Pimelodus mysteriosus* obtained through these new records, as well as to provide more information about the species diagnosis relative to syntopic species from the newly recorded locality.

Material and methods

Examined material includes 19 specimens of *Pimelodus mysteriosus* captured in several newly recorded localities mostly within the upper Paraná River floodplain (Fig. 1) and four paratypes of *P. mysteriosus*. A complete list of material examined is provided in Appendix 1. The following measurements were taken from all specimens: (1) standard length; (2) head length (from tip of snout to posterior margin of opercle, not including fleshy opercular membrane); (3) snout length (from tip of snout to anterior margin of orbit), (4) interorbital distance (shortest distance between bony orbital margins); (5) eye diameter. Pairwise regression analyses were performed on Microsoft® Excel® between all measurements in order to evaluate their usefulness in distinguishing *P. mysteriosus.*

Results and discussion

Pimelodus mysteriosus was found in syntopy with two congeners within the upper Paraná River basin: *P. maculatus* Lacepède and *P. ornatus* Kner. *Pimelodus mysteriosus* is readily

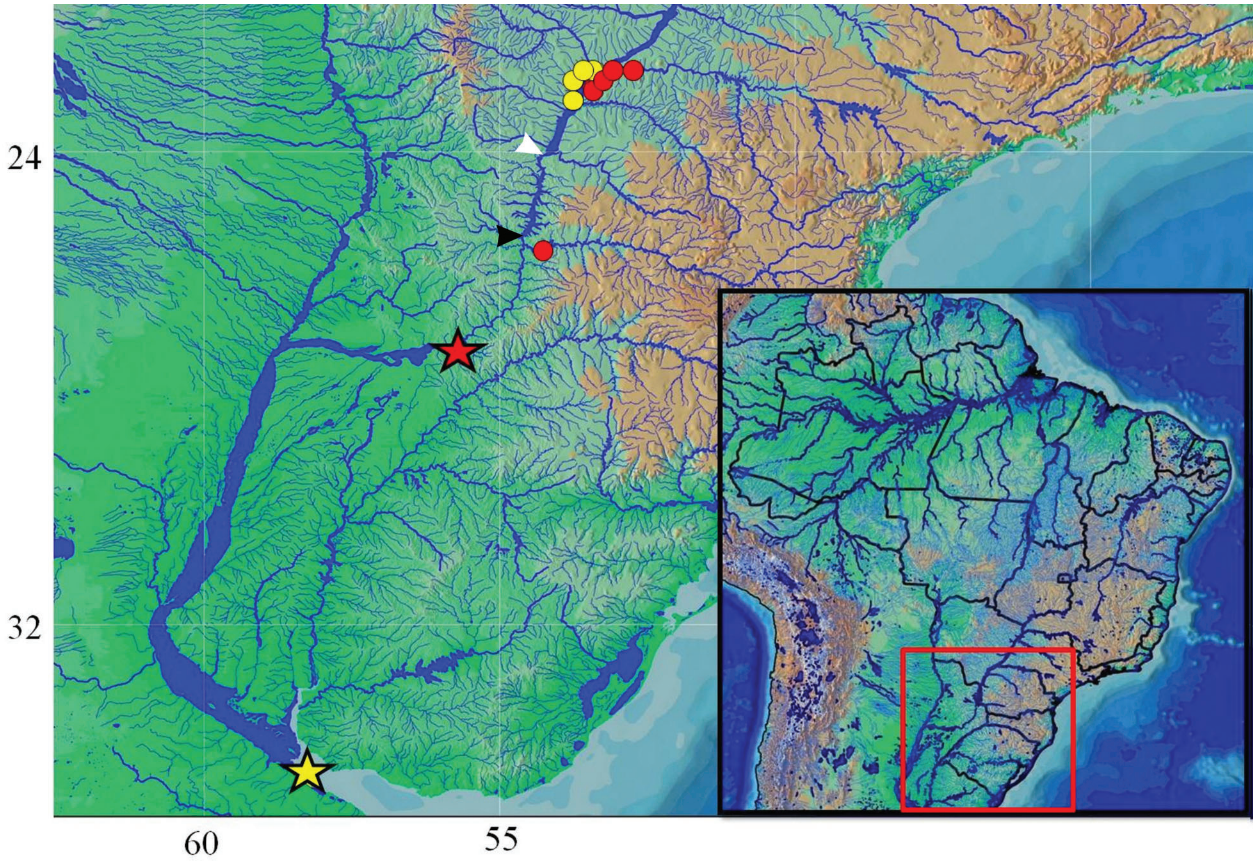

Figure 1. Geographic distribution of examined specimens of *Pimelodus maculatus* and *P. mysteriosus*. The white arrow indicates the locality of the former Sete Quedas falls; the black arrow indicates the locality of the Itaipu Dam. The yellow circle represents *P. maculatus* and the yellow star its type locality; red circle represents the new distribution of *P. mysteriosus* and the red star its type locality. One symbol may represent more than one locality.

Figure 2. Lateral view of (a) *Pimelodus mysteriosus*, NUP 10824, 160.0 mm SL, and (b) *P. maculatus*, NUP 12783, 214.4 mm SL, evidencing color pattern in alcohol and shape of adipose fin. Photograph (a) by Celso Ikedo.

distinguished from *P. ornatus*, and also from *P. argenteus* Perugia and *P. albicans* (Valenciennes) (both sympatric with *P. mysteriosus* in the lower Paraná River basin), by the spotted body (Fig. 2a) (*vs*. striped in *P. albicans* and *P. ornatus* and uniformily greyish in *P. argenteus*). Pimelodus brevis, until recently considered as valid in the lower Paraná River basin, has been synonymized in *P. argenteus* by Rocha & Pavanelli (2014).

Pimelodus mysteriosus differs from *P. maculatus* by having: (1) long maxillary barbel, frequently reaching beyond base of caudal fin in adult specimens (*vs.* not reaching base of anal fin); (2) exposed surface of supraneural and 1st and 2nd dorsal pterygiophores broad (*vs.* narrow); (3) anterior margin of pectoral spines with well-developed serration (*vs.* poorly developed); (4) teeth present in vomer and metapterygoid in all individuals (*vs.* absent from both bones in all individuals). We observed some other diagnostic characters of *P. mysteriosus* not mentioned by Azpelicueta (1998), such as adipose fin short, deep and somewhat triangular in shape (Fig. 2a), *vs.* long, its depth about half its length

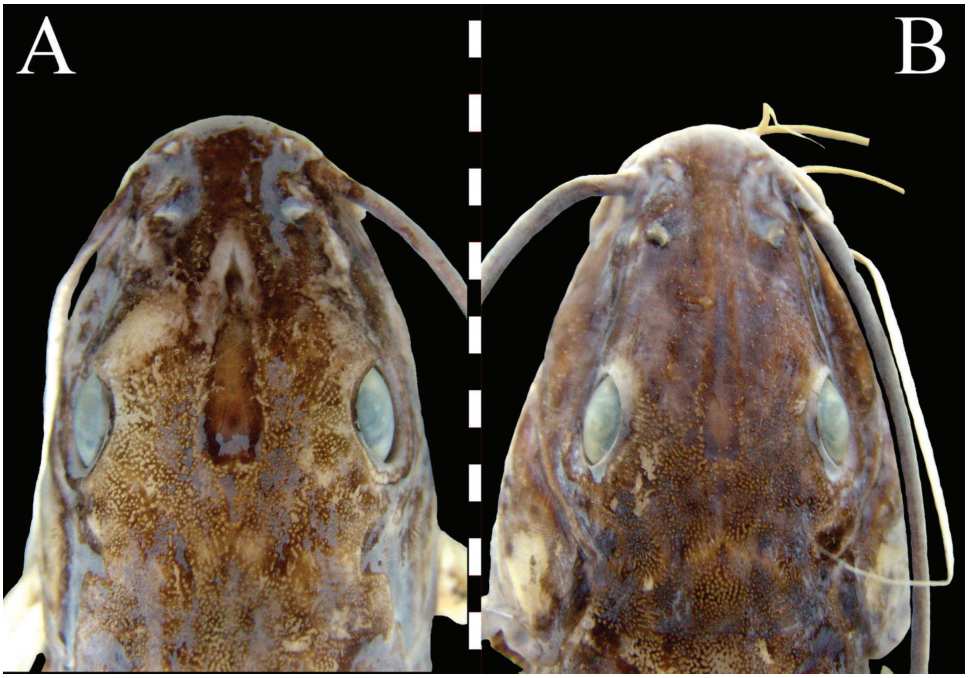

Figure 3. Dorsal view of head, evidencing interorbital distance in (a) *Pimelodus mysteriosus*, NUP 12778, 202.5 mm SL; and (b) *P. maculatus*, NUP 12783, 214.4 mm SL.

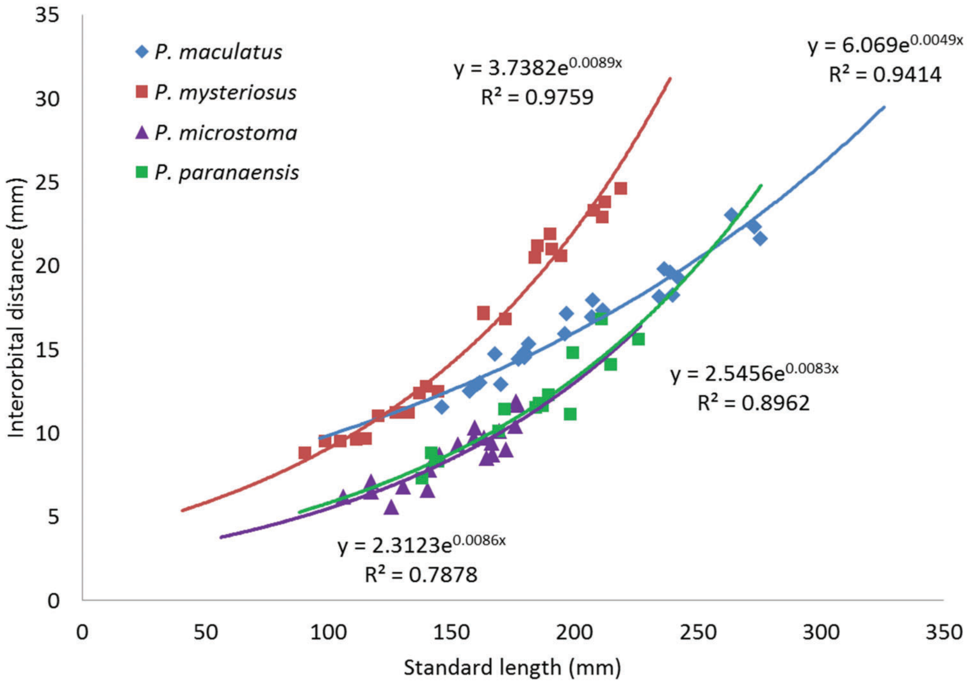

Figure 4. Regression analysis of interorbital distance in *Pimelodus maculatus* (N = 23), *P. microstoma* (N = 21), *P. mysteriosus* (N = 23) and *P. paranaensis* (N = 15) from the upper Paraná River basin.

in *P. maculatus* (Fig. 2b) and also in *P. microstoma* Steindachner and *P. paranaensis* Britski & Langeani, both sympatric species in the upper Paraná River basin. Also, the regression analyses and the measurement ranges showed that *P. mysteriosus* can be distinguished from sympatric species in the upper Paraná River basin by the interorbital distance (Figs. 3, 4; Table 1). Furthermore, live specimens of *P. mysteriosus* examined here showed a silvery pigmentation all over the body, partially hiding the dark spots of the flanks. *Pimelodus maculatus*, in contrast, did not present silvery pigmentation, but an intense yellow coloration, due to the presence of that pigment in its body mucus. A yellow pigmentation may be present also in *P. mysteriosus*, as stated by Azpelicueta (1998: 91) and Azpelicueta et al. (2008: 159), but in individuals analyzed herein it was never as strong as in *P. maculatus*.

As mentioned before, both the filling of the Itaipu Reservoir and the opening of the Canal da Piracema were responsible for the dispersion, followed in some cases by the establishment into the upper Paraná River basin of some species previously unable to overcome the Sete Quedas falls (Júlio Jr. et al. 2009; Agostinho et al. 2015). Any of those or both events may have caused the occurrence of *Pimelodus mysteriosus* in the upper Paraná River floodplain, despite of all specimens hosted in the NUP collection having been captured after 2002 (year of the opening of the Canal da Piracema).

Appendix 1

Material examined

Pimelodus maculatus. **Brazil.** All from the upper Paraná River basin, collected by Nupélia's team. Mato Grosso do Sul State. NUP 3977, 1, 212.8 mm SL, Onça Lagoon, tributary to

Table 1. Morphometrics of *Pimelodus maculatus* (N = 23), *P. microstoma* (N = 21), *P. mysteriosus* (N = 23) and *P. paranaensis* (N = 15) captured in the upper Paraná River basin. Efficient measurements in diagnosing *P. mysteriosus* are bolded.

	P. mysteriosus	***P. maculatus***	***P. microstoma***	***P. paranaensis***
Standard length (mm)	90.4 – 218.7	146.2 – 275.6	106.2 – 176.9	138.1 – 225.8
		% of Standard length		
Head length	25.7 – 29.9	27.0 – 30.2	25.5 – 28.0	28.7 – 30.7
Interorbital distance	**8.4 – 11.5**	7.6 – 8.8	4.5 – 6.7	5.3 – 8.0
		% of Head length		
Snout length	43.7 – 50.9	42.7 – 50.3	44.5 – 50.9	44.9 – 49.4
Interorbital distance	**29.8 – 40.6**	26.4 – 30.4	16.7 – 25.3	18.3 – 27.3
Eye diameter	17.1 – 30.3	16.8 – 22.2	21.3 – 27.7	17.4 – 23.2
		% of Snout length		
Interorbital distance	**63.2 – 80.8**	56.9 – 63.1	36.6 – 56.0	39.0 – 55.8

Baía River, 22°39’48.4”S53°12’1.6”W, 18 Mar 2011. NUP 3984, 1, 271.4 mm SL, Patos Lagoon, tributary to Ivinhema River, 22°49’33”S53°33’09”W, 14 Sep 2011. NUP 6659, 1, 253.2 mm SL, Patos Lagoon, 22°49’S53°33’W, 24 Jun 2008. NUP 8637, 2, 204-258 mm SL, Garças Lagoon, 22°43’27”S53°13’07”W, 17 Sep 2009. NUP 12111, 1, 228.9 mm SL, Cortado Channel, 22°48’43”S53°22’40”W, 06 Dec 2010. NUP 12112, 1, 159.4 mm SL, Pousada das Garças Lagoon, 22°42’1”S53°15’23”W, 05 Dec 2010. NUP 12432, 3, 154.6-202 mm SL, Ventura Lagoon, 22°51’23”S53°36’01”W, 10 Jun 2011. NUP 12443, 2, 174.4-268.2 mm SL, Patos Lagoon, 22°49’33”S53°33’9”W, 08 Jun 2011. NUP 12781, 1, 178.2 mm SL, Sumida Lagoon, 22°46’54”S53°29’22”W, 17 Sep 2011. NUP 12783, 1, 214.4 mm SL, 22°39’48”S53°12’1.6”W, 18 Mar 2011. Paraná State. NUP 11311, 2, 159.8-270.1 mm SL, Paraná River, 22°45’S53°17’W, 06 Mar 2005. NUP 12107, 3, 136.4-231.8 mm SL, Garças Lagoon, 22°43’27”S53°13’4”W, 6 Dec 2010. NUP 12109, 1, 173.6 mm SL, Pau Véio Lagoon, 22°44’50”S53°15’11”W, 06 Dec 2010.

Pimelodus microstoma. **Brazil.** All from the upper Paraná River basin. Paraná State. NUP 3874, 1, 105.5 mm SL, Pirapó River, 23°19’36”S51°50’41”W, 17 Sep 2004, Nupélia. NUP 7505, 1, 106.2 mm SL, Pitangui River, 24°52’22”S50°15’08”W, 06 May 2007, A. M. Gealh. NUP 7781, 3, 118.5-179.4 mm SL, Pitangui River, 24°52’22”S50°15’8”W, 06 Jan 2007, A. M. Gealh. NUP 9745, 6, 122.7-162.8 mm SL, Pitangui River, 24°52’22”S50°15’08”W, 14 Apr 2007, A. M. Gealh. NUP 9816, 2, 154.6-183.6 mm SL, Pitangui River, 24°50’45”S50°17’16”W, 06 May 2007, A. M. Gealh. NUP 10649, 4, 128.1-157.0 mm SL, Bonito River, 24°45’30”S51°24’49”W, 23 May 2009, D. Viana. NUP 11000, 1, 146.0 mm SL, Canal da Piracema, 25°06’03”S54°34’51”W, 19 May 2005, GETECH. NUP 14941, 6, 107.5-177.0 mm SL, Piquiri River, 24°56’54”S 52°35’49”W, 12 Sep 2012, V. P. Margarido et al. NUP 15312, 2, 106.3-126.2 mm SL, Cantu River, 24°43’S52°18’W, 09 Sep 2010, GERPEL. NUP 11375, 1, 167.5 mm SL, Pitangui River, 24°50’58”S50°17’13”W, 06 Jun 2007, A. M. Gealh.

Pimelodus mysteriosus. **Argentina.** Missiones State. MLP 9194, 2 paratypes, 115.1-127.2 mm SL, Paraná River close to the mouth of the Iguaçu River, Nov 1986, M. M. Azpelicueta et al. MLP 9195, 2 paratypes, 111.2-132.5 mm SL, Oro Verde, Paraná River, Oct 1985, O. García et al. **Brazil.** All from the upper Paraná River basin and collected by Nupélia’s team, except when noted otherwise. São Paulo State. NUP 6334, 1, 118.6 mm SL, Rosana Reservoir, 22°36’01”S52°52’20”W, Jan 2007. Mato Grosso do Sul State. NUP 10824, 2, 158.0-160.0 mm SL, Guaraná Lagoon, 22°43’17”S53°18’09”W, 18 Sep 2010. NUP 12110, 3, 101.8-175.3 mm SL, Ventura Lagoon, 22°51’23”S53°36’1”W, 02 Dec 2010. NUP 12113, 1, 86.2 mm SL, Ivinhema River, 22°47’59”S53°32’21”W, 30 Nov 2010. NUP 12438, 2, 169.1-184.4 mm SL, Peroba Lagoon, 22°54’30”S53°38’24”W, 10 Jun 2011. NUP 12441, 1, 199.9 mm SL, Onça Lagoon, 22°39’48”S53°12’2”W, 11 Jun 2011. NUP 12778, 1, 202.5 mm SL, Gavião Lagoon, 22°40’48”S53°13’53”W, 19 mar 2011. NUP 12782, 1, 212.9 mm SL, Peroba Lagoon, 22°54’30”S 53°38’24”W, 16 Sep 2011. NUP 12785, 1, 211.3 mm SL, Baía Channel, 22°41’26’S53°13’29”W, 18 Mar 2011. NUP 13630, 1, 139.3 mm SL, Finado Raimundo Lagoon, 22°47’40”S 53°32’1”W, 15 Mar 2012. NUP 13633, 1, 212.1 mm SL, Ventura Lagoon, 22°51’24”S53°36’01”W, 14 Mar 2012. Paraná State. NUP 12108, 1, 140.3 mm SL, Garças Lagoon, 22°43’27”S53°13’4”W, 6 Dec 2010. NUP 16111, 1, 36.9 mm SL, Iguaçu River, 25°39’02”S; 54°27’25”W, 09 Oct 2013, V. P. Margarido et al.

Pimelodus paranaensis. **Brazil.** All from the Corumbá River, upper Paraná River basin, collected by Nupélia’s team. Goiás State. NUP 5798, 3, 207.0-223.0 mm SL, 22 Aug 1997. NUP 5814, 1, 147.0 mm SL, 17°43’37’S48°32’54”W, 18 Oct 1996. NUP 5823, 3, 180.0-190.0 mm SL, 13 Jul 1996. NUP 5824, 4, 85.0-149.0 mm SL, 23 Sep 1996. NUP 5829, 1, 186.0 mm SL, 13 Jan 1999. NUP 5831, 2, 140.0-202.0 mm SL, 16 Jul 1996. NUP 5832, 1, 225.0 mm SL, 06 Apr 1999. NUP 5837, 1, 185.0 mm SL, 11 Aug 1998.

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References

AGOSTINHO, A.A., GOMES, L.C., THOMAZ, S.M. & HAHN, N.S. 2004. The upper Paraná River and its floodplain: main characteristics and perspectives for management and conservation. In The upper Paraná river and its floodplain: Physical aspects, ecology and conservation (S.M. Thomaz, L.C. Gomes & N.S. Hahn, eds.). Backhuys Publishers, Leiden, The Netherlands, p. 381-393.

AGOSTINHO, A.A., PELICICE, F.M., PETRY, A.C., GOMES, L.C. & JULIO Jr., H.F. 2007. Fish diversity in the upper Paraná River basin: habitats, fisheries, management and conservation. Aquatic Ecosystem Health & Management 10(2):174-186.

AGOSTINHO, A.A., SUZUKI, H.I., FUGI, R., ALVES, D.C., TONELLA, L., ESPINDOLA, L.A. 2015. Ecological and life history traits of *Hemiodus orthonops* in the invasion process: looking for clues at home. Hydrobiologia, 746(1):415-430, http://dx.doi.org/10.1007/s10750-014-2030-2.

AZPELICUETA, M. de las M. 1998. A new species of *Pimelodus* (Siluriformes: Pimelodidae) from the Paraguay and lower Paraná rivers. Neotropica (La Plata) 44(111-112):87-94.

AZPELICUETA, M. de las M., LUNDBERG, J.G. & LOUREIRO, M. 2008. *Pimelodus pintado*, a new species of catfish from affluent rivers of Laguna Merín, Uruguay, South America. Proceedings of the Academy of Natural Sciences of Philadelphia 157: 149-162, http://dx.doi.org/10.1635/0097-3157(2008)157[149:PPSPAN]2.0.CO;2.

JÚLIO Jr., H.F., DEI TÓS, C., AGOSTINHO, A.A. & PAVANELLI, C.S. 2009. A massive invasion of fish species after eliminating a natural barrier in the upper rio Paraná basin. Neotropical Ichthyology 7(4):709-718, http://dx.doi.org/10.1590/S1679-62252009000400021.

LANGEANI, F., CORRÊA E CASTRO, R.M., OYAKAWA, O.T., SHIBATTA, O.A., PAVANELLI, C.S. & CASATTI, L. 2007. Diversidade da ictiofauna do Alto Rio Paraná: composição atual e perspectivas futuras. Biota Neotropica 7(3):181-197, http://dx.doi.org/10.1590/S1676-06032007000300020.

MAKRAKIS, S., GOMES, L.C., MAKRAKIS, M.C., FERNANDEZ, D.R. & PAVANELLI, C.S. 2007. The Canal da Piracema at Itaipu Dam as a fish pass system. Neotropical Ichthyology 5(2):185-195, http://dx.doi.org/10.1590/S1679-62252007000200013.

PETRY, A.C., AGOSTINHO, A.A. & GOMES, L.C. 2003. Fish assemblages of tropical floodplain lagoons: exploring the role of connectivity in a dry year. Neotropical Ichthyology 1(2):111-119, http://dx.doi.org/10.1590/S1679-62252003000200005.

ROCHA, M.S. & PAVANELLI, C.S. 2014. Taxonomy of *Pimelodus brevis* Marini, Nichols & La Monte, 1933 (Siluriformes: Pimelodidae), an uncertain species from the rio Paraná basin. Neotropical Ichthyology 12(4):755-760, http://dx.doi.org/10.1590/1982-0224-20140059.

SOUZA-FILHO, H.S. & SHIBATTA, O.A. 2007. Description of a new species of *Pimelodus* (Siluriformes, Pimelodidae) from upper rio Paraguai basin. Iheringia, Série Zoologia 97:472-480.

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Range extension of *Boeckella bergi* Richard, 1897 (Crustacea: Copepoda: Centropagidae), with comments on the taxonomy of the species.

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PREVIATTELLI, D., PERBICHE-NEVES, G., MENU MARQUE, S., ROCHA, C.E.F. **Range extension of Boeckella bergi Richard, 1897 (Crustacea: Copepoda: Centropagidae), with comments on the taxonomy of the species.** Biota Neotropica. 15(3): e20140076. dx.doi.org/10.1590/1676-06032015007614

Abstract: We present new records of *Boeckella bergi* at several water bodies in Argentina and Brazil. Within these records the northernmost and southernmost limits of occurrence of *B. bergi* in South America are included. The ample range of distribution is consistent with former studies, but it is more extensive than previously known. Observations on habitat preferences are also made. This species is tolerant to temperate climate conditions in this region of South America, with wide amplitude of temperature between summer and winter seasons, and irregular patterns of precipitation.

Keywords: *Biogeography, distribution range, freshwater, Copepoda, South America, zooplankton.*

PREVIATTELLI, D., PERBICHE-NEVES, G., MENU MARQUE, S., ROCHA, C.E.F. **Extensão da faixa de ocorrência de Boeckella bergi Richard, 1897 (Crustacea: Copepoda: Centropagidae), com comentários sobre a taxonomia da espécie.** Biota Neotropica. 15(3): e20140076. dx.doi.org/10.1590/1676-06032015007614

Resumo: No presente artigo são apresentados novos registros de *Boeckella bergi* em vários corpos de água na Argentina e no Brasil. Dentro desses registros estão incluídos os limites setentrionais e meridionais de ocorrência de *B. bergi* na América do Sul. A ampla gama de distribuição é consistente com estudos anteriores, mas se mostra muito mais extensa do que conhecida anteriormente. Observações sobre a taxonomia e os habitats também são feitas. Esta espécie é tolerante a condições de clima temperado na região da América do Sul, com uma grande amplitude de temperatura entre o verão e inverno, e padrões irregulares de precipitação.

Palavras-chave: *Biogeografia, área de ocorrência, água doce, Copepoda, América do Sul, zooplancton.*

Introduction

Boeckella Guerne & Richard, 1889 is a copepod genus from the Centropagidae family, a group with gondwanic distribution (Boxshall & Jaume 2000). The genus is composed of 41 species (Boxshall & Halsey 2004), mainly restricted to the Southern Hemisphere. They are found in Australia, Tasmania, New Caledonia, New Zealand, Antarctica, circumantarctic islands and South America, all once belonging to the paleoantarctic fragment of Gondwana (Bayly 1992b).

The South American species of the genus *Boeckella* are endemic to this continent with exception of *B. poppei* (Mrázek 1901), which appears in the Malvinas Islands (Ekman 1905), several circumantarctic islands (Poppe & Mrázek 1895; Ringuelet 1958; Pezzani-Hernández 1973; Weller 1977; Paggi 1983; Janiec 1988) and also in both East and West Antarctica (Ekman 1905; Harding 1941; Heywood 1977; Bayly & Burton 1993). This distribution pattern would thus indicate a speciation process within the South American continent after the Gondwana splitting. However, the comprehension of the taxa history and evolution becomes difficult, since species distributions are often incomplete and unclear, especially regarding the northern limits and scarcely sampled regions in Patagonia.

Species of *Boeckella* thrive in the Andean biogeographic region, and some are found in the South American transition zone (*sensu* Morrone 2004), with a few extending their distributions into the Neotropical region. The easternmost occurrences correspond to *B. bergi*, until now reaching as far as the southernmost region of Brazil, at Lagoa dos Patos (Gloeden 1994).

In this study new records of *B. bergi* in South America are given, extending its occurrence to north and the south of previous records.

Material and Methods

Samples were taken by horizontal hauling of a 60µm mesh size plankton net. Specimens were collected from 13 locations in Brazil and Argentina (Table 1 and Figure 1). Here we

Table 1. New records of *Boeckella bergi* in Argentina and Brazil.

	Locality	Province / State	Date	Latitude S	Longitude W	Museum number
1	Dique Roggero	Buenos Aires	28/11/1999	34° 41’ 09.65”	58° 51’ 29.29”	MACN-In39443
2	Lago Pellegrini	Río Negro	01/03/1984	38° 41’ 53.01”	68° 00’ 58.94”	MACN-In39444
3	Laguna de los Padres	Buenos Aires	03/10/2004	37° 56’ 31.74”	57° 43’ 38.22”	MACN-In39445
4	Lagunita en Ao. Seco	Río Negro	17/02/2004	41° 45’ 50.16”	66° 30’ 06.78”	MACN-In39446
5	Lagunita circular Ruta 3	Santa Cruz	20/012001	49° 43’ 34.33”	68° 21’ 46.71”	MACN-In39447
6	Pozón Río Deseado	Santa Cruz	18/01/2001	46° 53’ 04.50”	68° 08’ 42.90”	MACN-In39448
7	Canterita anegada	Santa Cruz	30/01/2001	50° 25’ 19.32”	72° 40’ 47.70”	MACN-In39449
8	Charco en pasto anegado	Chubut	03/02/2001	45° 37’ 04.20”	68° 58’ 35.82”	MACN-In39450
9	Lago Pellegrini	Río Negro	02/11/1996	38° 41’ 53.01”	68° 00’ 58.94”	MACN-In39451
10	Dique Ameghino	Chubut	01/12/1984	43° 44’ 00”	66° 31’ 41”	MACN-In39452
11	Mallín Piedra Parada	Chubut	15/11/2007	42° 38’ 09.0”	70° 13’ 55.6”	MACN-In39516
12	Bom Jardim	Santa Catarina	28/10/2012	28°16’4.00”	49°54’38.26”	MZUSP-30600
13	Roadside pool	Santa Catarina	27/10/2012	28°23’37.30”	49°33’1.82”	MZUSP-30601

provide new records from Argentina in the provinces of Buenos Aires, Rio Negro, Chubut and Santa Cruz (Table 1 and Figure 1 left) and from Brazil in the state of Santa Catarina (Figure 1 right). They were found at two small water bodies at high altitudes – roadside pool near the city of São Joaquim, at 1350 m (Figure 1A) and a small pond near the city of Bom Jardim da Serra, at 1418 m (Figure 1B). Previous records were added from the revised literature (i.e. Mrázek 1901; Brian 1925; Pesta 1927; Richard 1897; Brehm 1935, 1936, 1937, 1954; Ringuelet 1958; Reid 1991; Gloeden 1994; Menu-Marque & Locascio de Mitrovich 1998; Menu-Marque *et al.* 2000), and are shown in Figure 1.

Vouchers containing 13 individuals (10 males and 3 females) of *B. bergi* from Brazil were deposited at Museu de Zoologia da Universidade de Sao Paulo (MZUSP) and the specimens from Argentina at Colección Nacional de Invertebrados del Museo Argentino de Ciencias Naturales “Bernardino Rivadavia” – (MACN-In) (Table 1).

Images and scan photos were taken from animals collected in 2012 in Brazil (Table 1). Images were acquired with the aid of a Zeiss Discovery V-20 stereoscopic microscope, and the software Axio-Vision 6.0. Specimens of both sexes were prepared for scanning electron microscopy (SEM) following protocols used by Felgenhauer (1987) and Huys & Boxshall (1991).

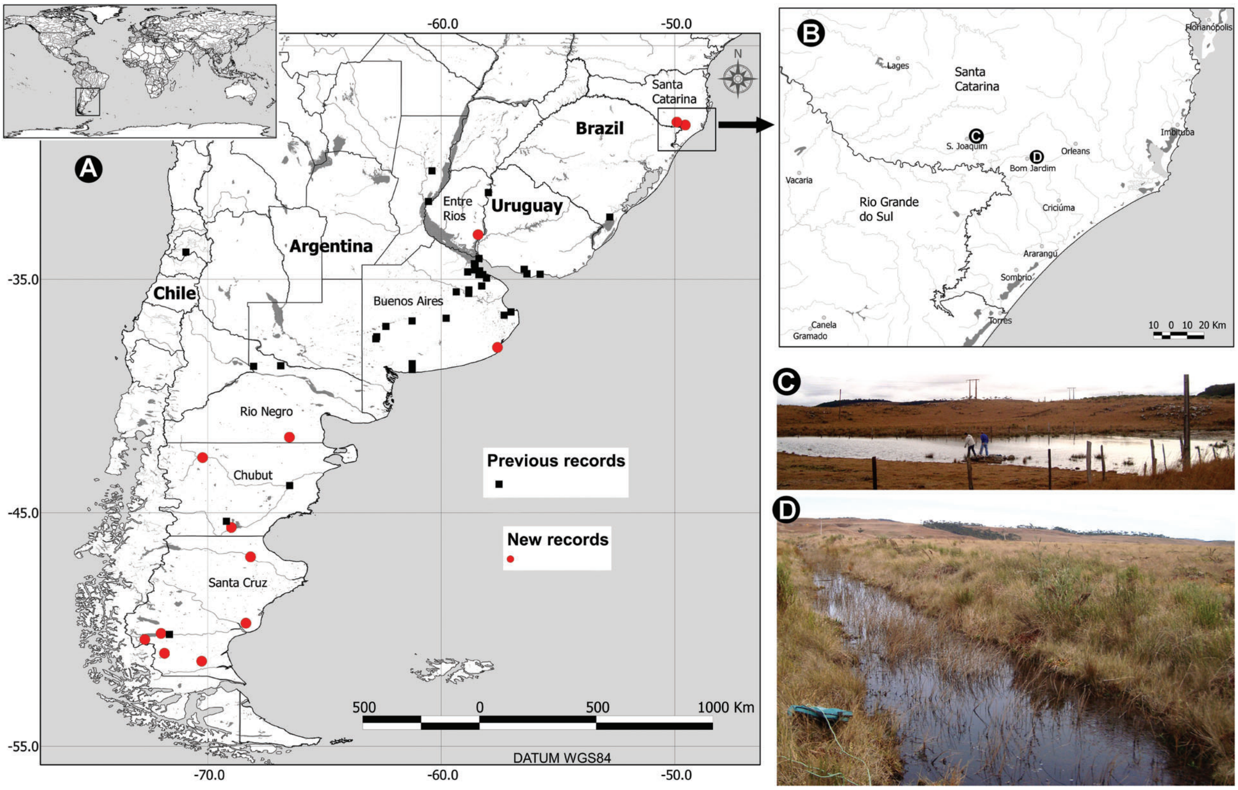

Figure 1. A. map of new and previous records of *Boeckella bergi* found in South America. B. New records of *Boeckella bergi* in Brazil, at pools of high altitude in São Joaquim (C) and Bom Jardim da Serra (D) localities.

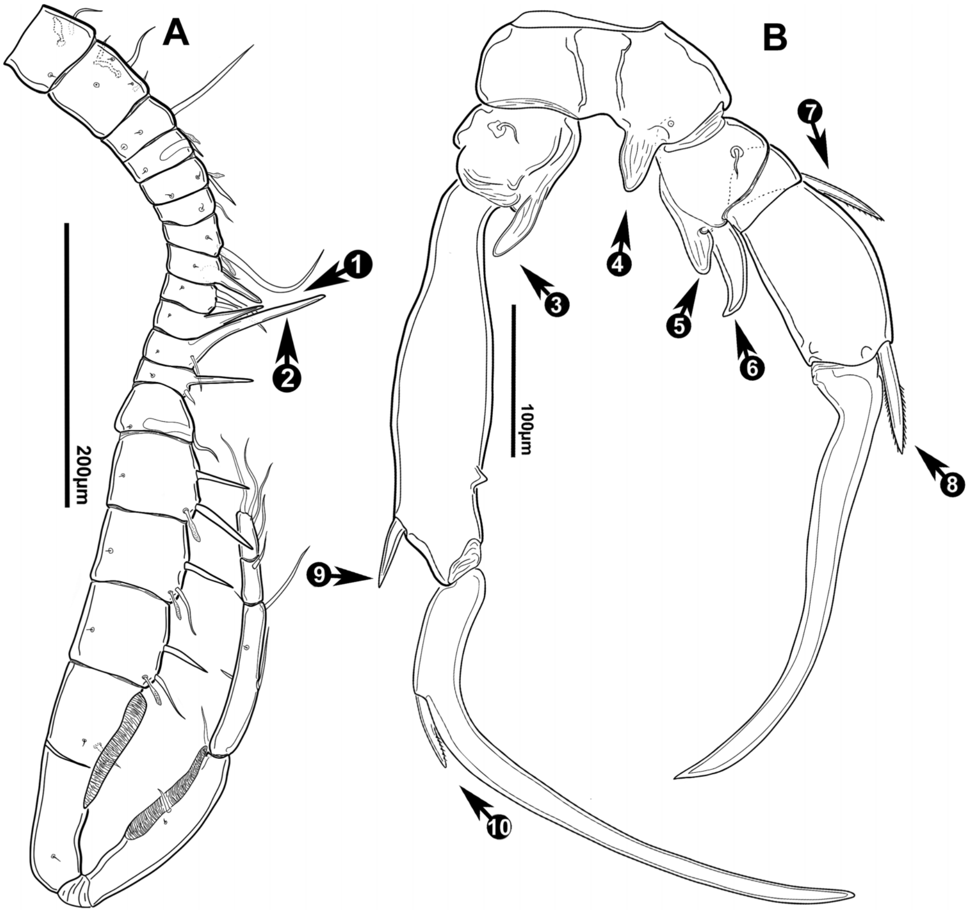

Figure 2. A. Drawings of dissections of male specimens of *Boeckella bergi* found in Santa Catarina. 1: spinous process on segment 10; 2. Spinous process on segment 11 (Scale: 200 µm). B. P5, caudal view (Scale: 100 µm); 3: left endopodite, 4: inner process on right coxopodite, 5: inner process on right basipodite, 6: right endopodite, 7 spine on right exopodite 1, 8: spine on right exopodite 2, 9: spine on left exopodite 1, 10: spine on left terminal claw.

Observations and photographs were taken with a Quanta 200 FEI electron microscope. Maps were built using Quantum GIS (QGIS) software (Nanni *et al.* 2012). Line drawings were made with the mentioned microscope equipped with camera lucida.

Results

We add 13 new records of *B. bergi* for South America, increasing the north most and south most records for its distribution area (Table 1; Figure 1A, B). The northernmost records were made in Brazil, showing that its distribution is more extensive than previously known.

Males of *B. bergi* are recognizable by the peculiar spinous processes in the right antennule and the fifth leg (P5) (Figure 3A). The organisms were identified according to the original description (Richard 1897) and later (1901) more detailed observations of the right geniculate antennule made separately by Mrazek and Daday. The fifth leg shown in our study (Figure 2B) is similar to Figure 2 from Richard (1897). The male right geniculate antennule showed an outstandingly long spinous process at segment 11 (Figure 2A), and also a modified seta at segment 19 (Figure 3C). Females of B. bergi possess posteriorly projected lateral wings at the fifth pediger, the left of which is conspicuously notched on its posterior margin (Figure 3A, B).

Discussion

Richard (1897) described the male of *B. bergi* upon material from a pond in the outskirts of Buenos Aires, listing as diagnostic characters: (1) the structure and armature of the fifth legs and (2) the long “hook” on segment 12 of the right antennule. In fact he made a mistake counting the segments, and as both Daday (1901) and Mrazek (1901) pointed out, the longest spinous process on the geniculate right antennule is located upon segment 11, as illustrated on Figure 2A. The female, in its turn, was described later by Mrazek (1901) upon specimens collected in a pond in Buenos Aires related to the Rio de la Plata estuary. He included this species within the new genus *Boeckellopsis* Mrazek 1901, carefully describing and illustrating both sexes. The distinctive diagnostic character for the female is the notch on the posterior edge of the left thoracic wing. Ignoring Mrazeck’s work, Daday (1902) redescribed both sexes using material from a pond next to Santa Cruz River in the Argentinean Patagonia, assigning it to the genus *Pseudoboeckella* Daday, 1902. Brehm (1937) created a number of subspecies and lately considered it as a new species (Brehm 1954),

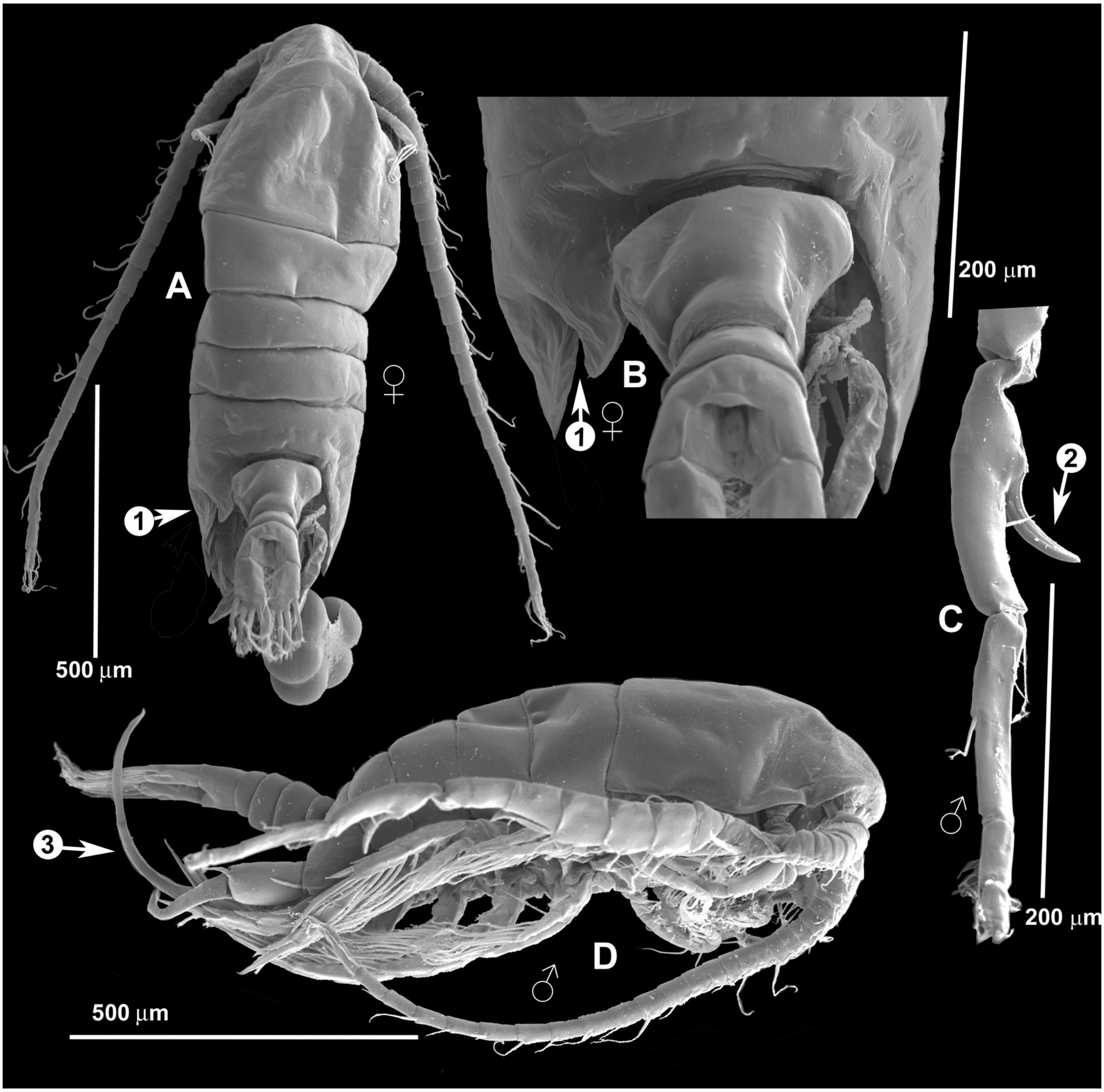

Figure 3. SEM photographs of *Boeckella bergi*. A and B. Adult female, dorsal view, arrow 1 showing notch on the posterior edge of the left thoracic wing. C. Segments 20, 21 and 22 of right geniculate antennule of male, arrow 2 showing modified seta on segment 19. D. Adult male, right lateral view, arrow 3 showing the terminal claws of the right fifth leg and arrow 4 showing spinous process on segment 20.

but according to Bayly (1992a) all of these taxa fall within the variability of *B. bergi*.

Concerning the geographic distribution, most of *B. bergi* records have been registered in Argentina (Menu-Marque & Locascio de Mitrovich 1998; Menu-Marque *et al.* 2000) and it was also found in small ponds close to the Rio de la Plata estuary on the Uruguayan coast (Brehm 1935, 1937). The presence in a single locality across the Andean range in Chile (Menu-Marque *et al.* 2000) may be assigned to fish stocking into Laguna de Aculeo where Argentinean silverside was introduced in the twentieth century. This species has a wide latitudinal range within Argentina spanning from about 50° S in the Patagonian province of Santa Cruz (Daday 1902), spreading across the Pampean plain in the province of Buenos Aires (Ringuelet 1958; Reid 1991; Mrázek 1901; Brian 1925; Pesta 1927) until 30°S in the Paraná River floodplain (Ringuelet 1958; Paggi 1980), and the northernmost record at 28°S from this study, at São Joaquim city (Brazil).

Boxshall & Jaume (2000) hypothesized that the genus invaded South America at least as early as 120 Mya (Aptian, Lower Cretaceous), and probably had a still wider distribution through the continent. According to these authors there is a latitudinal strip in which members of Centropagidae and Diaptomidae families coexist, with a gradual advance of the Diaptomidae southwards. In Argentina there are many waterbodies from 30° S in the Paraná River floodplain to the reservoirs of the northern border of Patagonia at almost 39° S where species of *Boeckella* and *Notodiaptomus* Kiefer 1936 coexist.

This latitudinal overlap of the families Centropagidae and Diaptomidae occurs both in Australia and South America, although in Argentina this area is more extended on the account of the wide distribution of *B. bergi* which coexists with diaptomids of the genus *Notodiaptomus* in the Rio de La Plata and its tributaries, many shallow lakes in the province of Buenos Aires and an artificial lake connected to the Negro River in northern Patagonia. *Boeckella gracilipes* Daday 1901 also coexists with *Notodiaptomus incompositus* (Brian 1925) in a large reservoir on the Limay River (Puig 1991). A similar coexistence was observed here, with *Argyrodiaptomus bergi* (Richard 1897) being found together with *B. bergi* in the pool from São Joaquim (Perbiche-Neves *et al*. 2011).

Many shallow lakes in the pampean plain used to have populations both of *N. incompositus* and *Boeckella gracilis* (Daday 1902), as reported by Ringuelet (1958). Although diaptomids were dominant, about twenty years from now *B. gracilis* populations have dwindled (SMM personal observation) to the point of disappearance in these water bodies (lagunas de Chascomús, La Brava, de los Padres, Monasterio), which seems to confirm Boxshall & Jaume's (2000) hypothesis in high latitudes.

With the new records at Santa Catarina State the distribution of the species is extended 600 km further north than its previous known range. Thus its latitudinal span is very wide, ranging from almost 28°S to over 50°S across southern South America. In spite of the extensive samplings, this species was never found in Tierra del Fuego. Possibly these new locations represent the northern distribution limit for both species in Brazil and temperature could be determinant for their occurrence. In Brazil, the only previous record was made by Gloeden (1994) at Lagoa Mirim.

This is the only South American species of the genus that has adapted to running waters. Many of the localities in which it has been collected in Argentina are streams, remnant ponds in river beds, reservoirs with short permanence time of the water, and shallow lakes that have strong currents during the rainy season. It is also the only member of the Centropagidae found in the Paraná River and in the freshwater section of the Rio de La Plata.

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References

BAYLY, I.A.E. 1992a. Fusion of the genera *Boeckella* and *Pseudoboeckell*a (Copepoda) and revision of their species from South America and sub-Antarctic islands. Revista Chilena de Historia Natural 65:17-63.

BAYLY, I.A.E. 1992b. The non-marine Centropagidae (Copepoda: Calanoida) of the world. The Hague: SPB Academic Publishing, 30p.

BAYLY, I.A.E. & BURTON, R.H. 1993. Beaver Lake, Greater Antarctica, and its population of *Boeckella poppei* (Mrazek) (Copepoda: Calanoida). Verhandlungen der Internationalen Vereinigung für theoretische und angewandte Limnologie 25:975-978.

BOXSHALL, G.A. & HALSEY, S.H. 2004. Introduction to Copepod diversity, Vol. 1. Ray Society Series, No. 166. The Ray Society, London, 966p.

BOXSHALL, G.A. & JAUME, D. 2000. Making Waves: The Repeated Colonization of Fresh Water by Copepod Crustaceans. Advances in Ecological Research. 31:61-79, http://dx.doi.org/10.1016/S0065-2504(00)31007-8

BREHM, V. 1935. Über die Süsswassserfauna von Uruguay. Archiv für Hydrobiologie 28:295-309.

BREHM, V. 1936. Über die tiergeographischen Verhaltnisse der circumantarktischen Süsswasserfauna. Biological Reviews 11:477-493, http://dx.doi.org/10.1111/brv.1936.11.issue-4

BREHM, V. 1937. Weitere Mitteilungen über die Süsswasserfauna von Uruguay. II Teil. Zur Variabilität der *Boeckella bergi* Rich. Zoologischer Anzeiger 120:301-306.

BREHM, V. 1954. Sobre los copépodos hallados por el profesor Birabén en la Argentina. (Crustacea). 1a. Comunicación. Neotropica 1:37-42.

BRIAN, A. 1925. Di alcuni Copepodi d'acqua dolce dell'Argentina raccolti dal Prof. F. Silvestri. Memorie della Societá Entomologica Italiana 4(6):177-200.

DADAY, E. 1902. Mikroskopische Süsswassertiere aus Patagonien, gesammelt von Dr. Filippo Silvestri in Jahre 1889-1900. Természetrajzu Füzetek 25:201-310.

EKMAN, S. 1905. Cladoceren und Copepoden aus antarktischen und subantarktischen Binnengewässern, gesammelt von der schwedischen antarktischen Expedition 1901-1903. Wissenschaftliche Ergebnisse der Schwedischen Südpolar-Expedition 1901-1903. Zool 5(3):1-40.

FELGENHAUER, B.E. 1987. Techniques for preparing crustaceans for scanning electron microscopy. Journal of Crustacean Biology 7:71-76, http://dx.doi.org/10.2307/1548626

GLOEDEN, I.M. 1994. Ocorrência de *Boeckella bergi* Richard, 1897 (Copepoda, Calanoida) na Lagoa Mirim, Rio Grande do Sul, Brasil. Nauplius 2:123-124.

HARDING, J.P. 1941. Lower Crustacea. Scientific Reports of the British Graham Land Expedition 1934–1937 1:319-322.

HEYWOOD, R.B. 1977. A limnological survey of the Ablation Point area, Alexander Island, Antarctica. Philosophical Transactions of the Royal Society of London (series B) 279:39-54.

HUYS, R. & BOXSHALL, G.A. 1991. Copepod evolution. I. London: The Ray Society, 468p.

JANIEC, K. 1988. *Pseudoboeckella poppei* (Copepoda, Calanoida) from Petrel Lake in Antarctic Penguin Island. Polish Archives of Hydrobiology 35:181-184.

MENU-MARQUE, S. & LOCASCIO DE MITROVICH, C. 1998. Distribución geográfica de las especies del género *Boeckella* (Copepoda, Calanoida, Centropagidae) en la República Argentina. Physis, Buenos Aires, Sección B, Las Aguas Continentales y sus Organismos 56:1-10.

MENU-MARQUE, S., MORRONE, J.J. & LOCASCIO DE MITROVICH, C. 2000. Distributional patterns of the South American species of *Boeckella* (Copepoda: Centropagidae): a track analysis. Journal of Crustacean Biology 20(2):262-272, http://dx.doi.org/10.1163/20021975-99990038

MORRONE, J.J. 2004. La zona de transición sudamericana: caracterización y relevancia evolutiva. Acta Entomológica Chilena 28(1):41-50.

MRAZEK, A. 1901. Süsswasser-Copepoden. Ergebnisse der Hamburger Magalhänsischen Sammelreise 6(2):1-29.

NANNI, A.S., DESCOVI FILHO, L., VIRTUOSO, M.A., MONTENEGRO, D., WILLRICH, G., MACHADO, P.H., SPERB, R., DANTAS, G.S. & CALAZANS, Y. 2012. Quantum GIS Geographic Information System. Open Source Geospatial Foundation Project. Available online at: http://qgis.osgeo.org. [Accessed: 03 July 2013].

PAGGI, J.C. 1983. Estudios limnológicos en la Península Potter, Isla 25 de Mayo, (Shetland del Sur, Antártida): morfología y taxonomía de *Pseudoboeckella poppei* Mrázek 1901, (Crustacea, Copepoda). Contribuciones Científicas del Instituto Antártico Argentino 303:1-34.

PESTA, O. 1927. Ein Beitrag zur Kenntnis der Copepodenfauna von Argentinien. Zoologischer Anzeiger 73:67-80.

PERBICHE-NEVES, G., PREVIATTELLI, D. & NOGUEIRA, M.G. 2011. Record of *Argyrodiaptomus bergi* (Crustacea: Copepoda: Calanoida) after 36 years and first record in Brazil. Zoologia 28(5):551-557, http://dx.doi.org/10.1590/S1984-46702011000500001

PEZZANI-HERNÁNDEZ, S. 1973. Descripción de adultos y estadios inmaduros en *Pseudoboeckella poppei* Mrázek, 1901 (Copepoda - Calanoida). Importancia de su morfología externa en la taxonomía y en sus hábitos alimentarios. Instituto Antártico Chileno, Serie Científica 3:28-44.

POPPE S.A. & MRÁZEK, A. 1895. Entomostraken des Naturhistorischen Museum in Hamburg. 2. Entomostraken von Süd-Georgien, 2. Jahrbuch. Hamburgischen Wissenschaftlichen Anstalten 12:135-138.

PUIG, A. 1991. Densidad y estructura comunitaria de crustáceos planctónicos en el embalse E.R. Mexía (Patagonia, Argentina). Biología Acuática 15:132-133.

REID, J.W. 1991. The Stillman Wright collection of Copepoda (Crustacea) from South America in the National Museum of Natural History, Smithsonian Institution. Proceedings of the Biological Society of Washington 104(4):736-741.

RICHARD, J. 1897. Sur quelques entomostracés d'eau douce des environs de Buenos Aires. Anales del Museo Nacional de Historia Natural de Buenos Aires 5:321-331.

RINGUELET, R.A. 1958. Los Crustáceos Copépodos de las aguas continentales de la República Argentina. Sinopsis sistemática. Contribuciones científicas de la Facultad de Ciencias exactas físicas y naturales, Universidad de Buenos Aires, Zoología 1:35-126.

WELLER, D.L.M. 1977. Observations on the diet and development of *Pseudoboeckella poppei* (Calanoida, Centropagidae) from an Antarctic lake. British Antarctic Survey Bulletin 45:77-92.

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Boraginales Juss. *ex* Bercht. & J.Presl in the Ecoregion Raso da Catarina, Bahia, Brazil

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Abstract: Raso da Catarina is one of the eight Ecoregions recognized for the Caatinga biome. This work includes the taxonomic study of Boraginales Juss. *ex* Bercht. & J.Presl in the Ecoregion Raso da Catarina, Bahia state, Brazil. The samples analyzed were collected from March 2009 to July 2013. The analyses were supplemented with dried collections kept in the herbaria: ALCB, IPA, HRB, HST, HTSA, HUEFS, HVASF, PEUFR and UFP. Two families, five genera and 16 species were recorded. The Cordiaceae family was represented by genera *Cordia* L. [*C. glabrata* (Mart.) A.DC., *C. rufescens* A.DC., *C. superba* Cham. and *C. trichotoma* (Vell.) Arráb. *ex* Steud.] and *Varronia* P.Browne [*V. curassavica* Jacq., *V. globosa* Jacq., *V. leucocephala* (Moric.) J.S.Mill. and *V. leucomalloides* (Taroda) J.S.Mill.] and Heliotropiaceae with the genera *Euploca* Nutt. [*E. paradoxa* (Mart.) J.I.M.Melo & Semir and *E. procumbens* (Mill.) Diane & Hilger], *Heliotropium* L. [*H. angiospermum* Murray, *H. elongatum* (Lehm.) I.M.Johnst. and *H. indicum* L.] and *Myriopus* Small [*M. candidulus* (Miers) Feuillet, *M. rubicundus* (Salzm. ex DC.) Luebert and *M. salzmannii* (DC.) Diane & Hilger]. The species most commonly found were *Cordia glabrata*, *Varronia globosa*, *V. leucocephala*, *Euploca procumbens*, *Heliotropium angiospermum* and *H. elongatum*, associated with sandy soils. *Cordia superba* and *C. trichotoma* were found in moist environments, higher altitudes, clay or sandy-clayey soils. *Euploca paradoxa* was collected on the banks of the São Francisco River, and *Varronia leucomalloides* occurs in the hiperxerophytic Caatinga associated with rocky or sandy soils and in areas of contact between Caatinga and Cerrado, these species were more restricted in the area. Comments are made on the morphology and taxonomy, illustrations, and data on geographical distribution and phenology, besides a key for the taxa studied.

Keywords: *floristic, taxonomy, semiarid, Caatinga, diversity.*

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Resumo: O Raso da Catarina é uma das oito Ecorregiões reconhecidas para o bioma Caatinga**.** Os espécimes analisados foram coletados no período de março/2009 a julho/2013, as análises foram complementadas com coleções herborizadas depositadas nos herbários: ALCB, IPA, HRB, HST, HTSA, HUEFS, HVASF, PEUFR e UFP. Foram registradas duas famílias, cinco gêneros e 16 espécies. A família Cordiaceae foi representada pelos gêneros *Cordia* L. [*C. glabrata* (Mart.) A.DC., *C. rufescens* A.DC., *C. superba* Cham. e *C. trichotoma* (Vell.) Arráb. *ex* Steud.] e *Varronia* P.Browne [*V. curassavica* Jacq., *V. globosa* Jacq., *V. leucocephala* (Moric.) J.S.Mill. e *V. leucomalloides* (Taroda) J.S.Mill.] e Heliotropiaceae com os gêneros *Euploca* Nutt. [*E. paradoxa* (Mart.) J.I.M.Melo & Semir e *E. procumbens* (Mill.) Diane & Hilger], *Heliotropium* L. [*H. angiospermum* Murray, *H. elongatum* (Lehm.) I.M.Johnst. e *H. indicum* L.] e *Myriopus* Small [*M. candidulus* (Miers) Feuillet, *M. rubicundus* (Salzm. ex DC.) Luebert and *M. salzmannii* (DC.) Diane & Hilger]. As espécies mais comumente encontradas foram *Cordia glabrata*, *Varronia globosa*, *V. leucocephala*, *Euploca procumbens*, *Heliotropium angiospermum* e *H. elongatum*, associadas aos solos arenosos. *Cordia superba* e *C. trichotoma* encontradas em ambientes mais úmidos, sobre altitudes mais elevadas, solos argilosos ou areno-argilosos. *Euploca paradoxa* coletada nas margens do rio São Francisco e, *Varronia leucomalloides* ocorrendo em Caatinga hiper-xerófita, associada a solos pedregosos ou arenosos, e em áreas de contato entre Caatinga e Cerrado, foram às espécies mais restritas na área. São apresentados comentários sobre morfologia e taxonomia, ilustrações, e dados sobre distribuição geográfica e fenologia, além de uma chave para os táxons estudados.

Palavras-chave: *florística, taxonomia, semiárido, Caatinga, diversidade*

Introduction

Gürke (1893) subdivided Boraginaceae *s.l.* into four subfamilies: Boraginoideae, Cordioideae, Ehretioideae and Heliotropioideae, a traditional treatment adopted by many taxonomists of the family. However, phylogenetic studies using morphological and molecular data recognized that Boraginaceae *s.l.* is not monophyletic. These studies has suggested the elevation of the subfamilies to the family rank (Böhle & Hilger 1997, Gottschling et al. 2001, Diane et al. 2002, Hilger & Diane 2003, Gottschling 2003, Gottschling et al. 2005, Weigend & Hilger 2010, Miller 2013).

All phylogenetic studies based on morphological and molecular data supported the circumscription of Boraginales including seven families, 130 genera and 2.700 species (Gottschling 2003, Weigend & Hilger 2010, Refulio-Rodriguez & Olmstead 2014). Their representatives are distributed in the Tropical, Subtropical and temperate regions of the world, with centers of diversity in Central America and the Northwestern and central regions of South America, East Asia and Mediterranean habitats of the Old and New World (Al-Shehbaz 1991).

Despite Boraginales being strongly supported in phylogenetic studies, in the Brazilian Check list of the Flora the classification adopted was a traditional treatment (Melo et al. 2014). In Brazil, the order includes ten genera and 132 species, distributed among the families Cordiaceae (2 gen./79 spp.), Heliotropiaceae (3 gen./ 45 spp.), Boraginaceae *s.s.* (3 gen./5 spp.) and Ehretiaceae (2 gen./ 3 spp.). In the Caatinga biome, two families, seven genera and 41 species were recorded for Boraginales.

The first and more comprehensive taxonomic treatment for the Boraginales in Brazil was carried out by Fresenius (1857) in *Flora Brasiliensis* (as Boraginaceae *s.l.*), which is still one of the most complete works for the group in this country. The most recent contributions on the taxonomy of this order in Brazil are generally local floristic surveys such as the works conducted by Smith (1970), Santa Catarina; Guimarães et al. (1971), Guanabara (São Paulo); Taroda & Silva (2002), Ilha de Cardoso (São Paulo); Cavalheiro et al. (2003), Picinguaba (São Paulo); Melo & França (2003), Grão-Mogol (Minas Gerais); Melo & Sales (2004, 2005), Xingó (Alagoas and Sergipe); Conceição (2007), Bahia; Melo & Andrade (2007), in an area of Ecological Station Raso da Catarina (Bahia); Melo et al. (2007), Serra Talhada (Pernambuco); Freitas et al. (2008), Fernando de Noronha (Pernambuco); Melo & Lyra-Lemos (2008), Alagoas; Melo (2009), Mirandiba (Pernambuco); Melo et al. (2009a), in an area of seasonal forest (Pernambuco); Melo et al. (2011), APA das Onças (Paraíba); Melo (2012), National Park of Catimbau (Pernambuco); Ranga et al. (2012), São Paulo; Melo et al. (2013), Goiás and Tocantins and Vieira et al. (2013), APA Serra Branca (Bahia). Besides the floristic surveys, taxonomic revisions of genera were also carried out. One can highlight the works of: Taroda & Gibbs (1986b), *Cordia* subgenus *Varronia* (Brazil); Taroda & Gibbs (1987), *Cordia* subgenus *Myxa* (Brazil); Stapf (2007), *Cordia* section *Pilicordia* (Brazil); Melo & Semir (2008), *Heliotropium* (Brazil); Melo & Semir (2010), *Euploca* (Brazil) and Cavalheiro et al. (2011), *Tournefortia* extra-Amazon (Brazil).

Despite the existence of studies on Boraginales for the semiarid of northeastern Brazil, specific works for the state of Bahia are scarce, especially those that include identification keys and taxonomic descriptions. Given the importance of Boraginales in the Caatinga vegetation, this work had as a goal carry out the survey of the species of the order in the Ecoregion Raso da Catarina in order to contribute to knowledge about the flora of the semiarid region of Bahia, as well as provide support for the development of plans to manage the existing conservation units that exist in this Ecoregion.

Material and Methods

The Raso da Catarina Ecoregion comprises 30.800 km^2 and is one of the eight Ecoregions recognized for the Caatinga. In the North-south direction it is narrow and elongated. In the North, West and East it is limited to the southern hinterland depression. The northeastern portion has limits with the Borborema Plateau and the southern part of the Bahia hinterland, in the Zona da Mata. The Ecoregion is a basin with soils that are very sandy, deep and little fertile. Its relief is usually flat, but with canyons in the western part (formed by sandstone outcrops). The altitudes above sea level vary from 400 to 600 m in the southern part (Bahia) and from 350 to 700 m in the northern part (Jatobá basin, Pernambuco). In the southern part (Bahia) most of the soils are composed of sand (deep, excessively drained, acid and very low fertility) and oxisol (deep, well drained, acid and low fertility) whereas in the northern part (Pernambuco) sands soils prevail. There exists little surface water in the region except in the areas of the canyons. The predominant vegetation is the sandy, bushy Caatinga, very dense and less thorny than the Caatinga of crystalline soils (Velloso et al. 2002).

The climate of the Ecoregion is semiarid with average rainfalls of 650 mm/year in the southern part (Bahia) and rainy season from December to July. In the northern part (Pernambuco) the climate is drier with average rainfalls of 450 mm/year and the rainy period is from January to April. Ambient temperatures are very high with large differences of temperature between day and night. The municipalities in this Ecoregion in the state of Bahia are: Canudos, Chorrochó, Cícero Dantas, Euclides da Cunha, Glória, Jeremoabo, Macururé, Paulo Afonso, Rodelas, Santa Brígida and Uauá. The Ecoregion includes six units of conservation, five in its southern part in the state of Bahia: Ecological Station Raso da Catarina, APA Serra Branca, State Park of Canudos, Biological Station of Canudos, and RPPN Farm Flor de Lis. The Biological Reserve of Serra Negra is located in the northern part, in the state of Pernambuco (Velloso et al. 2002, Szabo et al. 2007).

The expeditions concentrated in the conservation units (Figure 1) located in the southern part of the Ecoregion, portion Bahia; APA Serra Branca (09°53'15.5" to 09°44'34.6" S and 38°49'36.1" to 38°52'20.4" W); Biological Station of Canudos (09°55'58.6" to 09°58'25.2" S and 38°57'32.2" to 39° 01'38.5" W); Ecological Station Raso da Catarina (09°33'13" to 09°54'30" S and 38°29'20" to 38°44'00" W); State Park of Canudos (09°56'19.7" to 09°54'32.4" S and 39°06'13.3" to 39° 04'20.5" W) and RPPN Farm Flor de Lis (10°50'14.1" to 10° 50'26.4" S and 38°31'46.4" to 38°31'34.7" W).

The study was based on fieldwork carried out in the period between March 2009 and July 2013, besides information complemented by the analysis of species deposited in the herbaria ALCB, IPA, HRB, HUEFS, HVASF, PEUFR and UFP, acronyms according to Thiers 2013 (continuously updated), and in the herbaria HST and HTSA, acronyms according to the Brazilian network of herbaria (SBB 2013). Field collections and observations were performed during random walks exploring most of the study area. Herborization and material processing followed the methodology by Fosberg & Sachet (1965) and Mori et al. (1989), with collection of fertile material having flowers and/ or fruit. Observations were made about the distribution of the

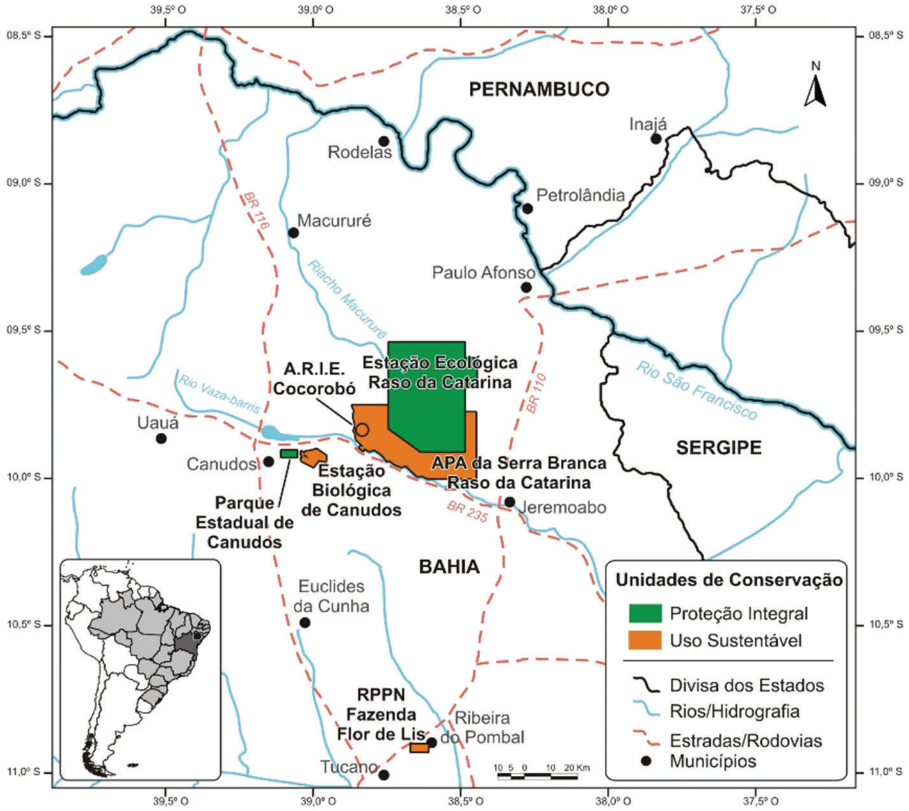

Figure 1. Location of conservation units of the Ecoregion Raso da Catarina, state of Bahia, Brazil.

species and the type of soil (Tricart 1972, Sampaio 1995). Specimens were deposited in the herbarium of the State University of Bahia (HUNEB – Collection Paulo Afonso) and duplicates were sent to the main herbaria in the state of Bahia.

Identifications were made based mainly on specialized bibliography (e.g., Johnston 1928, 1930, Taroda & Gibbs 1986a, 1986b, Diane et al. 2002, Melo & Sales 2004, 2005, Melo & Andrade 2007, Miller & Gottschling 2007, Freitas et al. 2008, Melo & Semir 2008, Melo et al. 2009a and Melo & Semir 2010), protologues, photos of type collections and consulting of the collections in the visited herbaria. For taxonomic descriptions, the terminologies proposed by Radford et al. (1974), Ribeiro et al. (1999) and Harris & Harris (2001) were adopted. Taxonomic treatment includes a key for the identification of taxa, descriptions, illustrations, and data of the geographical distribution and reproductive phenology of the species.

Results and Discussion

Boraginales Juss. *ex* Bercht. & J.Presl, *Prir. Rostlin*: 244. 1820.

Herbs, subshrubs, shrubs or trees, less frequently lianas, rare root parasites; glabrous or with trichomes presenting cystoliths or bodies similar to basal cystoliths and/or calcified walls. Leaves alternate, sub-opposite or more rarely opposite or verticillate, simple, without stipules, petiolate or sessile with different shapes. Inflorescences paniculate, glomerulate-globose, spicate, scorpioid or helicoid, terminal, falsely terminal or axillary or internodal; with or without bracts. Flowers regular, pentamerous, calyx dialisepalous or gamosepalous, corolla gamopetalous. Stamens 5, epipetalous, alternate to the corolla lobes, generally inserted in the height of the lower half of the tube or in the corolla mouth; anthers free or coherent with each other, introrse or extrorse, appendiculate or devoid of appendages, with longitudinal dehiscence. Gynoecium superior, syncarpous, 2-(6-14) carpels; ovary 2 or 4 locular by intrusion of a false septum, nectariferous disk generally present, fine or thickened; style entire to bipartite with 1-(2-4) stigmas. Placentation axial, parietal or basal; ovule 1 to many per locule, anatropous or hemianatropous. Fruit dry or fleshy, dehiscent or indehiscent, capsules, schizocarps or drupes. Seed 1 to many, embryo straight or curved.

In the Ecoregion Raso da Catarina, Bahia, two families, five genera and 16 species were found. Cordiaceae is represented by two genera: *Varronia* P.Browne and *Cordia* L., both with four species. Heliotropiaceae comprehends three genera: *Heliotropium* L. and *Myriopus* L., with three species each, and *Euploca* Nutt., with two species.

Cordia rufescens A.DC., *Euploca paradoxa* (Mart.) J.I.M.Melo & Semir, *Varronia leucocephala* (Moric.) J.S.Mill. and *V. leucomalloides* (Taroda) J.S.Mill. are endemic to Brazil. *Varronia leucocephala* and *V. leucomalloides* have a distribution restricted to the northeast region, being the first species endemic to the Caatinga and the second occurring in the Caatinga and Cerrado. *Varronia globosa* Jacq. is found from the south of the United States to the northeast of South America. However, in Brazil it occurs exclusively in the Caatinga vegetation from Ceará to Bahia. The remaining species have a large distribution on the Brazilian territory (Taroda & Gibbs 1986b, Melo et al. 2014).

Cordia glabrata (Mart.) A.DC., *V. globosa*, *V. leucocephala*, *E. procumbens* (Mill.) Diane & Hilger, *H. angiospermum* Murray and *H. elongatum* (Lehm.) I.M.Johnst., were species predominant in the studied area, being directly related to sandy soils common in the region. However, *Cordia superba* Cham. and *C. trichotoma* (Vell.) Arráb. *ex* Steud are found in environments that are more humid, at higher altitudes, clayey or sandy-clayey soils. *Euploca paradoxa,* collected at the banks of the São Francisco River, and *V. leucomalloides,* occurring in hiperxerophytic Caatinga associated with stony or sandy soils and in areas of contact between Caatinga and Cerrado, were the species more restricted in the studied area.

Identification key for the families and species

1. Inflorescences paniculate, spicate or glomerulate-globose; style bipartite .... **Cordiaceae**
  2. Leaves with margin entire or irregularly dentate in apical portion; inflorescences paniculate.
    3. Calyx smooth; corolla 3.5–5 cm long, deciduous. Young twigs nut-brown to brown.
      4. Young twigs generally reddish, glabrous, villous to tomentose; abaxial surface tomentose; calyx reddish, externally tomentose .... **2. *C. rufescens***
      4. Young twigs nut-brown to brown, scabrous to strigose; abaxial surface puberulous to glabrescent, hispid to strigose on nerves; calyx nut-brown to green-vinaceous, externally scabrous .... **3. *C. superba***
    3. Calyx costate; corolla 1.2–3.2 cm long, marcescent.
      5. Leaf blade oval, oboval to elliptical, abaxial surface with stellate trichomes; flowers 1.4–1.9 cm long; corolla lobes with subtruncate apex .... **4. *C. trichotoma***
      5. Leaf blade oval to orbicular, abaxial surface with simple trichomes; flowers 2.5–3.5 cm long; corolla lobes with obtuse to rounded apex .... **1. *C. glabrata***
  2. Leaves with margin serrate; inflorescence spicate or glomerulate-globose.
    6. Leaf blade with attenuate base; inflorescence spicate .... **5. *V. curassavica***
    6. Leaf blade with cuneate to truncate or cuneate to obtuse base; inflorescence glomerulate-globose.
      7. Branches hirsute intermingled by smaller floccose or densely floccose trichomes; inflorescence terminal and axillary .... **8. *V. leucomalloides***
      7. Branches scabrous to strigose or velvety intermingled by larger hirsute trichomes; inflorescence terminal and/or internodal.
        8. Calyx with filiform lobes at apex; corolla 2.5–7 mm long .... **6. *V. globosa***
        8. Calyx with acute lobes at apex; corolla 20–35 mm long .... **7. *V. leucocephala***
1. Inflorescences scorpioid, rare flowers solitary and axillary; style entire .... **Heliotropiaceae**
  9. Fruit schizocarpic with 2 to 4 nutlets.
    10. Anthers coherent at apex; fruit 4 nutlets with 1 seed each.
      11. Leaf blade lanceolate; flowers solitary, pedicellate, bracteate, corolla entirely yellow, lobes alternated by appendages; fruit depressed-pyriform, pubescent to strigose .... **9. *E. paradoxa***
      11. Leaf blade elliptical to oboval; flowers inserted in inflorescences, subsessile, ebracteate, corolla white, mouth yellow, lobes not alternated by appendages; fruit sub-globose, sericeous .... **10. *E. procumbens***
    10. Anthers free; fruit 2 nutlets with 2 seeds each.
      12. Petiole wingless; fruit depressed-globose, verrucose .... **11. *H. angiospermum***
      12. Petiole winged; fruit mitriform, costate.
        13. Leaf blade with adaxial surface bullate; stigma clavate; fruit with juxtapose nutlets .... **12. *H. elongatum***
        13. Leaf blade with adaxial surface flat; stigma sub-capitate; fruit with divergent nutlets .... **13. *H. indicum***
  9. Fruit drupaceous with 4 pyrenes.
    14. Branches grayish to whitish devoid of lenticels; inflorescences congested, pyramidal; fruit villous to tomentose .... **14. *M. candidulus***
    14. Branches brown to brown-grayish, with lenticels; inflorescences lax, secundiflorous; fruit glabrous to hirsute.
      15. Trichomes foliar with sharply discoid base; ovary obclavate; stigma short .... **15. *M. rubicundus***
      15. Trichomes foliar without discoid base; ovary conic-pyramidal; stigma elongated ..... **16. *M. salzmannii***

Cordiaceae R.Br. *ex* Dumort., Anal. Fam. Pl.: 25. 1829.

Trees, shrubs, rarely subshrubs, lianas or herbs. Leaves simple, alternate, rarely subopposed, petiolate or sessile with entire or serrate margin, persistent or deciduous. Inflorescences paniculate, spicate or glomerulate-globose, terminal, axillary and internodal, lax or congested, rare solitary flowers generally without bracts. Flowers dichlamydeous, actinomorphic, androgynous or functionally unisexual, many times presenting heterostyly of the distyly type; calyx 5-lobed, gamosepalous, rarely dialisepalous (*Coldenia*), tubular to campanulate, persistent, sometimes accrescent; corolla 5-lobed, gamopetalous, tubular (e.g., infundibuliform, hippocrateriform or salverform) often pale, rarely yellow, orange or red-orange, lobes patent or reflexed, alternate to the sepals. Stamens 5, with developed filaments, epipetalous, frequently pubescent at point of insertion; anthers free, introrse or extrorse, dorsifixed. Gynoecium bicarpelar, ovary falsely tetralocular by the intrusion of a septum, 2 ovules per locule, orthotropous or anatropous; style terminal bipartite; 4 stigmas, clavate to filiform. Fruit indehiscent, drupe, endocarp bony or fibrous, undivided. Seed 1, testa with transfer cells, endosperm abundant or absent, embryo straight or curved; cotyledons plicate.

Cordiaceae includes the genera *Coldenia* (monospecific), *Cordia* L. (ca. 250 spp.) and *Varronia* P.Browne (ca. 100 spp.). Their representatives are distributed in the Tropical and Subtropical regions, registered from the New World with centers of diversity in Central America and in northern South America with few species in temperate regions. Phylogenetic studies using morphological and molecular data supported the family as monophyletic. The main morphological characters that supported the family were: endocarp undivided, stigma with four lobes and plicate cotyledons (Gottschling 2003, Miller & Gottschling 2007, Stapf 2007). In Brazil the family is represented by *Cordia* (48 spp.) and *Varronia* (28 spp.). In the Caatinga vegetation there are 19 species of the family, among these 11 belonging to *Cordia* and eight to *Varronia.*

1. *Cordia glabrata* (Mart.) A.DC., Prodr. 9: 473. 1845. Figure 2a-f

Tree, 4–6 m tall; branches cylindrical, brown-grayish with longitudinal fissure, pubescent to tomentose or glabrous, lenticels whitish. Leaf with blade 6.2–5.5 × 4.5–14 cm, semi-coriaceous to coriaceous, discolorous, oval to orbicular, apex acute to rounded, margin entire, base obtuse, truncate to subcordate, adaxial surface glabrescent, abaxial surface tomentose, trichomes simple; petiole 0.8–4 cm long, cylindrical, not sulcate, pubescent to tomentose; venation brochidodromous reticulate. Inflorescence 4–16 cm long, panicle, terminal and internodal, tomentose; peduncle 2–7 cm long, tomentose. Flowers 2.5–3.5 cm long, sessile; calyx 1.7–2 cm long, tubular, costate, green, externally tomentose, internally strigose to sericeous, lobes 2.5–3.5 × 1.8–2 mm, oval, apex acute; corolla 2–3.2 cm long, salverform, white, brown when old, marcescent, glabrous, tube 1.8-2.5 cm long, cylindrical, lobes 0.9–1.2 × 1–1.2 cm, orbicular, patent, smooth, apex obtuse to rounded; stamens 5(-6), free, inserted 1–1.6 cm from base, filaments 1.2–2.4 cm long, brown, pubescent at base, anthers 4–6 × 2–2.8 mm, oblong to lanceolate, apex acute; ovary 1.5–2 cm long, globose, glabrous, nectariferous disk 1–2 mm long; style ca. 1.7 cm long to the brevistyle flowers, 2.4–3 cm long to longistyle flowers, stigmas 1–2 mm long, filiform, erect or recurved, glabrous. Drupes ca. 0.7 × 3–4.2 mm, ovoid, brown at maturity, glabrous to pubescent. Seed 1, ca. 4 × 3 mm, globose, green.

Material examined: BRAZIL, BAHIA: Canudos, ca. 5 km de Canudos, 09°14'44" S e 39°06'11" O, 397 m, 12.VIII.2004, fr., A.A. Santos et al. 2442 (HUEFS); Glória, Reserva Indígena Pankararé, 09°20' S e **38°15**′ O, 16.I.1993, fl. e fr., F.P. Bandeira 148 (ALCB); Serra de Itaparica, 09°10'22" S e 38° 32'16" O, 323 m, 16.VII.2007, fl. e fr., A.S. Conceição 1066 (HUEFS); Serra do Salgado, 09°14'22" S e 38°36'38" O, 337 m, 08.IX.2007, fl., A.S. Conceição 1182 (HUEFS); Jeremoabo, estrada entre Jeremoabo e Canudos, 10°01'32" S e 38°31'38" O, 298 m, 13.VII.2012, fl., D.D. Vieira 333 (HUNEB); fl., D.D. Vieira 334 (HUNEB); Estrada 30 km antes de Paulo Afonso, 10°04' S e 38°28' O, 08.X.1961, fl., A. Lima 78236 (HUEFS); Fazenda Serra Branca, Trilha em direção ao Tanque de Coleta, 09°54'01" S e 38°41'01" O, 399 m, 05.XI.2010, fl. e fr., L.R. Silva 12 (HUNEB); 09°54'09" S e 38°41'41" O,370 m, 04. IX.2012, fl., D.D. Vieira 388 (HUNEB); Santa Brígida, Estação Ecológica Raso da Catarina, 09°44' S e 38°07' O, 24. X.1982, fl., M.L. Guedes 550 (ALCB).

Cordia glabrata occurs in Bolivia, Paraguay and Brazil (Miller 2013). Widely distributed in Brazil, it has been registered from Bahia, Goiás, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Pará and Piauí, related to the Amazon rainforest, Caatinga and Cerrado (Melo et al. 2014).

In the study area it was found in rocky soils and anthropized areas forming small populations. It was collected with flowers from July to November and fruits in November and December.

In the study area the species can be confused mainly with *Cordia trichotoma*, since both represent arboreal habit, costate calyx and marcescent corolla. However, *C. glabrata* can be recognized because it has an oval to orbicular leaf blade, simple trichomes (vs. oval, oboval to elliptic, stellate trichomes in *C. trichotoma*), flowers 2.5–3.5 cm long (vs. 1.4–1.9 cm long), orbicular corolla lobes and obtuse to rounded apex (vs. oblong and subtruncate apex).

2. *Cordia rufescens* A.DC., Prodr. 9: 476. 1845. Figure 2g-j

Cordia piauhiensis Fresen. Fl. Bras. 8(1): 9. 1857.

Subshrub or shrub, 0.6–2 m tall, erect; branches cylindrical, generally with young twigs generally reddish, villous to tomentose. Leaf with blade 4–16.5 × 2.5–8.2 cm, semi-coriaceous, discolorous, oval, elliptic to oboval, apex acute to rounded, margin entire or dentate at apical portion, base cuneate, adaxial surface strigose, abaxial surface tomentose; petiole 0.3–1.2 cm long, subcylindrical, slightly sulcate, tomentose; venation brochidodromous. Inflorescence 4–8 cm long, panicle with helicoid branches, terminal, lax; peduncle 1.5–5.2 cm long, tomentose. Flowers 3.5–5 cm long, sessile; calyx 1–1.4 cm long, tubular-campanulate, smooth, reddish, externally tomentose, internally glabrous, lobes 3–4 × 3–4.2 mm, oval to depressed-oval, apex obtuse; corolla 3.5–4.6 cm long, infundibuliform, white, with chestnut blotches, deciduous, externally strigose, internally glabrous, tube 2.5–3 cm long, cylindrical, lobes ca. 0.9 × 1.6 cm, orbicular, slightly reflexed, wrinkled, apex rounded, slightly emarginate, rarely with acumen; stamens 4(-5), free, inserted 0.6–0.8 cm from base, filaments 1.2–2 cm long, chestnut, pubescent to the half of length, anthers 3–3.2 × 1.8–2 mm, oblong, apex acute; ovary 2–3 mm long, sub-globose, glabrous, nectariferous disk absent; style 1.5–2.8 cm long, stigmas 1–1.5 mm long, clavate, erect, glabrous. Drupes 1.6–2 × 1–1.5 cm, ovoid, apex apiculate, green when young, cream to yellow when mature, glabrous. Seed 1, 1.2–1.5 × 0.8–1 cm, ovoid, apex aristate, green, reticulate.

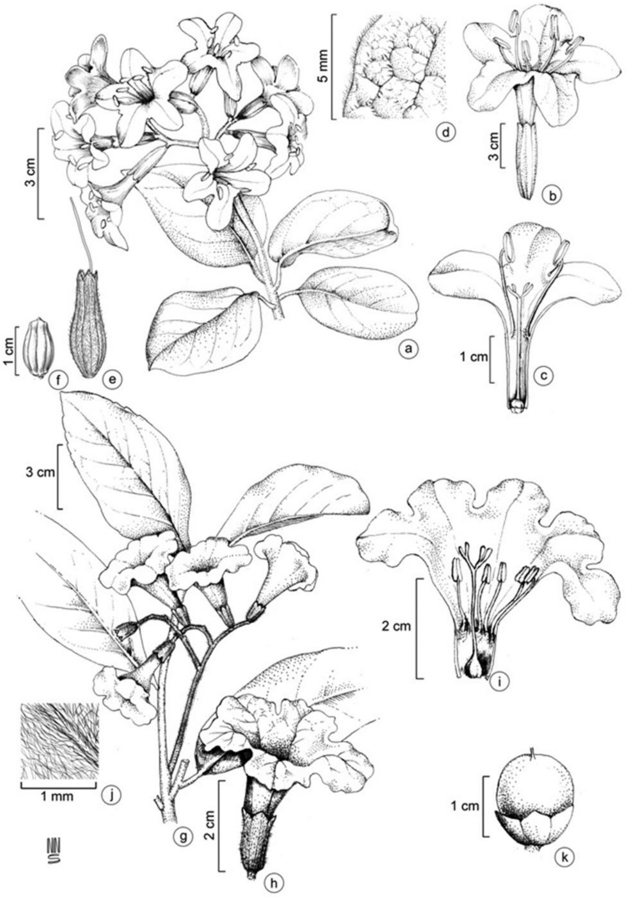

Figure 2. a-f) *Cordia glabrata*: a) flowering branch; b) flower; c) longitudinal section of flower, showing androecium and gynoecium; d) simple trichomes on the adaxial surface of the leaf; e) fruit enclosed by calyx; f) fruit. g-k) *Cordia rufescens*: g) flowering branch; h) flower; i) longitudinal section of flower, showing androecium and gynoecium; j) detail of indumentum on the abaxial surface of leaf ; k) fruit. a-d) L.R. Silva 12; e-f) D.D. Vieira 393; f-k) A.S. Conceição 1792.

Material examined: BRAZIL, BAHIA: Euclides da Cunha, Estrada para Sucupira do Galo, 10°21'00" S e 38°41'20" O, 546 m, 11.VI.2013, fl. e fr., D.D. Vieira 447 (HUNEB); Fazenda Santa Rosa, 38°00'53" S e 10°05'00" O, 18.VIII.2003, fr., M.L. Guedes et al. 10563 (ALCB); Jeremoabo, APA Serra Branca, Baixa Grande, Próximo ao povoado de Quelés, 09°58'31" S e 38°27'00" O, 569 m, 19.III.2009, fl. e fr., A.S. Conceição 1556 (HUNEB); 03.IX.2012, fl. e fr., D.D. Vieira 383 (HUNEB); Estrada saindo de Quelés, sentido Estação Ecológica Raso da Catarina, 09°58'01" S e 38°26'12" O, 497 m, 29.VII.2009, fl. e fr., A.S. Conceição 1802 (HUNEB); 09°55'14" S e 38°29'26" O, 509 m, 17.VI.2009, fl., D.D. Vieira 01 (HUNEB); 09°55'17" S e 38°29'24" O, 08.IX.2009, fl. e fr., M.V.V. Romão 540 (HUNEB); 09°57'11" S e 38°26'30" O, 513 m, 08.XII.2009, fl., D.D. Vieira 52 (HUNEB); Fazenda Barreirinhas, 10°16'00" S e 38°47'00" O, 21.X.2006, fl., M. Oliveira 2546 (UFP); Limite entre a APA Serra Branca e a Estação Ecológica Raso da Catarina, 09°53'43" S e 38°29'33" O, 648 m, 17.VI.2009, fl., A.S. Conceição 1654 (HUNEB); Paulo Afonso, Estação Ecológica Raso da Catarina, 09°52'22" S e 38°51'05" O, 31. I.2006, fl., M.M.M. Lopes et al. 463 (HUEFS); Estrada em direção à Mata da Pororoca, 09°48'17" S e 38°29'31" O, 711 m, 18.VIII.2012, fl., D.D. Vieira 351 (HUNEB); Trilha da encruzilhada, 09°48'18" S e 38°29'33" O, 596 m, 01.VII.2010, fl. e fr., A.A.S. Lopes 975 (HUNEB); Ribeira do Pombal, 10° 50'00" S e 38°32'00" O, 16.XIII.2003, M.L. Guedes 10436 (ALCB); Sentido Banzaê, 10°46'41" S e 38°34'42" O, 212 m, 10. VI.2013, bot. e fl., L.R. Silva 187 (HUNEB); Santa Brígida, Raso da Catarina, 09°58'05" S e 38°49'38" O, 611 m, 28. VI.2002, fl., L.P. Queiroz et al. 7278 (HUEFS).

This species is endemic to Brazil and dispersed in northeastern (Maranhão, Piauí, Ceará, Paraíba, Pernambuco, Bahia, and Alagoas), mid-western (Goiás) and southeastern (Minas Gerais) Brazil, in Caatinga and Cerrado environments (Johnston 1930, Melo et al. 2014).

It was collected in ecotonal areas of Caatinga-Cerrado, at the edge of forests and in environments that are recovering from burned-over land with flowers between June and December and flowers and fruits from July to March.

It is similar to *Cordia superba* mainly because both have leaves with entire or irregular margin in the apical portion, smooth calyx and the corolla with same size or superior to 3.5 cm long, deciduous. However, *Cordia rufescens* presents young twigs generally reddish, villous to tomentose (vs. nut-brown to brown, scabrous to strigose in *C. superba*), leaves with tomentose abaxial surface (vs. puberulous to glabrescent, hispid to strigose on nerves) and reddish calyx, tomentose externally (vs. nut-brown to green-vinaceous, externally scabrous).

3. *Cordia superba* Cham., Linnaea 4: 474. 1829. Figure 3a-f

Shrub or small tree, 1.5–4 m tall; branches cylindrical, young twigs nut-brown to brown, scabrous to strigose. Leaf with blade 4–17.5 × 2.2–7.5 cm, semi-coriaceous, discolorous, elliptical to oboval, apex acute to acuminate or rounded, margin entire or dentate at apical portion, base cuneate, obtuse or oblique, adaxial surface scabrous to glabrescent, abaxial surface puberulous to glabrescent, hispid to strigose on nerves; petiole 0.4–1 cm long, subcylindrical, sulcate, scabrous to hispid; venation brochidodromous. Inflorescence 5–9 cm long, panicle with helicoid branches, terminal, lax; peduncle 3.5–6 cm long, hispid to scabrous. Flowers 3.5–5.5 cm long, subsessile; calyx 1.2–1.6 cm long, tubular-campanulate, smooth, nut-brown to green-vinaceous, externally scabrous, internally glabrous, lobes 3.5–3.6 mm, oval, apex obtuse, slightly mucronate; corolla 3.5–5 cm long, infundibuliform, white, deciduous, externally scabrous to glabrescent, internally glabrous, tube 2.8–4 cm long, cylindrical, lobes 0.9–1.2 × 1.5–2 cm, orbicular, slightly reflexed, wrinkled, apex rounded with acumen; stamens 5, free, inserted 0.7–1 cm from base, filaments 1.3–1.6 cm long, nut-brown, pubescent to the half of the length, anthers 2.8–4 × 1.2–2 mm, oblong, apex acute; ovary 2–3 mm long, sub-globose, glabrous, nectariferous disk absent; style 1.2–1.8 cm long, stigmas 1–1.2 mm long, clavate, erect, glabrous. Drupes immature, ca. 1.6 × 1.2 cm, ovoid, apex apiculate, green, glabrous. Seed 1, ca. 1.1 × 0.6 cm, ovoid, apex aristate, green, reticulate.

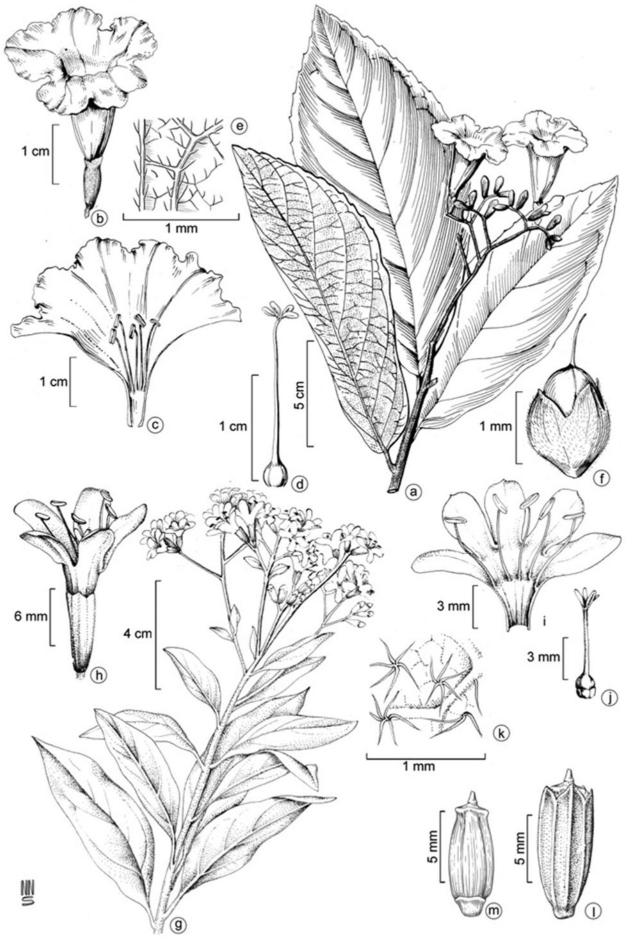

Figure 3. a-f) *Cordia superba*: a) flowering branch; b) flower; c) longitudinal section of flower, showing androecium; d) gynoecium; e) detail of indumentum on the abaxial surface of leaf; f) fruit. g-m) *Cordia trichotoma*: g) flowering branch; h) flower; i) longitudinal section of flower showing androecium; j) gynoecium; k) stellate trichomes on the adaxial surface of leaf; l) fruit enclosed by calyx; m) fruit. a-f) D.D. Vieira 461; g-k) D.D. Vieira 97; l-m) D.D. Vieira 380.

Material examined: BRAZIL, BAHIA: Cícero Dantas, estrada a 2 km da entrada de Cícero Dantas, 10°51'45" S e 38°33'52" O, 436 m, 10.VI.2013, fl., V.O. Amorim 237 (HUNEB); 10°34'30" S e 38°22'50" O, 432 m, 01.VII.2013, fl. e fr., D.D. Vieira 458 (HUNEB); 10°34'30" S e 38°22'50" O, 432 m, 01.VII.2013, fl., D.D. Vieira 459 (HUNEB); 10°34'30" S e 38°22'50" O, 432 m, 01.VII.2013, fl., D.D. Vieira 460 (HUNEB); 10°34'30" S e 38°22'50" O, 432 m, 01.VII.2013, fl., D.D. Vieira 461 (HUNEB).

Cordia superba is endemic from Brazil. It is distributed from Maranhão to Paraná in Caatinga, Cerrado and Atlantic forest environments (Melo et al. 2014).

In the study area it was found on sandy-clayey soils at the forest edge, close to the municipality of Cícero Dantas. Specimens were collected with flowers in June and with flowers and fruits in July.

The species is morphologically similar to *Cordia rufescens*. However, it can be easily differentiated by the color and indumentum of the young twigs, calyx and indumentum of the leaf blade (see comments in *C. rufescens*).

4. *Cordia trichotoma* (Vell.) Arráb. *ex* Steud., Nom. ed. 2: 419. 1840. Figure 3g-m

Tree, 4–10 m tall; branches cylindrical, brown-grayish with longitudinal fissure, pubescent, composed of stellate trichomes, lenticels whitish. Leaf with blade 3–12.7 × 1.2–4.5 cm, chartaceous to semicoriaceous, discolorous, oval, oboval to elliptical, apex acute to acuminate, margin entire, base cuneate, rarely rounded or oblique, adaxial surface strigose to glabrescent, ferruginous, abaxial surface pubescent to glabrescent, trichomes stellate, more pronounced on nerves; petiole 0.2–3 cm long, subcylindrical, sulcate, pubescent to sericeous; venation eucamptodromous. Inflorescence 3–15 cm long, panicle, terminal, lax to congested; peduncle 2–6 cm long, pubescent to tomentose. Flowers 1.4–1.9 cm long, subsessile; pedicel ca. 2 mm, cylindrical, tomentose; calyx 0.8–1 cm long, tubular, costate, green, externally tomentose, internally sericeous, lobes 1.4–1.8 × 0.6–1.1 mm, oval-lanceolate, apex slightly mucronate; corolla 1.2–1.7 cm long, hipocrateriform, white, brown when old, marcescent, glabrous, tube 0.7–1 cm long, cylindrical, lobes 0.8–1 × 0.5–0.7 cm, oblong, patent, smooth, apex subtruncate; stamens 5(-6), free, inserted 0.5–0.7 cm from base, filaments 0.6–1.1 cm long, brown, pubescent at base, anthers 2–1.5 × 0.8–1 mm, oblong to lanceolate, apex acute; ovary ca. 2 mm long, sub-globose, glabrous, nectariferous disk 1–1.2 mm long; style ca. 0.9 cm long in brevistyle flowers, ca. 1.4 cm long in longistyle flowers, stigmas 1.5–2.5 mm long, clavate, erect, glabrous. Drupe 0.5–0.7 × 2.5–3.2 mm, subcylindrical, brown at maturity, glabrous. Seed 1, 1.4–5.8 × 2–2.4 mm, ovoid, cream-colored.

Material examined: BRAZIL, BAHIA: Euclides da Cunha, Sítio do Jaime, 10°50' S e 39°00' O, 21.IV.2004, fl., M.L. Guedes et al. 11467 (ALCB); Jeremoabo, APA Serra Branca, Baixa Grande, Próximo ao povoado de Quelés, 09°58'31" S e 38°27'01" O, 564 m, 03.IX.2012, fl., D.D. Vieira 385 (HUNEB); Estrada de acesso ao povoado Quelés, sentido Estação Ecológica Raso da Catarina, 09°58'01" S e 38°26'12" O, 493 m, 28.VII.2009, fl., A.S. Conceição 1776 (HUNEB); fl., A.S. Conceição 1792 (HUNEB); 09°53'02" S e 38°32'39" O, 650 m, 22.IX.2010, fl., D.D. Vieira 97 (HUNEB); 09°57'48" S e 38°26'13" O, 493 m, 03. IX.2012, fl., D.D. Vieira 380 (HUNEB); Fazenda Barreirinhas, 10°16'00" S e 38°47'00" O, 21.X.2006, fl., M. Oliveira 2555 (UFP); Fazenda Natureza, 10°03'88" S e 38°43'88" O, 427 m, 12. VIII.2005, fl., E.B. Miranda et al. 887 (HUEFS); Muro, 10°04'16" S e 38°43'05" O, 439 m, 18.X.2009, fl., E. Melo et al. 6738 (HUEFS); Ribeira Pombal, 10°50' S e 38°32' O, 15.X.2003, fl., M. L. Guedes 10507 (ALCB).

Cordia trichotoma is registered to Brazil, Northeastern Argentina, Eastern Paraguay and Bolivia (Maia 2004, Miller 2013). In Brazil, the species is found in the Northeast, mid-west, Southeast and Southern regions in the vegetation of the Amazon rainforest, Cerrado, gallery forests and Caatinga (Taroda & Gibbs 1987, Melo et al. 2014).

In the study area the species has a restricted distribution in sandy and sandy-clayey soils. Collected with flowers from July to September and fruits between September and November.

The species can be confused with *Cordia glabrata* (see details in *C. glabrata*). However, *C. trichotoma* has an oval, oboval to elliptical leaf blade, stellate trichomes, flowers 1.4–1.9 cm long, oblong corolla lobes and subtruncate apex.

5. *Varronia curassavica* Jacq., Enum. Syst. Pl.:14. 1760. Figure 4a-d

Cordia curassavica (Jacq.) Roem. & Schult. Syst. Veg. 4: 460. 1819.

Shrub, 1.5–3.5 m tall, erect, sub-scandent to scandent; branches cylindrical, sulcate, brown-grayish, villous to hirsute, lenticels brownish. Leaf with blade 1.5–9 × 0.5–3 cm, chartaceous, discolorous, lanceolate, apex acute, margin serrate, base attenuate, adaxial surface sparsely strigose to glabrescent, abaxial surface pubescent to tomentose; petiole 0.3–1 cm long, cylindrical, sulcate, tomentose; venation semi-craspedodromous. Inflorescence 1.7–10.5 cm long, spicate, terminal and internodal, congested; peduncle 1.5–6 cm long, tomentose and hirsute. Flowers 4–7 mm long, sessile; calyx 2–4 mm long, campanulate, cream to green, externally pubescent, internally glabrous, lobes 1–1.5 × 0.8–1.2 mm, oval-lanceolate, apex trullate; corolla 3–5 mm long, infundibuliforme to salverform, white, glabrous, tube 2–4 mm long, cylindrical, lobes 1.2–2.5 × 0.8–1.8 mm, oval, reflexed, wrinkled,

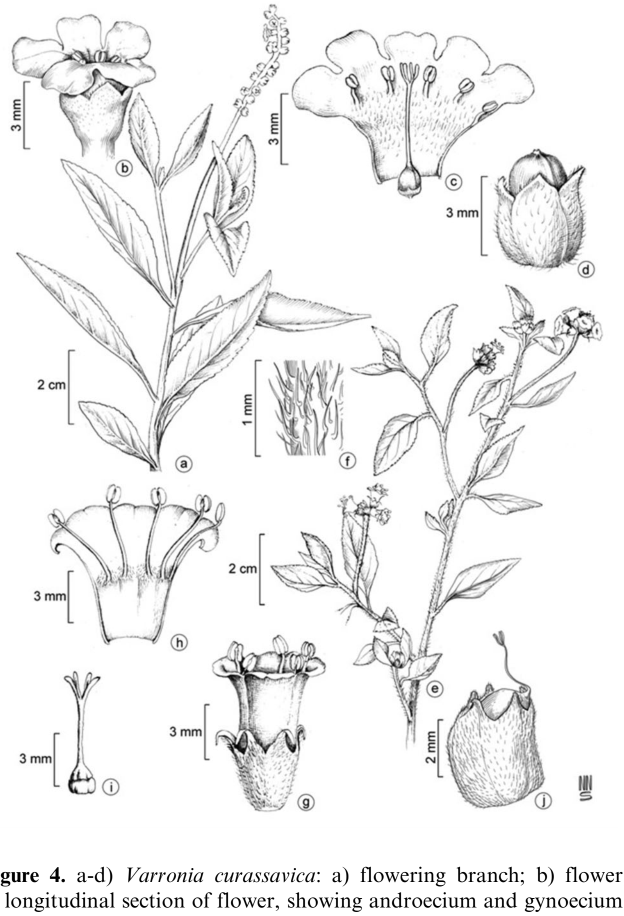

Figure 4. a-d) *Varronia curassavica*: a) flowering branch; b) flower; c) longitudinal section of flower, showing androecium and gynoecium; d) fruit. e-j) *Varronia globosa*: e) flowering branch; f) detail of indumentum of branch; g) flower; h) longitudinal section of flower showing androecium; i) gynoecium; j) fruit. a-d) A.S. Conceição 1756; e-i) R.R. Varjão 07; j) J.V. Santos 07.

apex obtuse to emarginate; stamens 5, free, inserted 2.5–3.5 mm from base, filaments 0.8–1.5 mm long, green, pubescent at base, anthers 0.8–1 × ca. 0.5 mm, orbicular, apex obtuse; ovary 0.8–1,5 mm long, sub-globose, glabrous, nectariferous disk ca. 0.2 mm long; style 0.9–1.5 mm long in brevistyle flowers; ca. 4 mm long in longistyle flowers, stigmas 0.5–0.8 mm long, clavate, erect, villous. Drupes 4–7 × 4 –6 mm, ovoid, green when young, red when mature, glabrous. Seed 1, 4.5 × ca. 3 mm, conical, light green, smooth.

Material examined: BRAZIL, BAHIA: Jeremoabo, Baixa dos Quelés, 09°58'05" S e 38°44'00" O, 506 m, 17.X.2009, fl., E. Melo et al. 6692 (HUEFS); Limite com a Estação Ecológica Raso da Catarina, 09°53'43" S e 38°29'33" O, 648 m, 17. VI.2009, fl. e fr., A.S. Conceição 1667 (HUNEB); Muro, 10°00'41" S e 38°43'56" O, 439 m, 18.X.2009, fl., E. Melo et al. 6771 (HUEFS); Trilha do Logradouro, 09°56'06" S e 38°28'48" O, 648 m, 19.VI.2009, fl., A.S. Conceição 1729 (HUNEB); Trilha dos Quelés, sentido Estação Ecológica Raso da Catarina, 09°57'17" S e 38°26'25" O, 575 m, 19.VI.2009, fl. e fr., A.S. Conceição 1756 (HUNEB); 09°57'29" S e 38°26'17" O, 502 m, 09.XII.2009, fl. e fr., M.V.V. Romão 558 (HUNEB); 09°53'02" S e 38°32'39" O, 650 m, 22.IX.2010, fl., D.D. Vieira 96 (HUNEB); 09°57'44" S e 38°25'60" O, 502 m, 09.VII.2012, fl. e fr., J.V. Santos et al. 28 (HUNEB); 09°58'18" S e 38°56'08" O, 407 m, 09.VII.2012, fl. e fr., J.V. Santos et al. 32 (HUNEB); 09°57'48" S e 38°26'13" O, 486 m, 05.VI.2012, fl. e fr., A.F.S. Brito 73 (HUNEB); Vaca Morta, 09°54'52" S e 38°41'41" O, 364 m, 16.IV.2008, fr., M.V.V. Romão 68 (HUNEB); 09°54'55" S e 38°41'45" O, 358 m, 12.III.2008, fl., A.S. Conceição 1218 (HUNEB); 09°53'17" S e 38°40'10" O, 384 m, 17.IV.2008, fl e fr., A.S. Conceição 1294 (HUNEB); Rodelas, 21.I.1987, fl., L.B. Silva & G.O. Matos e Silva 47 (HRB).

Varronia curassavica occurs in the Southeast of Mexico reaching Panama, the West Indies up to the Northeast of South America (Gibson 1970). In Brazil it is widely distributed, occurring in the northeastern (Alagoas, Bahia and Piauí), southeastern (Espírito Santo, Minas Gerais, Rio de Janeiro and São Paulo) and southern (Paraná and Rio Grande do Sul) regions, in Amazon rainforest, Caatinga and Atlantic forest (Melo et al. 2014).

In the study area this species is found only in the localities of Jeremoabo and Rodelas in environments of the hiperxerophytic Caatinga vegetation and in areas of contact with seasonal Caatinga-forest, on rocky, sandy or sandy-clayey soils. It was collected with flowers and fruits in January, March, April, June, July, September and December.

It can be securely recognized in the area as it is shrubby, erect, sub-scandent to scandent, leaf blade with attenuated base, spicate inflorescences, calyx lobes oval-lanceolate with trullate apex and infundibuliform to salverform corolla.

6. *Varronia globosa* Jacq., Enum. Syst. Pl.: 14. 1760. Figure 4e-j

Cordia globosa (Jacq.) Kunth, Nov. Gen. Sp. 3: 76. 1819.

Shrub, 1.5–4 m tall, erect; branches cylindrical, brown-grayish, scabrous to strigose, lenticels whitish. Leaf with blade 1.5–6.2 × 0.6–2.7 cm, chartaceous, discolorous, oval to lanceolate, apex acute, margin serrate, base cuneate to truncate, adaxial surface scabrous to strigose, sometimes having trichomes with tuberculate base, abaxial surface strigose to tomentose; petiole 0.2–0.8 cm long, cylindrical, not sulcate, strigose to hirsute; venation semi-craspedodromous. Inflorescence 1–2.4 cm long, glomerulate-globose, terminal and internodal, congested; peduncle 0.2–5 cm long, strigose. Flowers 4–9 mm long, sessile; calyx 3–5 mm long, campanulate, green, externally strigose, internally glabrous, lobes 1–3 × 0.5–1 mm, oval, apex filiform; corolla 2.5–7 mm long, infundibuliform, white, glabrous, tube 3-6 mm long, cylindrical, lobes 1.5–2 × 2.2–3 mm, orbicular, patent, smooth, apex truncate to emarginate; stamens 5, free, inserted 2.5–4 mm from base, filaments 1.5–2.5 mm long, white, pubescent at base, anthers 0.6–1.2 × 0.5–0.8 mm, oblong to oval, apex acute; ovary 1–1.5 mm long, pyriform, glabrous, nectariferous disk 0.8–1 mm long; style ca. 1.2 mm long in brevistyle flowers, 2.9–3.5 mm long in longistyle flowers, stigmas 0.5–1.2 mm long, clavate, erect, glabrous. Drupes 3.5–6 × 2–4.5 mm, globose, green when young, red when mature, glabrous. Seed 1, 3–4.5 × 1.5–2.5 mm conical to ovoid, green-brownish, smooth.

Material examined: BRAZIL, BAHIA: Canudos, Estação Biológica de Canudos, 09°42'57" S e 38°58'60" O, 400 m, 27. VI.2002, fl., L.P. Queiroz et al. 7215 (HUEFS); 10°16'60" S e 39°15'00" O, 16.II.2003, fl., F.H.M. Silva 336 (HUEFS); 09°45'55" S e 38°58'33" O, 381 m, 17.II.2004, fl. e fr., R.M. Harley 54861 (HUEFS); Base 1, próximo a cerca, 09°56'59" S e 38°59'32" O, 397 m, 29.III.2012, fl., D.D. Vieira 239 (HUNEB); Caminho para a Gruta do Minadouro, 09°46'09" S e 3°58'44" O, 383 m, fl., R.M. Harley 54872 (HUEFS); Toca Velha, próximo a casa de Sr. Zequinha, 09°56'47" S e 38°59'10" O, 383 m, 17.V.2012, fl., D.D. Vieira 297 (HUNEB); Trilha em direção à base 2, 09°56'67" S e 38°59'68" O, 400 m, 28.II.2012, fl., D.D. Vieira 233 (HUNEB); Parque Estadual de Canudos, Trilha do Vale da Morte, 09°55'06" S e 39°06'58" O, 378 m, 07. V.2013, fl., D.C. Silva 163 (HUNEB); Glória, BA 210, sentido Glória-Rodelas, ca. 3,5 km do Centro Administrativo José Messias, 09°31'38" S e 38°40'05" O, 310 m, 05.V.2007, fl., A.S. Conceição et al. 959 (HUEFS); Brejo do Burgo, 09°18'53" S e 38°21'30" O, 378 m, 14.VI.2013, fl. e fr., V.O. Amorim 285 (HUNEB); Serra de Itaparica, 09°10'22" S e 38°32'16" O, 323 m, 16.VII.2007, fl. e fr., A.S. Conceição 1081 (HUEFS); Jeremoabo, APA Serra Branca, 10°04' S e 38°21' O, 20.I.2006, fl., G.C. Sessegolo et al. 235 (ALCB); Estrada sentido Serra do Navio, 09°52'33" S e 38°39'09" O, 432 m, 10.VII.2012, fl. e fr., J.V. Santos et al. 38 (HUNEB); 09°51'56" S e 38°38'34" O, 484 m, 4.XI.2010, fl., R.R. Varjão 07 (HUNEB); 09°52'43" S e 38°39'12" O, 473 m, 10.VII.2012, fl. e fr., A.F.S. Brito 95 (HUNEB); Fazenda Serra Branca, ca. 4,5 km da Vaca Morta, 09°52'52" S e 38°39'45" O, 464 m, 18.IV.2008, fl. e fr., A.S. Conceição 1322 (HUNEB); Povoado Quelés, sentido Estação Ecológica Raso da Catarina, 09°57'17" S e 38°26'25" O, 575 m, 19.VI.2009, fl., A.S. Conceição 1747 (HUNEB); Tanque de Dentro, 09°51'56" S e 38°38'45" O, 156 m, 30.X.2008, fl. e fr., M.V.V. Romão 391 (HUNEB); Vaca Morta, 09°54'52" S e 38° 41'41" O, 364 m, 16.IV.2008, fl., M.V.V. Romão 71 (HUNEB); Estrada entre Jeremoabo e Canudos, 10°06'60" S e 38°47'50" O, 297 m, 27.VI.2007, fl., R.M. Santos 1653 (HUEFS); Paulo Afonso, Aldeia Serrota, 09°48'33" S e 38°08'33" O, 26.IV.2006, fl., M. Colaço 114 (HUEFS); 09°48'33" S e 38°08'33" O, 06. VI.2006, fl., M. Colaço 135 (HUEFS); Estação Ecológica Raso da Catarina, estrada da base da Petrobrás em direção à Mata da Pororoca, 09°46'50" S e 38°40'52" O, 658 m, 18.VIII.2012, fl., D.D. Vieira 341 (HUNEB); Ribeira do Pombal sentido Banzaê, 10°46'41" S e 38°34'42" O, 212 m, 10.VI.2013, fl. e fr., L.R. Silva 183 (HUNEB).

Varronia globosa is registered to the south of the United States, Mexico, Central America including the West Indies, Venezuela and the Northeast of South America (Nowicke 1969, Miller 1988). However, in Brazil it is found exclusively in the Caatinga vegetation from Ceará to Bahia (Taroda & Gibbs 1986b, Melo et al. 2014).

The species is widely distributed in the studied area, associated with bushy to shrubby-arboreal Caatinga on sandy, clayey or rocky soils. It blooms from February to November, virtually all year round.

Varronia globosa has characteristics similar to *V. leucocephala* and *V. leucomalloides*, being shrubby, glomerulate-globose inflorescence, campanulate calyx and infundibuliform corolla, the morphological features being more similar to these species. However, *V. globosa* can be differentiated from the two species by its scabrous to strigose branches (vs. velvety intermingled by larger hirsute trichomes in *V. leucocephala* and hirsute intermingled by smaller floccose or densely floccose trichomes in *V. leucomalloides*); terminal and internodal inflorescence (vs. terminal in *V. leucocephala* and terminal and axillary in *V. leucomalloides*), and mainly by the calyx with lobes of filiform apex (vs. acute in *V. leucocephala* and mucronate in *V. leucomalloides*).

7. *Varronia leucocephala* (Moric.) J.S.Mill., Novon 17(3): 374. 2007. Figure 5a-f

Cordia leucocephala Moric. Pl. Nouv. Amer. 9: 148. 1847.

Shrub, 1–2.5 m tall, erect; branches cylindrical, brown-grayish, velutinous intermingled by larger hirsute trichomes, lenticels whitish. Leaf with blade 2.2–9 × 0.6–4.5 cm, chartaceous, discolorous, oval, elliptical to oval-lanceolate, apex acute, margin serrate, base cuneate to obtuse, adaxial surface strigose, abaxial surface pubescent to tomentose; petiole 0.2–1.8 cm long, subcylindrical, slightly sulcate, velutinous, interspersed with larger trichomes, hirsute; venation craspedodromous. Inflorescence 2.8–4 cm long, glomerulate-globose, terminal, congested; peduncle 1–3.2 cm long, velutinous. Flowers 2.4–3.5 cm long, sessile; calyx 4-6 mm long, campanulate, light green, puberulent to strigose externally, internally glabrous, lobes 1–1.8 × 0.8–1.2 mm, oval, apex acute; corolla 20–35 mm long, infundibuliform, white, glabrous, tube 1.8–3 cm long, cylindrical, lobes 2.5–4 × 5–8 mm, suborbicular, patent, smooth, apex emarginate; stamens 5, free, inserted 0.5–0.7 cm from base at the different levels, filaments 1.5–3 cm long, white, pubescent at base, anthers 8–2 × 1–1.2 mm, oblong to oval, apex acute; ovary ca. 2 mm long, sub-globose, glabrous, nectariferous disk 0.2–0.4 mm long; style 0.7–0.9 cm long in brevistyle flowers, ca. 2.5 cm long in longistyle flowers, stigmas 0.8–1 mm long, filiform, erect, glabrous. Drupes 2–2.8 × 3–5 mm, ovoid, green when young, red when mature, glabrous. Seed 1, 2.5–3 × 1.8–2 mm, conical, light green, rugose.

Material examined: BRAZIL, BAHIA: Canudos, 10°01'16" S e 39°02'50" O, 504 m, 19.II.2004, fl., R.M. Harley 54906 (HUEFS); ca. 35,7 km de Canudos, 09°56'60" S e 38°06'44" O, 344 m, 28.VI.2002, fl., L.P. Queiroz 7268 (HUEFS); Euclides da Cunha, estrada Euclides da Cunha-Monte Santo, 10°48'33" S e 39°06'60" O, 439 m, 23.V.2003, fl., C. Correia 245 (HUEFS); Glória, Aldeia Serrota, 09°33'00" S e 38°48'33" O, 06.I.2006, fl., M. Colaço 86 (HUEFS); Brejo do Burgo, 09°20' S e 38°15' O, 02.VII.1995, fl., F.P Bandeira 204 (HUEFS); 09° 19'09" S e 38°26'30" O, 320 m, 14.VI.2013, fl. e fr., D.C. Silva 186 (HUNEB); Raso da Catarina, 09°33'00" S e 38°48'33" O, 05.VI.2004, fl., M.V.M. Oliveira 693 (HUEFS); Serra do Cágado, 09°20' S e 38°15' O, 11.I.1993, fl., F.P. Bandeira 112 (ALCB); Jeremoabo, APA Serra Branca, 10°04' S e 38°21' O, 20.I.2006, fl., G.C. Sessegolo et al. 222 (ALCB); Fazenda Serra Branca, estrada principal depois da base, 09°54'32" S e 38° 41'27" O, 468 m, 27.III.2012, fl. e fr., L.R. Silva 64 (HUNEB); Vaca Morta, 09°54'42" S e 38°41'56" O, 123 m, 23.VIII.2008, fl., M.V.V. Romão 298 (HUNEB); 09°53'17" S e 38°40'10" O, 384 m, 17.IV.2008, fl., A.S. Conceição 1295 (HUNEB); Paulo Afonso, acesso próximo a casa n° 1 do Raso da Catarina, 09°33' S e 38°29' O, 20.VI.1981, fl., M.L. Guedes et al. 298 (ALCB); Aldeia Serrota, 09°29' S e 38°12' O, 31. VIII.2006, fl., R.S. Gonçalves 28 (HST); Reserva Ecológica Raso da Catarina, 09°33' S e 38°29' O, 25.VI.1982, fl., L.P. Queiroz & M.L. Guedes 369/487 (ALCB); Estrada para Estação Ecológica Raso da Catarina, 09°39'08" S e 38°20'48" O, 360 m, 18.VIII.2012, fl., D.D. Vieira 361 (HUNEB); Rodelas, Salgado do Melão, 08°50' S e 38°46' O, 03. VIII.1994, fl., M.C. Ferreira 603 (HRB); Santa Brígida, 09°44' S e 38°07' O, 24.V.1984, fl., L.C. Oliveira-Filho 177 (ALCB); Uauá, Serra da Canabrava, 09°60' S e 39°60' O, 562 m, 21.V.2003, fl., J. Costa 397 (HUEFS).

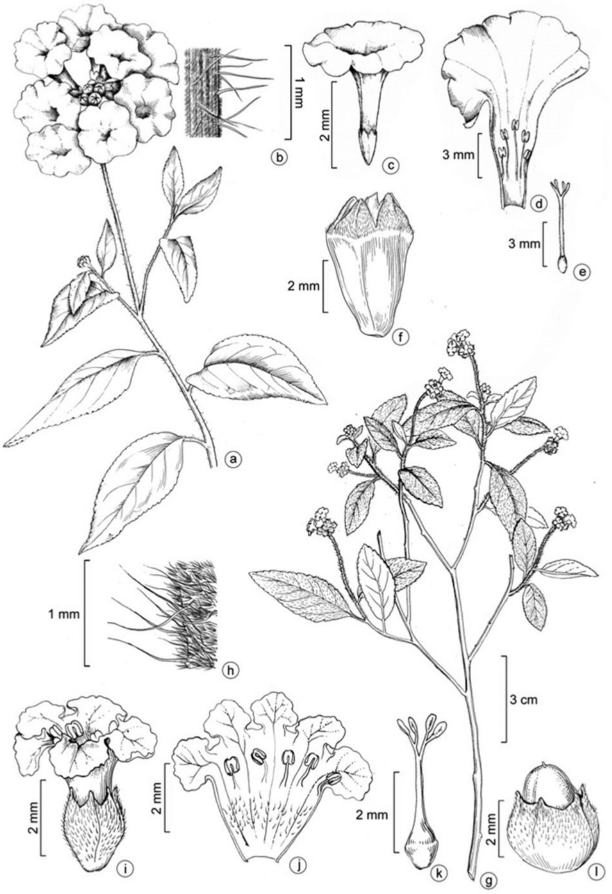

Figure 5. a-f) *Varronia leucocephala*: a) flowering branch; b) detail of indumentum of branch; c) flower; d) longitudinal section of flower, showing androecium; e) gynoecium; f) fruit. g-l) *Varronia leucomalloides*: g) flowering branch; h) detail of indumentum of branch; i) flower; j) longitudinal section of flower showing androecium; k) gynoecium; l) fruit. a-e) A.S. Conceição 1295; f) L.R. Silva 64; g-k) D.D. Vieira 434; l) D.D. Vieira 445.

The species is endemic to the Caatinga and registered for the states of Bahia, Ceará, Paraíba, Pernambuco and Piauí (Taroda & Gibbs 1986b, Melo et al. 2014).

In the study area the species is associated with the shrubby and shrubby-arborescent Caatinga in sandy and stony soils, common at the roadsides and in anthropized areas. It was collected with flowers between April and August.

Varronia leucocephala resembles to *V. globosa* and *V. leucomalloides* (see comments in *V. globosa*). It can be differentiated from the two species by the velutinous branches interspersed with large hirsute trichomes, terminal inflorescence, flowers having a calyx lobes with acute apex and corolla 20–35 mm long.

8. *Varronia leucomalloides* (Taroda) J.S.Mill., Novon 17(3): 374. 2007. Figure 5g-l

Cordia leucomalloides Taroda, Notes Roy. Bot. Gard. Edinburgh 44(1): 125. 1986.

Shrub, 1–2 m tall, erect; branches cylindrical, green-grayish, hirsute intermingled by smaller floccose or densely floccose trichomes. Leaf with blade 1.5–5 × 0.6–2 cm, chartaceous, discolorous, elliptical, oval to lanceolate, apex acute to cuneate, margin serrate, base cuneate to obtuse, slightly asymmetrical, adaxial surface tomentose to hirsute, abaxial surface densely floccose, hirsute on venation; petiole 0.2–0.4 cm long, cylindrical, tomentose to hirsute; venation craspedodromous. Inflorescence 0.8–1 cm long, glomerulate-globose, terminal and axillary, congested; peduncle 0.4–2 cm long, tomentose. Flowers 4–6 mm long, sessile; calyx 2.5–3 mm long, campanulate, cream to green, floccose externally, internally glabrous, lobes 0.6–0.8 × 0.4–0.5 mm, oval to lanceolate, apex mucronate; corolla 4–5 mm long, infundibuliform, white, glabrous, tube ca. 3 mm long, cylindrical, lobes 1.5–2 × 2–3 mm, broad-oval, reflexed, wrinkled, apex obtuse; stamens 5, free, inserted ca. 2 mm from base, filaments 0.6–1 mm long, green, glabrous, anthers 0.4–0.5 × 0.3–0.4 mm, oval, apex acute to rounded; ovary 0.8–1 mm long, globose, glabrous, nectariferous disk ca. 0.2 mm long; style 2–3 mm long, stigmas 0.3–0.5 mm long, clavate, erect or recurved, glabrous. Drupes 3.5–4 × 2.8–3.2 mm, sub-globose, green when young, red when mature, glabrous. Seed 1, 2.5–3.5 × 2–2.5 mm, ovoid, light green, smooth.

Material examined: BRAZIL, BAHIA: Canudos, Estação Biológica de Canudos, estrada que leva ao Saco 1 das araras, 09°58'26" S e 39°00'21" O, 550 m, 08.V.2013, fl., D.C. Silva 172 (HUNEB); 09°58'75" S e 39°00'01" O, 566 m, 29.II.2012, fl., D. D. Vieira 236 (HUNEB); 09°57'43" S e 39°00'58" O, 499 m, 08. V.2013, fl., D.D. Vieira 428 (HUNEB); 09°58'35" S e 38°59'46" O, 560 m, 08.V.2013, fl., D.D. Vieira 434 (HUNEB); Euclides da Cunha, Estrada para Sucupira do Galo, 10°21'00" S e 38° 41'20" O, 546 m, 11.VI.2013, fl. e fr., D.D. Vieira 445 (HUNEB); Jeremoabo, APA Serra Branca, Baixa da Forca, 10°00'05" S e 38°28'46" O, 562 m, 23.I.2013, bot., L.R. Silva 118 (HUNEB); Paulo Afonso, Estação Ecológica Raso da Catarina, estrada base da Petrobrás em direção à Mata da Pororoca, 09°46'79" S e 38°39'92" O, 684 m, 18.VIII.2012, fl., D.D. Vieira 344 (HUNEB); Estrada em direção a base do ICMBio, 09°39'04" S e 38°27'02" O, 562 m, 19.VIII.2012, fl., D. D. Vieira 360 (HUNEB); Paus-Pretos, 09°06'50" S e 38°58'55" O, 01.II.2006, fl., M.M.M. Lopes et al. 483 (HUEFS); Santa Brígida, 09°44' S e 38°07' O, 24.VI.1982, fl., L.P. Queiroz 304 (HUEFS).

Varronia leucomalloides was registered in the Northeastern region of Brazil. It was collected up to now in Caatinga and Cerrado vegetation in the states of Alagoas, Bahia, Ceará and Paraíba (Stapf 2010, Melo et al. 2014).

In the studied area it was found in the hiperxerophytic shrubby Caatinga, associated with rocky and sandy soils and in areas of contact between the Caatinga and the Cerrado. It blooms in February, June and August and fruits in June. Although the heterostyly is a hallmark of the genus, it was not possible to observe different sizes in the length of styles in that species.

Varronia leucomalloides is morphologically similar to *V. globosa* and *V. leucocephala* (see similarities in *V. globosa*). It is different from these two having terminal and axillary inflorescence, calyx with lobes of mucronate apex and especially the floccose indumentum present in the branches and calyx.

Heliotropiaceae Schrad., Comment. Soc. Regiae Sci. Gott. Recent. 4: 192. 1819.

Annual or perennial herbs, subshrubs, shrubs, lianas or small trees. Leaves simple, alternate, subopposite or opposite, petiolate or sessile, margin usually entire, persistent. Inflorescences scorpioid, terminal, falsely terminal, axillary and internodal, lax or congested, rare solitary and axillary flowers, usually without bracts, rarely bracteose. Flowers dichlamydeous, actinomorphic, androgynous; calyx 5-lobed, gamosepalous with short tube, campanulate, deeply lobed, persistent; corolla 5-lobed, gamopetalous, tubular (e.g., hipocrateriform, obcampanulate or tubular-salverform), greenish, white, yellow, orange or purple, lobes patent, alternating with sepals. Stamens 5, subsessile or sessile, epipetalous often puberulous at insertion point; anthers free, connate or coherent at apex, usually introrse, dorsifixed. Gynoecium bicarpelar, ovary falsely tetralocular by the intrusion of a false septum, 2 ovules 2 per locule, anatropous; style terminal entire; 1 stigma, conical, with apex uni or slightly bilobed, sterile. Fruit indehiscent, drupaceous or dehiscent, schizocarpics, bony endocarp separating into pyrenes (*Myriopus and Tournefortia*) or nutlets (*Euploca, Heliotropium* and *Ixhorea*) at maturity. Seeds 4, rarely 1 or 2, testa with transfer cells, endosperm sparse, embryo straight or curved; cotyledons linear to ovoid, never plicated.

Heliotropiaceae comprises the genera *Euploca* Nutt. (ca. 100 spp.), *Heliotropium* L. (ca. 200 spp.), *Ixhorea* Fenzl (monospecific, restricted to Argentina), *Myriopus* Small (ca. 20 spp.) and *Tournefortia* L. (ca. 100 spp.). Their representatives are distributed in Tropical and Subtropical zones of all the continents, being more diversified in seasonally dry habitats. Monophylly of the family is sustained by molecular data as well as by a complex conical stigma, an unique morphological synapomorphy within Boraginales (Diane et al. 2004, Hilger & Diane 2003). In Brazil, the family is represented by the genera *Euploca* (17 spp.), *Heliotropium* (nine spp.), *Myriopus* (six spp.) and *Tournefortia* (13 spp.). In Caatinga vegetation occurs 19 species, among these eight belonging to *Euploca*, five to *Heliotropium,* three to *Myriopus* and *Tournefortia* (Melo et al. 2014).

9. *Euploca paradoxa* (Mart.) J.I.M.Melo & Semir, Kew Bull. 64(2): 289. 2009. Figure 6a-e

Preslaea paradoxa Mart., Nov. Gen. Sp. Pl. 2: 76. 1827.

Herb or subshrub, 10–15 cm tall, prostrate, stoloniferous; branches cylindrical with the bark falling off longitudinally, brownish-green, strigose. Leaf with blade 0.3–1.2 × 0.1–0.4 cm, chartaceous to semi-crass, concolor, lanceolate, apex acute, margin entire, base attenuate, strigose on both surfaces, showing trichomes with discoid base; petiole 0.2–1.2 cm long, subcylindrical, sulcate, strigose; venation hyphodromous.

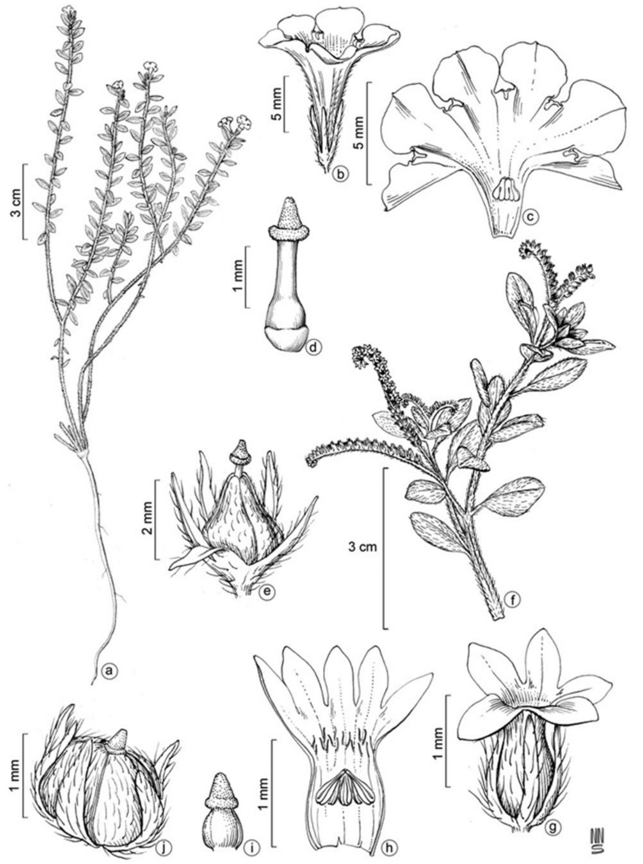

Figure 6. a-e) *Euploca paradoxa*: a) flowering branch; b) flower; c) longitudinal section of flower showing androecium; d) gynoecium; e) fruit. f-j) *Euploca procumbens*: f) fertile branch; g) flower; h) longitudinal section of flower showing androecium; i) gynoecium; j) fruit. a-e) D.D. Vieira 456; f-j) L.R. Silva 148.

Flowers 0.8–1.2 mm long, solitary, axillary, pedicellate; peduncle 0.2–0.4 mm long, cylindrical, strigose; bracts 3–4 × 1–1.8 mm, foliaceous, elliptic to lanceolate, strigose; calyx 3–4 mm long, deeply lobed, green, externally strigose, internally glabrous, lobes 3–3.8 × 0.6–0.8 mm, narrow-lanceolate, apex acute; corolla 0.8–1 mm long, campanulate, entirely yellow, externally strigose, internally glabrous, tube 3–7 mm long, cylindrical, lobes 2–3.2 × 2.4–3.6 mm, orbicular, patent, wavy, apex rounded to slightly cuspidate, alternate by appendages 0.8–1 mm long, involute, falcate, oval to broadly lanceolate; stamens 5, coherent at apex, inserted 2–3 mm from base, subsessile, anthers 0.8–1 × 0.4–0.6 mm, oval, apex rounded; ovary 0.5–0.8 mm long, depressed-globose, glabrous, nectariferous disk ca. 0.2 mm long; style 0.8–1 mm long, stigma 0.5–0.8 mm long, conical, glabrous, stigmatic disk ca. 0.2 mm long. Schizocarp 3–4 × 2–3 mm, depressed-pyriform, apex aristated, green at maturity, pubescent to strigose, 4 nutlets with 1 seed each. Seeds 4, 1–1.8 × 0.5–0.8 mm, elliptic, green to brown, smooth.

Material examined: BRAZIL, BAHIA: Glória, Lagoa de Itaparica, Ilha a 10 km à Oeste do Hotel, 09°02'21" S e 38° 18'00" O, 304 m, 19.I.2012, fl. e fr., V.M. Cotarelli 1211 (HVASF); Rodelas, próximo à bomba d'água, 08°50'17" S e 38°45'47" O, 330 m, 13.VI.2013, fl. e fr., D.D. Vieira 456 (HUNEB).

Euploca paradoxa is distributed in northeastern (Bahia, Paraíba, Pernambuco and Piauí) and mid-western (Goiás and Mato Grosso) regions (Melo et al. 2014). The species is commonly found in the Caatinga and more rarely at the edge of swamps, Cerrado and Campo Rupestre. In the state of Bahia it is frequent in fluvial areas bathed by the São Francisco River (Melo & Semir 2010).

In the study area it was collected in anthropogenic environments on sandy soils at the banks of the São Francisco River, growing alongside *Euploca procumbens.* It was collected with flowers and fruit in January and June.

The species can be recognized in the studied area mainly due its lanceolate leaf blade, solitary, pedicellate, bracteate flowers, completely yellow corolla, lobes alternated by appendages and a depressed-pyriform pubescent and strigose fruit.

10. *Euploca procumbens* (Mill.) Diane & Hilger, Bot. Jahrb. Syst. 125(1): 48. 2003. Figure 6f-j

Heliotropium procumbens Mill., Gard. Dict. 8: 10. 1768.

Herb or subshrub, 10–30 cm tall, erect or prostrate; branches cylindrical, fistulous, green-ashen, sericeous. Leaf with blade 0.8–3.2 × 0.5–1.5 cm, semi-crass, concolor to slightly discolorous, elliptical to oboval, apex acute to obtuse or mucronate, margin entire, base attenuate, sericeous on both surfaces, sometimes presenting trichomes with discoid base, more pronounced on the abaxial surface; petiole 0.3–1.4 cm long, subcylindrical, ventrally sulcate, sericeous; venation eucamptodromous. Inflorescence 0.8–6 cm long, scorpioid, terminal and axillary, congested, entire or forked; peduncle 0.6–3 cm long, strigose to sericeous. Flowers 2–3 mm long, subsessile, ebracteate; pedicel ca. 0.5 mm, cylindrical, sericeous; calyx 0.8–2.5 mm long, deeply lobed, green, externally sericeous, internally strigose, lobes 0.6–2.2 × 0.2–0.5 mm, oval to lanceolate, apex acute; corolla 1.5–2.5 mm long, tubular, white, mouth yellow, externally sericeous, internally glabrous, tube 1.2–2 mm long, cylindrical, lobes 0.4–0.6 × 0.2–0.4 mm, oboval, patent smooth, apex acute to obtuse, not alternated by appendages; stamens 5, coherent at apex, inserted 0.6–1 mm from base, subsessile, anthers 0.3–0.5 × 0.2–0.4 mm, oval to lanceolate, apex caudate; ovary 0.3–0.5 mm long, sub-globose, glabrous, nectariferous disk ca. 0.2 mm long; style obsolete, stigma 0.3-0.4 mm long, conical, pubescent, stigmatic disk 0.2–0.4 mm long. Schizocarp 1.2–2 × 1–1.8 mm, sub-globose, green at maturity, sericeous, 4 nutlets with 1 seed each. Seeds 4, 0.8–1 × 0.5–0.7 mm, oval, light green, smooth.

Material examined: BRAZIL, BAHIA: Canudos, estrada em direção à Estação Biológica de Canudos, passando pelo museu, 09°53'52" S e 39°01'51" O, 320 m, 05.IX.2012, fl. e fr., D.D. Vieira 391 (HUNEB); Parque Estadual de Canudos, Fazenda Velha, margem do açude, 09°54'33" S e 39°07'25" O, 360 m, 07.V.2013, fl. e fr., D.C. Silva 171 (HUNEB); Glória, Brejo do Burgo, 09°20' S e 38°15' O, 01.VII.1995, fl., F.P. Bandeira 250 (HUEFS); Jeremoabo, estrada entre Jeremoabo e Canudos, 10°01'32" S e 38°31'38" O, 298 m, 13.VII.2012, fl., D.D. Vieira 332 (HUNEB); 10°09' S e 38°28' O, Margem do rio Vaza Barris, 04.IV.2008, fl. e fr., K. Mendes 185 (UFP); Paulo Afonso, Estação Ecológica Raso da Catarina, 09°51'38" S e 38° 40'00" O, 454 m, 11.XII.2005, fl., A.O. Moraes et al. 86 (HST); Base do ICMBio, 09°39'85" S e 38°28'02" O, 598 m, 29.XI.2011, fl. e fr., D.D. Vieira 207 (HUNEB); 09°39'87" S e 38°28'02" O, 595 m, 19.VIII.2012, fl., D.D. Vieira 359 (HUNEB); Sede do Ibama, 09°46'44" S e 38°46'04" O, 600 m, 30.XI.2005, fl. e fr.,

F. França et al. 5331 (HUEFS); Rodelas, bomba d'água, 08° 50'17" S e 38°45'47" O, 330 m, 13.VI.2013, fl. e fr., D.D. Vieira 457 (HUNEB); Santa Brígida, 09°42'07" S e 38°08'27" O, 274 m, 27.XI.2009, fl., E. Melo et al. 7248 (HUEFS).

Euploca procumbens spreads from the South of the United States to Argentina as well as in the West Indies and in Brazil in northern (Acre, Pará, Rondônia, Roraima), northeastern (Alagoas, Bahia, Ceará, Maranhão, Paraíba, Pernambuco, Piauí, Rio Grande do Norte and Sergipe), mid-western (Goiás, Mato Grosso and Mato Grosso do Sul), southeastern (Minas Gerais and São Paulo) and southern (Rio Grande do Sul and Santa Catarina) regions. In the Brazilian territory it is found in all the vegetation types, mainly in the Caatinga where it is frequently observed sympatrically with *H. angiospermum* and *H. elongatum* (Melo & Semir 2010).

In the Ecoregion Raso da Catarina it is quite common in anthropized areas close to small farms, houses and vacant land lots. Thus, it can be considered an invasive species. Specimens were collected with flowers and fruits in July and November.

The species is easily recognized in the studied area by the elliptical to oboval leaf blade, flowers clustered in inflorescence, subsessile, ebracteate, white corolla with yellow mouth, lobes that are not alternated by appendages and by the sub-globose, sericeous fruit.

11. *Heliotropium angiospermum* Murray, Prodr. stirp. götting.: 217. 1770. Figure 7a-e

Herb or sub-shrub, 15–30 cm tall, erect; branches cylindrical, fistulous, sulcate, green, scabrous to strigose. Leaf with blade 2.2–9 × 1.2–4.4 cm, membranous, discolorous, oval to elliptical, apex acute to acuminate, margin entire, ciliate, base attenuate, strigose to pubescent on both surfaces; petiole 0.2–1.8 cm long, subcylindrical, sulcate, wingless, strigose to hirsute; venation eucamptodromous. Inflorescence 2.6–16 cm long, scorpioid, falsely terminal and axillary, lax to congested, entire or forked; peduncle 1–6 cm long, strigose to hirsute. Flowers 3–4 mm long, sessile; calyx 2–3 mm long, deeply lobed, green, strigose, lobes 1.8–2.8 × 0.3–0.6 mm, oblong to lanceolate, apex acute; corolla 3–4 mm long, obcampanulate, white to purple-colored, mouth yellow, externally strigose, internally tomentose, tube 2–2.5 mm long, subcylindrical, lobes 1.2–2 × 0.8–1.5 mm, orbicular, patent, smooth, apex rounded to obtuse; stamens 5, free, inserted 0.8–1.2 mm from base, subsessile, anthers 0.8–1.4 × 0.3–0.5 mm, oval to oblong, apex acute; ovary ca. 0.5 mm long, sub-globose, glabrous, nectariferous disk ca. 0.2 mm long; style obsolete, stigma 0.5–0.8 mm long, widely conical, sparsely strigose, stigmatic disk ca. 0.2 mm long. Schizocarp 2–3.2 × 2–3 mm, depressed-globose, green at maturity, verrucose. Seeds 4, 1.5–2 × 0.8–1.2 mm, ovoid, light green, smooth to rugose.

Material examined: BRAZIL, BAHIA: Canudos, estrada em direção à Estação Biológica de Canudos, passando pelo museu, 09°53'52" S e 39°01'51" O, 320 m, 05.IX.2012, fl. e fr., D.D. Vieira 392 (HUNEB); Jeremoabo, APA Serra Branca, Fazenda Barreirinhas, 10°16' S e 38°47' O, 21.X.2006, fl., M. Oliveira 2536 (UFP); Fazenda Serra Branca, 09°51'56" S e 38° 28'45" O, 479 m, 31.VII.2009, fl. e fr., A.S. Conceição 1862 (HUNEB); Povoado Quelés, sentido Estação Ecológica Raso da Catarina, 09°57'17" S e 38°26'25" O, 575 m, 19.VI.2009, fl. e fr., A.S. Conceição 1743 (HUNEB); Estrada entre Jeremoabo e Canudos, 10°01'32" S e 38°31'38" O, 298 m, 13.VII.2012, fl., D.D. Vieira 331 (HUNEB); Paulo Afonso, Estação Ecológica Raso da Catarina, Baixio do Cachimbo, 09°53'33" S e 38° 53'11" O, 550m, 10.VIII.2005, fl. e fr., E.B. Miranda et al. 858 (HUEFS); Base do ICMBio, 09°39'87" S e 38°28'02" O, 595 m, 19.VIII.2012, fl., D.D. Vieira 358 (HUNEB); Ribeira do Pombal, Estrada sentido Banzaê, 10°46'41" S e 38°34'42" O, 212 m, 11.VI.2013, fl. e fr., L.R. Silva 186 (HUNEB); RPPN Fazenda Flor de Lis, 10°50'08" S e 3832°'37" O, 203 m, 11. VI.2013, fl. e fr., V.O. Amorim 255 (HUNEB).

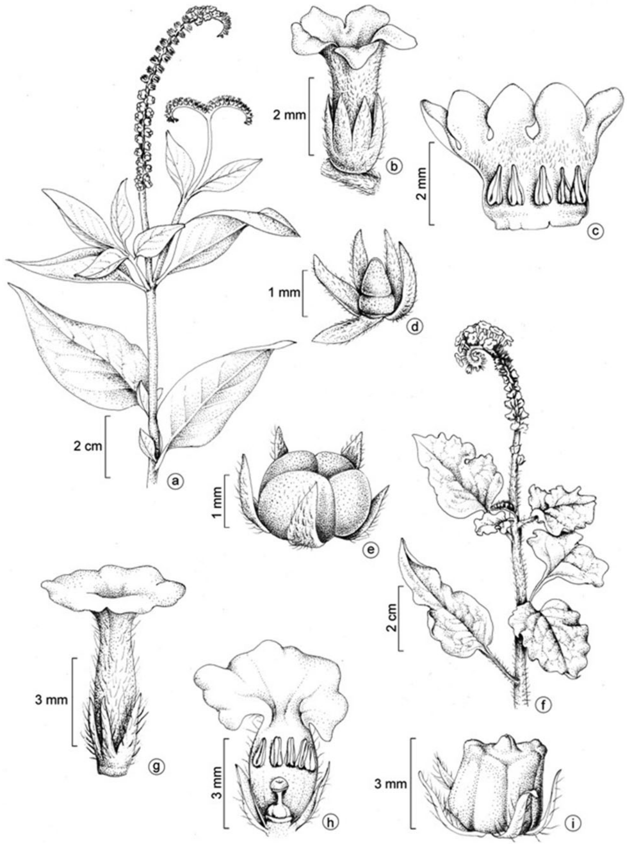

Figure 7. a-e) *Heliotropium angiospermum*: a) fertile branch; b) flower; c) longitudinal section of flower, showing androecium; d) gynoecium; e) fruit. f-i) *Heliotropium elongatum*: f) fertile branch; g) flower; h) longitudinal section of flower showing androecium and gynoecium; i) fruit. a-e) M.V.V. Romão 550; e-i) D.D. Vieira 05.

Heliotropium angiospermum is found from the South of the United States of America to Brazil, including the West Indies. In Brazil it occurs in northeastern and southeastern regions (Melo & Semir 2008, Melo et al. 2014).

In the studied area the species is widely found in anthropized areas, such as roadsides, small farms and houses. It also occurs in areas with herbaceous vegetation and bushy Caatinga, associated with sandy and clayey soils. Collected with flowers and fruit between March and September.

It resembles in the study area with its congeners by presence herbaceous or sub-shrubby habit, flowers clustered in scorpioid inflorescences, with white or purple corolla and yellow mouth. However, *H. angiospermum* can be easily recognized by having branches scabrous to strigose, wingless petiole, obcampanulate corolla, stigmas that are widely conical and depressed-globose fruit with a verrucose surface.

12. *Heliotropium elongatum* (Lehm.) I.M.Johnst., Contr. Gray Herb. Harv. Univ. 81: 18. 1928. Figure 7f-I

Herb or subshrub, 20–70 cm tall, erect to decumbent; branches angular, fistulous, green, strigose to hirsute. Leaf with blade 2.5–6 × 1.5–4 cm, membranaceous, discolorous, oval to deltoid, apex acute, margin irregular, base asymmetrical, attenuate or truncate, adaxial surface bullate, strigose, abaxial surface strigose to tomentose, stronger on nerves, both sides interspersed by larger aciculate trichomes; petiole 0.5–5 cm long, cylindrical, sulcate, winged, strigose to tomentose, interspersed with hirsute indumentum; venation eucamptodromous. Inflorescence 2–14 cm long, scorpioid, falsely terminal and axillary, congested; peduncle 5–5 cm long, strigose to tomentose, interspersed with hirsute indumentum. Flowers 4–7 mm long, sessile; calyx 2–2.8 mm long, deeply lobed, green, externally hairy, composed of trichomes aciculate, internally glabrous, marcescent, persistent on the axis of the inflorescence after the fall of the fruit, lobes 1.5–2.5 × 0.2–0.5 mm, lanceolate, apex acute to acuminate; corolla 3.8–6.5 mm long, hipocrateriform, white to purple-colored, mouth yellow, externally puberulous, interspersed by larger aciculiform trichomes, internally glabrescent, tube 3–5 mm long, subcylindrical, lobes 1–1.2 × ca. 1.5 mm, orbicular, patent, smooth, apex rounded; stamens 5, free, inserted 0.8–1.5 mm from the base, sessile, anthers ca. 1 × 0.3–0.5 mm, oblong, apex retuse; ovary ca. 0.5 mm long, globose, glabrous, nectariferous disk 0.2–0.4 mm long; style 0.3–0.5 mm long, cylindrical, stigma 0.4–0.5 mm long, clavate, glabrous, stigmatic disk ca. 0.1 mm long. Schizocarp 3.5–4.5 × 3–4 mm, mitriform, green at maturity, costate, glabrous or hispid, nutlets juxtaposed, apex slightly toothed. Seeds 4, 2.5–3 × 1.5–2 mm, trigonous, green or gray, smooth.

Material examined: BRAZIL, BAHIA: Canudos, Estação Biológica de Canudos, 09°42'07" S e 38°08'56" O, 05.I.2002, fl. e fr., M.S. Castro 66335 (ALCB); 10°16'60" S e 39°15'00" O, 20. VI.2003, fl. e fr., F.H.M. Silva 413 (HUEFS); Lagoa do Manezão, 09°57'02" S e 39°00'93" O, 424 m, 27.II.2012, fl. e fr., D.D. Vieira 220 (HUNEB); Roça de Das Neves, 09°56'16" S e 38°58'95" O, 368 m, 27.IV.2012, fl. e fr., D.D. Vieira 269 (HUNEB); 18.V.2012, fl e fr., D.D. Vieira 298 (HUNEB); Toca da onça, roça de Zé Boquinha, 09°58'60" S e 38°56'13" O, 414 m, 07.VI.2012, fl. e fr., D.D. Vieira 328 (HUNEB); Jeremoabo, APA Serra Branca, Estrada dos Quelés, 09°56'52" S e 38°27'12" O, 598 m, 08.XII.2009, fl. e fr., T.M.S. Melo 118 (HUNEB); 09°56'23" S e 38°28'07" O, 631 m, 22.IX.2010, fl. e fr., D.D. Vieira 100 (HUNEB); 09°57'41" S e 38°25'32" O, 509 m, 03. IX.2012, fl. e fr., D.D. Vieira 376 (HUNEB); Paulo Afonso, Estação Ecológica Raso da Catarina, 09°46'44" S e 38°46'04" O, 600 m, 30.XI.2005, fl. e fr., F. França et al. 5324 (HUEFS); Base do ICMBio, 09°39'85" S e 38°28'02" O, 598 m, 29.XI.2011, fl. e fr., D.D. Vieira 206 (HUNEB); Ribeira do Pombal sentido Banzaê, 10°46'41" S e 38°34'42" O, 212 m, 10.VI.2013, fl. e fr., L.R. Silva 185 (HUNEB); Rodelas, 08°50' S e 38°46' O, 22. I.1987, fl. e fr., G.O. Mattos 35 (ALCB); Praia de Zorobabel, 08°53'06" S e 38°42'23" O, 398 m, 13.VI.2013, fl. e fr., D.D. Vieira 455 (HUNEB).

Heliotropium elongatum occurs in South America, distributed in Argentina, Bolivia, Paraguay, Uruguay and in Brazil (Johnston 1928), where it is spread in all regions (Melo et al. 2014).

In the Ecoregion Raso da Catarina the species is associated with sandy soils. It is found in shrubby-arboreal vegetation, in open areas near fences and house yards and in the proximity of artificial water bodies. It was collected with flowers and fruits during almost all year.

Heliotropium elongatum may be confused with *H. indicum* because both present habit herbaceous to sub-shrubby, erect to decumbent, branches angular, fistulous, strigose to hirsute, winged petiole, aciculate trichomes on the leaves and flowers, fruit costate mitriform. The first species can be different because it presents a leaf blade that is bullate on the adaxial surface (vs. flat in *H. indicum*), clavate stigma (vs. sub-capitate in *H. indicum*), and by juxtaposed nutlets in fruits (vs. divergent in *H. indicum*).

13. *Heliotropium indicum* L., Sp. pl. 1: 130. 1753. Figure 8a-e

Herb or subshrub, 30–60 cm tall, erect to decumbent; branches angular, fistulous, green, strigose to hirsute. Leaf with blade 2.6–1.6 × 1.5–6.5 cm, membranous, discolorous, oval, deltoid to rhombic, apex acute to acuminate, margin entire or irregular, base asymmetric, narrowing to petiole or truncate, adaxial surface flat, puberulous, abaxial surface scabrous, both surfaces interspersed with larger aciculate trichomes; petiole 0.4–5.5 cm long, subcylindrical, sulcate, winged, scabrous to strigose, interspersed by hirsute indumentum; venation eucamptodromous. Inflorescence 2.5–20 cm long, scorpioid, terminal and axillary, congested only at apex; peduncle 1–4 cm long, strigose, interspersed by hirsute indumentum. Flowers 4–6 mm long, sessile; calyx 2.5–3.5 mm long, deeply lobed, green, externally strigose to hirsute, composed of trichomes aciculate, internally glabrous, marcescent, persistent on the axis of the inflorescence after the fall of the fruit, lobes

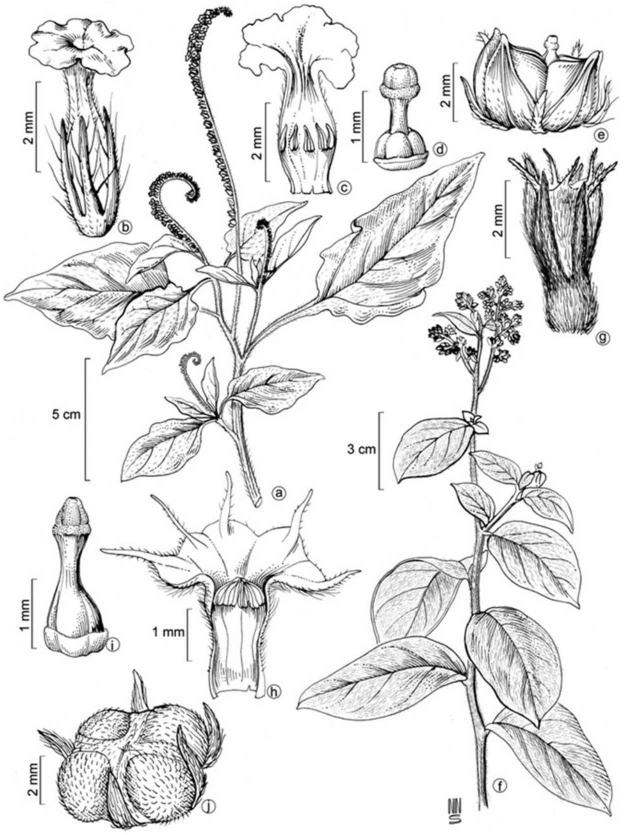

Figure 8. a-e) *Heliotropium indicum*: a) fertile branch; b) flower; c) longitudinal section of flower, showing androecium; d) gynoecium; e) fruit. f-j) *Myriopus candidulus*: f) fertile branch; g) flower; h) longitudinal section of flower showing androecium; i) gynoecium; j) fruit. a-e) D.D. Vieira 441; f-j) D.D. Vieira 451.

1.8–2.8 × 0.2–0.4 mm, narrow-oval to lanceolate, apex acute to acuminate; corolla 4–5 mm long, hipocrateriform, white to purple-colored, mouth yellow, externally pubescent, interspersed with larger aciculiform trichomes, internally glabrous, tube 3.5–4.2 mm long, subcylindrical, lobes 0.6–0.8 × 1–1.2 mm, orbicular, patent, smooth, apex rounded; stamens 5, free, inserted 1.2–1.8 mm from base, sessile, anthers 0.8–1 × 0.2–0.3 mm, oblong-oval to lanceolate, apex acute; ovary 0,5–0.8 mm long, longitudinally 4-sulcated, glabrous, nectariferous disk ca. 0.2 mm long; style 0.4–0.8 mm long, cylindrical, stigma ca. 0.5 mm long, sub-capitate, glabrous, stigmatic disk ca. 0.2 mm long. Schizocarp 3–4 × 3.5–4.2 mm, mitriform, green at maturity, costate, glabrous, nutlets divergent, apex strongly dentate. Seeds 4, 1.5–2.5 × 1–1.5 mm, ellipsoid, green, smooth.

Material examined: Ribeira do Pombal, RPPN Fazenda Flor de Lis, 10°50'28" S e 38°31'57" O, 191 m, 11.VI.2013, fl. e fr., D.D. Vieira 441 (HUNEB).

Heliotropium indicum has a cosmopolitan distribution, associated predominantly with tropical regions (Melo et al. 2009b). In South America it occurs in Bolivia, Paraguay, Argentina, Uruguay and Brazil (Johnston 1928). In the Brazilian territory it is distributed in all the regions and phytogeographical domains (Melo et al. 2014).

In the studied area it was collected on sandy, flooded soils, in an anthropized area close to an artificial aquatic body, with flowers and fruit in June.

Heliotropium indicum is morphologically similar to *H. elongatum*, mainly because both present winged petioles. However, *H. indicum* can be differentiated by presenting a flat leaf blade on adaxial surface, subcapitate stigma and principally the fruits with divergent nutlets.

14. *Myriopus candidulus* (Miers) Feuillet, J. Bot. Res. Inst. Texas, 2(1): 264. 2008. Figure 8f-j

Tournefortia candidula (Miers) I.M.Johnst., Contr. Gray Herb. 92: 84. 1930.

Shrub, 1.2–1.7 m tall, scandent; branches cylindrical, grayish to whitish, pubescent, devoid of lenticels. Leaf with blade 1.9–7.5 × 1–5 cm, chartaceous, discolorous, oval, apex acute to cuspidate, margin entire, base rounded, adaxial surface densely pubescent, abaxial surface tomentose, trichomes with discoid base on adaxial surface; petiole 0.2–0.4 cm long, cylindrical, sulcate, tomentose; venation eucamptodromous. Inflorescence 2–7.5 cm long, scorpioid with secundary branches, clustered in panicle, terminal, congested, pyramidal; peduncle 1.4–2 cm long, pubescent to tomentose. Flowers 5–6 mm long, sessile; calyx 3–4.5 mm long, deeply lobed, green-cinereous, densely villous externally, internally sparsely pubescent, lobes 3–4 × 0.8–1.1 mm, lanceolate, apex acute, with unequal sizes between them, two major and three minor; corolla 4–5 cm long, tubular, white, green-cinereous, externally densely villous, internally glabrous, tube 2.5–3.2 mm long, cylindrical, lobes 1.5–1.8 × 0.6–1 cm, narrow-oval, erect, involute, apex apiculate; stamens 5, coherent, inserted 1.8–2.5 mm from base, sessile, anthers 0.6–0.8 × 0.2–0.3 mm, lanceolate, apex apiculate; ovary 0.8–1 mm long, conical to sub-globose, glabrous, nectariferous disk 0.2–0.3 mm long; style 0.8–1 mm long, stigma ca.0.5 mm long, conical-triangular, elongated, glabrous, stigmatic disk ca 0.3 mm long. Drupes 3–4.5 × 5–7 mm, 4 pyrenes, sub-globose, green when young, white with 4 spherical black spots, corresponding to the seeds, when mature, villous to tomentose. Seeds 4, 2–3 × 1.8–2.6 mm, suborbicular, brownish, smooth.

Material examined: Euclides da Cunha, Estrada para Sucupira do Galo, 10°21'00" S e 38°41'20" O, 546 m, 11. VI.2013, fl. e fr., D.D. Vieira 451 (HUNEB); D.D. Vieira 453 (HUNEB); D.D. Vieira 454 (HUNEB); Ribeira do Pombal, 10° 50' S e 38°32' O, 16.VIII.2003, fl. e fr., M.L. Guedes 10508 (ALCB); Tabuleiro entre Pombal e Tucano, 10°50' S e 38°32' O, 03.II.1973, bot. e fl., A.L. Costa s.n. (ALCB).

Myriopus candidulus occurs in Venezuela, Guiana and Brazil (Johnston 1930). In the Brazilian territory it is distributed in the northern (Pará), northeastern (Bahia, Ceará, Maranhão and Pernambuco) and southeastern (São Paulo and Rio de Janeiro) regions, in environments of the Amazon rainforest, Caatinga, Cerrado and Atlantic forest, being more abundant in the northeastern region (Cavalheiro et al. 2011, Melo et al. 2014).

In the studied area it was collected in areas of plains, on sandy soils and vegetation of Caatinga-seasonal forest contact. Specimens were collected with flowers in January and with fruits and flowers in June and August.

It can be easily recognized in the study area by show up branches grayish and whitish without lenticels, congested inflorescences, pyramidal, flowers with a green-cinereous calyx and white corolla to green-cinereous, both densely villous as well as by the villous to tomentose drupe.

15. *Myriopus rubicundus* (Salzm. ex DC.) Luebert, Taxon, 60(3): 677. 2011. Figure 9a-g

Tournefortia rubicunda Salzm. ex DC., Prodr. 9: 526. 1845.

Shrub, 1.5–2 m tall, erect to decumbent, forming clumps; branches cylindrical, brown-grayish, glabrous or sparsely strigose, lenticels whitish. Leaf with blade 2.5–10.5 × 0.8–4 cm, membranous, discolorous, oval to lanceolate, apex acute to acuminate, margin entire, base acute to obtuse, sometimes oblique, adaxial surface densely strigose, abaxial surface sparsely strigose, trichomes with sharply discoid base on both surfaces; petiole 0.2–1.1 cm long, cylindrical, sulcate, strigose; venation eucamptodromous. Inflorescence 2–6 cm long, scorpioid with secondary branches clustered in panicles, terminal and internodal, lax, secundiflorous; peduncle 0.4–1.5 cm long, strigose to sericeous. Flowers ca. 5 mm long, sessile; calyx 2–3.2 mm long, deeply lobed, green, externally strigose, internally glabrescent, lobes 1.8–3 × 0.2–0.6 mm, lanceolate, apex acute to acuminate, with unequal sizes among each other, three major and two minor; corolla 3–4.5 cm long, tubular, green to orange, externally sericeous, internally glabrous, tube 2.5–4 mm long, cylindrical, lobes 1.5–3 × 0.2–0.5 cm, linear, patent, apex filiform; stamens 5, coherent, inserted 2.5–3.8 mm from base, sessile, anthers 0.6–1 × ca. 0.2 mm, oval to lanceolate, apex apiculate; ovary 0.6–1 mm long, obclavate, glabrous, nectariferous disk ca. 0.2 mm long; style 1.5–2 mm long, stigma ca. 0.5 mm long, conical-triangular, short, puberulous, stigmatic disk ca. 0.2 mm long. Drupes 3–5 × 2–4 mm, 4 pyrenes, sub-globose, green when young, yellow, orange-colored or red when mature, glabrous to hirsute. Seeds 4, 1.5–2.5 × 1.2–2 mm, suborbicular, brown, smooth.

Material examined: BRAZIL, BAHIA: Glória, Aldeia Serrota, 09°48'33" S e 38°08'33" O, 26.IV.2006, fl., M. Colaço et al. 117 (HUEFS); Brejo do Burgo, 09°20' S e 38°15' O, 03. VII.1995, fl. e fr., F.P. Bandeira 231 (HRB); Euclides da Cunha, Sítio do Jaime, 39°00' S e 10°50' O, 21.IV.2004, fl., M.L. Guedes et al. 10844 (ALCB); Jeremoabo, APA Serra Branca, estrada do Tamburi, próximo a baixa dos Quelés, 09°57'44" S e 38°25'60" O, 502 m, 09.VII.2012, fl., J.V. Santos 29 et al. (HUNEB); Fazenda

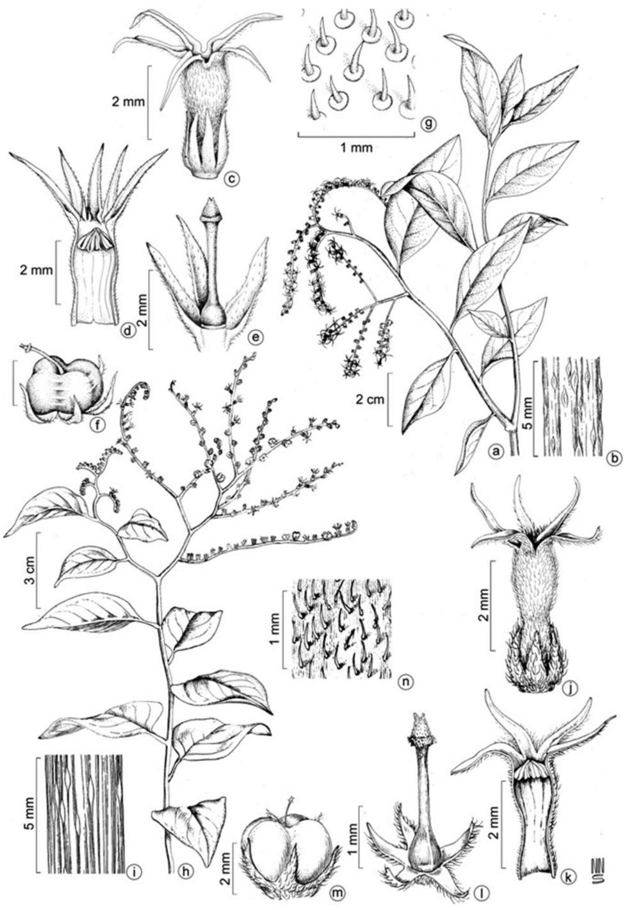

Figure 9. a-g) *Myriopus rubicundus*: a) fertile branch; b) lenticels; c) flower; d) longitudinal section of flower showing androecium; e) gynoecium; f) fruit; g) trichomes with discoid base on the adaxial surface of leaf. h-n) *Myriopus salzmannii*: h) fertile branch; i) lenticels; j) flower; k) longitudinal section of flower showing androecium; l) gynoecium; m) fruit; n) trichomes without discoid base on the adaxial surface of leaf. a-g) A.S. Conceição 1352; h-n) D.D. Vieira.

Serra Branca, ca. 8 km da base da Vaca Morta, 09°52'10" S e 38° 38'53" O, 479 m, 18.IV.2008, fl. e fr., A.S. Conceição 1352 (HUNEB); Raso da Catarina, 10°09' S e 38°28' O, 15.V.1981, fr., G. Pinto 105 (HRB); Trilha do Araçá, 09°52'19" S e 38°38'32" O, 476 m, 08.V.2008, fl. e fr., M.V.V. Romão 115 (HUNEB); Vaca Morta, 09°54'52" S e 38°41'41" O, 364 m, 16.IV.2008, fr., M.V.V. Romão 47 (HUNEB); 09°54'24" S e 38°41'23" O, 367 m, 17. IV.2008, fr., A.S. Conceição 1280 (HUNEB); Paulo Afonso, Estação Ecológica Raso da Catarina, estrada base da Petrobrás em direção à Mata da Pororoca, 09°46'50" S e 38°40'52" O, 658 m, 18.VIII.2012, fl. e fr, D.D. Vieira 340 (HUNEB); 09°46'79" S e 38° 39'92" O, 684 m, 18.VIII.2012, fl., D.D. Vieira 346 (HUNEB); Ribeira do Pombal sentido Banzaê, 10°46'41" S e 38°34'42" O, 212 m, 10.VI.2013, fr., L.R. Silva 182 (HUNEB); Santa Brígida, 09°44' S e 38°07' O, 26.VI.1982, fl., L.P. Queiroz 381 (HUEFS); Raso da Catarina, 09°06'55" S e 38°48'27" O, 622 m, 28.VI.2002, fl., L.P. Queiroz 7288 (HUEFS).

Myriopus rubicundus occurs from México to Central America, including the West Indies, and from north to west of South America (Johnston 1930). In Brazil it occurs from the Amazonas and Pernambuco to Rio Grande do Sul in areas of Caatinga, Cerrado and Atlantic forest (Cavalheiro et al. 2011, Melo et al. 2014).

In the studied area the species is associated with the shrubby-arboreal Caatinga, being common in shadowy areas where it rests on some trees. It was collected with flowers and fruits from April to August.

It is morphologically similar to *M. salzmannii*, mainly because of its lenticelled branches and lax inflorescences. It can be easily differentiated of the latter by its shrubby habit forming clumps, cylindrical branches with whitish lenticels, foliar trichomes with sharply discoid base, obclavate ovary and short, conical-triangular stigma.

16. ***Myriopus salzmannii*** (DC.) Diane & Hilger, Bot. Jahrb. Syst., 125(1): 47. 2003. Figure 9h-n

Tournefortia salzmannii DC., Prodr. 9: 524. 1845.

Shrub, 2–3.5 m tall, decumbent or scandent; branches subcylindrical, brown, villous when young and glabrous, lenticels brownish on branches older. Leaf with blade 2.5–7.5 × 1–4,5 cm, membranous, discolorous, oval to elliptical, apex acute to acuminate, margin entire, base rounded, adaxial surface strigose, abaxial surface strigose to slightly sericeous, trichomes without discoid base; petiole 0.2–1 cm long, cylindrical, sulcate, villous; venation brochidodromous. Inflorescence 1.5–14 cm long, scorpioid with secondary branches clustered in panicles, terminal and internodal, lax, secundiflorous; peduncle 0.5–2.5 cm long, villous to tomentose. Flowers 3.5–5 mm long, sessile; calyx 2–2.5 mm long, deeply lobed green, externally strigose, internally glabrous, lobes 0.3–0.5 × 1.6–2.2 mm, lanceolate, apex acute; corolla 3.5–4.5 mm long, tubular, orange, externally villous to tomentose, internally glabrescent, tube 3–3.5 mm long, cylindrical, lobes 2–2.5 × 0.2–0.3 mm, linear, patent, involute, apex filiform; stamens 5, coherent, inserted 2.5–3 mm from the base, sessile, anthers 0.5–0.8 × 0.2 mm, oval to lanceolate, apex apiculate; ovary ca. 1 mm long, conical-pyramidal, glabrous, nectariferous disk obsolete; style ca. 1.5 mm long, cylindrical, stigma ca. 0.5 mm long, conical-triangular, elongated, pubescent, stigmatic disk 0.5-0.8 mm long. Drupes 3–4.5 × 3–5 mm, 4 pyrenes, globose, green when immature, orange-colored to reddish when mature or rarely white, presenting 4 spherical black spots, corresponding to the seeds, glabrous. Seeds 4, 2–3 × 1.5–2.3 mm, depressed-globose, black, rugose.

Material examined: BRAZIL, BAHIA: Canudos, Estação Biológica de Canudos, Capoeira da Finada Doninha, 09°56'68" S e 38°59'73" O, 394 m, 08.V.2013, fl., D.D. Vieira 436 (HUNEB); Roça de Caboclo, próximo à base 2, 09°56'71" S e 39°00'95" O, 430 m, 28.II.2012, fl., D.D. Vieira 227 (HUNEB); Roça da Biodiversitas, 09°57'11" S e 39°00'41" O, 419 m, 28.II.2012, fl. e fr., D.D. Vieira 229 (HUNEB); Trilha em direção à base 2, 09°56'67" S e 38°59'68" O, 400 m, 28.II.2012, fl., D.D. Vieira 232 (HUNEB); Roça de Dominguinhos de Ermoges, 09°57'10" S e 39°00'41" O, 417 m, 26.IV.2012, fr., D.D. Vieira 251 (HUNEB); 09°56'85" S e 39°00'52" O, 412 m, 07.VI.2012, fl., D.D. Vieira 327 (HUNEB); Toca da onça, roça de Zé Boquinha, 09°58'60" S e 38°56'13" O, 414 m, 07.VI.2012, fl., D.D. Vieira 329 (HUNEB); Euclides da Cunha, Estrada para Sucupira do Galo, 10°21'00" S e 38°41'20" O, 546 m, 11.VI.2013, fr., D.D. Vieira 446 (HUNEB); Jeremoabo, 10°24'16" S e 38°40'16" O, 410 m, 21.II.2006, fl. e fr., E. Melo et al. 4274 (HUEFS); APA Serra Branca, Baixa dos Quelés, próximo ao tanque, 09°57'48" S e 38°26'13" O, 486 m, 05.VI.2012, fl. e fr., A.F. S. Brito 71 (HUNEB); Estrada saindo de Quelés, sentido Estação Ecológica Raso da Catarina, estrada secundária a direita, 09° 52'88" S e 38°32'70" O, 653 m, 05.V.2011, fl e fr., D.D. Vieira 151 (HUNEB); 09°56'57" S e 38°27'39" O, 555 m, 17.VI.2011, fr., R.R. Varjão 130 (HUNEB); Paulo Afonso, Estação Ecológica Raso da Catarina, Trilha da encruzilhada, 09°48'18" S e 38°29'33" O, 596 m, 01.VII.2010, fr., A.A.S. Lopes 984 (HUNEB); Ribeira do Pombal, 10°50' S e 38°32' O, 15.VIII.2003, fr., M.L. Guedes 10509 (ALCB); Sentido Banzaê, 10°46'41" S e 38°34'42" O, 212 m, 10. VI.2013, fr., L.R. Silva 184 (HUNEB).

The species occurs in Paraguay, Bolivia, Argentina and Brazil (Johnston 1930), where it spreads in the regions Northeast and Southeast in the Caatinga, Cerrado and Atlantic rainforest vegetation (Cavalheiro et al. 2011, Melo et al. 2014).

In the Ecoregion Raso da Catarina it occurs from the shrubby Caatinga to environments of transition between Caatinga and forest. Scandent individuals resting on shrubs or trees are commonly found. It was collected with flowers and fruits from February to July.

Myriopus salzmannii can be recognized in the studied area by presents shrubby habit, decumbent or scandent, subcylindrical branches with brownish lenticels, foliar trichomes without discoid base, conical-pyramidal ovary and elongated, conical-triangular stigma.

List of Additional Material Examined

Andrade-Lima, D.: 747695 (1). **Barreto, V.**: 229 (16), 243 (15). **Batista, M.A.**: 04 (2). **Bautista, H.P.**: 750 (6). **Cardoso, D.**: 104 (1), 621 (4), 899 (15), 1195 (15), 1210 (2). **Carvalho-Sobrinho, J.G.**: 2541 (8). **Conceição, S.F.**: 121 (5), 126 (11), 127 (15), 131 (16), 196 (11), 286 (12). **Costa, A.L.**: s/n (6), s/n (14). **Dias Martins, C.T.V.**: 02 (4). **Fonseca, W.N.**: 380 (11), 419 (7). **Fotius, G.**: 3496 (12), 3859 (10). **França, F.**: 1873 (1). **Gomes, F.S.**: 161 (11). **Guedes, L.M.**: 2849 (5), 12073 (4), 12074 (7), 16094 (12), 16211 (6). **Harley, R.M.**: 3406 (11), 16311 (7). **Jesus, N.G.**: 889 (16). **Lima, L.**: 220 (10). **Lordêlo, R.P.**: 57357 (1). **Mangabeira, M.O.**: 2522 (10). **Mariano, K.R.S.**: 33 (6). **Melo, E.**: 1949 (15), 6495 (1), 7525 (5). **Moraes, M.V.**: 190 (2). **Paula-Souza, J.**: 9756 (5), 9767 (12), 9897 (7), 10164 (1). **Pesqueira, U.S.**: 32 (9). **Queiros, L.P.**: 1732 (4), 9013 (6), 9022 (11). **Sant'Ana, S.C.**: 506 (16). **Santos, A.K.A.**: 47 (3). **Santos, V.J.**: 553 (8). **Souza, R.D.**: 26 (8). **Souza, R.P.**: 42 (5). **Stapf, M.N.S.**: 249 (2), 266 (7), 296 (3), 268 (4).

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References

AL-SHEHBAZ, I.A. 1991. The genera of Boraginaceae in the Southeastern United States. J. Arnold Arbor. 1:1-169.

BÖHLE, U.R. & HILGER, H.H. 1997. Chloroplast DNA systematics of "Boraginaceae" and related families: a goodbye to the old familiar concept of 5 subfamilies. Scr. Bot. Belg. 15:30.

CAVALHEIRO, L., PERALTA, D.F. & FURLAN, A. 2003. Flórula fanerogâmica da planície litorânea de Picinguaba, Ubatuba, SP, Brasil: Boraginaceae. Hoehnea 30(3):173-179.

CAVALHEIRO, L., RANGA, N.T. & FURLAN, A. 2011. Tournefortia L. (Boraginaceae): espécies do Brasil extra-amazônico. Hoehnea 38(2):221-242, http://dx.doi.org/10.1590/S2236-89062011000200004

CONCEIÇÃO, S.F. 2007. A subfamília Heliotropioideae (Boraginaceae Juss.) no Estado da Bahia, Brasil. Dissertação de Mestrado, Universidade Estadual de Feira de Santana, Feira de Santana.

DIANE, N., FÖRTHER, H. & HILGER, H.H. 2002. A systematic analysis of *Heliotropium, Tournefortia*, and allied taxa of the Heliotropiaceae (Boraginales) based on ITS1 sequences and morphological data. Am. J. Bot. 89(2):287-295, http://dx.doi.org/10.3732/ajb.89.2.287

DIANE, N., FÖRTHER, H., HILGER H.H. & WEIGEND, M. 2004. Heliotropiaceae. In Families and Genera of the Flowering Plants (K. Kubitzki, ed.). Springer, Berlin, p. 62-70.

FOSBERG, F.R. & SACHET, M.H. 1965. Manual for tropical herbaria. Utrecht, Netherlands.

FREITAS, A.M.M., MELO, J.I.M. & QUEIROZ, L.P. 2008. Boraginaceae A. Juss. do Arquipélago de Fernando de Noronha, Pernambuco, Brasil. Iheringia. Série Botânica 63(2):257-262.

FRESENIUS, G. 1857. *Cordia*ceae, Heliotropieae et Borragineae. In Flora Brasiliensis (C.F.P. Martius, A.G. Eichler & I. Urban, eds.). W. Munchen, Leipzig, v.9, p. 1-60.

GIBSON, D.N. 1970. Flora of Guatemala: Boraginaceae. Botany 24:111-167.

GOTTSCHLING, M. 2003. Phylogenetic analysis of selected Boraginales. PhD in biology, Freie Universität, Berlin.

GOTTSCHLING, M., HILGER, H.H., WOLF, M. & DIANE, N. 2001. Secondary structure of the ITS1 transcription and its application in a reconstruction of the phylogeny of Boraginales. Plant Biol. 3(6):629-636, http://dx.doi.org/10.1055/s-2001-19371

GOTTSCHLING, M., MILLER, J.S., WEIGEND, M. & HILGER, H.H. 2005. Congruence of a phylogeny of *Cordia*ceae (Boraginales) inferred from ITS1 sequence data with morphology, ecology, and biogeography. Ann. Mo. Bot. Gard. 92(3):425-437.

GUIMARÃES, E.F., BARROSO, G.M., ICHASO, C.L.F. & BASTOS, A.R. 1971. Flora da Guanabara: Boraginaceae. Rodriguésia 38: 194-220.

GÜRKE, M. 1893. Boraginaceae. In Die natürlichen Pflanzenfamilien (A. Engler & K. Prantl, eds.). V.W. Engelmann, Leipzig, v.15, p. 49-96.

HARRIS, J.G. & HARRIS M.W. 2001. Plant identification terminology: an illustrated glossary. Spring Lake Publishing, Spring Lake.

HILGER, H H. & DIANE, N. 2003. A systematics analysis of Heliotropiaceae (Boraginales) based on *trnL* and ITS1 sequence data. Bot. Jahrb. Syst. 125(1):19-51, http://dx.doi.org/10.1127/0006-8152/2003/0125-0019

JOHNSTON, I.M. 1928. Studies in Boraginaceae 7: The South American species of *Heliotropium*. Contrib. Gray Herb. Harvard Univ. 81:3-73.

JOHNSTON, I.M. 1930. Studies in Boraginaceae 8: Observations on the species of *Cordia* and *Tournefortia* known from Brazil, Paraguay, Uruguay and Argentina. Contrib. Gray Herb. Harvard Univ. 82:3-89.

MAIA, G.N. 2004. Caatinga: árvores e arbustos e suas utilidades. D&Z Computação Gráfica e Editora, São Paulo.

MELO, J.I.M. 2009. Boraginaceae. In Flora de Mirandiba (M. Alves, M.F. Araújo, J.R. Maciel & S. Martins, orgs.). Associação Plantas do Nordeste, Recife, p. 89-96.

MELO, J.I.M. 2012. Flora do Parque Nacional do Catimbau, Pernambuco, Brasil: Boraginaceae *sensu lato*. Biotemas 25(4):111-122, http://dx.doi.org/10.5007/2175-7925.2012v25n3p145

MELO, J.I.M. & ANDRADE, W.M. 2007. Boraginaceae *s.l.* A. Juss. em uma área de Caatinga da ESEC Raso da Catarina, BA, Brasil. Acta Bot. Bras. 21(2):369-378, http://dx.doi.org/10.1590/S0102-33062007000200011

MELO, E. & FRANÇA, F. 2003. Flora de Grão Mogol, Minas Gerais: Boraginaceae. Bol. Bot. Univ. São Paulo 21(1):127-129.

MELO, J.I.M. & LYRA-LEMOS, R.P. 2008. Sinopse taxonômica de Boraginaceae *sensu lato* A. Juss. no Estado de Alagoas, Brasil. Acta Bot. Bras. 22(3):701-710, http://dx.doi.org/10.1590/S0102-33062008000300008

MELO, J.I.M. & SALES, M.F. 2004. *Heliotropium* L. (Boraginaceae - Heliotropioideae) de Pernambuco, Nordeste do Brasil. Rodriguésia 55(84):65-87.

MELO, J.I.M. & SALES, M.F. 2005. Boraginaceae A. Juss. na região de Xingó: Alagoas e Sergipe. Hoehnea 32(3):369-380.

MELO, J.I.M. & SEMIR, J. 2008. Taxonomia do gênero *Heliotropium* L. (Heliotropiaceae) no Brasil. Acta Bot. Bras. 22(3):754-770, http://dx.doi.org/10.1590/S0102-33062008000300013

MELO, J.I.M. & SEMIR, J. 2010. Taxonomia do gênero *Euploca* Nutt. (Heliotropiaceae) no Brasil. Acta Bot. Bras. 24(1):111-132, http://dx.doi.org/10.1590/S0102-33062010000100012

MELO, J.I.M., ALVES, M. & SEMIR, J. 2009b. Padrões de distribuição geográfica das espécies de Euploca e *Heliotropium* (Heliotropiaceae) no Brasil. Rodriguésia 60(4):1025-1036.

MELO, J.I.M., LOPES, C.G.R. & FERRAZ, E.M.N. 2009a. Boraginaceae A. Juss. *sensu lato* em uma Floresta Estacional de terras baixas em Pernambuco, Brasil. Rev. Caatinga 22(4):179-186.

MELO, J.I.M., MOURA, D.C. & PICK, R. 2007. Boraginaceae A. Juss, na região de Serra Talhada, Pernambuco. Rev. Bras. Biociênc. 5(2):336-338.

MELO, J.I.M., SILVA, F.K.G., GONÇALVES, M.B.R., LIMA, E.A, LUCENA, L.A.F. & MACHADO-FILHO, H.O. 2011. Boraginaceae *sensu lato* da área de Proteção Ambiental (APA) das Onças, São João do Tigre, Paraíba. Biofar, Rev. Biol. Farm. 5:24-33.

MELO, J.I.M., RANGA, N.T. & CAVALHEIRO, L. 2013. Boraginaceae. In Flora dos Estados de Goiás e Tocantins – Coleção Rizzo (J.A. Rizzo, ed.). Editora da Universidade Federal de Goiás, Goiânia, v.43, p. 1-64.

MELO, J.I.M., STAPF, M.N.S., CAVALHEIRO, L. & VIEIRA, D.D. 2014. Boraginaceae. In Lista de Espécies da Flora do Brasil. Jardim Botânico do Rio de Janeiro, Rio de Janeiro. http://floradobrasil.jbrj.gov.br/jabot/floradobrasil/FB64 (último acesso em 10/10/2014).

MILLER, J.S. 1988. A revised treatment of Boraginaceae for Panama. Ann. Mo. Bot. Gard. 75:456-521, http://dx.doi.org/10.2307/2399433

MILLER, J.S. 2013. A revision of *Cordia* section *Gerascanthus* (Boraginales: *Cordia*ceae). J. Bot. Res. Inst. Texas 7(1): 55-83.

MILLER, J.S. & GOTTSCHLING, M. 2007. Generic classification in the *Cordia*ceae (Boraginales): resurrection of the genus Varronia P. Br. Taxon 56(1):163-169.

MORI, S.A., MATTOS-SILVA, L.A., LISBOA, G. & CORADIN, L. 1989. Manual de manejo do herbário fanerogâmico. Centro de Pesquisas do Cacau, Ilhéus.

NOWICKE, J. 1969. Flora of Panama: Boraginaceae. Ann. Mo. Bot. Gard. 56:33-69, http://dx.doi.org/10.2307/2395165

RADFORD, A.E., DICKINSON, W.C., MASSEY, J.R. & BELL, C. R. 1974. Vascular plant systematics. Harper & Row, New York.

RANGA, N.T., MELO, J.I.M. & SILVA, L.C. 2012. Boraginaceae. In Flora Fanerogâmica do Estado de São Paulo (M.G.L. Wanderley, G.J. Shepherd, T.S. Melhem, A.M. Giulietti & S.E. Martins, eds.). Fapesp/IBt, São Paulo, v.7, p. 117-142.

REFULIO-RODRIGUEZ, N.F. & OLMSTEAD, R.G. 2014. Phylogeny of Lamiidae. Am. J. Bot. 101(2): 1-13, http://dx.doi.org/10.3732/ajb.1300450

RIBEIRO, J.E.L.S., HOPKINS, M.J.G., VICENTINI, A., SOTHERS, C.A., COSTA, M.A.S., BRITO, J.M., SOUZA, M.A.D., MARTINS, L.H.P., LOHMANN, L.G., ASSUNÇÃO, P.A.C.L., PEREIRA, E.C., SILVA, C.F., MESQUITA, M.R. & PROCÓPIO, L.C. 1999. Flora da Reserva Ducke: Guia de identificação das plantas vasculares de uma floresta de terra-firme na Amazônia Central. Instituto Nacional de Pesquisas da Amazônia, Manaus.

SAMPAIO, E.V.S.B. 1995. Overview of the Brazilian caatinga. In Seasonally dry tropical forests (S.H. Bullock, H.A. Mooney & E. Medina, eds.). Cambridge University Press, Cambridge, p. 34-63.

SBB. 2013. Rede brasileira de herbários. In Sociedade Botânica do Brasil. http://www.botanica.org.br/ (último acesso em 03/10/2013).

SZABO, A.V., ROCHA, A.C.S., TOSATO, J.A.C. & BARROSO, W. 2007. Área de proteção ambiental (APA) Serra Branca Raso da Catarina. In As caatingas: debates sobre a Ecorregião do Raso da Catarina (J. Marques, org.). Fonte Viva, Paulo Afonso, p. 21-40.

SMITH, L.B. 1970. Boragináceas. In Flora Ilustrada Catarinense (P.R. Reitz, ed.). Herbário Barbosa Rodrigues, Itajaí, p. 1-85.

STAPF, M.N.S. 2007. Avaliação da classificação infragenérica de *Cordia* L. (*Cordia*ceae) e revisão taxonômica de *Cordia* sect. *Pilicordia* DC. para o Brasil. Tese de doutorado, Universidade Estadual de Feira de Santana, Feira de Santana.

STAPF, M.N.S. 2010. Notas nomenclaturales sobre Varronia (Boraginaceae s.l.) en Brasil. Rodriguésia 61(1):133-135.

TARODA, N. & GIBBS, P.E. 1986a. Studies on the genus *Cordia* L. (Boraginaceae) in Brazil. A new infrageneric classification and conspectus. Rev. Bras. Bot. 9:31-42.

TARODA, N. & GIBBS, P.E. 1986b. A revision of the Brazilian species of *Cordia* subgenus *Varronia* (Boraginaceae). Notes Roy. Bot. Gard. Edinburgh 44(1):105-140.

TARODA, N. & GIBBS, P.E. 1987. Studies on the genus *Cordia* L. (Boraginaceae) in Brazil. An outline taxonomic revision of subgenus *Myxa* Taroda. Hoehnea 14:31-52.

TARODA, N. & SILVA, L.C. 2002. Boraginaceae. In Flora Fanerogâmica da Ilha do Cardoso (M.M.R.F. Melo, F. Barros, M.G.L. Wanderley, M. Kirizawa, S.L. Jung-Mendaçolli & S.A.C. Chiea, eds.). São Paulo, v.9, p. 105-114.

THIERS, B. 2013 [continuously updated]. Index Herbariorum: a global directory of public herbaria and associated staff. In New York Botanical Garden's Virtual Herbarium. http://sweetgum.nybg.org/ih/ (último acesso em 28/07/2013).

TRICART, J. 1972. The landforms of the humid tropics, forests and savannas. Geographies for Advanced Study, Longman, London.

VELLOSO, A.L., SAMPAIO, E.V.S.B., GIULIETTI, A.M., BARBOSA, M.R.V., CASTRO, A.A.J.F., QUEIROZ, L.P., FERNANDES, A., OREN, D.C., CESTARO, L.A., CASTRO, A.J.E., PAREYN, F.G.C., SILVA, F.B.R., MIRANDA, E.E., KEEL, S. & GONDIM, R.S. 2002. Ecorregiões propostas para o bioma caatinga. The Nature Conservancy do Brasil, Associação Plantas do Nordeste, Recife.

VIEIRA, D.D., CONCEIÇÃO, A.S., MELO, J.I.M. & STAPF, M.N. S. 2013. A família Boraginaceae *sensu lato* na APA Serra Branca/Raso da Catarina, Bahia, Brasil. Rodriguésia 64(1):151-168.

WEIGEND, M. & HILGER, H.H. 2010. Codonaceae – a newly required family name in Boraginales. Phytotaxa 10: 26-30, http://dx.doi.org/10.11646/phytotaxa.10.1.3

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article

Purification and physico-chemical study of serum albumins of two neotropical fish species from the São Francisco River Bassin, Brazil

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Abstract: This paper presents results from a study of albumin from pacu (*Piaractus mesopotamicus,* Holmberg 1887) and the catfish pintado (*Pseudoplatystoma corruscans,* Spix & Agassiz, 1829), two neotropical fish species inhabitants of Brazilian rivers, comparing their molecular mass and discussing their secondary structures based on spectropolarimetric (circular dychroism) measurements. Genetic controlled specimens were obtained from two fish hatcheries, located in Mococa (pacu) and in São João da Boa Vista (pintado), both in São Paulo State, Brazil. After a period of adaptation in holding tanks, fish blood samples were taken by punctioning their abdominal aorta. Purified albumin was obtained by gel filtration. SDS-PAGE electrophoresis was performed for the molecular mass estimation. Circular Dichroism spectra were registered for albumins of the two fish species over the range of 190-250 nm (far-UV), which shown two negative bands at 217 and 208 nm, a positive peak at 196 nm and a crossover at 200 nm. This profile is compatible with proteins that content predominantly alpha-helix structure.

Keywords: *Spotted sorubim, Pseudoplatystoma corruscans, Pacu, Piaractus mesopotamicus, fish serum albumin, circular dychroism.*

SILVA, D., CORTEZ, C.M., NOGUEIRA, N.P., BASTOS, F.F.C. **Purificação e estudo físico-químico de albuminas de duas espécies de peixes neotropicais da Bacia do Rio São Francisco, Brasil.** Biota Neotropica. 15(3): e20140179. http://dx.doi.org/10.1590/1676-0611-BN-2014-0179

Resumo: Este artigo apresenta os resultados de um estudo sobre as albuminas de pacu (*Piaractus mesopotamicus,* Holmberg 1887) e pintado (*Pseudoplatystoma corruscans,* Spix & Agassiz, 1829), duas espécies neotropicais de peixes nativas do Brasil, determinando as suas massas moleculares e discutindo suas estruturas secundárias, com base em medidas de espectropolarimetria (dicroísmo circular). Espécimes controlados geneticamente foram obtidos de duas diferentes pisciculturas, uma localizada na cidade de Mococa (pacu) e a outra, na cidade de São João da Boa Vista (pintado), ambas no Estado de São Paulo, Brasil. Após um período de adaptação em tanques apropriados, amostras de sangue foram coletadas por punção da aorta abdominal dos peixes. Albumina pura foi obtida por gel filtração dessas amostras e as massas moleculares foram determinadas a partir dos dados da eletroforese SDS-PAGE. Espectros de dicroísmo circular das albuminas dos peixes foram registrados na região de 190-250 nm (far-UV), os quais mostraram duas bandas negativas, a 217 e 208 nm, um pico positivo a 196 nm e um *crossover* a 200 nm; perfil este compatível com proteínas que contem predominantemente estrutura alfa-hélice.

Palavras-chave: *Albumina de peixe, Pintado, Pseudoplatystoma corruscans, Pacu, Piaractus mesopotamicus, dicroísmo circular.*

Introduction

Among of transport proteins in blood plasma, only albumin is able to bind a wide diversity of drugs reversibly with high affinity. Albumin is typically the major anionic protein in vertebrate plasma, representing more than 52% of the total plasmatic protein content. It has an important role in transport endogenous ligands and xenobiotics mostly through the formation of non-covalent complexes at specific binding sites. Albumin also plays an essential role in organisms when protects them by binding toxic metabolites, such as bilirubin, as well as functioning as a reservoir of the nitric oxide (Kragh-Hansen 1990; Curry *et al.* 1998; Sugio *et al.* 1999; Bertucci and Domenici 2002; Stamler *et al.* 1992). According to Shao *et al.* (1993), this protection function presents a special importance in the Chinese cobra, since serum albumin avoids that the snake becomes victim from its own venom.

The study of albumins represents a challenge as they have not a single property by which they can be identified (Maillou and Nimmo 1993). Much data about quantity and structure of mammalian albumins, mainly bovine (BSA) and human (HSA) serum albumin, can be found in literature (Silva *et al.* 2004a, 2004b, 2004c, Bertucci and Domenici 2002, Kragh-Hansen 1990), but very few information about fish albumin is available (Silva *et al.* 2009a, 2009b). The shortage of data about fish albumin makes to establish a pattern a difficult task, even so for the same family (Perrier *et al.* 1974, Davidson *et al.* 1989). However, it is known that, in general, these proteins have at least one residue of tryptophan (Feller *et al.* 1994) along their chain.

In this study we have isolated, purified, and studied albumin from pacu (*Piaractus mesopotamicus,* Holmberg 1887) and pintado (*Pseudoplatystoma corruscans,* Spix & Agassiz 1829), two neotropical fish species inhabitants of Brazilian rivers, obtained from fish hatcheries located in São Francisco River basin in São Paulo State, Brazil, establishing their molecular mass and discussing their secondary structures based on spectropolarimetric (circular dychroism, CD) measurements.

Material and Method

Genetic controlled early specimens of pacu and pintado, wt = 300 ± 15 g, were obtained from two fish hatcheries, one located in Mococa (pacu) and another in São João da Boa Vista, both in São Paulo State, Brazil. They were supplied with well-aerated water (normoxic conditions) in holding tanks at constant temperature of about 28°C. After an adaptation period, they were used in experiments. Fish were fed with commercial feed pellets. Blood samples were taken from the abdominal aorta of live fish using non-heparinzed syringes.

Serum from fish blood was previously treated with ammonia sulfate, dialyzed, and chromatographed in blue sepharose affinity column. Purified albumin was obtained by gel filtration. SDS-PAGE electrophoresis was performed for molecular mass estimation.

The chromatographic method used was that described by Travis and Pannell (1973). Serum was applied to a HiTrap Blue column, and fractionated with 50 mM potassium phosphate pH 7.4 at 2 ml/min, monitoring the absorbance at 280 nm. After discarding non-bound fractions, albumin was washed out with a gradient of 0 to 1.5 M of elution buffer (KCl in phosphate buffer). Total serum protein concentration was determined using the Peterson's method (Peterson 1977) and albumin serum concentration was determined by the Basil Doumas method (Doumas *et al.* 1971).

To study the secondary structure of albumin we used the spectrospolarimetric method within the CD technique. CD spectra were registered over the range of 190-250 nm (far-UV).

Results and Dicussion

Gel filtration and electrophoresis showed a molecular weighs for both pacu and pintado albumins, around 66 kDa, presenting strong similarity to BSA. These results agree to the values considered by Maillou and Nimmo (1993), who suggested that the molecular weigh of fish albumin can be next to 70 kDa, basing on their electrophoretic analysis using serum of two different species of fish. For two members of the Salmonidae family, the chinook salmon (Oncorhynchus tshawytscha) and brown trout (Salmo trutta), Brennan *et al.* (1998) found molecular masses of 65 and 67 kDa for Salmon and trout albumins, respectively.

The total serum protein concentrations measured by Peterson's method (1977) were 16 mg/ml and 34 mg/ml for pintado and pacu, respectively. By means of the brome cresol green method, we determined albumin fractions of 1.6 mg/ml, for pintado, and 2.0 mg/ml, for pacu. These values are in accordance to the suggestion that serum albumin concentration in fishes can be much lower than of albumin concentration in mammals, which vary from 30 to 40 mg/ml. Due to the low plasmatic ratio, it was thought in the past that albumin was not present in fish serum. But, experiments performed by Byrnes and Gannon (1992) identified cDNA sequences of *Salmo salar* albumin, and its homology with albumins of others vertebrates was already demonstrated (Metcalf *et al.* 1998).

In recent study, Zhang *et al.* (2013) studied the total protein content in plasma from six kinds of mammals and fish and purified albumin. They found that total plasma protein and albumin content in mammals were nearly two times and four times higher than that in fish, respectively. For salmon and trout albumins, values of plasmatic concentration estimated were approximately 15 mg/ml in both species (Brennan *et al.* 1998).

The values of albumin concentration we found for the two fish were lower than those found for others fish species. To explain this large variation grade, it is important consider that fishes form the largest group among vertebrates with a wide variability of shapes, dimensions, and anatomical and metabolic characteristics. Physiologically, such variability reflects the great capacity of adaptation of the group to the aquatic environment diversity (Roberts 1981). Pacu and Pintado are two neotropical fresh water fish species, adapted naturally to quite different habitats from those salt and cold water fish species studied by the majority of the authors. On the other hand, pacu and pintado have different nutritional and living habits from each other. While pacu is omnivorous, feeding themselves of plants and fruits, pintado is a benthic carnivorous specie. It might explain the difference we found in their serum protein concentration.

Despite the different concentrations, the CD spectra show similar secondary structure profile for two fish species. Figure shows CD spetra of pacu and pintado, respectively, obtained at 25°C (50 mM phosphate buffer, pH 7.4). These spectra were registered over the range of 190-250 nm (far-UV), and they present two negative bands at 217 and 208 nm, a positive peak at 196 nm and a crossover at 200nm. Selcon 3 method was used for estimating the albumin secondary structure content (Table 1), and the data analysis has shown the spectrum profiles are compatible with proteins that content predominantly alpa-helix structure.

We believe that fish plasmatic proteins can function as an effective biomarker, since their concentration can vary as reflex of nutritional, physiological and/or geographic conditions. In addition, the total and relative ratio of serum protein can be affected by pathological conditions and besides the presence of environmental stressors (Grasman *et al.* 2000, Ellsaesser and Clem 1987). Fishes can also exhibit polyploidy, responsible for many of the variations in plasma proteins (Komatsu *et al.* 1970). Thus, we see a high importance in studies about serum

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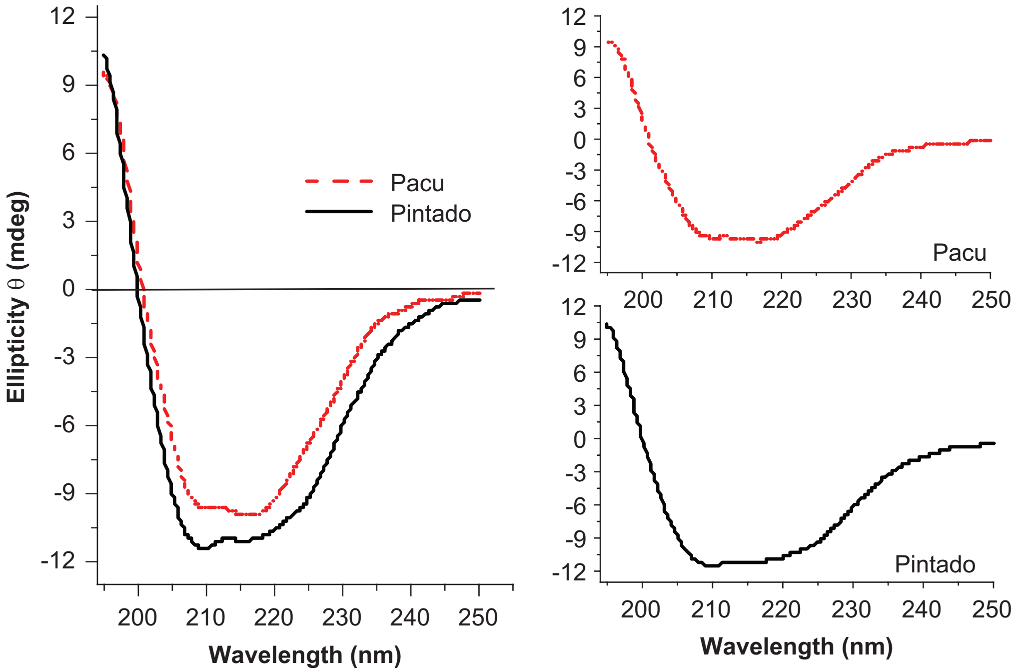

Figure. CD spectrum between 195 e 250 of albumin for Pacu and Pintado at 25°C, 50 mM phosphate buffer, pH 7.4.

Table 1. Secondary structure content for pacu and pintado serum albumin

	Alpha-helix	Beta-helix	Beta-turn	Unrd
Pacu	49	9	16	25
Pintado	41	12	20	27

Unrd = disordered.

fish proteins and their interactions, because these data could be of particular interest in ecotoxicology and environmental risk assessment.

Conclusions

Our results allow conclude that: (1) total serum protein concentrations of pintado and pacu are 16 mg/ml and 34 mg/ml, respectively; (2) serum concentration of albumin in fish (1.6 mg/ml, for pintado, and 2.0 mg/ml, for pacu) is very lower than albumin concentration in mammalian; (3) the molecular mass for pacu and pintado serum albumin are about 66 kDa, presenting similarity to BSA; (4) the secondary structure content analysis by Selcon 3 method shows predominantly alpha-helix profile for two fish species studied; and (5) CD negative band at 217 nm suggests difference in its conformation when compared to BSA and HSA.

References

BERTUCCI, C. & DOMENICI, E. 2002. Reversible and covalent binding of drugs to human serum albumin: Methodological approaches and physiological relevance. Curr. Med. Chem. 9: 1463-1481, http://dx.doi.org/10.2174/0929867023369673.

BYRNES, L. & GANNON, F. 1992. Sequence analysis of a second cDNA encoding Atlantic salmon (Salmo salar) serum albumin. Gene 120: 319-320, http://dx.doi.org/10.1016/0378-1119(92)90115-6.

CURRY, S., MANDELKOW, H., BRICK, P. & FRANKS, N. 1998. Crystal structure of human serum albumin complexed with fatty acid reveals an asymmetric distribution of binding sites. Nat. Struct. Biol. 5: 827-835, http://dx.doi.org/10.1038/1869.

DAVIDSON, W.S., BARTLETT, S.E., BIRT, T.P. & GREEN, J.M. 1989. Identification and purification of serum albumin from rainbow trute (Salmo gairdneri). Comp. Biochem. Physiol. 93B: 5-9.

DOUMAS, T., WATSON, W.A. & BIGGS, H.G. 1971. Albumin standards and the measurement of serum albumin with bromocresol green. Clin. Chim. Acta. 31: 87-96, http://dx.doi.org/10.1016/0009-8981(71)90365-2.

ELLSAESSER, C. & CLEM, L.W. 1987. Blood serum chemistry measurements of normal and acutely stressed channel catfish. Comp. Biochem. Physiol. 88A: 589-594, http://dx.doi.org/10.1016/0300-9629(87)90087-9.

FELLER, G., PONCIN, A., AITTALEB, N., SCHYNS, R.E. & GERDAY, C.H. 1994. The Blood proteins of the Antarctic ice fish Channichthys rinoseratus: biological significance and purification of the two main components. Comp. Biochem. Physiol. 109B: 89-97.

GRASMAN, K.A., Armstrong, M., Hammersley, D.L., Scanlon, P.F. & Fox, G.A. 2000. Geographic variation in blood plasma protein concentrations of young herring gulls (*Larus argentatus*) and Caspian terns (*Sterna caspia*) from the Great Lakes and Lake Winnipeg. Comp. Biochem. Physiol. 125C: 365-375.

KOMATSU, S.K., MILLER, H.T., DEVRIES, A.L., OSUGA, D.T. & FEENEY, R.E. 1970. Blood plasma proteins of cold-adapted antarctic fishes. Comp. Biochem. Physiol. 32: 519-527, http://dx.doi.org/10.1016/0010-406X(70)90469-X.

KRAGH-HANSEN, U. 1990. Structure and ligand binding properties of human serum albumin. Dan. Med. Bull. 37: 57-84.

MAILLOU, J. & NIMMO, I.A. 1993. Identification and some properties of an albumin-like protein in the serum of pre-spawning Atlantic salmon (*Salmo salar*). Comp. Biochem. Physiol. 104B: 401-405.

METCALF, V., BRENNAN, S., CHAMBERS, G. & GEORGE, P. 1998. The albumins of Chinook salmon (*Oncorhynchus tshawytscha*) and Brown trout (*Salmo trutta*) appear to lack a propeptide. Arch. Bioch. Biophys. 350: 239-244, http://dx.doi.org/10.1006/abbi.1997.0509.

PERRIER, H., DELCROIX, J.P., PERRIER, C. & GRASS, J. 1974. Disc electrophoresis of plasma proteins of fish; localization of fibrinogen, transferrin and ceruloplasmin in the plasma of the rainbow trout (*Salmo gairdnerii richardson*). Comp. Biochem. Physiol. 49B: 679-668.

PETERSON, G.L. 1977. Simplification of protein assay method of Lowry at. al. which is more generally applicable. Anal. Biochem. 83: 346-356, http://dx.doi.org/10.1016/0003-2697(77)90043-4.

ROBERTS, R.J. 1981. Patologia de los peces, cap.I. Ed. Mundi-Prensa, Madrid.

SHAO, J., SHEN, H. & HAVSTEEN, B. 1993. Purification, characterization and binding interactions of the Chinese-cobra (Naja naja atra) serum antitoxic protein CSAP. Biochem. J. 293: 559-566, http://dx.doi.org/10.1042/bj2930559.

SILVA, D., CORTEZ, C.M., BASTOS, J.C. & LOURO, S.R.W. 2004c. Methyl parathion interaction with human and bovine serum albumin. Toxicology Lett 147: 53-61, http://dx.doi.org/10.1016/j.toxlet.2003.10.014.

SILVA, D., CORTEZ, C.M. & LOURO, S.R.W. 2004a. Chlorpromazine interactions to sera albumins. A study by the quenching of fluorescence. Spectrochim. Acta A: Mol. Biomol. Spectr. 60: 1215-1223, http://dx.doi.org/10.1016/j.saa.2003.08.003.

SILVA, D., CORTEZ, C.M. & LOURO, S.R.W. 2004b. Quenching of the Intrinsic Fluorescence of Albumin by Chlorpromazine and Hemin. Braz. J. Med. Biol. Res. 37: 963-968.

SILVA, D., CORTEZ-MOREIRA, M., CUNHA-BASTOS, V.L.F., CUNHA-BASTOS, J. & CORTEZ, C.M. 2010b. Spectroflurimetric Study of the Interaction of Methyl-parathion with Fish Serum Albumin. Fish. Physiol. Bioch. 36: 427-433, http://dx.doi.org/10.1007/s10695-009-9312-z.

SILVA, D., CORTEZ-MOREIRA, M., CUNHA-BASTOS, V.L.F., CUNHA-BASTOS, J.C. & CORTEZ, C.M. 2010a. The Interaction of Methyl-parathion with Serum and Alabumin of the Neotropical Fish Piaractus mesopotamicus. Ecotoxicol. Environ. Saf 73: 32-37, http://dx.doi.org/10.1016/j.ecoenv.2009.09.003.

STAMLER, J.S., SINGEL, D.J. & LOSCALZO, J. 1992. Biochemistry of nitric oxide and its redox-activated forms. Proc. Natl. Acad. Sci. USA. 89: 444–448, http://dx.doi.org/10.1073/pnas.89.1.444.

SUGIO, S., KASHIMA, A., MOCHIZUKI, S., NODA, M. & KOBAYASHI, K. 1999. Crystal structure of human serum albumin at 2.5 Å resolution. Protein. Eng. 12: 439-446, http://dx.doi.org/10.1093/protein/12.6.439.

TRAVIS, J.E. & PANNELL, R. 1973. Selective removal of albumin from plasma by affinity. Chromatography. Clin. Chim. Acta. 49: 40-52, http://dx.doi.org/10.1016/0009-8981(73)90341-0.

ZHANG, W., LIANG, G., WU, L., TUO, X., WANG, W., CHEN, J. & XIE, P. 2013. Why mammals more susceptible to the hepatotoxic microcystins than fish: evidences from plasma and albumin protein binding through equilibrium dialysis. Ecotoxicology 22: 1012-1019, http://dx.doi.org/10.1007/s10646-013-1086-5.

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