Differential Use of Forest Patches by the Military Macaw Ara militaris (Psittacidae) in Coastal Tropical Forests of Jalisco, Mexico

Authors: Flores-López, Everardo, Montero-Castro, Juan Carlos, Monterrubio-Rico, Tiberio C., Ibarra-Manríquez, Guillermo, López-Toledo, Leonel, et al.

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DIFFERENTIAL USE OF FOREST PATCHES BY THE MILITARY MACAW *ARA MILITARIS* (PSITTACIDAE) IN COASTAL TROPICAL FORESTS OF JALISCO, MEXICO

USO DIFERENCIAL DE PARCHES DE VEGETACIÓN POR EL GUACAMAYO MILITAR *ARA MILITARIS* (PSITTACIDAE) EN LOS BOSQUES TROPICALES COSTEROS DE JALISCO, MÉXICO

Everardo Flores-López[1], Juan Carlos Montero-Castro[1 *],
Tiberio C. Monterrubio-Rico[1], Guillermo Ibarra-Manríquez[2],
Leonel López-Toledo[1, 3] and Carlos Bonilla-Ruz[4]

Summary.—Bahía de Banderas in Jalisco, Mexico, contains important vegetation areas for the maintenance and nesting of Military Macaws *Ara militaris*. However, the forests of the region are not used randomly by Military Macaws across the landscape. This study aimed to evaluate differences in floristic composition, diversity and structure among forest patches used by the macaws for nesting/roosting or for feeding, and at sites from which the macaws are absent. Field sampling was conducted in 16 plots of 1,000m^2 of tropical subdeciduous forest. Statistically significant differences were found in the floristic composition between patches used and avoided by Military Macaws. The used areas were approximately twice as diverse as the avoided areas. The forests at used sites presented a great abundance of species registered as part of their diet, in addition to non-food species such as *Oxandra lanceolata*, a tree that may be an important component of macaw habitat. In contrast, the dominant species in avoided areas are those associated with disturbed areas and do not provide food for Military Macaws. Our results indicate that Military Macaws select forest fragments in response to disturbance, using forest patches that offer suitable opportunities for nesting and feeding.—Flores-López, E., Montero-Castro, J.C., Monterrubio-Rico, T.C., Ibarra-Manríquez, G., López-Toledo, L. & Carlos Bonilla-Ruz, C. (2020).

1 Facultad de Biología, Universidad Michoacana de San Nicolás de Hidalgo, Avenida Francisco J. Múgica s/n, Ciudad Universitaria, Morelia, Michoacán, CP 58030, México.

2 Instituto de Investigaciones en Ecosistemas y Sustentabilidad, Universidad Nacional Autónoma de México, Antigua carretera a Pátzcuaro no. 8701, Ex-Hacienda de San José de la Huerta, Morelia, Michoacán, CP 59180, México.

3 Instituto de Investigaciones sobre los Recursos Naturales, Universidad Michoacana de San Nicolás de Hidalgo, Av. San Juanito Itzícuaro s/n, Col. Nueva Esperanza, Morelia, Michoacán, CP 58330, México.

4 Unidos por las Guacamayas A. C., María Montessori 650, Coto La Joya, Acuamarina 212, Col Aramara, Puerto Vallarta, Jalisco, CP 48314, México.

* Corresponding author: cestrum2003@yahoo.com.mx

Differential use of forest patches by the Military Macaw *Ara militaris* (Psittacidae) in coastal tropical forests of Jalisco, Mexico. *Ardeola*, 67: 423-432.
Key words: beta diversity, disturbed forests, floristic composition, forest structure, macaw foraging.

RESUMEN.—Bahía de Banderas en Jalisco, México, contiene importantes áreas de vegetación para el mantenimiento de las actividades reproductivas del guacamayo militar *Ara militaris*. Sin embargo, los bosques de la región no son utilizados al azar a través del paisaje por el guacamayo. El objetivo de este estudio fue evaluar las diferencias en la composición florística, la diversidad y la estructura entre los parches de bosque utilizados para anidar, alimentarse, así como sitios no visitados por el guacamayo. El muestreo de campo se realizó en 16 parcelas de 1.000 m^2 de bosque tropical subcaducifolio. Se encontraron diferencias estadísticamente significativas en la composición florística entre parches utilizados y no utilizados por el guacamayo. Las áreas utilizadas fueron aproximadamente dos veces más diversas que las no utilizadas. Los bosques en los sitios utilizados presentan gran abundancia de especies registradas como parte de su dieta; además de otras especies, como *Oxandra lanceolata*, la cual podría ser un componente importante en el hábitat de los guacamayos. En contraste, las especies dominantes en los parches no utilizados son plantas asociadas a áreas perturbadas y no proporcionan suministro de alimentos para el guacamayo. Nuestros resultados indican que el guacamayo selecciona fragmentos de bosques en respuesta a la perturbación, utilizando los parches de bosque que contienen una estructura adecuada para anidar y alimentarse.—Flores-López, E., Montero-Castro, J.C., Monterrubio-Rico, T.C., Ibarra-Manríquez, G., López-Toledo, L. y Carlos Bonilla-Ruz, C. (2020). Uso diferencial de parches de vegetación por el guacamayo militar *Ara militaris* (Psittacidae) en los bosques tropicales costeros de Jalisco, México. *Ardeola*, 67: 423-432.
Palabras clave: alimentación de guacamayos, beta diversidad, bosques perturbados, composición florística, estructura del bosque.

INTRODUCTION

In tropical forests, disturbance and habitat loss affect the viability of an important number of plant species and increase the risk of extinction of mammals and birds (Dirzo & Raven, 2003). In the case of parrots (Psittacidae), some species are able to selectively use the limited resources that disturbed areas provide (Morales-Pérez, 2005; Ríos-Muñoz & Navarro-Sigüenza, 2009). However, large parrot species, such as the Military Macaw *Ara militaris*, are more selective of the habitats they use, particularly those where they nest and feed (Monterrubio-Rico *et al*., 2005). The Military Macaw has been severely affected by nest poaching and is very sensitive to anthropogenic disturbance, entirely avoiding areas of agriculture and livestock production (Morales-Pérez, 2005; BirdLife International, 2016). In contrast, it has been reported that it nests in conserved sites and those located further than 1,500 m from the nearest human settlement (Bonilla-Ruz *et al.,* 2014). On the Mexican Pacific coast, it is estimated that the Military Macaw's distribution has been reduced by 15.6% due to land use change and illegal capture for trade (Marín-Togo *et al.,* 2012).

Most Military Macaws nest on high vertical cliffs (Bonilla-Ruz *et al*., 2007; Rivera-Ortíz *et al*., 2008; Jiménez-Arcos *et al*., 2012) but nesting also occurs in tree cavities (Bonilla-Ruz *et al.,* 2014; Avilés-Ramos, 2016). The most common nest trees are *Enterolobium cyclocarpum*, *Tabebuia rosea*, *Astronium graveolens*, *Ficus crocata* and *Piranhea mexicana*; in the last of these, several pairs occasionally share the same tree (Bonilla-Ruz *et al.,* 2014).

Among the different vegetation types in which the Military Macaw has been reported, tropical subdeciduous forest appears to be a very suitable habitat (Rivera-Ortíz *et al*., 2013; Monterrubio-Rico *et al.,* 2016). However, it has been observed that forest use by macaws is neither random nor uniform. Indeed, it appears that Military Macaws inhabit very specific sites in which to nest, roost and feed (Bonilla-Ruz *et al.,* 2014; Avilés-Ramos, 2016; de la Parra-Martínez, 2016). Although there may be food trees where they nest and roost, macaws fly up to 20km daily in search of better feeding sites (Gaucín, 2000; Bonilla-Ruz *et al.,* 2007).

Although the Military Macaw is classified globally as 'Vulnerable' (BirdLife International, 2016) and as 'Endangered' in Mexico (SEMARNAT, 2010), information concerning the characteristics of the forests used by this species remains very limited. It is, therefore, necessary to gather information regarding the landscape composition and structure in order to understand how these community traits influence habitat selection and use (Rivera-Ortíz *et al*., 2013; Bonilla-Ruz *et al*., 2014). Understanding the requirements of Military Macaws in terms of the composition, diversity and structure of the woody flora of the forests where it nests, roosts and feeds will enable the design of specific programmes for their conservation, restoration and long-term management (Amaya-Villarreal *et al.,* 2015). The aims of this study were to document the floristic composition, species diversity and structural characteristics of the woody flora within the nesting/roosting and feeding areas of Military Macaws, including areas from which they are absent, in the region of Bahía de Banderas, Jalisco, Mexico, which could be useful for the management and restoration of its habitats.

Methods

The study was conducted in the region of Bahía de Banderas in Jalisco, Mexico, which is located in the Sierra Madre del Sur (INEGI, 2009). Eight tropical subdeciduous forest sites were located at altitudes ranging from 20 to 650m a.s.l. (Supplementary Material, Appendix 1, Figure A1). Based on previous studies (Bonilla-Ruz *et al*., 2014; Avilés-Ramos, 2016), the sites were classified according to the activities registered for Military Macaw: nesting/roosting sites: Boca de Tomatlán (nesting) and Yelapa (roosting); feeding sites: Jorullo, Yelapa2, Tecomatas and Bioto; and sites from which the macaw is absent: El Salto and Primavera. Elderly settlers, who live near the last two sites, confirmed the lack of macaw nesting or feeding records there.

At each of the eight sites, two Gentry type transect-sampling plots (Gentry, 1982) were established. Along each transect the diameter and height of all trees and shrubs of diameter at breast height (DBH) ≥ 2.5cm were recorded. In the case of lianas, the diameter was recorded at the base of the supporting trunk. Exsicates of species registered in study sites were deposited in the herbarium EBUM (Universidad Michoacana de San Nicolás de Hidalgo Herbarium). The list of vascular plants used by Military Macaws, compiled by Avilés-Ramos (2016), was consulted to compare with food source species recorded at study sites (see Supplementary Material, Appendix 2, Table B1).

In order to investigate differences in floristic composition among the nesting/roosting, feeding and avoided sites, a permutational multivariate analysis of variance of distance matrices (ADONIS-VEGAN; Anderson, 2001) was conducted, with 999 permutations, using a matrix of Euclidean distances, a procedure recommended in similar studies (Rivera-Ortíz *et al.,* 2013). In order to identify the main species responsible for the floristic dissimilarity, the "similarity percentages" procedure (SIMPER-VEGAN; Clarke, 1993) was used. Furthermore, in order to evaluate the similarities in floristic composition among sites, a cluster analysis was conducted with Ward's method, using the Bray-Curtis Index. In order to account for the influence of geographic distance between sites on floristic similarity, a Mantel test with 999 permutations was conducted, using a matrix of Euclidean distances for the geographic data and a matrix of Bray-Curtis distances.

The effective number of species (q = 0, and q =1) was estimated (Hill, 1973); in order to compare q = 0 among the different sites, rarefaction curves were used with 84% and 95% confidence intervals (Colwell *et al.*, 2012). The values of q = 1 were compared, as recommended by Jost (2006). The non-parametric estimator Chao1 was used to generate the expected number of species (Chao, 1984).

The importance value index (IVI) was estimated for each species (Curtis & McIntosh, 1951). Standardised range abundance curves were produced in order to compare the arrangement of the communities among the different sites (McGill *et al.,* 2007). Differences among sites in terms of the density of individuals, trunk diameter and height of the woody flora were evaluated using a Kruskal-Wallis non-parametric analysis of variance (Ostertagová *et al.*, 2014). Data normality was previously rejected with a Shapiro-Wilk test. Histograms of the diameter and height class of the woody flora present in the different sites were generated. The diameter classes were grouped by 5cm intervals. For height, three categories were used, corresponding to the strata reported in the areas close to the region of study (Bravo-Bolaños *et al.*, 2016). All analyses were conducted in R v. 3.5 (R Development Core Team, 2018).

Results

A total of 2,922 individual trees were surveyed, these belonging to 50 families, 123 genera and 163 species. Some of these species have restricted distributions or are catalogued under risk categories, according to the IUCN and the NOM-059-SEMARNAT-2010 (Supplementary Material, Appendix 3, Table C1). The ADONIS test indicated the existence of significant differences in species composition among the sites used by Military Macaws ($r = 0.48576$, $p < 0.05$). The SIMPER analysis showed that the species that contributed considerably to the differentiation of the groups were *Ateleia standleyana* (ratio = 3.0234, $p < 0.05$) and *Croton draco* (ratio = 6.5323, $p < 0.05$), which were present only in the avoided sites, while *Brosimum alicastrum* (ratio = 1.7664, $p < 0.05$) and *Oxandra lanceolata* (ratio = 1.6990, $p < 0.05$) stand out in the nesting/roosting and feeding sites. The cluster analysis (Supplementary Material, Appendix 1, Figure A2) grouped the avoided sites group with three feeding sites, and another grouping included one feeding site together with the nesting/roosting sites ($r = 0.82$). The floristic similarity was unrelated to geographical distances (Mantel Test: $r = 0.1731$, $p = 0.193$).

The rarefaction curves indicate that, from a sampling effort of 13 transects, a statistically significant difference is present in species richness among sites, with the highest values recorded in nesting/roosting and feeding sites (Supplementary Material, Appendix 1, Figure A3). The nesting/roosting and feeding sites are 2.2 and 2 times more diverse, respectively, than the avoided sites (Table 1).

Comparing the Chao1 index, completeness of sampling was better in nesting/roosting sites and lower in feeding sites (Table 1). The species with the highest IVI in the nesting/roosting and feeding sites included *B. alicastrum*, *O. lanceolata, H. polyandra* and *A. guacuyule,* which (apart from *O. lanceolata*) are consumed by Military Macaws, while at least for the ten species highlighted in this regard in avoided sites, there is no evidence that they are used by the macaws for feeding or nesting (Supplementary Material, Appendix 3, Table C1). Of the 23 species

TABLE 1

True diversity and sampling completeness of the different sites. The first value (q = 0) is equivalent to the species richness, while the second value (q = 1) indicates the number of species that present the same abundance in the community.
[Diversidad verdadera y completitud del muestreo de los diferentes sitios. El primer valor (q = 0) es equivalente a la riqueza de especies, mientras el segundo (q = 1) indica el número de especies que presentan la misma abundancia en la comunidad.]

Sites	q = 0	q = 1	Chao1	Completeness (%)
Nesting/roosting	83	43.9	94.3	88.01
Feeding	118	39.9	158.1	74.6
Avoided	58	20.3	73.1	79.3

recorded in the study region to supply part of the macaw diet (Supplementary Material, Appendices 2 & 3, Tables B1 & C1), 13 species were collected in the nesting/roosting sites, the most abundant being *B. alicastrum, O. lanceolata,* and *H. polyandra* (Figure 1). In the feeding sites, 19 food source species were collected, of which the highest number of individuals were found for *Casearia corymbosa*, *H. polyandra*, and *A. guacuyule* (Figure 1). In the avoided sites, there were seven food source species but they were not among the most abundant present (Supplementary Material, Appendix 3, Table C1).

Density of individuals, trunk diameter and height of the woody flora differ significantly from a normal distribution (respectively: $W_{16} = 0.87565$, p-value = 0.03322; $W_{2922} = 0.68278$, $p < 0.0001$; $W_{2922} = 0.83361$, $p < 0.0001$). The nesting/roosting sites presented woody flora of statistically greater height ($h_2 = 103.43$, $p < 0.0001$) and diameter

TABLE 2

Comparison of structural variables of diameter at breast height (DBH), height and density of the woody flora in the nesting/roosting, feeding and avoided sites.
[Comparación de las medias de las variables estructurales: densidad, altura y diámetro a la altura del pecho (DHB) de la flora leñosa de los sitios de anidación/dormidero, alimentación y evitados.]

Sites	DBH (cm)	Height (m)	Individuals/ha
Nesting/roosting	23.70 ± 1.0 [a]	11.70 ± .31 [a]	385 ± 71.66 [a b]
Feeding	18.31 ± .48 [b]	8.47 ± .15 [b]	231.71 ± 15.59 [a]
Avoided	14.26 ± .64 [c]	8.17 ± .17 [b]	514.37 ± 51.30 [b]
Kruskal-Wallis	$h_2 = 87.43$ $p < 0.0001$	$h_2 = 103.43$ $p < 0.0001$	$h_2 = 10.01$ $p < 0.01$

Different letters denote significant differences

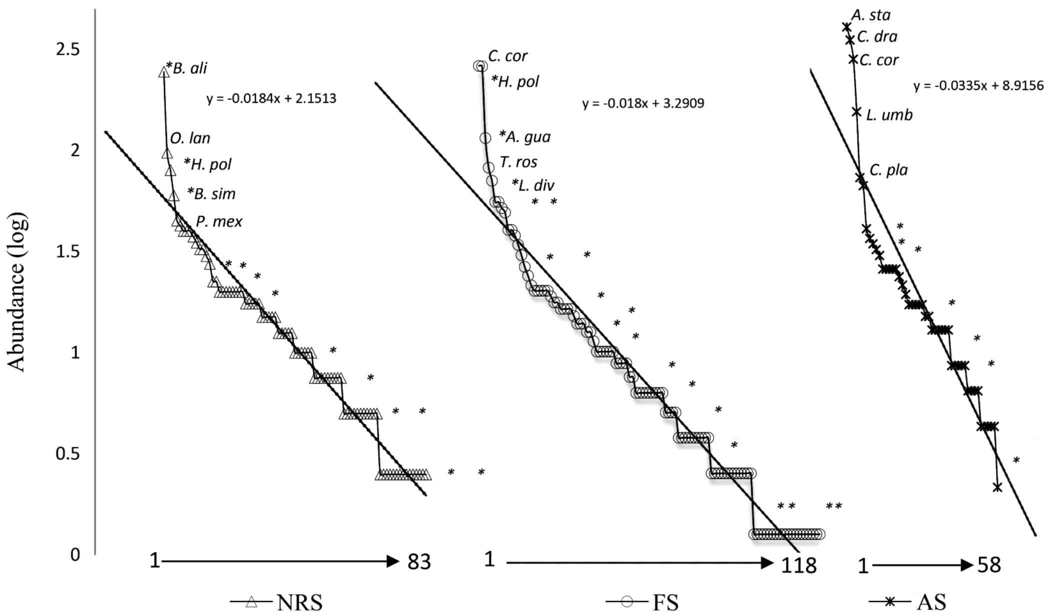

FIG. 1.—Range-abundance curves of nesting/roosting (NRS), feeding (FS) and avoided sites (AS). The Y axis represent species abundance on a logarithmic scale and the X axis represents the order of higher to lower abundance of the different species recorded. The five most abundant species are represented on each curve: *A sta = Ateleia standleyana, A. gua = Attalea guacuyule, B. ali = Brosimum alicastrum*, *B. sim = Bursera simaruba*, *C. pla = Coulteria platyloba*, *C. cor = Casearia corymbosa*, *C. dra = Croton draco*, *H. pol = Hura polyandra*, *L. umb = Lippia umbellata*, *L. div = Lysiloma divaricatum, O. lan = Oxandra lanceolata*, *P. mex = Piranhea mexicana,* and *T. ros = Tabebuia rosea*. Species that form part of the diet of Military Macaw are marked with an asterisk (*).
[Curvas de rango abundancia de los sitios de anidación/dormidero (NRS), alimentación (FS) y evitados (AS). El eje Y representa la abundancia de las especies en una escala logarítmica. El eje X representa el orden de mayor a menor abundancia de las diferentes especies registradas. Se representan las cinco especies más abundantes en cada curva: A sta = Ateleia standleyana, A. gua = Attalea guacuyule, B. ali = Brosimum alicastrum, B. sim = Bursera simaruba, C. pla = Coulteria platyloba, C. cor = Casearia corymbosa, C. dra = Croton draco, H. pol = Hura polyandra, L. umb = Lippia umbellata, L. div = Lysiloma divaricatum, O. lan = Oxandra lanceolata, P. mex = Piranhea mexicana, *y* T. ros = Tabebuia rosea. *Se marca con un asterisco (*) las especies que forman parte de la dieta del guacamayo militar.]*

($h_2 = 87.54$, $p < 0.0001$), while the avoided sites presented woody flora of lower diameter (Table 2). The density of individuals per hectare was considerably greater in avoided sites and nesting/roosting sites than in feeding sites (Table 2). In terms of the diametric classes, the nesting/roosting sites presented a lower percentage of individuals (24.8%) of reduced diameter and a greater proportion of individuals (35.3%) of diameter ≥ 22.6cm; the opposite pattern applied in the avoided sites and feeding sites (Supplementary Material, Appendix 1, Figure A4a). The nesting/roosting sites presented the lowest value (23.05%) of individuals of < 5m in height but the highest percentage (25.4%) of individuals ≥ 15.1m, a result that differs from the patterns found in the feeding and avoided sites (Supplementary Material, Appendix 1, Figure A4b).

Discussion

Rubio-Rocha *et al*. (2007) and Rivera-Ortíz *et al*. (2013) note that Military Macaws only frequent the best conserved and more diverse forested sites in the landscape. Our results support this finding since nesting/roosting and feeding sites presented approximately twice the amount of diversity than the avoided sites. Similarly, the floristic composition of the nesting/roosting and feeding sites differed statistically from that of the avoided sites, unlike between nesting/roosting and feeding sites (Supplementary Material, Appendix 1, Figure A2). The data analysed are evidence that the nesting/roosting sites harbour woody flora of greater height and DBH than the feeding and avoided sites. This agrees with other reports (Morales-Pérez, 2005; de la Parra-Martínez *et al*., 2015) that indicate that Military Macaws nest, feed and roost at sites that feature tall and thick trees, increasing the chances of finding suitable cavities. The avoided sites presented woody flora of less height and smaller diameters than those of the nesting/roosting sites. Selective logging has possibly occurred in these areas, targeting the larger trees for timber (Avilés-Ramos, 2016; Bravo-Bolaños *et al.,* 2016). This results in a forest structure with fewer thick tree trunks and therefore a low number of cavities suitable for nesting (Marsden & Pilgrim, 2003). In the avoided sites, the most abundant plant species, such as *A. standleyana*, *C. corymbosa* and *C. draco* (Figure 1), are not used by Military Macaw for feeding, and their dimensions are not adequate for nesting cavities. In addition, these plant species are commonly associated with degraded soils, disturbed forests, high solar exposure and secondary succession (Linares & Sousa, 2007; Ramón, 2009; López-Toledo *et al.,* 2012).

Various studies have reported that the Military Macaw uses up to 10% of plant species as food in other regions (Loza-Salas, 1997; Íñigo-Elías, 1999; Gaucín, 2000; Contreras-González *et al*., 2009), but the present study found a slightly higher proportion of species, 14.1%, reported as food sources. This apparent higher proportion of food plant species could result from the sampling methodology used, which considered three vegetation variants. Our results also confirm preliminary observations that plant species that provide food resources for the Military Macaw are often present in the nesting sites; therefore, the selection of nesting forest stands by the macaws may be influenced by tree cavity availability and the presence of higher proportions of trees used as food.

It has been argued that tropical subdeciduous forest is preferred by Military Macaws since the natural detachment of large tree branches forms cavities in the trunks suitable for these birds (Monterrubio-Rico *et al*., 2014). This is perhaps why Military Macaws in the study region seem to prefer to nest in *P. mexicana*, a tree considered a key species for the macaw population in the region, as it is the only species where two or three nesting pairs may use different cavities in the same tree simultaneously for nesting (Bonilla-Ruz *et al.,* 2014; Avilés-Ramos, 2016). As a consequence, this tree species merits attention in terms of its conservation status, given that it is only found in this habitat. Moreover, it is the only Mexican species of the genus and is endemic to the tropical forests of the Jalisco coast, southern Sinaloa and northern Nayarit (Pennington & Sarukhán, 2005). Conversely, the importance of *O. lanceolata* that we detected was unexpected, since there is no previous evidence that the Military Macaw uses this species. The possibility thus exists that Military Macaws make direct use of this tree, although no supporting evidence is yet available, and this should be investigated in future studies.

The Mexican Pacific coast has experienced an important loss of primary forest, which is inhabited by populations of at least seven parrot species (Marín-Togo *et al.,* 2012). Due to the reduction of the tropical subdeciduous forest in which Military Macaws nest, and of the forest that provides their diet at a local level, it is necessary to restore forests by increasing the abundance of plant species that provide their food supply, as well as the tree species that reach larger dimensions for future nest cavities. It is also important to inform local inhabitants of the importance of old growth forest fragments (Monterrubio-Rico *et al*., 2014). Reduction or loss of species on which Military Macaws feed, or in which they nest, may limit their nesting success and eventually contribute to the decline of their populations (de la Parra-Martínez, 2016). Patches of vegetation with an abundance of *P. mexicana* and *O. lanceolata* and with large trees that provide food should be demographically monitored and strictly conserved. We concur with Rivera-Ortiz *et al*. (2017), who consider that such activities as ecotourism, scientific research, community work and environmental education could be the most appropriate avenues for the management and conservation of the habitat of this species in the region.

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Supplementary Electronic Material

Additional supporting information may be found in the on-line version of this paper. See the volume 67(2) on www.ardeola.org

Appendix 1

Figure A1. Locations of sampled sites.

Figure A2. Cluster analysis of the eight study sites.

Figure A3. Rarefaction curves.

Figure A4. Structural synthesis of the woody flora communities from sampling sites.

Table A1. Species with highest ecological importance value index (IVI) values.

Appendix 2

Table B1. Woody flora reported in the Military Macaw diet in Mexico.

Appendix 3

Table C1. Plant species list by risk category (IUCN and NOM-059-SEMARNAT-2010), as well as forest type where each was collected.

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