Diet of the critically endangered brown-headed spider monkey (*Ateles fusciceps fusciceps)* in the Ecuadorian Chocó: Conflict between primates and loggers over fruiting tree species

Citlalli Morelos-Juárez, Andrea Tapia, Galo Conde, Mika Peck

Identifying key food resources for critically endangered species is vital in the design of effective conservation strategies, particularly if these resources are also targeted by anthropogenic activities such as logging. The province of Esmeraldas in NW Ecuador is heavily dependent on commercial logging. It also maintains the only healthy population of the critically endangered brown-headed spider monkey (*Ateles fusciceps fusciceps*). The unprotected forest remnant of Tesoro Escondido, in the buffer zone of the Cotacachi Cayapas Ecological Reserve, is home to an estimated 130 individuals of a global population of approximately 250. There is an urgent need for information to develop effective conservation action plans for the species, in particular the impact of logging activity on key feeding resources. We characterised the floristic composition of the habitat of *A. f. fusciceps* and estimated the availability of fruit resources for the annual cycle of 2012-2013 in sixteen 0.1 hectare vegetation plots. We determined feeding preferences for *A. f. fusciceps* using behavioural observations applying the Chesson ε index to identify key feeding tree species. We reviewed regional logging permits to identify species targeted for extraction by the timber industry and calculated extraction volumes in primary forest for key feeding tree species to identify potential conflict between logging and primate diet. We identified 65 fruiting tree species from 34 families that formed the diet of *A. f. fusciceps.* The Chesson ε index identified twelve species as *preferred species* with further phenological observations identifying seven species as *staple foods* and two palms as potential *fall back fruits*. Additionally, high densities of the lipid rich fruits of *Brosimum utile* make this an important resource for this primate throughout the year. Of 65 feeding tree species identified for *A. f. fusciceps*, 35 species are also targeted as sources of timber. Five key feeding species would be depleted under current sustainable management extraction protocols while two other species would be significantly impacted in terms of local abundance.Given the critically endangered status of *A. f. fusciceps*, remaining primary forest in NW Ecuador requires urgent protection, including thorough revision of current logging protocols to ensure long term survival of the species.

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Diet of the critically endangered Brown-headed Spider Monkey *Ateles fusciceps fusciceps* in the Ecuadorian Chocó: Conflict between primates and loggers over fruiting tree species

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ABSTRACT

Identifying key food resources for critically endangered species is vital in the design of effective conservation strategies, particularly if these resources are also targeted by anthropogenic activities such as logging. The province of Esmeraldas in NW Ecuador is heavily dependent on commercial logging. It also maintains the only healthy population of the critically endangered brown-headed spider monkey (*Ateles fusciceps fusciceps*). The unprotected forest remnant of Tesoro Escondido, in the buffer zone of the Cotacachi Cayapas Ecological Reserve, is home to an estimated 130 individuals of a global population of approximately 250. There is an urgent need for information to develop effective conservation action plans for the species, in particular the impact of logging activity on key feeding resources. We characterised the floristic composition of the habitat of *Ateles fusciceps fusciceps* and estimated the availability of fruit resources for the annual cycle of 2012-2013 in sixteen 0.1 hectare vegetation plots. We determined feeding preferences for *A. f. fusciceps* using behavioural observations applying the Chesson ε index to identify key feeding tree species. We reviewed regional logging permits to identify species targeted for extraction by the timber industry and calculated extraction volumes in primary forest for key feeding tree species to identify potential conflict between logging and primate diet. We identified 65 fruiting tree species from 34 families that formed the diet of *Ateles fusciceps fusciceps*. The Chesson ε index identified twelve species as *preferred species* with further phenological observations identifying seven species as *staple foods* and two palms as potential *fall back fruits*. Additionally, high densities of the lipid rich fruits of *Brosimum utile* make this an important resource for this primate throughout the year. Of 65 feeding tree species identified for *A. f. fusciceps*, 35 species are also targeted as sources of timber. Five key feeding species would be depleted under current sustainable management extraction protocols while two other species would be significantly impacted in terms of local abundance.Given the critically endangered status of *Ateles fusciceps fusciceps* remaining primary forest in NW Ecuador requires urgent protection, including thorough revision of current logging protocols to ensure long term survival of the species.

Keywords: *Ateles fusciceps fusciceps*, Conservation, Diet, Chocó, Logging industry, Resources

INTRODUCTION

The brown-headed spider monkey *Ateles fusciceps fusciceps* is one of the 25 most endangered primates globally (Schwitzer et al., 2014), it is considered critically endangered (IUCN Red List 2014) with an estimated remaining population of 250 individuals (Tirira, 2004). They can be found in the tropical and subtropical forests of Esmeraldas province (NW Ecuador) within the Tumbes-Chocó-Magdalena biodiversity hotspot (Myers et al., 2000). As with other biodiversity hotspots, this forest ecosystem is characterized by its high levels of endemism and accelerated historical and current rates of habitat loss. The main threats faced by the brown-headed spider monkey are habitat loss and hunting, both of which have caused a reduction of 80% in population size over the last 45 years (Tirira, 2004). Habitat loss in Esmeraldas is mainly a result of commercial and domestic timber extraction and land conversion to monocrops, such as the African palm. Esmeraldas has become one of the principal exporters of monocrop products, such as palm oil and banana. The palm oil business is considered to have converted between 60,000 and 100,000 hectares of forest in that province (Buitrón, 2001). Regional reports suggest that coastal forests in Western Ecuador have been reduced to 2% of the original coverage, leading to a rapid reduction in wildlife, especially in forests below 300 m.a.s.l., which are not included within current national protected areas (Critical Ecosystem Partnership Fund, 2005).

Habitat loss in particular has affected populations of *A. f. fusciceps* . The species requires a large home range of old growth unfragmented forest with sufficient fruit resources and forest loss has drastically reduced its population densities (Madden and Albuja (1989); Tirira (2004)). Moreover, in NW Ecuador the remaining suitable habitat of 989km^2 lies in unprotected areas (Peck et al., 2010).

Primates of the genus *Ateles* are forest dwelling, frugivorous and heavily dependent on ripe fruits; between 75% and 90% of their diet is based on fruit (Wallace, 2005; Di Fiore et al., 2008). They also feed on new leaves (preferring the leaves of trees from families Cecropiaceae, Menispermaceae, Malvaceae, Passifloraceae and Fabaceae) and consume flowers, insects and seeds in lower proportions. The genus *Ateles* is considered a ripe fruit specialist, with a high preference for fruits with elevated nutritional content (such as proteins and lipids) over nutritionally poorer yet more abundant food resources (Dew, 2005; Stevenson, 2000a).

In disturbed and fragmented habitat the availability of some plant species is reduced, leading to significant impacts on nutrition, physiology and stress to spider monkeys (Pozo-Montuy and Serio-Silva, 2006). Temporal and spatial variation in the availability of fruit has also been reported to have major repercussions on the distribution, grouping, sociality and reproduction of primates (Janson, C. H. Van Schaik, 1993). For instance, it has been observed that reproduction coincides with times of maximal fruit production (Knott, 1998), most probably to maximize survival of newborns (Di Fiore et al., 2008). It is important to note that the high degree of fission-fusion shown by spider monkeys is also thought to be related to resource availability (Di Fiore et al., 2008).

Spider monkeys play a vital role in the maintenance of the diversity of the forest in terms of ecosystem function as seed dispersers (Stevenson, 2000b), especially in NW Ecuador, where *A. f. fusciceps* is the only arboreal disperser of large seeded fruit trees and hence plays a critical role in tree diversity in these forests (Calle, 2013). Reduction in abundance of spider monkeys may also impact the ecological sustainability of selectively logged forests (Link et al., 2006). NW Ecuador, particularly Esmeraldas province, relies economically on activities associated with commercial logging (Stallings and Sierra, 1998; Sierra, 2001); it is also the province where the only healthy population of *A. f. fusciceps* has been found (Moscoso, 2010). The relationship between species targeted by commercial timber extraction and key resources for spider monkeys has been previously reported by Felton et al. (2010) in a reduced impact logging (RIL) concession in Bolivia, however, this is the first study in NW Ecuador investigating conflict over key resources between logging activity and spider monkeys.

Identifying key food resources for this endangered primate is vital for their effective conservation. Furthermore establishing whether competition exists between *A. f. fusciceps* and the timber industry over these resources would enable more effective design of forest management plans and ensures species survival. In this study our objectives were to: 1) Characterize the floristic composition of the habitat of *A. f. fusciceps* ; 2) Estimate the availability of fruit resources for brown-headed spider monkeys throughout an annual cycle; 3) Identify key feeding tree species and 4) Based on legal regional logging permits, identify conflict between feeding requirements of *A. f. fusciceps* and logging activity.

METHODS

Study site

The study site is located within the Tesoro Escondido forest cooperative (referred as Tesoro from now on) which lies in the buffer zone of the Cotacachi Cayapas Ecological Reserve (CCER) in the Chocó Biogeographic Region in NW Ecuador (0°31" N 79°0' W). This study site was chosen as it harbours the highest density of *A.f.fusciceps* in NW Ecuador (Moscoso, 2010).

The study area has been classified as evergreen lowland tropical forest by Sierra (1996). This type of vegetation is restricted in Ecuador to Esmeraldas Province and areas north of Manabi (Sierra, 1999). It

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is characterised by the presence of trees taller than 30 metres and dominated by species of the families Myristicaceae, Arecaceae (Palmaceae), Moraceae, Fabaceae and Meliaceae.

Mean annual precipitation in the Chocó ecoregion is 6000mm, ranging from 4000 to 9000 mm annually (Vázquez and Freile, 2005; Vargas, 2002) with two distinct seasons. The rainy season runs from November until May and the dry season from June to October. Altitude in Tesoro ranges from 163 to 687 m.a.s.l. The nearest human settlements to the study area are Hoja Blanca to the Northwest (6km), Chontaduro to the North (5km) and Cristóbal Colón to the South (15 km), whereas the nearest protected areas are El Pambilar Wildlife Refuge to the North (8km) and the CCER to the Northeast (30km) (see Figure 1). Permission for research was granted by the Ecuadorian Ministry of Environment (Ministerio del Ambiente) No: 001-2013-IC-FLO-FAU-DPE-MA. Tesoro encompasses around 3000 hectares of

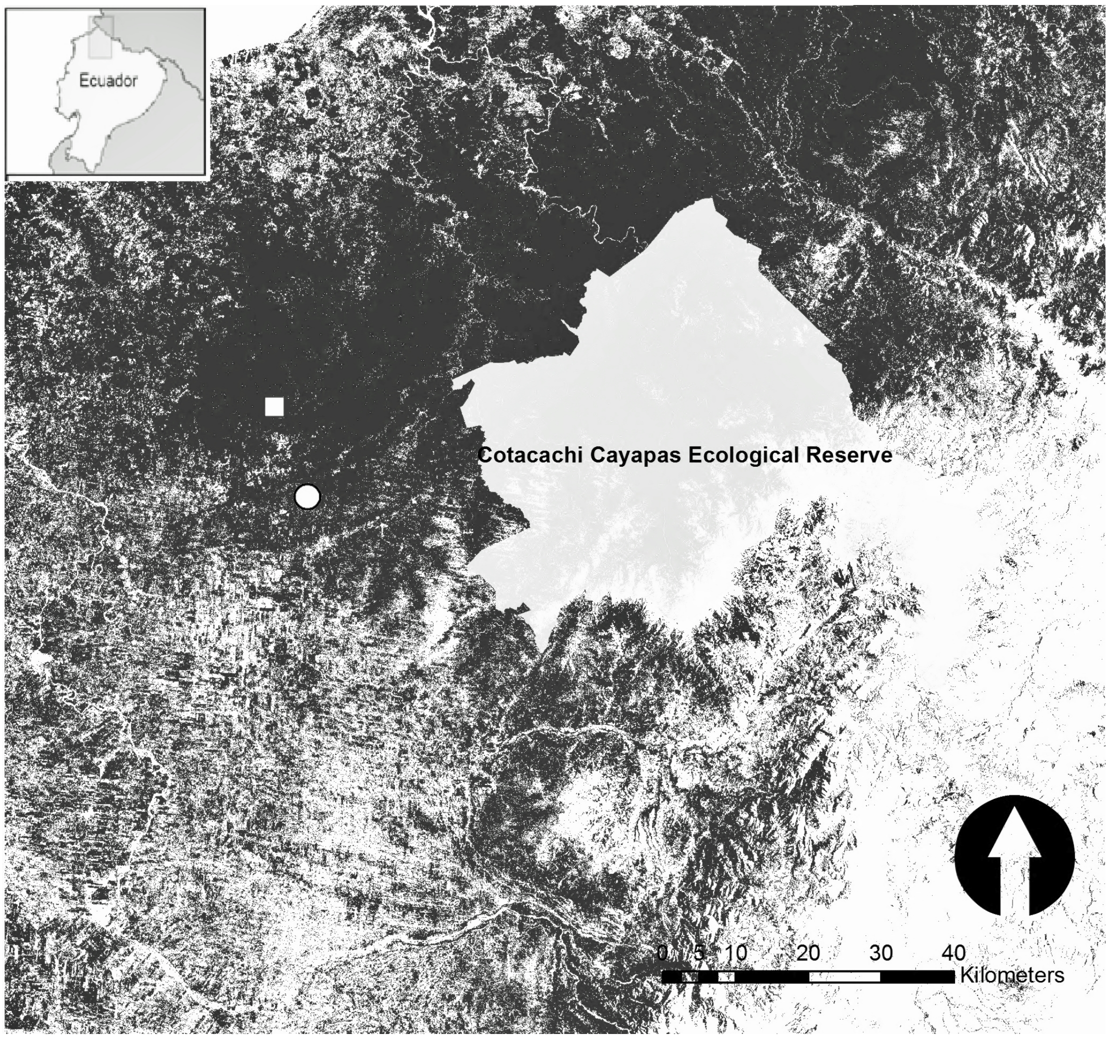

Figure 1. Location of the study site Tesoro Escondido (circle) in reference to the Cotacachi Cayapas Ecological Reserve and the Pambilar Wildlife Refute (square) in NW Ecuador. Background layer shows remaining forest in the region (adapted from Hansen et al. (2013)

unprotected land, of which approximately 6% has been converted into fields for crops and pasture by resident farmers. The remainder is primary forest interspersed with small secondary forest patches (pers. obs.).

As a remnant of the Chocó forests, Tesoro is incredibly biodiverse (Myers et al., 2000), however it also lies within a mosaic of social and economic influences which impact on the conservation of its forests. The agricultural frontier advances towards primary forests mainly through establishment of cacao plantations and expansion of pastures, moreover pressure from extractive companies in the area is further reducing and fragmenting primary forests at a rapid pace.

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Commercial timber extraction is principally undertaken by two companies: Endesa-Botrosa S.A and Verde Canandé. The timber company Endesa-Botrosa S.A. operates in lands around Tesoro in the Canandé Watershed. They legally own at least 25 thousand hectares of primary forest, and 600 hectares are in Tesoro itself. Verde Canandé is a smaller timber company also operating around Tesoro, established as a community based business, with the aim of practicing low impact timber harvest and implementing sustainable forestry.

Study design

Prior to sampling we opened a 4.5km transect (trail A) in a North to South direction at Tesoro. We mapped the transect by taking GPS points (Garmin eTrex Legend) at 25m intervals. We used this transect principally for primate population and behavioural surveys.

As no phenological studies for this particular forest exist and there is no dietary information for *A. f. fusciceps* , we applied the Area Based Method as suggested by Marshall and Wich (2013). This method provides phenological data for potential food species, allowing further analysis for feeding selectivity. It monitors all plant stems that meet a basic criteria (i.e. Diameter at Breast Height (DBH) >10cm) within a delineated area (plot), throughout the focal species range (Marshall and Wich, 2013).

We established 16 rectangular plots (Marshall and Wich, 2013) of 10m x 100m every 250m on either side of the existing transect. Stems were included within the plot if more than half of the stem area fell inside the plot.

In each plot all trees with a DBH greater than 10 cm were tagged and identified on site to species level by a local expert where possible. For each tagged tree we measured DBH and estimated its height. For trees whose identification was not possible on site, samples were collected following standard protocols (Rodriguez and Rojas, 2006) for further identification at the National Herbarium in Quito. Lianas were not included in the phenology surveys.

Each month from July 2012 to July 2013 the crowns of all individual trees were inspected with binoculars, to detect the presence of flowers and fruits. As we were unfamiliar with the fruits we did not make any distinction between ripe and immature fruits.

Fruit availability

We calculated a monthly index of fruit availability for spider monkeys in Tesoro using the basal area of trees. Basal area is considered to be an accurate index of fruit crop size (Peters et al., 1988), and has been previously used by Felton et al. (2008) to estimate food availability in a study on Peruvian spider monkeys (*Ateles chamek*). We included all trees from the vegetation plots since we did not know *a priori* which species formed part of the diet of *A. f. fusciceps*. We also included trees that were recorded as feeding trees during behavioural field observations of spider monkeys but were not present in the plots.

For trees we calculated the index as follows:

Monthly Tree index (index T):

$$\text{IndexT} = \sum_i (pi \times BAi) \times 100 \tag{1}$$

where *pi* is the proportion of surveyed individuals of species *i* that were observed carrying fruits or flowers each month, and *BAi* is the basal area per hectare of species *i*.
We also calculated an index for palms. In this case we did not use the basal area for the calculation since palm trunks do not grow incrementally and are therefore not a good indicator of fruit crop size. Instead we used their densities, as described in Felton et al. (2008).

Monthly Palm Index (Index P):

$$\text{IndexP} = \sum_i (pi \times di) \times 100 \tag{2}$$

where *pi* is the proportion of surveyed individuals of palms observed carrying fruits or flowers each month and *di* is the density of palms.

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Feeding tree species for *A. f. fusciceps* in Tesoro

Activity budget data was collected by following and observing groups of spider monkeys both on and off Trail A. We carried out 10 minute instantaneous group sampling (adapted from Altmann (1974) to record subgroup numbers, composition and activity. When an individual or a subgroup of spider monkeys was observed feeding on a tree for more than five minutes the species of tree (if known) and the plant part (flower or fruit) was recorded. The tree was tagged, DBH measured and a geographic positioning system (GPS) waypoint was taken. We used a correlation test (Spearman's correlation coefficient) to determine whether the size of trees (DBH) was related to the time spent feeding by spider monkeys. Fruit samples of feeding trees were collected, dried and bromatological analysis was undertaken in the Food Laboratory at the Universidad San Francisco de Quito (USFQ), to determine their caloric value. Values obtained were: percentage of water by using the Halogen Lamp Method, crude protein by the Kjeldahl Method (Barreto et al., 1990) and lipids by the Soxhlet Method (Soxhlet, 1879).

Preference index

We calculated a selectivity index (Chesson ε index) to determine food species preference for *A. f. fusciceps*. This index compares the proportion of a given tree species in the diet with the relative availability of the trees in the environment. It allows ranking of tree species in order of frequency in the diet. Its main advantage is that it is unaffected by changes in relative tree species abundance (Chesson, 1983).

This index is based on Manlys α selection index, applicable in situations where the feeding activity is assumed not to deplete the plant species, as is the case with spider monkeys. Chesson's ε (Chesson, 1983) ranges from -1 to +1. Negative values represent fruits that are 'avoided' (According to Chesson, 'avoidance' refers to those species appearing less frequently in the diet than their availability in the environment allows). An index value of 0 suggests no selective feeding on that particular plant species. This index has previously been used in the study of food selection by primates (i.e. Harrison (2009); Rivera and Calmé (2005) and is calculated as follows:

$$\varepsilon = (m\alpha - 1)/((m-2)\alpha + 1, \tag{3}$$

where m is the total number of fruit species in the diet; α is calculated as follows:

$$\alpha = \frac{ri/pi}{\sum_i (ri/pi)} \tag{4}$$

where ri is the percentage of time primates spend feeding on species i throughout the year and pi is the relative abundance of species i in the environment (based on basal area/ha from vegetation plots). Due to the small number of observations of feeding activity on leaves and flowers, they were not included in the analysis.

Identifying conflict over keystone feeding trees

We requested access to permits granted for timber extraction from the Ecuadorian Ministry of Environment (MAE) for the Esmeraldas Province from the past four years (2010-2014) for each tree species. This information is available to the public upon official request. They contain the specific location of extraction with coordinates, type of extraction programme (i.e. native trees, sustainable extraction, plantation) name of the company (or person) responsible for the plot, the duration of the permit (mostly between 90 and 365 days), the tree species (with scientific and common names), the size of the land in hectares, the volumes approved to be extracted and the volumes that were actually extracted and mobilized.

We filtered the information to obtain volumes approved for extraction only for the species that we identified as key species for spider monkeys (see Chesson index results) as well as staple fruit trees (trees that were consumed throughout the year). For these species we chose the highest volume per hectare that was approved for extraction based on their sustainable extraction protocols.

We calculated the volumes of key fruit species from the vegetation plots and subtracted the maximum volume per hectare. We then compared the original available volume of key fruit species per hectare in our plots with that following the hypothetical extraction of the maximum volume approved for each species to identify potential conflict between logging and diet.

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RESULTS

Floristic composition of the forest in Tesoro

The vegetation plots covered a total area of 1.6ha and contained 621 individual trees with DBH ¿10cm. We identified 101 individual species of trees belonging to 68 genera and 37 families. Of the 621 trees, 57 of them could not be identified to species level, this was due to difficulty in obtaining adequate samples.

The dominant family with 135 individuals was Palmaceae, 76 belonging to the genus *Iriartea* species *Iriartea deltoidea* and 59 to the genus Wettinia species *Wettinia quinaria*. The second most common family was Moraceae with 65 individuals. Most belonged to the genus *Brosimum* (dominated by *Brosimum utile*). The complete list of species in Tesoro is presented in Appendix 1.

Phenology

The highest number of trees carrying fruits was observed in the month of July, with almost 25% of trees in the plots carrying fruit. A second peak was observed in the month of May. December and January showed the lowest level of fruiting trees in the plots (see Figure 2).

There is a clear fruiting peak in the months of July and August and a decrease in the amount of available fruit in the months of December and January. For fruiting palms the opposite pattern is seen with increased availability of fruits in November and a lower abundance in July (See Figure 3), however palms provided ripe fruit almost continuously throughout the year.

Seven species of trees carried fruit for at least 10 months of the year; (*Brosimum utile, Calyptranthes plicata, Trema integerrima, Virola sebifera, Protium ecuadorense, Jacaratia spinosa, Pouruma chocoana*. In addition, at least 8 species from the genus *Inga* and the two palms *Iriartea deltoidea* and *Wettinia quinaria* also carried fruit for most of the year. Of these, four species bore fruit throughout the year: (*Brosimum utile, Calyptranthes plicata, Trema integerrima* and *Virola sebifera*). All of these continuously fruiting species were seen to be part of the diet of *A. f. fusciceps* , hence we refer to them as *staple foods*.

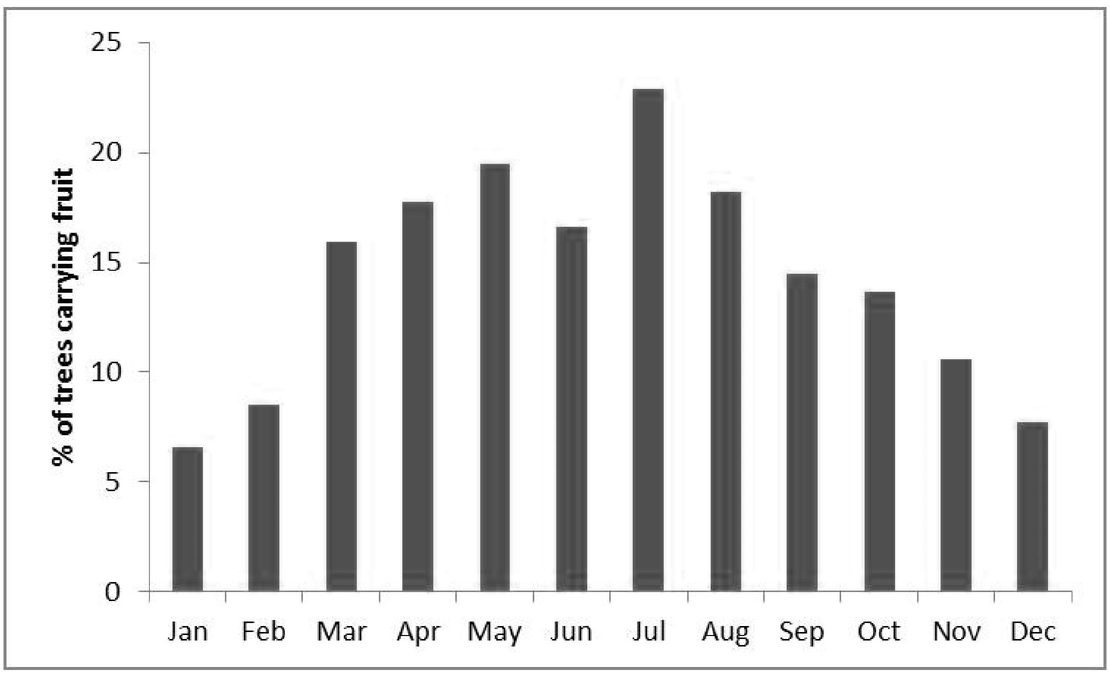

Figure 2. Percentage of fruiting trees per month in Tesoro, July 2012 to July 2013.

Feeding trees of *A. f. fusciceps* in Tesoro

Between July 2012 and December 2013, we tagged 296 different feeding trees. We identified 65 feeding trees to species level. Feeding trees belong to at least 34 families and 51 genera (See Appendix 2 for a complete list of feeding trees). Palmaceae was the dominant family with 42 trees (all of them belonging to the species *Iriartea deltoidea*), followed by Moraceae with 35 trees; 15 of which were *B.utile* and third, Myristicaceae (35 trees). The highest number of feeding tree species used by spider monkeys were

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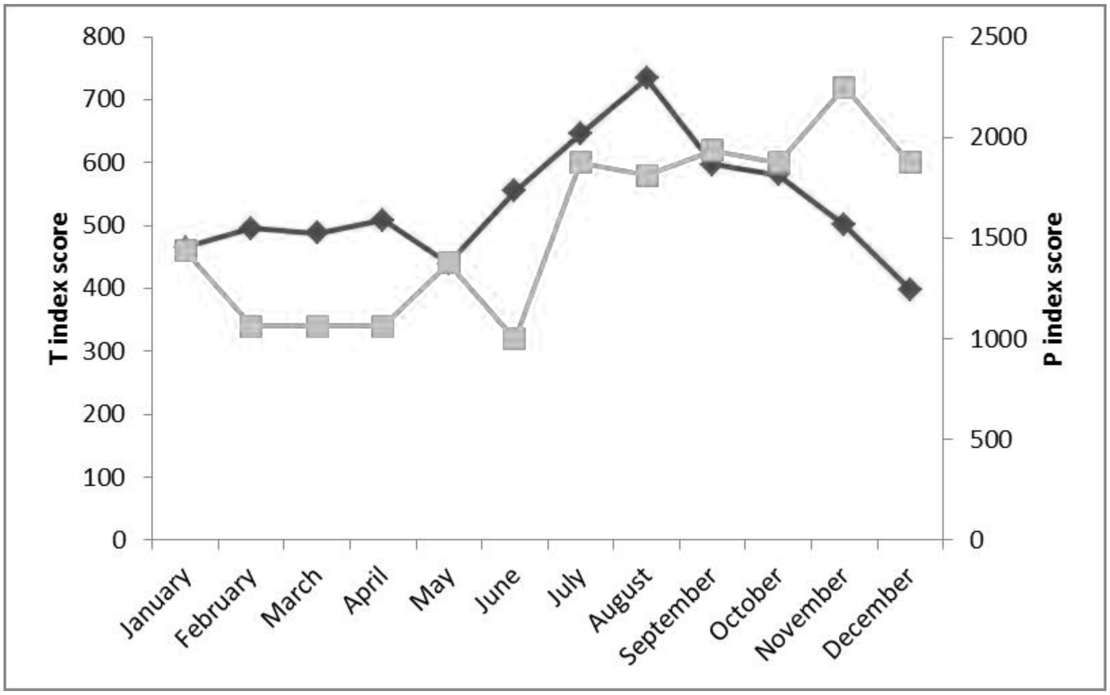

Figure 3. Monthly availability of fruit resources from trees in Tesoro Escondido, July 2012 to July 2013 shown in light grey compared to available fruits from trees shown in dark grey. We included 78 species from vegetation plots and feeding trees

in the months of August and July (Figure 4). The mean DBH for all species of feeding trees was 55.5 cm (Figure 5). There was a positive correlation between the size of feeding trees (DBH) and time (in minutes) spent feeding on them ($r = 0.24$, $n = 244$, $p < 0.001$) (Figure 6). In total 14 species of trees accounted for 80% of the total time spent feeding by spider monkeys: *Iriartea deltoidea; Calyptranthes plicata; Pouruma chocoana; Brosimum utile; Inga.sp.; Nectandra guadaripo; Clarisia biflora; Garcinia madruno; Solanum sp.; Minquartia guianensis; Calocarpum sapota; Virola dixonii; Lunania parviflora* and *Matisia sp.*). In *ad libitum* observations, spider monkeys were also seen feeding on lianas, flowers, new leaves, seeds and bark. We also observed them drinking water from bromeliads. No predation on other animals was observed.

Feeding preference

Fruit from at least 59 species of tree were seen to be consumed by spider monkeys in Tesoro during the study. The Chesson ε index identified twelve as *preferred species* (see Figure 7). Bromatological analysis was carried out on 13 of these tree species (see Table 1). Results showed that species belonging to the genus *Inga* and species *Cleidion casteneifolium* provided the highest percentages of protein, whereas *Garcinia madruno* and *Brosimum utile* ranked higher in terms of percentage of lipids. Finally *Iriartea deltoidea* and *Solanum sp* contributed higher percentages of carbohydrates.

Selective logging in Tesoro

Logging permits obtained from the Ecuadorian Ministry of Environment (MAE) comprised data from 2010 to 2014. We requested data on extraction permits for individual tree species, of which 211 permits were granted for 81 different sites in Esmeraldas. Timber extraction was carried out under 8 different types of management programme: Sustainable management, simplified management, plantations, natural regeneration, pioneer species, relict trees, legal conversion and balsa plantations (For a detailed explanation of these management programs see MAE2004a. Permits were granted for a total of 133 species.

Of 59 feeding tree species identified in Tesoro, 35 species are also targeted as sources of timber, including *preferred fruits* and *staple fruits*. Of the 16 key species shown in Figure 8, five tree species would be depleted under current sustainable management extraction protocols (over 100% extraction allowed for *Virola spp, Pouruma minor, Matisia spp., Trema integerrima, Minquartia guianensis*). Two

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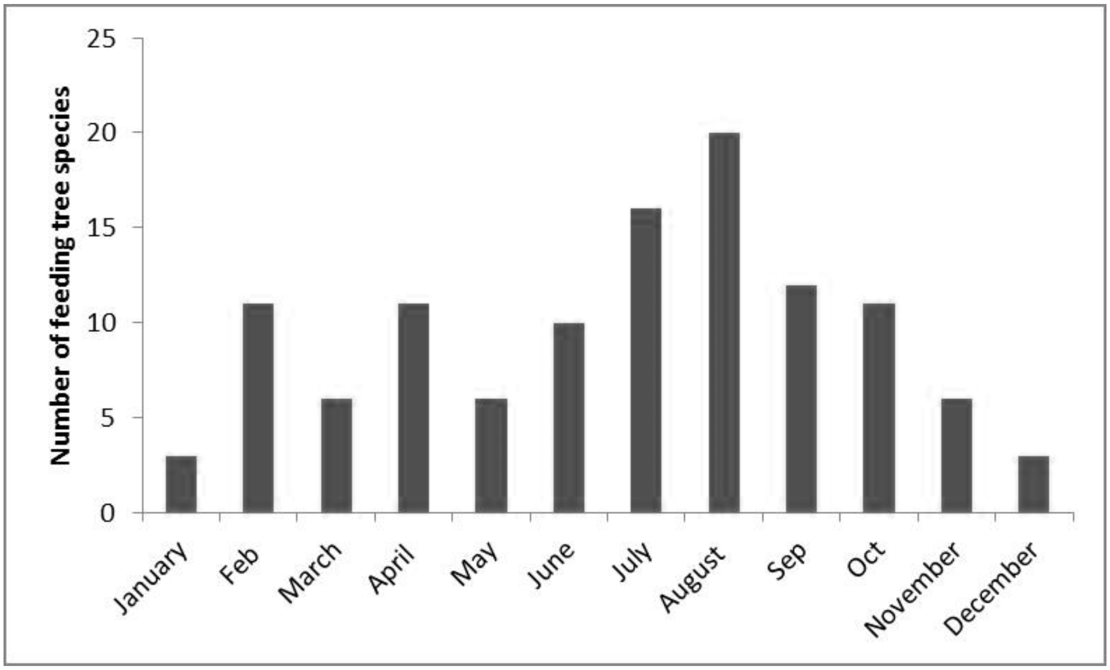

Figure 4. Number of feeding trees used per month by spider monkeys in Tesoro throughout the year

other species would be significantly impacted in terms of local abundance (69% reduction in abundance for *Ficus spp* and 90% reduction for *Protium ecuadorense*).

DISCUSSION

The results of our study in Tesoro Escondido, NW Ecuador, provide the first data set on dietary preference for the critically endangered brown-headed spider monkey.

Results of vegetation surveyed in Tesoro are consistent with other studies in the Chocó and in Esmeraldas Province (evergreen lowland tropical forest) (Sierra, 1999). We found at least 100 species (DBH >=10cm) in 1.6 ha, similar diversity to results from previous studies in the region (Valencia et al., 1988; Palacios et al., 1994; Tirado, 1994). The families Moraceae, Palmaceae and Fabaceae were dominant, however Meliaceae and Myristicaceae were underrepresented in Tesoro compared to studies by Sierra (1999). Our study also registered species that had not been reported for the genus, mainly due to the unique nature of the area and the lack of studies in NW Ecuador, for instance *Pouruma chocoana*, native to the tropical forests of Ecuador (Jorgensen and Leon, 1999).

The area-based method, used for the vegetation plots, provided a good description of habitat and fruit availability, however this particular methodology is not focused principally on feeding tree species, which tend to be rare (Marshall and Wrangham, 2007). The hybrid method (combining the area-based method and survey of feeding trees found outside plots) would have provided more information on the specific phenology of feeding trees. We recommend future work to collect phenological data of identified feeding trees outside the existing vegetation plot network. The area surveyed by the vegetation plots provides valuable information, however in forests as diverse as the Chocó, the data fails to describe the full extent of plant diversity.

The pattern of fruit availability observed is similar to that seen at a site with similar rainfall patterns in Bolivia (Felton et al., 2008). Data collection in December and January was carried out under heavy rainfall which potentially diminished the ability of observers in the field, and could account in part for the low T Index value seen for these months. On the other hand it is interesting to note that the availability of the Palmaceae family was high during these months. This suggests a role of palms as possible fall-back fruits for *A. f. fusciceps* in Tesoro when other sources of fruits are reduced.

If we compare the percentage of trees carrying fruit and the T index per month, we note a high percentage of trees in May carrying fruit however we also observe a low T index value. The reason for this lies in the fact that the T index is calculated using the basal area, which derives from the diameter of

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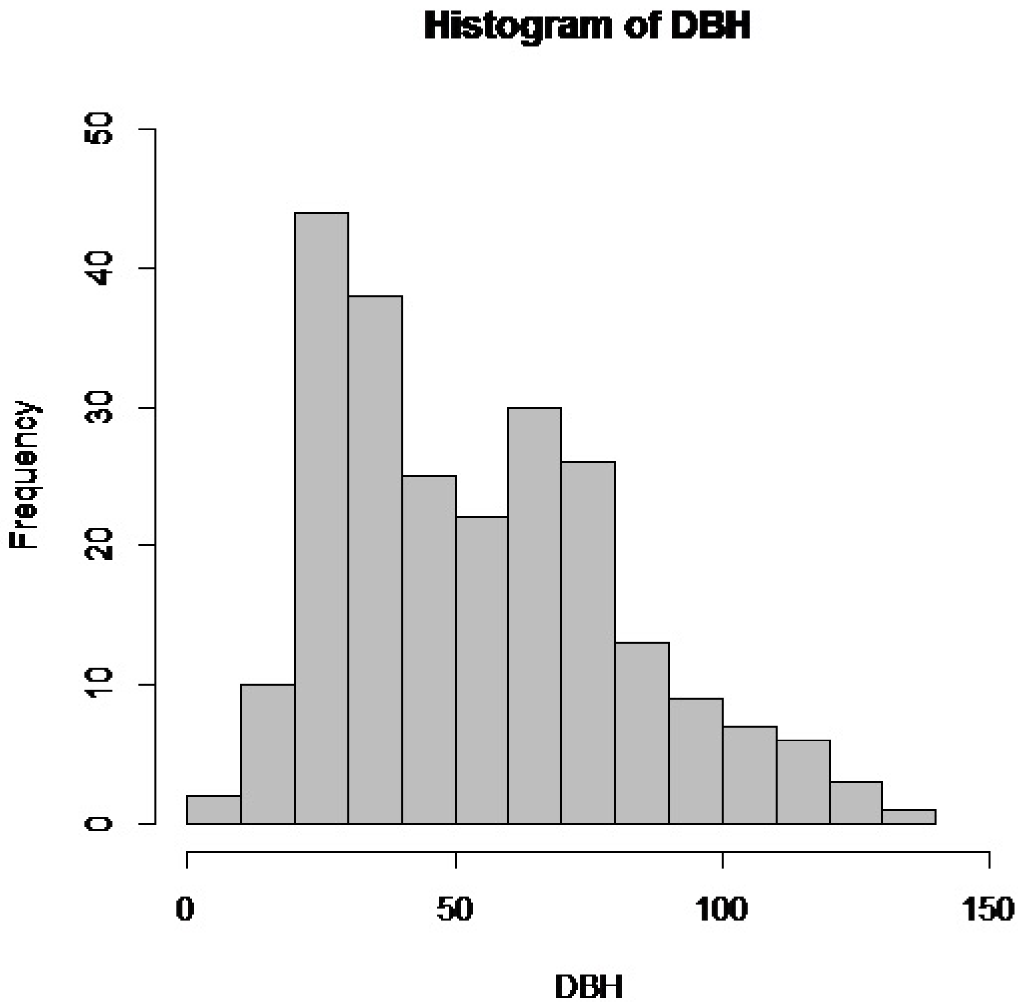

Figure 5. Frequency distribution of DBH's of feeding trees (palms not included) in Tesoro

trees. For May, there were a higher number of small fruiting trees (i.e. with a small DBH) resulting in a low overall T index value.

The analysis highlighted potential staple foods for *A. f. fusciceps* , in particular tree species fruiting throughout the year (*Brosimum utile, Calyptranthes plicata, Trema integerrima and Virola dixonii*). Of these species *Trema integerrima* is not considered an important food resource for spider monkeys in Tesoro, based on both time spent feeding and the Chesson index. On the other hand, *A. f. fusciceps* did spend a significant percentage of their total time feeding on *Brosimum utile, Calyptranthes plicata* and *Virola dixonii*. Furthermore, these three food species provide high levels of important crucial nutrients throughout the year.

Our results corroborate the use of the genus *Brosimum* in the diet of *Ateles*, previously reported in other studies (Di Fiore et al., 2008). Our data confirms the importance of *Brosimum utile* in the diet of *A. f. fusciceps* that was initially observed in a two month pilot study, where Tapia (2014) reported a higher feeding effort (number of bites per fruit) for *B.utile* compared to 28 other species. This study concludes that *A. f. fusciceps* strongly favours this tree species. Furthermore, fruits from *B.utile* show a very high lipid content, which has been reported as a factor influencing dietary preferences, especially in times of ripe fruit scarcity and during reproduction (Janson, C. H. Van Schaik, 1993; Dew, 2005). It is interesting to note that we did not find *B.utile* amongst preferred food resources according to the Chesson index

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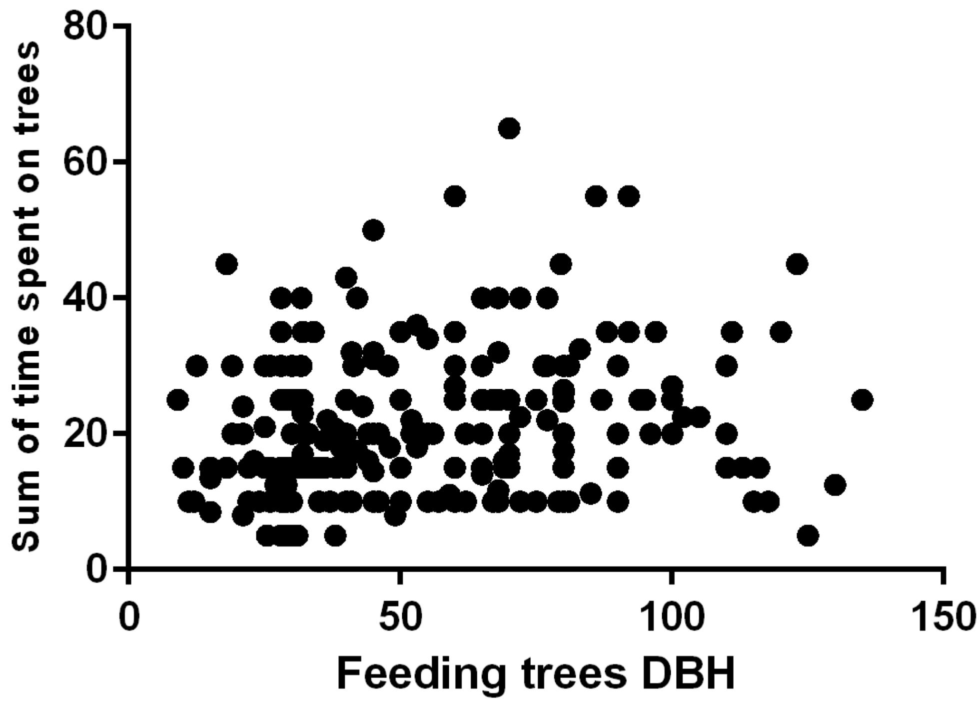

Figure 6. Scatterplot of time spent feeding (in minutes) by spider monkeys in Tesoro and tree sizes (DBH)

analysis. This is principally due its high abundance in Tesoro; the strength of the Chesson index is that it is a good method for identifying frequently used species that are at lower abundance. The importance of *B.utile* lies in the fact that it provides a high lipid food resource throughout the year for *A. f. fusciceps* , and hence we consider it a *staple food*. The Chesson index was however useful at identifying a key species in Tesoro: *Virola dixonii*, a high lipid food resource available throughout the year.

All the reported feeding data describes ripe fruit, however in *ad libitum* observations spider monkeys in Tesoro were also seen to feed on unripe fruits, leaves (mostly new leaves) and flowers (i.e. flowers from *Licania glauca*). We also observed them drinking water from bromeliads, which has been previously reported by Campbell et al. (2005) and by (Santorelli et al., 2011) for *Ateles geoffroyi*. We never saw them descending to the ground, however we did find a potential salt lick and suggest placement of camera traps at this site to further investigate possible terrestrial behaviour (Blake et al., 2010).

A limitation of this study was the fact that brown-headed spider monkeys were not habituated at the beginning of the field season, hence collecting data on activity took more time than expected. In order to habituate primates researchers need to be able to follow groups or individuals throughout the day. However in areas of extreme topography, such as in Tesoro, this becomes nearly impossible. Even with this limitation, we managed to collect data on their diet and analyse food preferences. Comparing our results with data from long-term studies with habituated groups (Di Fiore et al., 2008), we can conclude that our study provides a realistic overview of the dietary and feeding preferences of this species (MAE, 2004).

The positive correlation observed between time spent feeding and tree size (DBH) shows the preference of spider monkeys for larger trees which tend to carry larger volumes of fruit. The importance of this correlation in the context of a timber extraction area is that trees targeted by loggers, based on minimum harvesting diameters, are always larger than 40cm-60cm DBH (depending on species).

Spider monkeys are key seed dispersers and vital in the regeneration of the forest (Stevenson, 2001; Calle, 2013), in fact in our *ad libitum* observations spider monkeys would swallow entire fruits and defecate them intact. We only observed spider monkeys spit out the seeds of *I.deltoidea*, which has been

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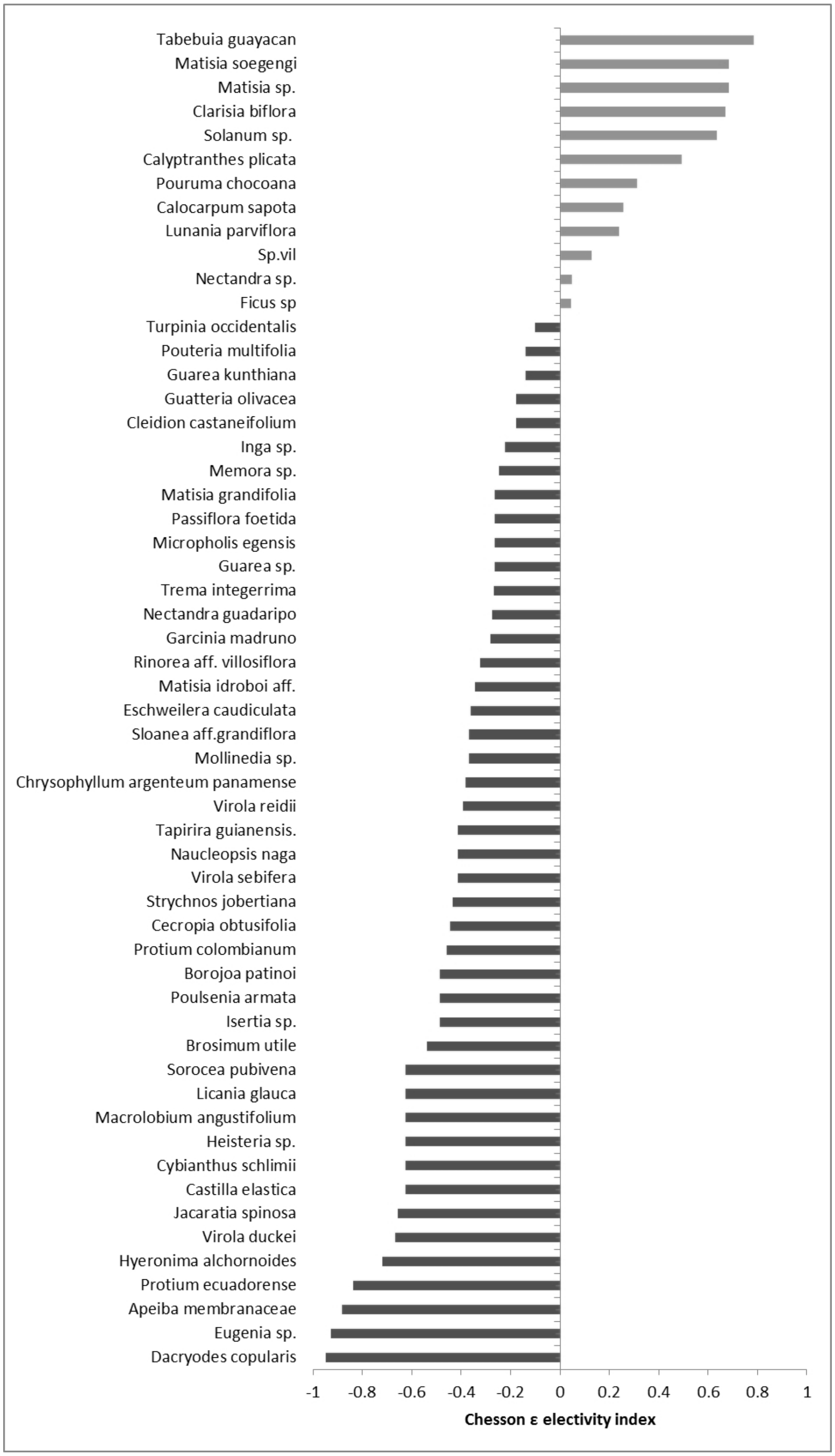

Figure 7. Chesson ε index values for the tree species used as food sources by *Ateles fusciceps fusciceps* in Tesoro Escondido. The higher the preference for a particular species, the higher the value (maximum value is 1). Complete avoidance is denoted by -1, while 0 represents random selection. Note that *Sp.vil* is the common name

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Table 1. Nutritional value of 13 species of fruit in Tesoro Escondido

Species	Protein %	Lipid %	Carbohydrate %
Inga sp	13.59	0.39	78.44
Calypthrantes plicata	3.33	0.33	27.90
Garcinia madruno	2.95	12.35	77.50
Calocarpum sapota	2.82	4.08	24.05
Ficus insipida	10.91	2.39	69.68
Iriartea deltoidea	1.25	0.43	92.57
Matisia soegengi	3.99	2.14	81.27
Brosimum utile	7.89	9.90	75.5
Clarisia biflora	1.54	1.31	13.33
Solanum sp.	5.72	1.90	84.30
Cleidion castaneifolium	10.52	8.32	69.55
Isertia.sp.	8.20	1.09	80.64
Lunania parviflora (Hirtella sp)	9.49	6.30	77.34

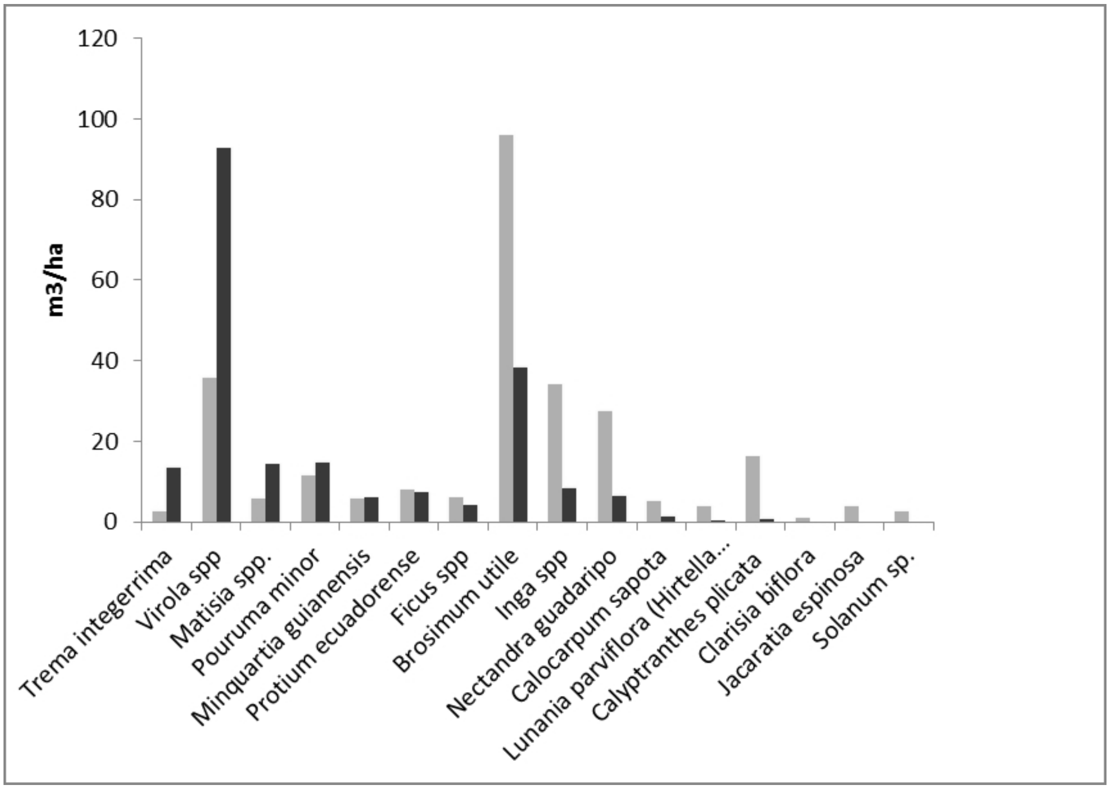

Figure 8. Volumes of key species for *Ateles fusciceps fusciceps* ; in light grey existing volume in Tesoro, in dark grey maximum volume approved for extraction in permits by the Ecuadorian Ministry of Environment.

previously reported by Link et al. (2006). We suggest further research on the role of *Ateles fusciceps fusciceps* as a keystone seed disperser in the Esmeraldas province.

This study is the first to analyse timber extraction regulations in the context of the conservation of the critically endangered *A. f. fusciceps* , whose main requirement for survival is primary continuous primary forests. Our findings suggest that key tree species for *A. f. fusciceps* are also highly preferred as timber species, particularly *Brosimum utile* and *Virola spp (Virola dixonii)*. They both rank in the highest number of granted permits and in the highest volumes approved for extraction. Even though spider monkeys can

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be flexible in terms of their feeding preferences, the loss of staple foods, especially nutrient-rich ones, are likely to have detrimental effects on primate populations, (See review by Cowlishaw and Dunbar (2000)).

Logging, even under sustainable forest management (SFM), has been shown to have serious negative impacts, both directly and indirectly on animal biodiversity (Zimmerman and Kormos, 2012) and on primates specifically (Peres, 2001; Rimbach et al., 2013). Secondary impacts include road building, colonization and hunting (Zimmerman and Kormos, 2012).

Moreover, extensive research indicate that current government SFM protocols for tropical forests (minimum cutting cycle, minimum DBH limit, harvest intensity) are inadequate and guarantee commercial depletion and even extirpation of most timber species within three cutting cycles (see review by Zimmerman and Kormos (2012)). Recommendations by various studies suggest that shifting from industrial logging to small-scale community timber and non-timber forest management options, can result in the protection of tropical forest ecosystems that simultaneously promote sustainable livelihoods (Zimmerman and Kormos, 2012; Bray et al., 2003).

Recommendations by the Ecuadorian Ministry of Environment suggests establishment of permanent protection zones in areas where the presence of endangered flora or fauna has been confirmed (MAE, 2004). Nevertheless, current management plans by local timber companies do not present a comprehensive survey of endangered fauna or flora in the area (Morales-Castillo, 2005). Furthermore Ecuadorian forestry law for sustainable forest management programmes, stipulates the need for protection of trees used by endangered fauna. In this context our results provide valuable information that can be used to enforce this law and to expand it to other forest management programmes.

Given the above, we recommend the following to ensure long-term viability of the remaining populations of *A. f. fusciceps* :

- The Ecuadorian Ministry of Environment should carry out surveys to determine the presence of *A. f. fusciceps* and act accordingly by ensuring these areas are gazetted as areas of permanent protection.
- However, if permits are already in place the Ecuadorian Ministry of Environment should carry out a review of timber extraction protocols to minimise impacts to *A. f. fusciceps* .This review should ensure protection of keystone food tree species identified in this study for *A. f. fusciceps* .
- Connectivity of the remaining forests in the region should also be considered by adapting current extraction protocols to protect keystone feeding species for *A. f. fusciceps* .

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