Lemurs in cacao: presence and abundance within the shade plantations of northern Madagascar

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Short title: Lemurs in cacao plantations

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Abstract:

The recognition that much biodiversity exists outside protected areas is driving research to understand how animals survive in anthropogenic landscapes. In Madagascar, cacao (*Theobroma cacao*) is grown under a mix of native and exotic shade trees and this study sought to understand if lemurs were present in these agroecosystems. Between November 2016 and March 2017, discussions with farmers, nocturnal reconnaissance surveys and camera traps were used to confirm the presence of lemurs in the Cokafa and Mangabe plantations near Ambanja, northwest Madagascar. Four species of lemur were encountered in nocturnal surveys; *Mirza zaza, Phaner parienti*, *Microcebus sambiranensis* and *Cheirogaleus* sp. with encounter rates of 1.2, 0.4, 0.4 and 0.3 individuals/ km respectively. The presence of *Lepilemur dorsalis* was confirmed by camera trap. This is the first time lemurs have been studied in cacao plantations, and understanding how these threatened animals use anthropogenic landscapes is vital for their conservation.

Introduction

A major threat to wildlife is forest fragmentation and loss of habitat due to the conversion of natural ecosystems to agriculture. However, whilst not replicating tropical forest, agroecosystems have been found to play an important role in species conservation while providing farmers with economic alternatives to more intensive farming methods (Estrada and Coates-Estrada 1997, Estrada et al. 2012, Martin et al. 2012, Guzmán et al. 2016, Hending et al. 2018). These 'melting pot' landscapes of exotic and native species have the potential to benefit wildlife and people, and have been described as the "missing link" between conservation and sustainable development (Kull et al. 2013). With many threatened species living outside of protected areas, simply separating agriculture from conservation is no longer a viable solution for all species or all landscapes (Perfecto and Vandemeer 2008, Scherr and McNeely 2008).

In Madagascar, the conversion of forest to other land uses such as agriculture has been rapid and significant; 44% of forest was lost between 1953 and 2014 and 46% of that remaining is now less than 100m from the forest edge (Vieilledent et al. 2018). As a consequence, 95% of lemurs are threatened with extinction (C. Schwitzer, pers. comm.). It is vital to understand the role of agroecosystems on lemur survival in these highly fragmented and anthropogenic landscapes (Irwin et al. 2010; Schwitzer et al. 2011). Indeed, it has been observed that lemur population densities can be higher in areas with slight disturbance, especially those with a higher variety of tree species (Ganzhorn et al. 1997). An area that has received little attention is that of cacao (*Theobroma cacao*) which, whilst currently with limited production in Madagascar, is recognised as having significant income potential for local people (World Bank 2017).

Planting of cacao takes place under shade trees in Madagascar. These trees not only provide the cacao plants with shelter, they are also associated with protection against soil erosion, carbon storage and nutrient cycling (Rice and Greenberg 2000, Donald 2004, Tscharntke et al. 2011). Research has shown that these traditional cacao plantations can provide habitat for many species, including primates, bats and birds (see Reitsma et al. 2001, Merker et al. 2005, Faria & Baumgarten 2007, Bisseleua et al. 2009) and have higher levels of biodiversity than other crop types (Estrada and Coates-Estrada 1997, Rice and Greenberg 2000, Perfecto and Vendermeer 2008, Kull et al. 2013). Primates have been recorded using the shaded cacao to feed and move between forest fragments (Merker et al. 2005, Estrada et al. 2012, Raboy et al. 2014, Hockings et al. 2016) and mantled howler monkeys *(Alouatta palliata)* have been observed living in plantations for decades (Muñoz et al. 2006). These animals may also be beneficial for the plantations as they act as seed dispersers, their faeces may improve the soil and they can provide useful pest control by eating insects (Estrada et al.

2012, Zárate et al. 2014, Hockings et al. 2016). Potential disadvantages to animals through increased interactions with people can include a greater vulnerability to predators, disease, a poorer quality of diet, and hunting by human populations (Muñoz et al. 2006, Irwin et al. 2010, Raboy et al. 2014). Furthermore, local people may bear the economic costs of crop damage by primates (Estrada et al. 2012, Hockings et al. 2016). Understanding the complex interface between people and lemurs in increasingly fragmented landscapes is important for the future development of sustainable farming and the conservation of biodiversity in Madagascar.

This study examined the use of cacao plantations by lemur species in Ambanja, northern Madagascar, where farmers had reported the presence of "small lemurs" in their plantations (N. Engle pers. comm.). We aimed to confirm (i) if lemurs were indeed present, (ii) identify the species, (iii) calculate their abundance and (iv) characterise the shade trees in the cacao plantations.

Methods

Study Site

Research was conducted in the Cokafa and Mangabe cacao plantations close to Ambanja in northern Madagascar (Figure 1). Cokafa is a co-operative of 32 members and 29 participated in this study. As some farmers hold multiple parcels of land, this resulted in a sample of 43 plantations for this area These plantations are found in two clusters separated by a road and are therefore known here as Cokafa North and Cokafa South (13°43'31.97"S, 48°22'31.56"E). They form part of a complex mosaic of other cacao estates, forest fragments and agricultural areas owned/ managed by local farmers that are not part of the co-operative. Mangabe (13°43'2.91"S, 48°25'46.00"E), in contrast, is a single plantation owned by one farmer but divided into eighteen parcels. Itis surrounded by rice/ crop cultivation with natural vegetation to its south-eastern borders. Degraded forest fragments continue to the south of cultivated areas. The small holder plantations across the three sites (total size 598,965m^2, mean 12,743m^2) range in size from a plantation in Cokafa North of 869m^2 to Mangabe which has the largest area at 381,761m^2.

Shade tree characteristics

Each shade tree within the Cokafa and Mangabe plantation boundaries was identified to at least genus level by experienced Malagasy field researchers. Its location was recorded in a GPS along with DBH, tree height, crown diameter and height of the first branch. The presence or absence of lianas on each tree was also recorded.

Discussions with farmers

During November - December 2016, informal discussions were conducted in Malagasy with farmers to assess the reliability of previous reports given to representatives of Madecasse Chocolate & Vanilla of lemur presence. Farmers were asked if they had seen or heard lemurs within or beyond their plantations and the behaviour they observed, in addition to cacao production practices.

Nocturnal Surveys

Throughout February 2017, nocturnal lemur reconnaissance surveys were conducted in the plantations at the three research sites. Two researchers walked slowly (1km/hour) taking a route as close to the centre of each plantation/ parcel as possible between 18:00 and 22:00 (Cokafa North 2.76km, Cokafa South 1.44km and Mangabe 3.78km). Every lemur seen, GPS location, tree species and basic behavioural data were recorded; feeding, moving, grooming, resting. A total of eleven night walks took place and each plantation was surveyed at least three times (Cokafa North N= 5, Cokafa South N =3, Mangabe N=3).

Camera Traps

Six Bushnell Trophy Cam (Essential E2) camera traps were deployed across the study areas. Due to the small plantation sizes, they were placed at regular intervals (200-400m) across the three sites rather than in each plantation. The camera traps were left in situ at each site (Cokafa North, Cokafa South or Mangabe) for 30 days before being moved to the next site. Specific placement was predominately on jackfruit (*Artocarpus heterophyllus)* and silk trees (*Albizia* spp.), the most common trees in the plantations, but was also directed by discussions with farmers who identified areas where lemur vocalisations had previously been heard, in addition to knowledge of optimum lemur habitat. Camera traps were set up at a height of approximately 9m pointed at a trunk or branch, and surrounding vegetation was cleared to reduce the number of false triggers (Gregory et al. 2014).

Results

Shade tree characteristics

All 3,263 shade trees were identified in the plantations (N=947 in Cokafa North, N=626 in Cokafa South and N=1690 in Mangabe) – Table 1. The majority of shade trees were planted by people, therefore, the plantations are not natural forest, rather a mixture of native and exotic tree species that have utility for humans; e.g., food, timber or medicine. Thirty nine different shade tree species were present but were lumped into eight categories as it was not always possible to identify to species level. The three most common types of tree across the three sites were silk trees, jackfruit and ylang ylang (*Cananga odorata)*. There are approximately 30 species of silk tree in Madagascar; one, *Albizia lebbeck*, is believed to have been introduced from Asia due to its religious importance (Morat 1972 in Binggeli 2003) but they are also used by local people for building materials, fuel, dugout canoes, firewood, medicinal purposes and as shade trees for agriculture. Jackfruit is a common fruit tree in Madagascar and ylang ylang is well known for its essential oil and medicinal properties.

Banana plants (*Musa* spp.) are also present in all plantations but not recorded as a shade tree as they do not serve that function. Eight percent of shade trees have lianas but there is a difference in distribution across sites; 13% of trees in Cokafa North have lianas compared to 4% in Cokafa South and 8% in Mangabe. Generally, trees were taller in the Cokafa plantations than in Mangabe.

Discussions with farmers

Informal interviews with farmers confirmed that 'akomba' (the local name for some of the diurnal lemurs in the area) were no longer present in Cokafa or Mangabe. Some reported having seen 'black and red lemurs' moving together in the plantations and using pictures they identified them as black lemur *(Eulemur macaco*). They were last seen in 2010/11 and there is no evidence that they are still present. This was supported by observations during this study although bamboo lemur *(Hapalemur sp.)* were seen outside of the plantations by SS and one individual was trapped by local people close to Mangabe and reported to SS during the study period. Farmers stated that they believed 'valivihy' (nocturnal lemurs) were present due to hearing their calls in the evening. They were unable to identify the specific lemur species from images.

Nocturnal Surveys

There were 67 encounters with four species of nocturnal lemur in the cacao plantations; northern giant mouse lemur *(Mirza zaza)*, Sambirano fork-marked lemur *(Phaner parienti)*, Sambirano mouse

lemur *(Microcebus sambiranensis* and dwarf lemur (*Cheirogaleus sp*[1]*)*. – Figure 2, Table 2. The highest encounter rates for northern giant mouse lemur and Sambirano fork marked lemur were recorded in Cokafa South (1.8 and 0.9 individuals/km respectively) but no dwarf lemur were seen at this site. Sambirano mouse lemurs were most often encountered in Cokafa South and Mangabe plantations (0.7 individuals/km). Animals were usually solitary but northern giant mouse lemurs, dwarf lemurs, and Sambirano fork-marked lemurs were seen in pairs on several occasions and there was one sighting of four Sambirano fork-marked lemurs together in Cokafa North.

Lemurs were observed on thirteen different tree species during the reconnaissance walks; 31% of encounters were on silk trees, 21% on cacao, 10% on mango (*Mangifera indica*) and 10% on marula (*Sclerocarya birrea)*. Northern giant mouse lemurs were observed on nine different shade tree species, as well as on banana and cacao, but other lemur species were recorded across a smaller range of tree type. For example, dwarf lemurs were seen on four species of shade tree and cacao, but 50% of observations were on 'bonara gasy' (a type of silk tree). Sambirano fork-marked lemurs were also recorded on four species of shade tree (jackfruit, silk trees, mango and marula). This was in contrast with Sambirano mouse lemurs which were only observed on one species of shade tree (orange, *Citrus* spp.*)* and banana, and 75% of encounters were on cacao.

For the majority of observations, the lemurs were moving (67%), only resting during 21% of the encounters. Northern giant mouse lemurs and Sambirano fork-marked lemurs were also observed feeding on marula, banana, jackfruit and silk trees.

Camera traps

The camera trap findings generally support the observations of lemur species in the plantations during the nocturnal surveys: northern giant mouse lemurs, dwarf lemurs. and Sambirano fork-marked lemurs were all captured by the cameras but not Sambirano mouse lemurs. Gray's sportive lemur were also recorded on two images for one night on the camera trap in Cokafa North but these animals were not observed during surveys in the plantations.

[1] Dwarf lemurs are currently undergoing taxonomic reclassification and it was not possible to identify the specific species present in the plantations. In 2013, Thiele et al. suggested that dwarf lemurs in the Ambanja area should be a new species (*C. sp. Ambanja*), however it was not formally defined (Thiele et al. 2013, Lei et al. 2014). Further research is planned to identify which dwarf lemur species is present in the cacao plantations.

Discussion

This was a small study so results need to be interpreted as such, however, it did confirm reports that nocturnal lemurs are living within the shaded cacao plantations close to Ambanja in northwest Madagascar. To our knowledge, this is the first time lemurs have been studied within this type of agricultural ecosystem; whilst there has been one previous anecdotal report of Sambirano fork-marked lemurs in the shade trees of a cacao plantation (Colquhoun 1998), most research has tended to focus on these animals in 'natural' environments. Of the five lemur species recorded here, three are classified as Endangered (northern giant mouse lemur, Sambirano fork-marked lemur, Sambirano mouse lemur) and one as Vulnerable (Gray's sportive lemur) on the IUCN redlist (Table 2). These animals are, therefore, of international conservation concern.

Lemurs were generally encountered most often in Cokafa South and encounter rates for northern giant mouse lemurs were highest in these plantations. There has been little research on this species but it has been suggested that higher density may be associated with the presence of mango trees (Rasoloharijaona et al 2005, Markolf et al. 2008) and Cokafa South has more mango trees than the other two sites. Researchers have also suggested that the northern giant mouse lemurs prefer taller trees with lianas as they use them for nesting/ sleeping sites (Rode et al. 2013). Whilst trees are taller in the Cokafa plantations generally, Cokafa South has the lowest number of lianas when compared to the other sites (Table 1). However, this inconsistency has been observed in other studies; encounter rates were lowest in Sahamalaza Iles-Radama National Park despite liana presence (Markolf et al. 2008, Rode-Margono et al. 2016).

Sambirano fork-marked lemurs were recorded at all sites, with the highest encounter rates in Cokafa South. There is little known about this species but, like northern giant mouse lemurs, this fork-marked lemur is believed to prefer the tall trees that are common in this area (Hending et al. 2018). Dwarf lemurs, however, were not seen at all sites and were also encountered less frequently than the other lemurs. This could be a feature of the season of study as these animals hibernate for six months or more during the austral winter (April to October) and it is possible they were becoming torpid at the time of study (Ganzhorn 1995, Fietz and Ganzhorn 1999, Olivieri et al. 2005).

Mouse lemurs have been previously recorded in anthropogenic environments including eucalyptus, vanilla, coffee, banana and cashew plantations incorporating a mix of native and exotic trees (Ganzhorn 1987, Deppe et al 2007, Hending et al. 2018). In this study they were most often observed on cacao but not feeding on the crop; this may reflect their preference for lower level vegetation rather than the taller shade trees. Mouse lemurs are considered adaptable and have

been observed in secondary and/ or edge habitats possibly due to an increase in insect prey and/ or additional protection from predators offered by denser secondary vegetation (Ganzhorn 1987, Ganzhorn 1995, Hending et al. 2017). They have also been recorded using sleeping sites in and feeding from the gum of silk trees which are the most widely grown shade tree in this study (Radespiel et al. 2006, Hending et al. 2017). Sambirano mouse lemurs were not seen on the camera traps however this is likely due to the location of the traps as they were placed high in the trees and mouse lemurs often utilise the lower canopy (Hending et al. 2017).

It is difficult to ascertain why Gray's sportive lemur was not seen during the nocturnal survey and only seen once on a camera trap in Cokafa North. There have been very few studies on this species and it is known to have a restricted range in the Sambirano region (Andriaholinirina et al. 2014). Whilst it has been observed in timber plantations (Andrews et al. 1998), further research is needed to understand habitat preferences for this species.

Conclusion

It is unlikely that agricultural plantations will ever provide optimum habitat for lemurs in Madagascar however they could provide a buffer against fragmentation and corridors between forest patches (Ganzhorn 1987, Rice and Greenberg 2000, Deppe et al. 2007, Estrada et al. 2012, Raboy et al. 2014, Gerard et al. 2015, Hending et al. 2018). Ideally cacao shade trees would be native species and planted to mimic a natural forest where possible (Scherr and McNeely 2008), however, the reality is that local people will select trees that have an important function to their livelihoods and/ or wellbeing. Native species are also often replaced by exotic trees when they die in the plantations (Donald 2004). Introduced species of plant can offer benefits, however, to lemurs and people (Deppe et al. 2007, Eppley et al. 2015, Gerard et al. 2015); indeed, the majority of food crops in Madagascar are introduced (Kull et al. 2013). Therefore, farmers should be supported to maintain shade trees that represent a mix of exotic and native species and encouraged to leave patches of natural habitat within their agricultural areas (Tscharntke et al. 2011, Kull et al. 2013). Silk trees may offer some potential here as they seem to be favoured by both people and lemurs (Radespiel et al. 2006); it has been suggested that the pods provide an important source of protein for black lemurs (Simmen et al. 2007). Furthermore, a move from shade cacao to 'full sun' cacao should be discouraged; while offering some short term benefits for people it has been found to increase the risk of insects and disease in the plantations and is believed to have contributed to the collapse of the cacao industry in Malaysia (Donald 2004, Tscharntke et al. 2011). Furthermore, moderate shade

253 cover has a positive impact on yield (Bisseleua et al. 2009) and a decrease in the density and
254 diversity of shade trees can lead to a decrease in biodiversity (Perfecto and Vandermeer 2008).
255 Planting 'full sun' cacao without shade trees would also offer little to no benefit to lemur
256 conservation and/ or biodiversity more generally (Rice and Greenberg 2000, Muñoz et al. 2006).

257 Agroforestry is important for wildlife and people, especially as protected areas represent so little of
258 the landscape and are becoming increasingly disconnected (Scherr and McNeely 2008, Schwitzer et
259 al. 2011, Tscharntke et al. 2011). With much of Madagascar's natural forest degraded,
260 agroecosystems such as shaded cacao could become important to the conservation of lemurs and
261 primates more generally (Holloway 2003, Estrada et al. 2012, Zárate et al. 2014, Gerard et al. 2015,
262 Hending et al. 2018). Over seventy percent of the world's cacao is grown in smallholdings (Rice and
263 Greenberg 2000, Donald 2004, Kull et al. 2013), and thus provides a valuable income to subsistence
264 farmers. One concern with a reliance on any commodity, however, is that international markets can
265 change or the crop can be affected by disease or adverse weather (Rice and Greenberg 2000, Muñoz
266 et al. 2006, Estrada et al. 2012). However, agroforestry offers the potential for alternative income
267 through the addition of other shade grown crops e.g., pink peppercorn (World Bank 2017).
268 Furthermore, the presence of cacao cooperatives has been shown to have a positive impact on
269 wealth and well-being through volatility at other sites (Calkins and Ngo 2010). This is encouraging
270 for the continued development of sustainable plantations that benefit both wildlife and people in
271 Madagascar.

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Statement of Ethics

The study adhered to the Code of Best Practice for Field Primatology and ethics approval for the research with people was given by Bristol Zoological Society's Welfare and Research Advisory Board. As part of the consent process, all farmers were approached individually to ask for permission to conduct the research and information sheets were provided in the local language.

Disclosure Statement

Madecasse Chocolate and Vanilla assisted with access to the plantations but did not influence the study design or comment on this paper.

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Author Contributions

The paper was written by Amanda Webber with comments from David Fernandez and Joel Allainguillaume; these three authors collaborate on this research project. James Solofondranohatra and Simon Razafindramoana collected the field data and also contributed to the paper, along with Charlotte Parker who assisted with the literature review. Mark Steer and Mark Abrahams provided support with GIS.

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Figure 1. Map of Cokafa and Mangabe with smallholder plantations delineated and insert of the location of the study site in north western Madagascar. The site is a complex matrix of agriculture (including plantations and rice paddies) and forest fragments.

Figure 2. Photographs of the lemur species observed in Cokafa North, Cokafa South and Mangabe cacao plantations. A) Sambirano fork-marked lemur (*Phaner parienti)*, B) Northern giant mouse lemur (*Mirza zaza),* C) Dwarf lemur (*Cheirogaleus sp*.), D) Sambirano mouse lemur (*Microcebus sambiranensis), (E) Gray's sportive lemur (Lepilemur dorsalis) - camera trap only.*

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