Home range- and behavioural analysis of the Saddleback tamarin (Leontocebus fuscicollis) in Madre de Dios, Peru

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Abstract

60% of primates in the world are threatened with extinction, while 75% have declining populations. The biggest threats to primates are the result of human activity. In this study, I have been looking at the primate Spix’s Saddleback tamarin (Leontocebus fuscicollis) and tried to estimate the home range size of four different study groups, while also trying to assess if there are differences in the type of trees in the areas where the tamarins are present compared to where they are absent. I have also compared the behaviour of the four different study groups. The data was collected in the Tambopata nature reserve in the Madre de Dios region in Peru during the summer of 2022, with the help and support from the research organisation Fauna Forever. To complement the observations, previously collected data from 2019-2021 was also used. The tamarins were followed using a group follow method, and the behaviour was noted every 10 minutes using an instantaneous scan sampling method. The tree composition data was gathered from previously created tree plots, made by the Fauna Forever staff. I found that the home range sizes of the four study groups varied between 2.6 ha and 17.9 ha. The data from the tree plots showed no statistically significant difference in where the tamarins chose to live. There was also no statistically significant difference between the four study groups in behaviour, except for how high up in the trees they groups spent their time. There was a lack of good data in this study, due to time- and material constraints, but overall the home ranges were of close to similar size as earlier studies, and the behaviour of the tamarins was in general also consistent with earlier studies. More research would be needed to answer the further questions that arose during this study concerning the ecological constraints of the tamarins home range.
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1. Introduction

1.1 Conservation of primates in Peru

The sustainable development goals are part of the UN resolution 70/1 Transforming our world: the 2030 Agenda for Sustainable Development. Goal 15 is to "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss" (United Nations – Sustainable Development 2021). 60% of primates in the world are threatened with extinction, while 75% have declining populations. The rainforests of Madre de Dios in southeast Peru are home to no less than 18 species of primates, among them Black-faced back spider monkey (Ateles chamek), Common woolly monkey (Lagothrix lagotricha), Madidi titi monkey (Plecturocebus aureipalattii, earlier Callicebus brunneus), and Pygmy marmoset (Cebuella pygmaea). Out of the eighteen primate species found in Madre de Dios, six are classified as Near Threatened, Vulnerable or Endangered on the IUCN red list (The IUCN Red list of Threatened Species 2021). Sixteen of the species are decreasing in number. However, despite the huge diversity of primates to be found in the rainforests of southeast Peru, and despite their threatened status, little is known about the species’ home ranges and the factors that help explain their group size and shape.

The biggest threats to primates are the result of human activity (Shanee et al. 2023). Different species have different needs when it comes to their living area, and as logging heavily alters living areas, it naturally affects the species habitating there. Conservation of a species is about conservation of habitat. Even if a species is not threatened, we need to know about their habitat, in order to make sure that we do not affect their habitat and thereby push them into a threatened status.

Earlier studies have shown that primates are not likely to survive in parts of the Amazon heavily disturbed by humans, both due to crop losses and hunting (Naughton- Treves et al. 2003). A 2023 study tried charting out the biggest threats to the 55 primate species in Peru with hunting ending up as the biggest threat, followed by logging and agriculture. These threats, as well as the threat of climate change, affected all species to some degree (Shanee et al. 2023).

The government of Peru is working on different ways to combat the threats to wildlife. However, while there are many different ways to go about protecting land in Peru and even though the Peruvian government stated in 2009 at the Copenhagen Climate Conference their goal of zero deforestation by 2020, deforestation still happens on a large scale and there is a negative attitude among the people towards conservation. Ministry workers working with conservation have been taken hostage and threatened when trying to enter protected areas, most likely due to the illegal activity taking place in the areas (Shanee 2016). The illegal activity, such as gold mining, is widespread and takes up a lot of the government's time, which is also why conservation of wildlife is underprioritised. There are clearly many challenges regarding conservation in Peru.
1.2 Naturalistic observation of home range and behaviour in primates

When talking about the habitat of a species you can discuss either the home range or the territory. The two concepts are similar, but there are some important differences. From now on, in this report home range will refer to the area where a primate group can be seen spending time, feeding and so on, while territory will mean the area the primate group protects from other groups (Burt 1943). Home ranges can overlap somewhat between groups, but territories normally do not overlap when it comes to primates.

To estimate the home range area, it is common to use either minimum convex polygon (MCP) or a version of kernel density estimation. The different methods have different advantages, but the general consensus seems to be that MCP generally overestimates the home range area since it potentially includes areas where the species in question has not been observed (Pimley et al. 2005). The results from a Kernel density estimation on the other hand have in some studies been deemed more accurate, when compared to the results of MCP (Volampeno et al. 2011; Pimley et al. 2005).

When studying the behaviour of primates either a naturalistic observational method or an experimental method is used. The naturalistic observation method refers to studying primates in their natural habitat, without interference, while the experimental method is performed in a controlled environment, limiting variables. There are different advantages to both. Advantages to using a naturalistic observational method is that the study species is in their natural habitat, with natural behaviours appearing as well as a chance to observe the natural threats, which one cannot see in a lab due to ethical considerations. Advantages with an experimental method, however, is that variables can be controlled, such as weather or exterior threats - which one naturally cannot control using a naturalistic observational method (Delval 2023).

If choosing to do a naturalistic observational method there is still the option of what type of sampling method to use. One method is scan sampling, where the observer records the activity of all individuals in the whole group at specific time points, for example for 3 minutes every 10 minutes (Delval 2023). Some disadvantages with this method are that you miss the behaviour types that occur during the interval, and with primates it has been shown the method can overestimate the time spent moving (Delval 2023; Amato et al. 2013). Another method is focal-animal sampling, where the observer notes every event of the pre-decided focal unit during a pre-decided time limit for a pre-decided number of sessions. The observer may also have to note down who initiates interactions and to whom (Delval 2023). In contrast to scan sampling, focal sampling can overestimate time spent with social interactions (Amato et al. 2013). There are many more methods, such as the controversial one-zero sampling, where the observer records the occurrence or non-occurrence of some behaviours during sample intervals, or sequence sampling, where all behaviours are recorded in order during a specific time sequence (Delval 2023). As the many methods have different advantages and disadvantages, the choice of method depends on what the observer intends to study.
1.3 Leontocebus fuscicollis

The *Leontocebus fuscicollis*, or Spix’s Saddleback tamarin, is a primate classified as “Least concern” on the IUCN red list, but with a decreasing population trend. They are found in Bolivia, Peru, western Brazil, Ecuador and Colombia (figure 1) (Heymann et al. 2021).

Figure 1: The geographic range of *L. fuscicollis* according to the IUCN Red List (IUCN (International Union for Conservation of Nature) 2021. Leontocebus fuscicollis. The IUCN Red List of Threatened Species. Version 2022-2). Note that this map mainly shows the main geographic range and not the complete range. *L. fuscicollis* can be found in other places as well, outside of this range, such as in the south-eastern parts of Peru.

The energy expended daily by many primates in the Amazon rainforest is mainly focused on foraging for food and defending territorial, or home range, boundaries. Here, primate food consists of a wide variety of fruit (from trees, shrubs and vines), leaves, flowers, nectar, sap as well as insects, bird eggs and even fungi in some cases (Rylands 1987). The importance of each is dependent on the primate species in question. For the *L. fuscicollis* the main food is fruit, nectar and insects. In times of fruit scarcity *L. fuscicollis* also consumes nectar and will increase the intake of arthropods (Porter 2001). As observed during my study, there are even rare cases when the *L. fuscicollis* choose to eat lizards.

As for behaviour, *L. fuscicollis* is a social animal spending time in groups. The groups can vary in size - one study found that the groups consisted of 2-10 individuals with an average of 6 individuals (Soini 1987), while other studies have found that the tamarins can be found in groups of up to 16 individuals (Bennett et al. 2001). While being described as territorial, tamarins (*Saguinus*) have generally shown home range overlap of about 20-40% (Garber 1993). The size of the home range can vary a lot, with one study finding that the studied groups of *L. fuscicollis* had a home range size of 17-23 ha, with another study finding that the mean home range size between 13 studied groups was 32.8 ha, and finally a third study claiming that the home range size varied between 48 and 56 ha during the year (Buchanan-Smith 1990; Yoneda 1984; Rehg 2006).
A comparative study based in Bolivia, comparing behaviour between *L. fuscicollis* and the sympatric species *Saguinus labiatus* and *Callimico goeldii* have shown that *L. fuscicollis* generally stay in the understory and middle canopy, generally staying between 5 and 25 metres up, with an average height of 7 metres (Porter 2004). A study from 1987 showed that, while the *L. fuscicollis* spend time at different heights, more than 80% of their time was spent below 11 m, and only in 2% of the observed time were they found at heights above 20 m (Soini 1987). The comparative study also showed that *L. fuscicollis* spends more than 50% of its time resting, and about 22% travelling (Porter 2004).

According to the study by Shanee et al. from 2023 charting the biggest threats to primates in Peru, *L. fuscicollis* got a threat score of 7 on a scale from 0 (lowest) to 10 (highest) (the lowest ranked species got a score of 5 while the highest ranked species got a score of 9 in this study). The biggest threats to Spix’s Saddleback tamarin specifically were climate change altering the habitat and affecting the weather, as well as oil and gas drilling, intentional hunting and unintentional effects due to logging (Shanee et al. 2023). *L. fuscicollis* is not the most threatened primate of all in Peru, but it still scores relatively high on the threat scale. While the threat of hunting is mostly a very intentional attack on the species, it is shown that *L. fuscicollis* gets affected unintentionally by both logging and drilling. With more knowledge about the species’ habitat preferences and home range, we have the possibility of diminishing these unintentional effects.

### 1.4 Goal of the study

The goal of this study is to investigate to what extent *L. fuscicollis* group size and home-range size varies with forest type in Amazonian Peru. Once home ranges have been mapped, it will therefore be necessary to assess forest characteristics within, as well as outside of these ranges, to determine what variables may explain the presence or absence of Spix’s Saddleback tamarins in these areas. Another objective is to compare the behaviour of populations of Spix’s Saddleback tamarins and see if there are differences and similarities between the different populations in terms of height in trees and type of behaviour.

The overall aim of this study is to expand the scientific knowledge on the Spix’s Saddleback tamarin and their environment in the Amazon. Information on home ranges, as well as the factors that explain the variability in home range size is useful in assessing primate densities, in understanding competition between populations, in determining the effect of human activities on species, and ultimately in primate conservation decision-making processes (Brugiere and Fleury, 2000). It is therefore essential to expand our knowledge of these species in order to halt the loss of primate diversity.
2. Methods

Asociacion Fauna Forever has since the mid-90s worked with mapping and protecting different areas in the region Madre de Dios, in south-eastern Peru. The Secret Forest research station (from now on SFO) is a research station that belongs to Fauna Forever. It is situated about 2 hours travel time by car and boat from the gateway city of Puerto Maldonado. The station lies at the centre of a network of private reserves covering 3,000 hectares. It is also very close to the 274,000 hectares Tambopata National Reserve, where research focused on protected area benefits is done. There are a total of 9 different forest types associated with these various areas, which allows for the study of the effects of forest type as an explanatory variable for wildlife abundance and diversity.

With the station as base, the Fauna Forever crew have created several trails crossing the jungle in order to properly be able to survey the wildlife (figure 2). Tambopata National Reserve is a species rich area, and several species of monkeys can be found on the trails surrounding the research station. Common primates in the area are Colombian Howler monkeys (*Alouatta seniculus*), Tufted Capuchins (*Sapajus apella*), Squirrel Monkeys (*Saimiri sp.*), Dusky Titi monkeys (*Callicebus moloch*) and Spix’s Saddleback Tamarins (*L. fuscicollis*). There have also been recordings of Spider Monkeys (*Ateles sp.*) about two km from the river, on the opposite side of the river from SFO. While the focus of this study was the Spix’s Saddleback tamarin, sometimes the tamarins could be found in groups with, or close to, other species of monkeys.

I studied home range size and pattern of the primates using a group-follow method, which involves first finding a social group of a primate species of interest, and subsequently following it through the forest (at an appropriate distance that keeps disturbance to a minimum) with a Global Positioning System (GPS) device set to tracking mode, which records geographical positions every few minutes (similar to Brugiere and Fleury, 2000). In this way, a group can be followed for many hours over successive days (depending on the accessibility of the forest and the abilities of the observers to keep up).

All of the data I use in this study was collected in the forest surrounding the SFO, between 2019 and 2022, with one third of the track data being collected by me between the 15th of June and the 10th of August 2022. The collected data consists of gps tracks from tamarin follows as well as behavioural data and tree composition data.
Figure 2: Map over the trails (white lines) and the river (blue line) around Secret Forest research station (Google n.d.). The star marks the location of the SFO research station.

2.1 Track collection

The main part of the data consists of GPS tracks from tamarin monkey follows. The concept “follows” from here on refers to one time when a recordist has been out, seen the tamarins and managed to follow them for at least 10 minutes.

The follows were conducted by a recordist going out into the jungle, while actively looking and listening for movement and the call of the tamarins. The greatest opportunity to find the tamarin monkeys was in the morning and before sunset, when the temperature was lower and they were foraging for food or shelter. When we found a group of tamarins, the GPS was turned on to tracking, and the tamarins were observed and followed for as long as possible. In the cases when the tamarins disappeared from sight for a longer period of time or we could not follow them, we turned off the tracking. We then saved the track onto the GPS.

To collect the tracks, we used a Garmin eTrex 32x GPS. In total 23 GPS tracks from tamarin follows were collected by me between the 15th of June and the 10th of August 2022. To complement my data, I got track data from the years 2019, 2020, 2021 and 2022, collected by various mammal research coordinators at Fauna Forever. In total, I used 35 tracks.

On the occasions that we heard tamarins, but were unable to see them, or when it would be too hard to follow them - or if they were seen quickly but disappeared - a waypoint was taken on the GPS to mark a spot where the tamarins had been. In total I collected 19 waypoints on 18 separate dates, during the summer of 2022.
2.2 Behavioural data

While doing the follows, we also collected behavioural data and information on group size, using the naturalistic observational method scan-sampling (Delval 2023). Every 10th minute from starting the follow, we recorded behavioural data. We estimated the number of individuals in the tamarin group and if they were adults, young adults or younglings, as well as estimated how high up in the trees each individual was and what each individual was doing at the time of collection. Categories for behaviour were: “Moving” (M), “Foraging” (FOR), “Feeding” (FD), “Resting” (R), “Socialising” (S), “Other” (O) and “Out of sight” (OOS).

“Moving” means that the monkeys are moving around - either running away or jumping from tree to tree in the same area.

“Foraging” means that it is clear that the monkey is looking for food, by either running and digging on the ground or looking in trees, or similar behaviour.

“Feeding” means that the recorder has seen the monkey eat.

“Resting” means that the monkey is just relaxing quietly in a tree - not moving around, feeding or foraging.

“Socialising” means that the monkeys are chatting to each other.

“Other” means that they are doing some other behaviour that is not included in the earlier mentioned types.

“Out of sight” means that at the time of noting down the behaviour the monkey is not visible. This would be when the recordist has earlier seen e.g., 5 monkeys, but at the time of recording the behaviour only 3 are visible - even though the 2 others are still around. Since we cannot guess their behaviour, even when we know the monkeys are present, OOS is written instead. Sometimes a height can still be recorded for OOS, because the recordist knows where the monkey is, but cannot see the exact behaviour since the monkey is hiding behind something.

2.3 Tree composition inventory

Fauna Forever have worked heavily with making tree plots along all of the trails surrounding SFO, to record the number and type of trees that can be found in the area. I used this data to analyse the vegetation in the areas where the tamarin monkeys mostly spend their time, compared to the areas where they spend little to no time.

To make a tree plot of 10x50 m, we started by randomly deciding on how many degrees of an angle the plot should be made compared to the trail, as well as where on the trail the plot should be made. Then, when at the right place on the trail, we walked 20 metres into the jungle from the trail. The spot 20 metres in from the trail was the centre spot of the tree plot.
When at the centre, we found the chosen angle with a compass, and then walked 25 metres in one direction. We walked along with the angle of the plot, with a thread to mark out the middle line of the plot. We measured and recorded every tree with a diameter of at least 31.4 cm within 5 metres on each side of the middle line. If the species was known, we recorded that as well. When we had recorded every tree along that 25 metre-middle line (and 10 m radius), we once again drew out the thread, but in the other direction of the middle point. We repeated the same procedure, with recording trees within 5 metres of each side of the middle line. After that, the 10x50 m plot was finished. See figure 3 for an illustration of how a tree plot is made.

![Tree plot illustration](image)

Figure 3: Illustration of a tree plot, with measurements. The green parts illustrate the forest, while the brown line illustrates a trail.

The tree plots around SFO were 10x50 m and were randomly distributed (figure 4). The reason for excluding trees of a circumference smaller than 31.4 cm is that these trees are less likely to survive a few seasons. In total, I included data from 31 tree plots in this study, and analysed it in different ways (for how the data was used, see 2.4.2 Tree composition analysis).
Figure 4: Map over the locations of the tree plots (Google n.d.). The grey dots represent plots outside the home ranges (13). The purple dots are plots within the home ranges (11). The brown dots are plots between the home ranges (7). The yellow dots are plots within the home ranges where the coordinates were missing (3), so I had to make a rough estimation of their placement, based on prior knowledge.

2.4 Data analysis

2.4.1 QGIS

Within a Geographic Information System (GIS) environment it is possible to calculate the home range size of groups, as well as create heat maps to look at where the tamarins spend most of their time - or at least where they are most often observed. While both ArcGIS and QGIS exist, I have used the free, open-source map program QGIS (QGIS.org) in my study.

2.4.1.1 Combine tracks

At first, I inserted all the tracks and waypoints from the GPS units that I was going to use into QGIS. Based on the tracks’ location and direction, and based on collected information about group size, I sorted the tracks and waypoints into four groups (my suggested separation of different groups and home ranges) that were colour coded to more easily separate them from each other. The groups are named Yellow, Red, Pink and Green.

To combine the tracks, I used the function Merge Vector Layers under Data Management Tools, and merged all tracks and waypoints in one group into one point vector. This I did for
all four groups. I made polygons based on the combined point vectors, marking the boundaries of the different groups' home range. The size of the home ranges can be found by using the field calculator and adding the area as a field to the attribute table. By doing that, I got the area in square metres.

2.4.1.2 Heat maps

To create heat maps, I used the function Heatmap (Kernel Density Estimation). The function creates a density, or heat map, raster of an input point vector layer using kernel density estimation. The program calculates the density based on the number of points in a location, with larger numbers of clustered points resulting in larger values. I started with combining all the groups’ tracks into four point layers. Then, I put these point layers in the Heatmap function as the basis for the raster layers. I put the radius to 0.000252 degrees, and based on this the program automatically put the:
- rows to 62
- columns to 51
- pixel size X to 0.000187
- pixel size Y to 0.000187 degrees (figure 6).

2.4.2 Tree composition analyses

To analyse the habitat of the tamarin monkeys, I did several different analyses with the program R (R Core Team 2021) through Rstudio (Rstudio 2020). I calculated the average number of trees per plot, separating the plots within, between and outside the home ranges. I also calculated the average circumference and diameter of trees in plots within, between and outside the home ranges. Then, I did a One-way Anova, comparing the diameter of the trees between the different group home ranges, as well as between the area within the home ranges to the area between and outside the home ranges. I did all of this to assess if there was a certain size of tree or density of trees that affected the presence of the tamarins.

Moreover, I did a Pearson’s Chi-squared test on the count of trees per species comparing the area within the home ranges to the areas between and outside the home ranges. Based on the result from this test I did another Pearson’s Chi-squared test, comparing the area within the home ranges to the areas between and outside the home ranges based on the counts of the type of trees (e.g., palm tree, fruit tree) present.

2.4.3 Behavioural analyses

To learn more about the Spix’s Saddleback tamarins as a species, I did analyses of the behaviour, comparing the different populations with each other. I did these analyses in R-studio. I analysed the count of how often each behaviour was shown per population with a Pearson’s Chi-squared test, while I compared the average height per follow per group with a One-way Anova. Moreover, I compared the average height for all separate behaviour types per follow per group using a Two-way Anova. I also calculated the average sizes of the groups, as well as the percentage of time spent at different heights by different groups.
3. Results

3.1 Home range

The tamarins were mostly found and tracked around bigger trails, and close to the stream (figure 5). Based on the minimum convex polygons created in QGIS (figure 6), the home ranges were found to be 17.9 ha for the yellow group, 13.1 ha for the red group, 8 ha for the pink group and 2.6 ha for the green group.

Figure 5: Heat map showing where tamarins were tracked, with a lighter colour for areas not as frequently visited and darker red areas for areas often visited (Google n.d.).
Figure 6: Map showing the minimum convex polygons (estimated home range in QGIS) and their location compared to the trails (Google n.d.). The coloured dots are the GPS points from all tracks, coloured to match the bound for each group.

3.2 Tree composition analyses

For the tree plots the average number of trees in the plots, as well as the average circumference of the trees and average diameter of the trees for the areas within, between and outside the home ranges can be found in the table 1.

Table 1: The average number of trees in the plots, average circumference and diameter of the trees in plots within, between and outside the home ranges, with the standard deviation.

<table>
<thead>
<tr>
<th></th>
<th>Average nr trees in plot</th>
<th>Average circumference</th>
<th>Average diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within (14 plots)</td>
<td>29 ± 3.9</td>
<td>63.3 ± 35.4 cm</td>
<td>20.1 ± 11.3 cm</td>
</tr>
<tr>
<td>Between (7 plots)</td>
<td>29.6 ± 5.6</td>
<td>65.2 ± 38.1 cm</td>
<td>20.8 ± 12.1 cm</td>
</tr>
<tr>
<td>Outside (13 plots)</td>
<td>26.5 ± 4.5</td>
<td>65.7 ± 39.8 cm</td>
<td>20.9 ± 12.7 cm</td>
</tr>
</tbody>
</table>

There was no difference in the diameter of trees between the four groups of tamarins (One-way Anova; $F_{3,346} = 0.20, p = 0.89$). There was also no difference in the diameter of
trees comparing the areas within the home ranges to the area between and the areas outside the home ranges (One-way Anova; $F_{2,88} = 0.36$, p = 0.70).

There was no difference in the tree species in the areas within the home ranges compared to the areas where the primates were not present ($X^2 = 15.036$, df = 158, p = 1). Moreover, there was no correlation between type of tree (e.g., fruit plant, palm tree, flowering tree) and presence of tamarins ($X^2 = 1.1444$, df = 10, p=1).

### 3.3 Behavioural analyses

The average number of individuals per group was found to be 5.2 individuals for the yellow group, 5.1 individuals for the red group, 4.8 individuals for the pink group and 7.7 individuals for the green group.

Looking at all of the studied tamarins, they spent approximately 21% of their time at a height of 20 m or higher, while almost 55% of their time was spent at 11 m or lower, with an overall mean height of 12.4 metres. The most common behaviour was moving, which was more than 2 times more common than resting, and roughly 10 times more common than the other types of behaviour.

There was no difference in the behaviour between the groups according to the Pearson’s Chi-squared test ($X^2 = 1.48$, df = 18, p=1). There was also no difference in the mean height per follow between the groups (One-way Anova; $F_{3,31} = 0.63$, p = 0.60).

Figure 7 was made to visualise the differences in mean height per behaviour, the groups being separated with colours.
Figure 7: Box plot visualising the mean height per behaviour, separating the study groups. On the x-axis are the types of behaviour (FOR = Foraging, M = Moving, R = Resting, FD = Feeding, S = Socialising, OOS = Out of sight, O = Other). On the y-axis is the mean height in metres. Each colour of the boxes represents the respective group, so yellow boxes represent the yellow group, red boxes represent the red group, pink boxes represent the pink group and green boxes represent the green group.

There was no difference between behaviour and the mean height (Behaviour Two-way Anova; $F_{6,50} = 0.76$, $p = 0.60$). There was, however, a difference between the group and the mean height (Group Two-way Anova; $F_{3,50} = 3.04$, $p = 0.04$). There was no interaction effect between behaviour and group (Behaviour*Group Two-way Anova; $F_{9,50} = 0.93$, $p = 0.51$).

The difference in height between groups was an effect of that the red group was higher up in the trees compared to the pink group (Tukey; $p=0.09$). No other comparison was significant (Tukey; $p>0.23$).
4. Discussion

As shown above, the home ranges were found to be between 2.6 ha and 17.9 ha for the different groups. There were no statistically significant differences in tree composition between the areas where the tamarins were present compared to where they were not present. There were also no statistically significant differences behaviour wise between the four different study groups, except for a difference in how high up in the trees the groups mostly spent their time.

4.1 Home range

When comparing the sizes of the home ranges to previous studies, 3 out of 4 of the calculated home ranges in this study are smaller than what other studies have found, which is a clear indication that the sample size is a bit too small to be able to properly assess the actual home ranges of the *L. fuscicollis*. In other studies, the home range of *L. fuscicollis* has been calculated anywhere between 17 ha and 56 ha (Buchanan-Smith 1990; Rehg 2006), while my groups had sizes ranging from 2.6 ha to 17.9 ha, with only the yellow group having a size larger than 17 ha.

As many older tracks could not be included in this study due to a lack of data; either missing behavioural data or missing track file, I was left with less data than anticipated (35 usable tracks out of more than 50). However, even if all tracks would have been usable I would most likely still have too few tracks to do a proper analysis of some of the groups, such as group green. Moreover, as the majority of the tracks used were collected during the dry season (24 out of 35), seasonal changes in where the tamarins spent time in their home ranges were most likely not captured this time. It has previously been shown that the tamarins have dietary changes between dry and wet season, with the importance of exudates in the diet increasing in the dry season compared to fruit for *L. fuscicollis* (Rehg 2006). While also consuming less fruit in the dry season, the tamarins also fed on fewer species in the dry season compared to the wet season (Rehg 2006). This would likely also mean that the area the tamarins spend their time in changes with the season, to allow for these dietary changes.

A further reason for the low number of tracks is that we were unsuccessful with locating sleeping sites. Ideally, we would have located separate sleeping sites for the different groups so that we could have followed the groups from sunrise to sunset, similarly to what older studies have done before (Porter 2004). This would have rendered us hours more of behavioural and home range data per follow, while we would also be able to conduct successful follows on more days. Out of the 60 days I spent in Peru, I was able to collect 23 tracks on 18 separate days. This means that I was able to follow the tamarins on roughly a third of the days spent in the jungle. If we would have located sleeping sites, we could perhaps have doubled the amount of tracking days. For further studies, locating sleeping sites would be of utmost necessity to gain as much data as possible.

Even though the amount of data is small, we can still visually analyse differences in the home ranges of the different groups and look for trends. Based on the map of the home ranges
(figure 6) we can see that while the groups have home ranges close to each other, there is very little overlap. The yellow group seems to stay relatively close to the stream going through the forest. This can also be seen on the heat map (figure 5), where the darkest red part is following the river. It could also be possible that the home range of the yellow group continues further north-west, as we, during one follow, lost them going in that direction. Another thing to note is that there is a possibility that the yellow group actually was two groups, or that the more southern tracks (closest to the river bank) should be included with the tracks for the pink group instead. To eliminate these queries, more data would be needed.

The home range of the pink group can be assumed to continue all the way south down to the river bank. During followings of the pink group, the tamarins could often be seen going in the direction of the river bank, but it was not possible to follow them further that way due to a steep precipice blocking the way. The yellow group and the red group are clearly different groups, but similarly to the yellow group, the red group could have a larger home range going north. In the case of home range use, we can see that the red group mostly has been found in the crossing between two trails, as that area is dark red on the home range map (figure 5). Not much can be said about the green group due to the very low amount of data (only 3 tracks).

4.2 Tree composition inventory

As nothing proved to be significant in the analyses of the vegetation plots, what we can observe is that there is no real difference in the height of trees, size of the trees, number of trees or type of trees between the areas where the *L. fuscicolli* is present and the areas where the tamarins are absent. What we can conclude is either that the type of trees is not something that seemingly affects where the tamarins choose to live, or that the forest is generally homogeneous so no differences in tree composition can be observed between present and absent areas.

There can, however, still be other factors in the vegetation, or in the habitat at large, that affect where the tamarins are present that this study has not tested for. The tamarins have preferences for certain types of fruit, as one study found that at least half of the preferred fruit species were fruits with larger seeds and small pulps (Ripperger et al. 2014), a factor that is not tested in this study as all fruit tree species are analysed together. Other factors could also be territories of threats, trees that are good for hiding or nesting, or relative closeness to water. To my knowledge, these factors have not been analysed in previous studies, but could be subjects of future research.

4.3 Behavioural analysis

The average number of individuals per group in this study matches other (4.8-7.7 individuals) studies reporting group sizes between 2 and 16 individuals (Soini 1987; Bennett et al. 2001). When it comes to time spent at different heights, the groups in this study generally spent time higher up than what have been found in earlier studies. While the groups in this study had an average height of 12 metres and 21% of their time was spent at 20 metres or higher, an earlier study showed that tamarin groups had an average height of 7 metres (Porter 2004), and
another study showed that only 2% of the tamarins’ time was spent at 20 metres or higher (Soini 1987). Why the tamarins in this study spend time higher up than earlier studies have shown is unclear and could be researched more.

There was no difference in behaviour between groups. When looking at the mean height there was no difference between the different types of behaviour, but there was a difference in height between groups. When further observing the differences between the different groups there was no significant difference between any groups, but the groups with the greatest difference in mean height per follow per behaviour was the red and pink group, with the red group generally being found higher up in the trees than the pink group.

In this study, instantaneous scan sampling was used to record behaviour, and, as seen in other studies, scan sampling overestimates the time the primates are spent moving (Amato et al. 2013). A lot of different types of behaviour was often happening during the intervals, but when the time came to record the behaviour, the tamarins were once again moving. However, scan sampling is still useful to get an overall view of how the primates use their time.

The analysis of the behavioural data suffers similarly to the track data from a lacking amount of data. Another thing to be noted is that the behavioural data was collected by several different observers, over four years. Due to this, there may be discrepancies in the height estimations between the different observers. To eliminate this issue, a laser meter could be used in the future to estimate how high up in the tree the primate was seen.

4.4 Continuing the research

The main purpose of this study was to gather information about the home ranges of *L. fuscicollis*, such as size and the possible constraints in tree composition limiting the home ranges, as well as learn more about the behaviour of the species. All of this information can then be used to assess tamarin densities and in determining the effect of human activities on the species, and hopefully diminish both the intentional and unintentional effects.

With the data at hand, we cannot draw any firm conclusions as to why the *L. fuscicollis* groups studied in this study have chosen to live within the areas that they have as there were no real differences in tree composition separating the areas where they were present compared to not present. The behaviour of the studied groups proved to be similar. What we can see is that different groups seem to prefer staying at different heights in the trees, which tells us that there is a need for a dynamic forest for different groups to be able to prosper.

This study can work as a starting point for further studies. While there is too little data to properly assess the accurate home ranges, we can from this study get an idea of where the tamarins spend their time, and can build upon the already existing data, and collect more. While we do not see an effect on the type of trees, we can in the future look at other ecological factors that might affect the home range. As we already know, it is important to
keep going, and keep unlocking the answers explaining the way different species work in order to properly protect them - and in the end promote biodiversity.

The threat towards primates is huge, and is getting bigger each day, with threats stemming from human effects being the ultimate menaces (Shanee et al. 2023). Many primate species are continuously decreasing in number, getting closer to dangerously low levels (The IUCN Red list of Threatened Species 2021). While legislation is necessary, it is difficult to pass laws protecting nature in the face of great opposition from humans living in protected areas (Shanee 2016). The importance of learning more about the L. fuscicollis, and other primates as well, cannot be underestimated, as primates in general are suffering from human created threats. It is therefore our responsibility to keep investigating and learning more to protect the species.
5. Conclusion

In conclusion, the home ranges were found to be between 2.6 ha and 17.9 ha for the different groups. There were no differences in tree composition between the areas where the tamarins were present compared to not, nor any differences in the behaviour between the four different study groups, except for a difference in how high up in the trees the groups were generally found. There was a lack of good data in this study, due to time- and material constraints, but overall, the home ranges were of close to similar size as earlier studies, and the behaviour of the tamarins was in general also consistent with earlier studies. This study has answered some questions, while also encountering new questions that could be answered with further studies.

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