# Title page

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**Title:** Effects of selective logging on reintroduced spider monkeys (*Ateles chamek*) behavior, strata- and area use in Madre de Dios, Peru

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**Abstract:**

Within the last decades, deforestation increased worldwide, especially in the amazon basin. This affects black faced black spider monkeys (*Ateles chamek*) directly by hunting of lumberjacks or indirectly by habitat destructions. Reintroductions as conservation tool increased in the last years for this species. We therefore investigated the effects of selective logging on the reintroduction of *A. chamek* in the southeastern rainforest of Peru. We compared behavior-, strata- and area use data of two reintroduction processes, one from 2014 with selective logging in the area and one from 2022 with no selective logging. We found significant differences for behavior categories “moving” and “feeding” and strata use categories “understory” and “canopy”. However, due to low R-squared values we believe, that selective logging had only little impact. Home range size in 2014 was only half the size of 2022 which could be an effect of selective logging, but also of several other factors like food availability. We encourage future studies to test several – instead of one - effects on behavior- strata- and area use during reintroduction processes in *A. chamek*.

**Keywords:** conservation, habitat destruction, home range, *Platyrrhini*, timber

**Acknowledgements:** I would like to thank *Kawsay Biological Station* and their people who helped during data collection. Special thanks to Raul Bello who provided the data of 2014. I would like to thank Ev. Studienwerk Villigst e.V. for their financial support.

## Introduction

Human disturbances, especially habitat loss, are the major factors for species extinction (Primack & Morrison 2013). In recent years, logging events have increased immensely in the amazon basin, due in part to a lack of legal restrictions, a high demand on the world market, and road constructions (https://wwf.panda.org/, https://time.com/). This trend is unlikely to change, as the world's wood demand has continued to rise, especially in emergent countries (with high timber productions) like South American nations (https://ojo-pub-lico.com/919/shihuahuaco-species-threatened-global-trade). Moreover, industrial countries have begun to transition from building houses out of traditional stone-building to more sustainable wood constructions (Švajlenka & Kozlovská 2018).

Timber species in this region such as Shihuahuaco (*Dipteryx micrantha*) and Lupuna (*Ceiba pentandra*) are often foraging hubs and foraging connectors (Peters et al. 2016). Therefore, it is important to understand how animals react and adapt to (possible) disturbances of selective logging, to see if this type of timber could be a solution for satisfying the rising wood demand or whether it needs to create an effective conservation program to protect the species against negative effects.

The IUCN red list of threatened species classifies the black faced black spider monkey (*Ateles chamek*) as endangered with a declining population trend (IUCN 2021). Spider monkeys often use the above mentioned tree species as resting trees, sleeping trees, and as a food source (Bello 2018). Spider monkeys, compared to other platyrrhine monkey species, are particularly affected by human disturbances due to their large home ranges, their dietary niche and their slow reproductive circles (Rimbach et al. 2013; Lange & Robson 2019; Felton 2008). In this region, a previous population of *A. chamek* went extinct due to high hunting pressure (Rosin & Swamy 2013).

Reintroduction is a conservation method employed to avoid the permanent extinction of a species in an area. Since 2011 a new (stable) population of *A. chamek* got reintroduced (Pottie et al. 2021). The success of a reintroduction of *A. chamek* depends on several factors (Bello 2018; Pottie et al. 2021). There are no previous studies that have investigated the effects of selective logging as a factor of successful spider monkey reintroduction. Therefore, the aim of this study is to investigate the impact of selective logging on the reintroduction process of *A. chamek*.

Recent studies (Rimbach et al. 2013; Ordóñez-Gómez et al. 2016) on spider monkeys (*Ateles hybridus* and *Ateles geoffroyi*) have examined fecal glucocorticoid metabolite (fGCM) levels, which is associated with animal stress-level, health, and fitness. Both studies found that fragment size and human disturbances (such as logging and hunting) increases fGCM. Ordóñez-Gómez et al. (2016) also concluded that spider monkeys living in fragmented areas with less forest cover have a lower mean percentage of time spent travelling and a higher mean percentage of time spent resting. In contrast to those results, Gonzalez-Zamora et al. (2011) found that spider monkeys (*Ateles geoffroyi*) spent more time feeding and less time resting in fragmented forests compared to continuous forests. However, these studies examined the effect of logging (fragmentation) and not the influence of selective logging.

As such, prior results may be relevant to the outcomes of this study though the type of logging in this study differs significantly.

The contrary results from recent studies, the lack of research on the effects of selective logging on the reintroduction success and the deficiency of data for *Ateles chamek* all demonstrate the importance of this study and further research on the topic of selective logging on reintroduced primate species.

## Material&Methods

### Study site

Kawsay biological station was founded in 2018 in the south-east of Peru, near the border to Bolivia (12°31'32.7"S 69°01'00.2"W, see Figure 1). It is located in an approximate 200 ha large governmental established conservation area in the buffer zone of the Tambopata National Reserve. However, before its creation, there were annual selective logging events performed illegally by neighboring farmers. The vegetation is dominated by subtropical wet forests in primary and secondary structure due to deforestation (Azovskaja 2020).

**Fig. 1** Map of Kawsay biological station (red point) and its surrounding areas and the city of Puerto Maldonado (center left). (Satellite data: Google, TerraMetrics 2023)

Study group

Within this protected area live several groups of reintroduced black faced black spider monkeys (hereinafter referred to as spider monkeys). Most of them were rescued from the pet trade. Since the first reintroduction in 2010, each year (excluding 2012 and 2015) a group of spider monkeys has been reintroduced, totaling 42 individuals overall (Pottie et al. 2021). The most recent reintroduction was a group of eight females and two males in April 2022. This group is the main study object for the 2022 season of data collection. This group is compared with the released group of 2014 (seven females, one male). All of these released monkeys went through the rehabilitation process at the same nearby rescue center before being released (Bello 2018).

Monitoring

Spider monkeys were monitored daily after a cool down phase of 18 days post reintroduction. Monitoring consisted of a group of researchers entering the rain forest and locating the released group of spider monkeys by imitating spider monkey calls. Habituated monkeys answering partly to those calls. Once they located a group of monkeys, the researchers would begin to follow them and monitor their behavior. Monitored spider monkeys seemed to not change their behavior because of human presence due to a lack of interest in them. Behavior was recorded according to the following categories: feeding, resting, moving and other (vocalization, social interaction, excretions). Moreover, notes about strata use were taken. Categories for strata were floor (<2 m), understory (<15 m), canopy (>15 m) and emergent layer (>30 m). For 4 hours a day, data was collected regarding the spider monkeys' behavior and strata use every five minutes. The hours of data collection were split equally through the day from 6:00 am to 6:00 pm. To record the home range, GPS positions were recorded every 30 minutes while following the spider monkeys. The monitoring ended each day after a set time, unless the monkeys settled in a sleeping tree for the night before then. The monitoring period lasted eight weeks, from the 2nd of May to the 23rd of June 2022. In 2014, spider monkeys got monitored from the 2nd of October to the 9th of December.

Statistical analysis

For statistical analysis, we compared monitoring data from 2014 (with big selective logging events) with the most recent dataset from 2022. For the behavior and strata use data, we calculate the mean percentage of each category for every monitoring hour. Afterwards we used two independent samples t-tests to see if the mean values of 2014 and 2022 differed significant. We adjusted the significance level for multiple testing with the Bonferroni attempt and reduced our p-value to 0.047 to reject our null hypothesis. We tested all variables for normal distribution, (equal) homogenous variances and outliers and adjusted them if needed. We calculated linear regressions with the behavior- and strata use data as dependent variables and logging as an independent variable. By doing so, we were able to find the amount of impact ($R^2$) logging had on behavior and strata use.

To analyze the home range, we used the GPS data to create two maps, a heatmap via kernel density estimation and a 100% minimum convex polygon (MCP). According to Gregory (2017), using different home range methods in one study produce better results and outcomes. We used the statistical software R (version 4.3.0, R Core Team 2023) for the calculation of the models and the geographic information system QGIS (version 3.24, QGIS Development Team (2023)) for the home range analysis.

## Results

During 69 days of data collection in 2014, 7008 data points were collected. In 2022, 16904 data points were collected within 53 days, resulting in a total of 23912 data points across both years. In 2022, during the pre-release phase before data collection, some individuals disappeared and some split up from the group during collection, resulting in three to eight individuals per day for evaluation.

### Behavior and strata use

We compared the relative amount of behavior and strata use per hour in the two study years 2014 and 2022. We have not tested the behavior category "other" and the strata category "floor", because we determined it to be irrelevant during the data collection. Out of 23912 collected datapoints, only 90 were in the category "floor" and 38 in "other".

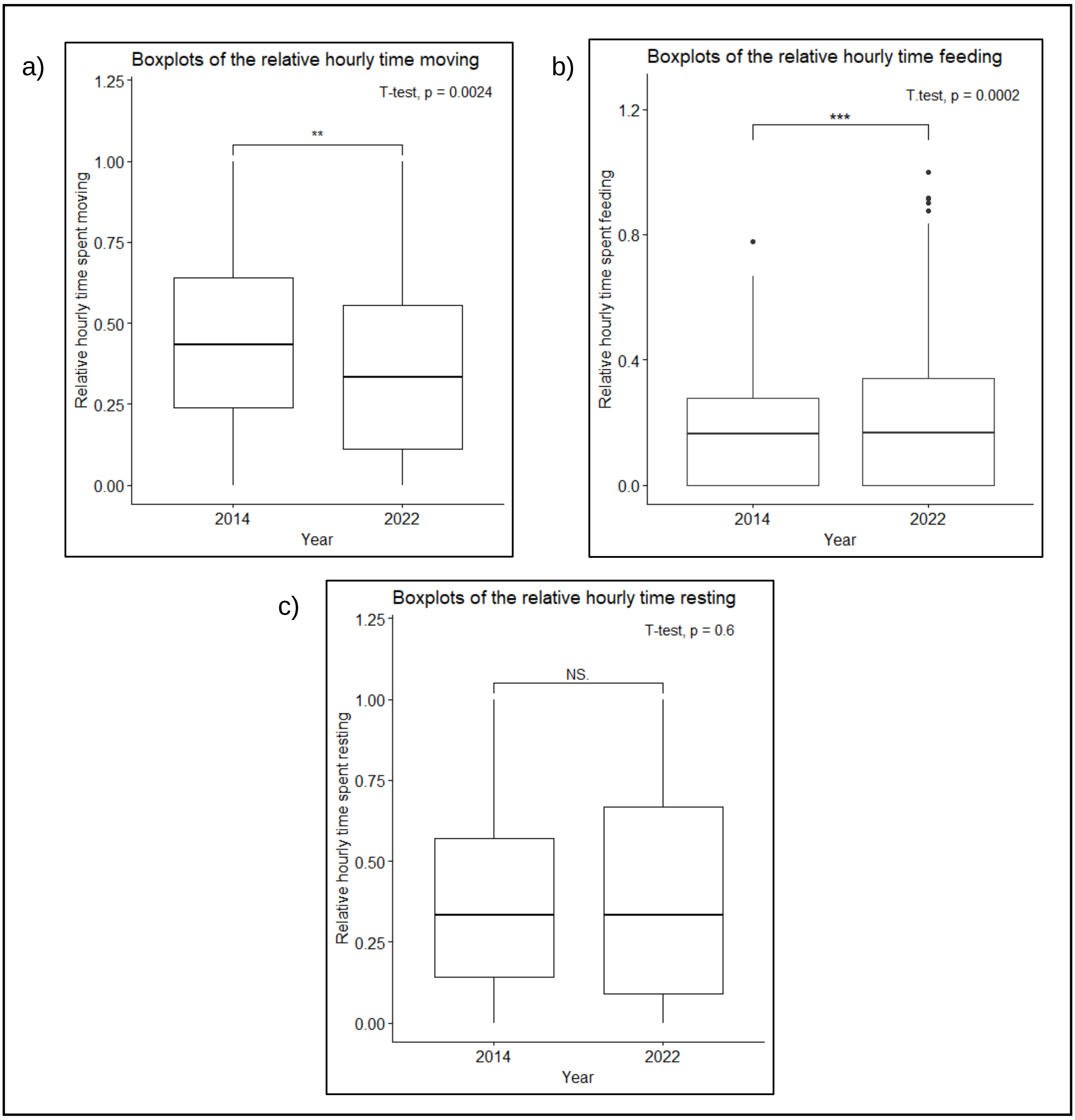


**Fig. 2** Differences in relative hourly spent time in the behavior categories a) “moving”, b) “feeding” and c) “resting” in the study years 2014 and 2022.

For behavior categories, we found significant differences in “moving” ($p = 0.002$) and a mean in 2014 of 44% and 36% in 2022 (Fig. 2a) and “feeding” ($p < 0.001$) and mean values of 18% in 2014 and 24% in 2022 (Fig. 2b). There were no significant differences within the category of “resting” ($p = 0.622$) (Fig.2c).

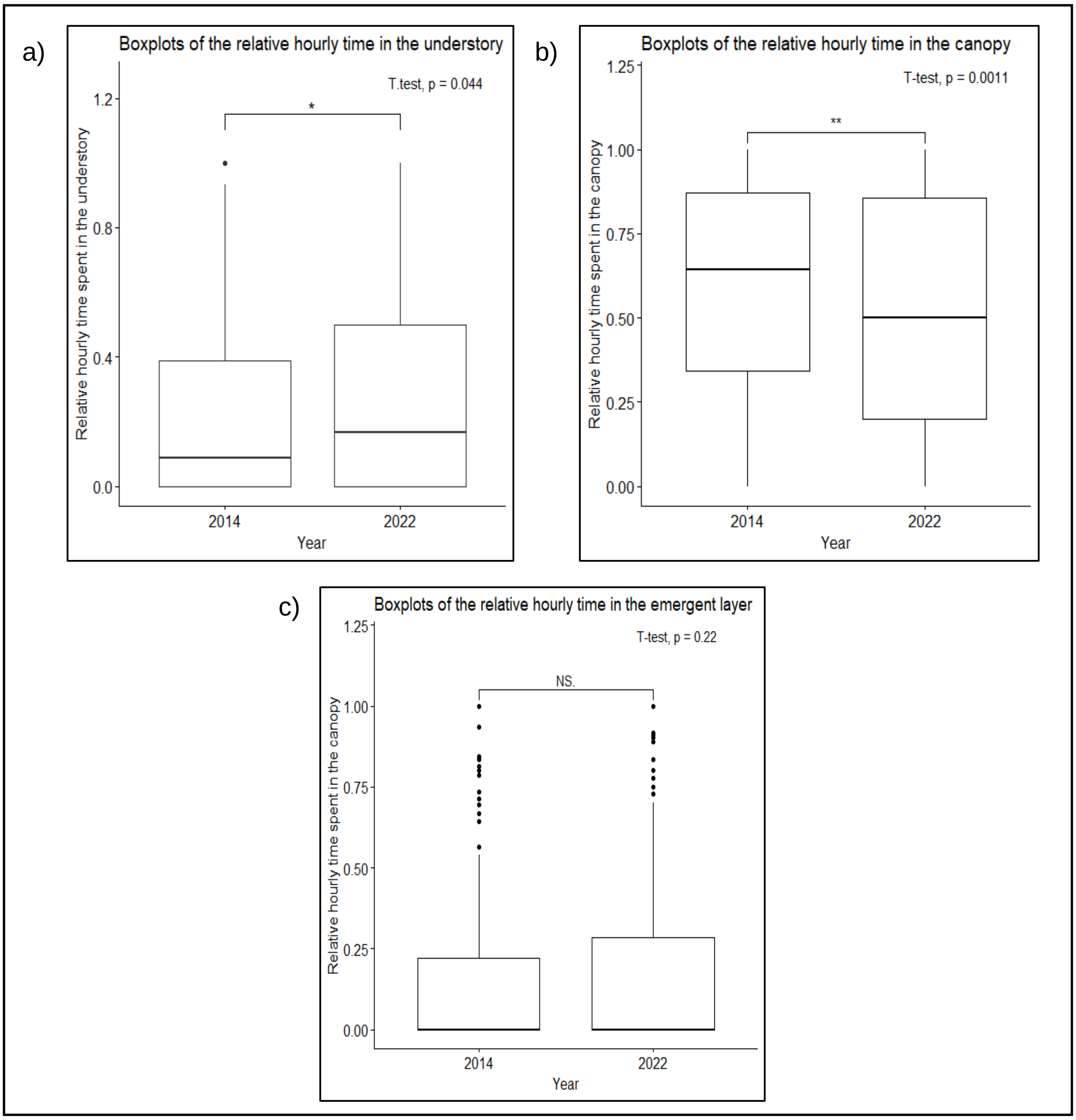


**Fig. 3** Differences in relative hourly spent time in the strata categories a) “understory”, b) “canopy” and c) “emergent layer” in the study years 2014 and 2022.

For the strata use categories, “understory” and “canopy” had significant differences. Spider monkeys spent on average 21% of their time in the “understory” in 2014 and 27% in 2022 (p = 0,045, Fig. 3a). Spider monkeys spent on average 61% of their time in the “canopy” in 2014 and 52% in 2022 (p = 0.001, Fig. 3b). There were no significant differences in the use of the “emergent layer” (p = 0.218, Fig. 3c).

Linear regressions were calculated next with the variables that had significant differences in the T-test as dependent and “logging” which is equally binary coded to the years 2014 and 2022 as independent variable. We tested for linear relationships between the variables, homoscedasticity, normal distribution of the residuals, and all models met these assumptions.

**Tab 1** Main outcomes of linear regressions with significant variables from previous T-tests.

| **Variable** | **Intercept** | **Estimate** | **p-value** | **$R^2$** |
|---|---|---|---|---|
| moving | 0.364 | 0.07 | 0.002 | 0.009 |
| feeding | 0.242 | -0.061 | 0.002 | 0.002 |
| canopy | 0.519 | 0.09 | 0.003 | 0.009 |
| understory | 0.268 | -0.052 | 0.045 | 0.003 |

Results of the linear regressions were equal to the previous T-tests, however with this method we calculated adjusted $R^2$s for each model. Adjusted $R^2$ for “moving” as dependent variable and “logging” as independent variable is 0.0093 = 0,93%, for “feeding” 0.009 = 0,9%, “canopy” 0.0087 = 0,87% and “understory” 0.0033 = 0,33%.

## Home range sizes

We had 640 GPS points from 69 days in 2014 and 449 GPS points from 53 days in 2022 for home range calculations. In a first step, we calculated the 100% MCP of each group. The total area spider monkeys used in 2014 is 62,92ha. In 2022, spider monkeys used an area of 136ha.

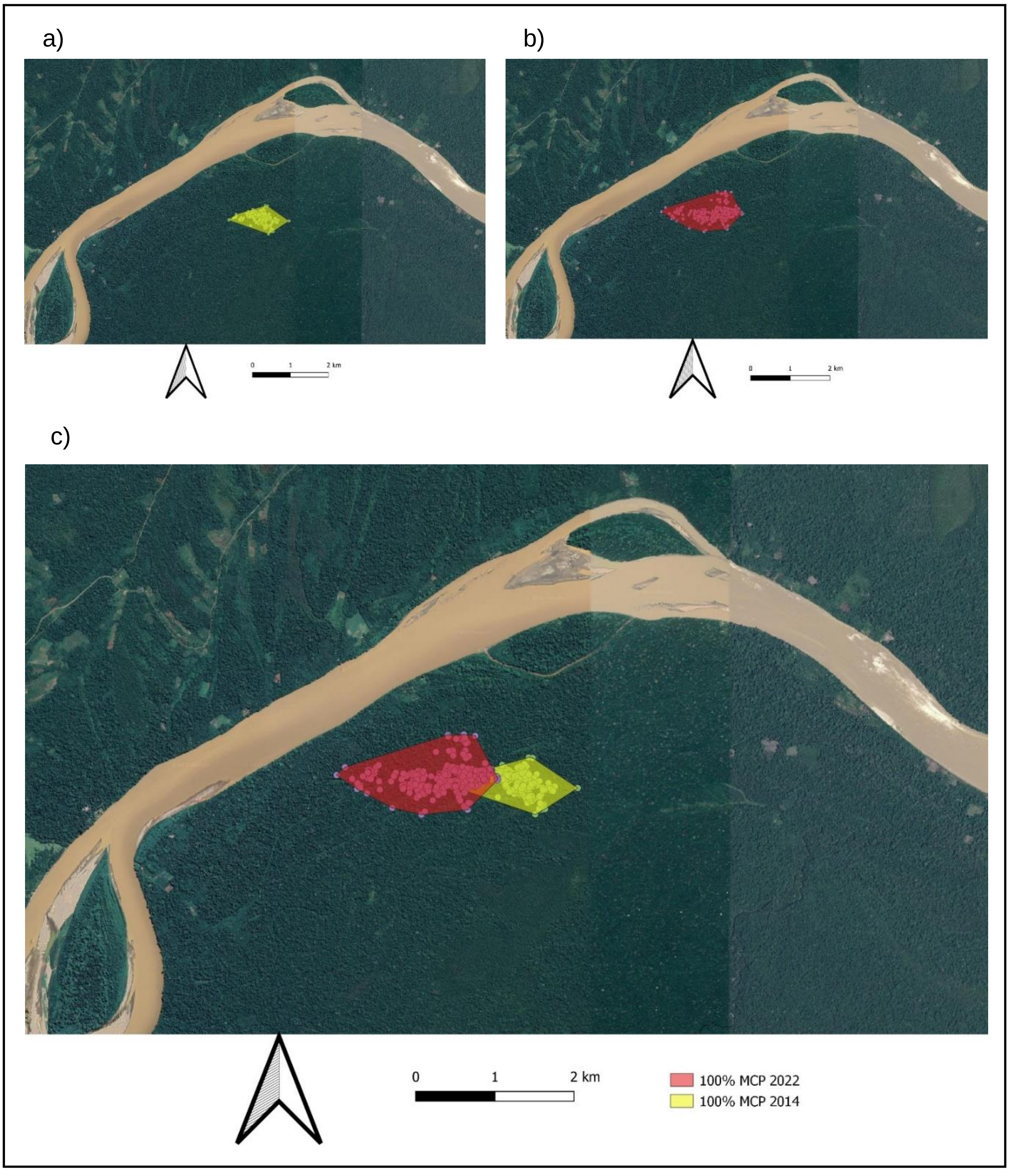


**Fig 4** 100% MCPs for a) 2014, b) 2022 and c) both years together (Satellite data: Google, TerraMetrics 2023)

In a second step we calculated heatmaps to identify the area use within the home ranges.

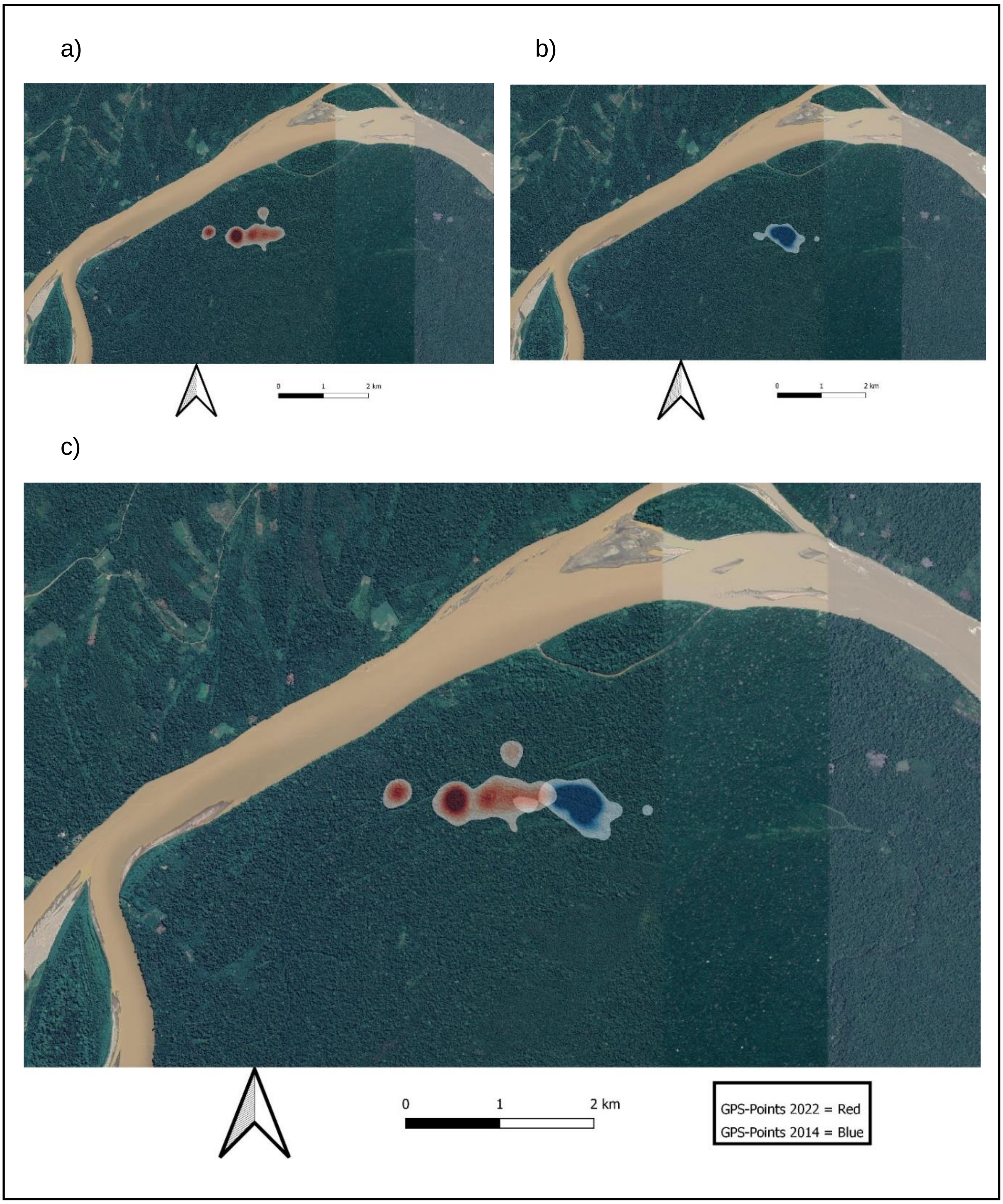


**Fig. 5** Heatmaps for the years a) 2022, b) 2014 and c) both years together (Satellite data: Google, TerraMetrics 2023)

## Discussion

### Behavior and strata use

We found significant differences in two behaviors (moving, feeding) and two classifications of strata use (canopy, understory) between the years of 2014 and 2022. Although our models found a significant impact of the independent variable "logging", the adjusted $R^2$ reveals the limitations of this study. Adjusted $R^2$ values of under 1% is marginal for behavior studies. There are several possible reasons which could explain the low values.

Comparing two groups, even from the same species, can lead to intergroup variation as a result of ecological affordances like food availability, temperature or weather and social determinants like group size, structure or history of the group (e.g. being reintroduced from pet trade) (Kaufhold & Leeuwen, 2019). We assume, that intergroup variation also influenced our study results. First, we have no ecological data from 2014, but unpublished data from the repeated data collection in 2022 showed, that climate factors and weather can have a significant impact on behavior too. Moreover, while data was collected in the dry season in 2022, it had been collected in the wet season for 2014, which can be a factor for different behavior use (Chaves et al. 2011; Reyna-Hurtado et al. 2017).

We cannot compare social determinants between the two groups, because of missing information from the 2014 group. However, we still assume, that social determinants influence spider monkeys' behavior. We can see in the unpublished data from 2022, that the time after monkeys got released in the wild has significant impact on behavior and strata use variables. Additionally, one dominant female in the 2022 group, who quickly became dominant in the group, had previously been reintroduced in the area. This individual's experience could lead to different behavior use of the group, e.g. into less moving because food patches are already known.

Altogether, using our analysis method, we cannot prove positive or negative impact of selective logging on spider monkeys' behavior and strata use. Due to the low adjusted $R^2$ we can hypothesize that spider monkeys adapted quickly to the selective logging events. However, as described before, several other factors could influence our results too. We therefore encourage future studies to focus on the topic of selective logging and its impact on reintroductions for primates.

### Home range sizes

We found large differences between the area use in 2014 and 2022. While the group in 2014 was single centered in a total area of 63ha, the 2022 group used several areas in a total range of 136ha which is more than double the area size of 2014.

We could not test if selective logging was the main factor for the change in area use, but it is probably not the only one. One big factor which has to be considered are the different seasons during which data collection took place. Wallace (2006) found, that fruit availability and therefore season (with an increase in fruit availability during the wet season) has a significant impact on *A. chamek* home ranges. This can also be seen in our results, as the 2022 group moved in a bigger area, likely to find scarce and more separated food sources. Moreover, as already mentioned before, one monkey, who was the dominant individual of the 2022 group, had previous reintroduction experiences. This could enable faster adaption during the reintroduction process and hence a wider exploration of the forest. Lastly, predators can influence area use as well (Bello 2018). Personal observations during the data collection noted that a puma (*Puma concolor*) attacked the 2022 group and killed one monkey. The other individuals fled into a different part of the forest, avoiding that old area over several weeks.

Altogether, the wider area use in 2022 in comparison to 2014 could be a result of selective logging in 2014, however we cannot prove this conclusively through data collected via our study method. We therefor encourage more investigations in this study field.

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