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Rehabilitation Assessment of a Juvenile Woolly Monkey (Lagothrix lagotricha poeppigii) Troop on Sumak Allpa Island, Ecuador

Christine Walder
SIT Study Abroad

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Walder, Christine

Academic Directors: Silva, Xavier and Robayo, Javier

Project Advisor: Wagner, Martina and Vargas, Hector

Bowdoin College

Biology and Environmental Studies

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Abstract

The silvery woolly monkey, *Lagothrix lagotricha poeppigii*, is listed as vulnerable by CITES because of habitat degradation, hunting, and illegal trafficking; compounding this problem the monkeys do not successfully breed in captivity. Sumak Allpa, a non-profit foundation in Orellana, Ecuador, has established a rehabilitation program on Sumak Allpa Island to reintegrate monkeys into their natural habitat. A troop of three juvenile monkeys that had spent all but 3-5 months of their life in captivity was introduced to the island in September of 2012 and beginning April 14, 2014 the monkeys' diet was assessed to determine the feasibility of removing human-provided food. The food provided was gradually reduced over the course of a week, and the monkeys' reaction to this was monitored until May 3rd, when the study ended. The monkeys successfully transitioned into independence from human food sources, and their reaction to the reduced food supply was similar to that seen in woolly monkeys during times of reduced fruit abundance, with less time spent on social behavior and less time consuming insects. Their diet included 53 different plant species pertaining to 25 plant families. Of these, more than half the monkeys' time eating was spent on cecropia, guava, donsel, abio, pambil, guayaba, and granadilla. The Cecropiaceae, Fabaceae, Arecaceae, Myrtaceae, Moraceae, and Sapotaceae families were most important in terms of time spent eating. The monkeys occupied a range of 25-30 Ha. The monkeys' diet is comparable to *L. poeppigii* troops in nearby Yasuni National Park, and seasonal and habitat variation most likely account for most differences in diet.

Abstracto

El mono chorongo, *Lagothrix lagotricha poeppigii*, está listado como vulnerable por CITES a causa de la degradación de su propio hábitat, la cacería, y el tráfico ilegal; en adición los monos no se reproducen exitosamente en la captividad. Sumak Allpa, una organización en Orellana, Ecuador, estableció un programa para rehabilitar a los monos en la Isla Sumak Allpa y reintegrarlos a su hábitat natural. Una tropa de tres chorongos juveniles quienes estaban enjaulados desde 3-5 meses de edad fueron introducidos a la isla en septiembre de 2012. Empezando el 14 de abril, 2014, la dieta de los monos fue investigada para determinar la viabilidad de quitar la comida proveída por los humanos. La comida fue reducida gradualmente para una semana, y la reacción de los monos fue monitoreada hasta el 3 de mayo. Los monos hicieron la transición a la independencia de los humanos con éxito, y su reacción era similar a la reacción típicamente vista en épocas de menos fruta. Su dieta incluyó 53 especies de plantas que pertenecieron a 25 familias. De estos, más de la mitad del tiempo de comer fue gastado en la cecropia, la guava, el donsel, el avío, el pambil, la guayaba, y la granadilla. Las familias Cecropiaceae, Fabaceae, Arecaceae, Myrtaceae, Moraceae, y Sapotaceae eran las más importantes. Los monos ocuparon un rango de 25-30 Ha. Su dieta es comparable a otras tropas de *L. poepegii* en el Parque Nacional Yasuní, y cambios anuales y diferencias en hábitat probablemente causaron las diferencias más grandes entre los monos de Sumak Allpa y Yasuní.

ISP Topic Codes: 608, 622, 604
Keywords: *Lagothrix,* woolly monkeys, monkey conservation, diet, foraging ecology

Introduction

Sumak Allpa

Sumak Allpa is a non-profit foundation located in the Ecuadorian Amazon on Sumak Allpa Island, commonly known as La Isla de los Monos. Sumak Allpa Island is approximately 30 km downstream along the Napo River from the city of Coca, in the province of Orellana in Ecuador. Sumak Allpa, which means "land of no pain," is dedicated to preserving and supporting indigenous cultures as well as the jungle ecosystem. As part of this mission, Sumak Allpa Island has been established as a monkey reserve to rehabilitate monkeys that were taken from their natural habitat, often as part of illegal trafficking or deforestation. The 113.5-hectare island provides a natural but sheltered jungle ecosystem for the monkeys. On the island, the monkeys learn to survive in the wild, have formed many social groups, and are reproducing. Sumak Allpa currently houses seven monkey species: the pigmy marmoset (leoncillo or mono de bolsillo), the golden-mantled tamarin (chichico amarillo or chichico de manto dorado), the woolly monkey (chorongo or mono barrigudo), the black-mantled tamarin (chichico negro or bebeleche), the saki monkey (mono volador), the night monkey (mono nocturno or tutamono) and the squirrel monkey (barizo or mono ardilla). The long-term goal of Sumak Allpa is to grow the monkey populations on the island to much greater numbers and then release monkeys back into the wild. Much of the Ecuadorian Amazon's primate population has been decimated by hunting and deforestation, meaning that large tracks of land are without significant monkey populations and are in need of repopulation. Monkeys are important seed dispersers (Yumoto et al 2009) and generate important revenue for indigenous groups through tourism (personal communication with Hector Vargas; www.sumakallpa.org).

Lagothrix lagotricha poeppigii *background information*

Lagothrix poeppigii, commonly known as the silvery woolly monkey, is a large atelin primate with populations located in Ecuador, Brazil, and Peru (Stevenson et al 2008). In Ecuador, it is found in the provinces of Orellana, Napo, Pastaza, Morona Santiago and Zamora Chinchipe. Animals are dark brown to reddish in coloration, with a prehensile tail that is 1-1.5 times longer than the body. Individuals typically weight between 5-10kg (Fooden 1963). Babies are weaned at approximately one year of age, and females reach sexual maturity after approximately eight years. The longest recorded lifespan among *Lagothrix spp.* in captivity is twelve years (Harvey and Clutton-Brock, 1985), although they are believed to live for up to thirty years.

The species tends to live in large social groups of up to 50 individuals (Fooden 1963), and groups consist of either solitary males or male groups (Di Fiore and Fleischer 2005). Female-only groups and solitary females have not been recorded (Di Fiore 2002). There is less inter-male aggression than observed in many other primate species, and most individuals within the group have an opportunity to mate (Defler 1995). There is believed to be a very low level of

male dispersal, while females are more likely to leave their troop for another one (Di Fiore and Fleischer 2005). However, instances of male dispersal have been recorded (Maldonado and Botero 2009).

L. poeppigii is mainly frugivorous, although it supplements its diet with insects, leaves, and flowers. *L poeppigii* depend on primary forest for the majority of their food, and do not live in disturbed or secondary forest (Stevenson et al 2008). They generally travel about 2 km per day through the forest canopy (Dew 2005), and rarely leave the canopy. Different studies have observed different levels of consumption of various food groups (Di Fiore 2004, Defler and Defler 1996, Peres 1994, Stevenson et al 1994, and Soini 1986), although in general approximately 70-80% of its diet is composed of fruit.

Di Fiore (2004) conducted a year-long study of *L. poeppigii* diet in Yasuni National Park, which is very close to Sumak Allpa Island and therefore expected to contain similar food sources. Di Fiore found that food is foraged from at least 208 different species of fruiting trees, although a full third of the woolly monkey diet comes from the *Inga, Ficus,* and *Spondias* genera. From April to May, the monkeys' diet consisted of approximately 79-77% fruit, 15-16% prey, 5-6% leaves, and 1-2% other.

In a study of seven sub-adult woolly monkeys on Sumak Allpa Island during the month of April, Mathis (2013) found that Sumak Allpa Island provides a healthy source of food for woolly monkeys. During the time of the study, the most important food species were frutipan, figs, pambil, capirona, chingo, donsel, balsa, and cecropia. The most important plant families were Moraceae, Arecaceae, Rubiaceae, and the family of an unidentified vine. Discrepancies between Di Fiore (2004)'s work and Mathis (2013)'s work may be because Sumak Allpa Island is varzea forest rather than the *terra firme* forest of Yasuni.

Woolly monkey conservation and rehabilitation

The silvery woolly monkey has been listed as vulnerable by CITES because it is believed that the population has declined by at least 30% over the last forty-five years (Stevenson et al 2008). It is threatened by deforestation and habitat loss, hunting, and illegal trafficking. Many indigenous groups hunt the monkey for bush meat, and hunting activities threaten to eliminate the species completely (de la Montaña 2013). Females with babies are often killed, and the female is eaten while the baby is taken as a pet (Cueva et al; personal communication with Hector Vargas); woolly monkeys are said to be intelligent and easily domesticated (Fooden 1963). Although *L. poeppigii* exists in captivity, captive populations are in the decline and are associated with a variety of health issues such as spontaneous abortions, hypertension, and early death (Age van Heugten 2008). Because of this, captive silvery woolly monkey breeding programs do not appear to be a viable option for ensuring the continued existence of the species. Other programs that work more closely with the monkey's natural habitat must be developed to increase the species' population.

Currently, Sumak Allpa is the only project in Ecuador with a long-term goal of releasing monkeys into the wild to repopulate areas with low monkey population (pers. communication with Hector Vargas). Other projects typically do not go beyond rehabilitating monkeys, and the monkeys are kept in captivity.

Juvenile woolly monkey troop on Sumak Allpa Island

A troop of four juvenile woolly monkeys (*Lagothrix poeppigii*) was introduced to Sumak Allpa Island approximately a year ago as part of a rescue and rehabilitation program through Sumak Allpa. The monkeys are believed to have originated from the Napo River, possibly from Tiputini or Yasuni National Park. The monkeys' mothers were hunted and the babies were captured at approximately 3-5 months of age. For approximately six months, the juvenile monkeys were kept as pets in a house near the city of Coca. They were kept in a cage and occasionally released. Their diet consisted mainly of bread, milk, cheese, rice, and bananas. The owners of the monkeys sold them to Sumak Allpa after learning that Ecuadorian authorities were threatening to confiscate the monkeys, believing that Sumak Allpa would offer the most healthy and natural living opportunity for the monkeys. The four monkeys arrived on the island on September 1st, 2012, when they were estimated to be between 9-14 months old. The troop consisted of two males and two females. Upon arriving at the island, a veterinarian examined the monkeys and deparasitized them. One female, who was very skinny, was given multivitamins. She eventually died, although every effort was made to save her. The monkeys were liberated near the dock and houses on Sumak Allpa Island where a feeding platform had been suspended several meters in the air. For the first week, the monkeys explored and lived in three trees near the platform. During the second week, they began to explore more and were observed eating from guava leaves, guayaba, and ant larva. From that point, their territory expanded slowly from the initial three trees to several hectares. It was hoped that the juvenile monkeys would join a troop of 7 adult woolly monkeys living on the island, but this was not the case. The troop is made up of one male and six females, and the alpha male may have viewed the two juvenile males as a future threat. Because of this, it is believed that the juvenile monkeys are learning what to eat based on instinct (pers. communication with Hector Vargas)

At the beginning of this study, the juvenile woolly monkey troop was still receiving food from Sumak Allpa. Every effort was made to provide the food in as natural and realistic a manner as possible, and only in-season fruit was given to the monkeys. The feeding platform was suspended in the air because it is not natural for a monkey to walk on the ground. Each day, 10-15 bananas, a cluster of grapes, 3-4 guavas, or 2-3 anonas were placed on the feeding platform. Grapes were tied to trees to mimic growing on the trees. It is estimated that, at the beginning of the study, approximately 20% of the monkeys' alimentation was provided by Sumak Allpa. However, sometimes the monkeys were observed to go for two or three days without taking food from the platform. Hector Vargas, the director of Sumak Allpa, has also observed that the troop is beginning to transition from spending more time in secondary forest and populated areas to spending more time in primary forest. It is his belief that this troop can be

weaned entirely from human support, but more research is required to assess the troop's current level of re-integration into the Amazon jungle and out of human society.

Objectives

Over the course of this study, the diet, territory, and daily activities of the juvenile woolly monkey troop will be assessed to determine its level of dependence on human support and the feasibility of complete re-integration into a natural habitat. A healthy diet is expected to consist of a variety of fruits, flowers, leaves, and insects; in addition, this troop's diet can be compared to similar studies on *Lagothrix poeppigii* diets in Ecuador conducted by Di Fiore (2004) in Yasuni and Mathis (2013) conducted on Sumak Allpa Island with an adult woolly monkey troop. The location of plants the monkeys feed from will also be mapped to determine the range of the troop; a large range encompassing primary forest and a diversity of fruiting plants will serve as an indicator of successful re-integration into the wild. If the monkeys are determined to be eating from a variety of food sources over a substantial range, the food provided to them by humans will be reduced and eventually cut off completely. The monkeys' reaction to this process will be monitored carefully to ensure that they are not going hungry. It is expected, based on Hector Vargas' current observations on the monkeys' eating habits and ranging behavior, that human-provided food will be successfully removed from the troop's diet.

METHODS AND MATERIALS

Study Site

Sumak Allpa Island is a 115 Hectare island located on the Napo River in the Orellana Province of Ecuador, approximately 30 km downstream from Coca Francisco de Orellana, Ecuador. The island is approximately 3 km long and 860 meters wide. Two types of varzea forests are found on the island: regularly flooded forest and a less flooded portion. Approximately 70% of the island is primary forest and the remaining 30% is secondary forest that was used as farmland until 2005, when the island was purchased by the Sumak Allpa Foundation. Several houses and other buildings are located near the island's dock, but the remainder of the island is left in its wild state with minimal paths and some small bridges to facilitate movement about the island.

Figure 1. Map of Sumak Allpa Island and relative location of Yasuni National Park

Monkey observation

Observation of the monkey troop was conducted from 6am to 9am and from 3pm to 6pm on a daily basis between the 13th of April and the 3rd of May 2014. This time window is known to be the period of highest activity levels for woolly monkeys. I completed a total of twenty-nine observation periods, thirteen in the morning and sixteen in the afternoon. Several mornings were missed due to rain and environmental education activities. I observed the monkeys for a total of 3171 minutes, or 52:51 hours.

For the first few days, I was accompanied and helped by Miguel Gualinga, a guide that works on Sumak Allpa Island. All other observation periods were conducted alone. I began searching for the monkeys at the beginning of the observation period, and began by looking in the area where they had last been seen. As I learned the troop's preferred route, I began to follow it to search for the monkeys more efficiently.

During observation periods, I used a focal observation method to observe a single monkey for five-minute intervals. I randomly observed an individual and then switched to another one after five minutes, making sure to observe each individual for roughly the same amount of time each day. During the five minutes of observation, I noted behavior—eating, foraging, traveling, playing, and other behavior. Eating was defined as consuming food, and was divided into fruit, flowers, leaves, and insects. I recorded what was being eaten and marked the specific tree being eaten from. Eating data was taken from direct observation as well as from monitoring of debris that fell during feeding. Foraging was defined as manipulating leaves, twigs, or other parts of the plant without placing anything in the mouth. Traveling was defined as moving through the canopy without searching for food. Other behavior included resting, grooming, vocalizations, and interacting with other species.

Although focal observation was the main method that I used, it was sometimes impossible to observe a single individual as woolly monkeys are often located high in the canopy out of sight. When focal observation was not possible, I noted what the group in general was doing.

Monitoring of provided food

At the beginning of this study, food was provided on a daily basis for the woolly monkey troop. Food consisted of in-season fruits typical of a wild woolly monkey troop's diet, and for the duration of this study small, ripe bananas (oritos) were provided. Food was placed on a platform suspended several meters in the air (see Figure 2) every morning between the hours of 6am and 6:30am. The number of bananas placed on the platform is provided in Table 1, and the number of bananas was reduced from 18 on April 13th to zero on April 20th, 7 days later. The number was reduced gradually each day to ensure that the troop noticed the smaller food supply present at the platform and stopped viewing it as a plentiful food source, encouraging them to

seek alimentation elsewhere. The monkeys' diet was carefully monitored while the human-provided food supply was being reduced to ensure the monkeys' continued health

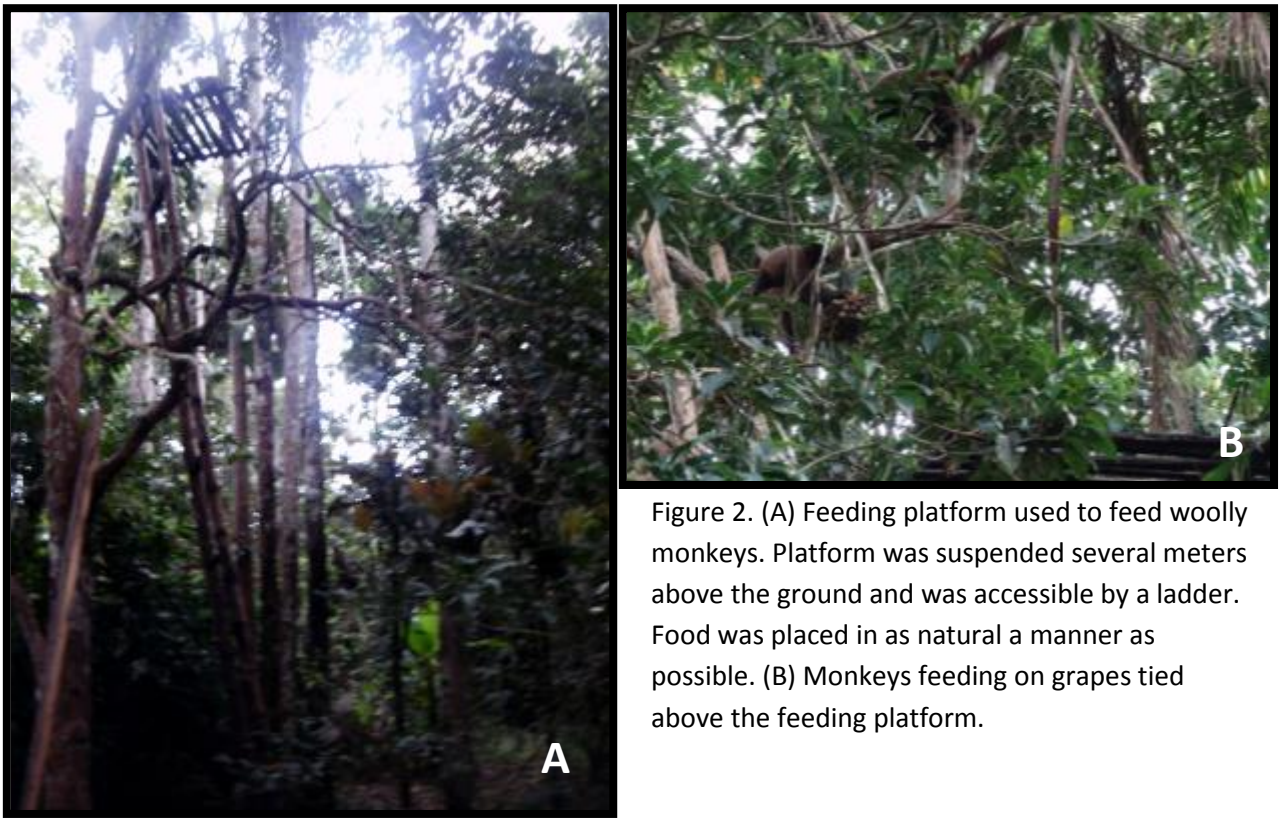


Figure 2. (A) Feeding platform used to feed woolly monkeys. Platform was suspended several meters above the ground and was accessible by a ladder. Food was placed in as natural a manner as possible. (B) Monkeys feeding on grapes tied above the feeding platform.

Table 1. Feeding data. Small bananas (oritos) were placed on a feeding platform suspended several meters in the air on a daily basis. The number of bananas placed was gradually decreased beginning on April 14th, and beginning on April 20th no food was placed on the platform.

Date	Number Bananas Given	Number Bananas Eaten	Time Eating Bananas
4/13/14	18	18	7:55-8:08; 14:00
4/14/14	16	5	6:15
4/15/14	12	12	13:17-13:44
4/16/14	8	8	6:31-6:37
4/17/14	4	4	7:13-7:15
4/18/14	4	4	18:30
4/19/14	4	4	6:10
4/20-5/6/14	0	0	n/a

Identification and mapping of food sources

Each plant from which the troop was observed eating plant matter (fruit, flowers, and leaves/shoots) was marked with a unique number using flagging tape and a permanent marker. For the last two days of this study, I created a rough map of each plant's location and identified the plant if I had not already done so. Help identifying plants was provided by Mauro Yumbo,

Hector Vargas, and Miguel Gualinga. If monkeys were eating something I could not identify, I would bring a sample and ask for help from Yumbo, Vargas, or Gualinga in identifying it. Plants that had not already been identified at the end of the study were identified in the field by Yumbo. Nobody was able to identify several vines and trees, and these are referred to as "vine 1," "tree 1," etc. The plant family and species name was identified using several field guides and internet searches if it was not already known. However, as the local guides often were familiar only with the plant's Quichua name, they are generally referred to by this name for the rest of the paper. Table 2 provides more detailed information on the plants utilized by the woolly monkeys.

Data analysis

Average feeding bout length was calculated by dividing total time observed feeding from each species by the number of foraging events for that species.

Microsoft PowerPoint was used to create the map of plants eaten from.

All graphs and statistical analyses were carried out using GraphPad Prism version 6.00 for Windows, GraphPad Software, La Jolla California USA, www.graphpad.com.

RESULTS

Activity

The time the monkeys spent during each observation period eating from plants, eating insects, foraging, traveling, playing, and engaging in other activities was monitored. The activity of the monkey troop during each observation period is shown in Figure 3. On average, monkeys spent 39% of their time eating plant material, 22% of their time eating insects, 12% of their time foraging, 8% of their time traveling, 7% of their time playing, and 11% of their time engaged in other activities not included in the above categories. In addition, the number of bananas placed on the feeding platform each day is depicted in Figure 3, and more detailed information on the feeding of the monkeys is in Table 1.

After food was no longer provided to the troop, there was a significant decrease in time spent playing, from 10.8% to 4.3% (t-test; p=0.038, df=29) as well as a significant increase in time spent traveling from 5.1% to 10.9% of total time observed (t-test; p=0.008, df=29).Although the time spent eating plants increased (from 33.8% to 43.8%) and the time spent eating insects decreased (from 26.7% to 17.6%), these changes were not significant. No difference was noted in time spent foraging, and foraging was observed 13.0% before and 10.1% of total time after bananas were removed (Figure 4). Differences were not significant for plants, insects, and foraging most likely because there was a large spread in the data due to daily variation in activities.

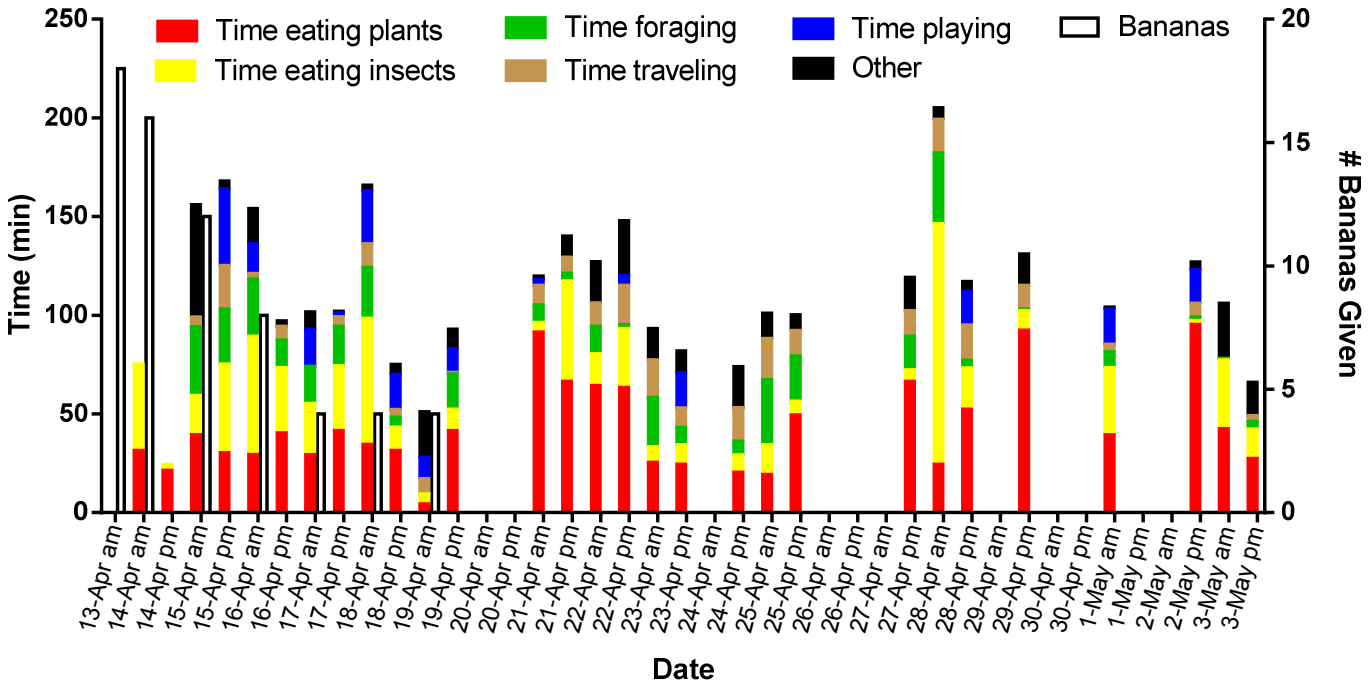


Figure 3. Time observed carrying out various activities. Other includes resting, grooming, vocalizations, and other behavior. Bananas placed on the feeding platform daily are indicated on the right y-axis, while times spent on all activities correspond to the left y-axis.

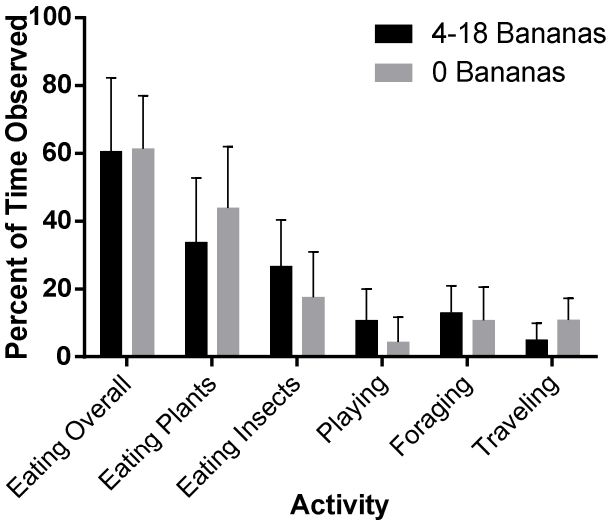
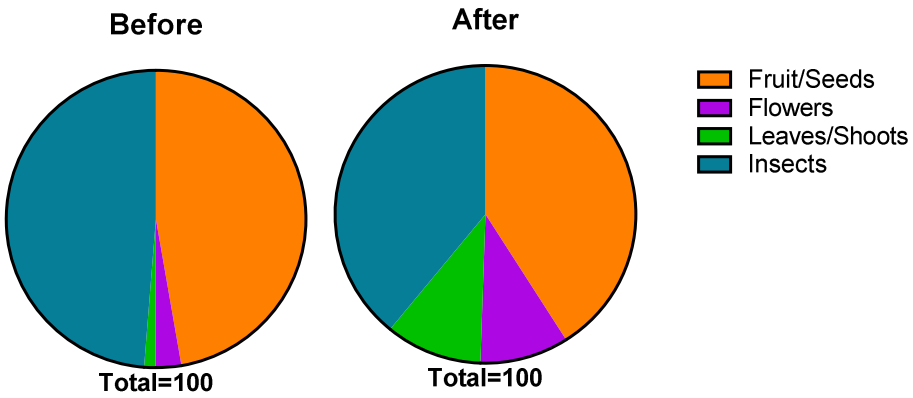


Figure 4. Time spent on each activity while bananas were provided to the monkeys (April 14th-April 19th) and when no bananas were provided (April 20th-May 3rd). There was an average decrease in time spent playing per observation period after bananas were removed (t-test; p=0.038, df=29). Time spent traveling also significantly increased per observation period (t-test; p=0.008, df=29). Although results were not significant, time spent eating plants increased while time spent eating insects decreased (p=0.15 and p=0.07, respectively). The overall time spent eating did not change (p=0.9). $N_{4\text{-}18\ Bananas}$=14, $N_{0\ Bananas}$=17. Error bars represent ±1 standard deviation of the error.

Of all the time they spent eating, the monkeys spent the greatest amount of time eating fruits and seeds (Figure 5). They also spent a significant amount of time eating insects, and only spent slightly less time eating insects than plant material. After the monkeys were no longer given bananas, the amount of plant matter eaten increased while the amount of time spent eating insects decreased. The amount of time eating leaves and flowers increased the most notably, while the amount of time eating fruit decreased slightly.

Figure 5. Percent of total time eating devoted to eating fruits/seeds, flowers, leaves/shoots, and insects before and after bananas were removed.



The plants monkeys were observed eating from were mapped (Figure 6), although it is important to note that this is a rough approximation of each tree or liana location rather than an exact map. From this, the monkeys' approximate range can be estimated. The troop was observed occupying an area of approximately 25-30 Ha, 10-12 Ha of which is comprised of primary forest. The area near the dock and houses is secondary forest, while the westernmost portion of the island is primary forest.

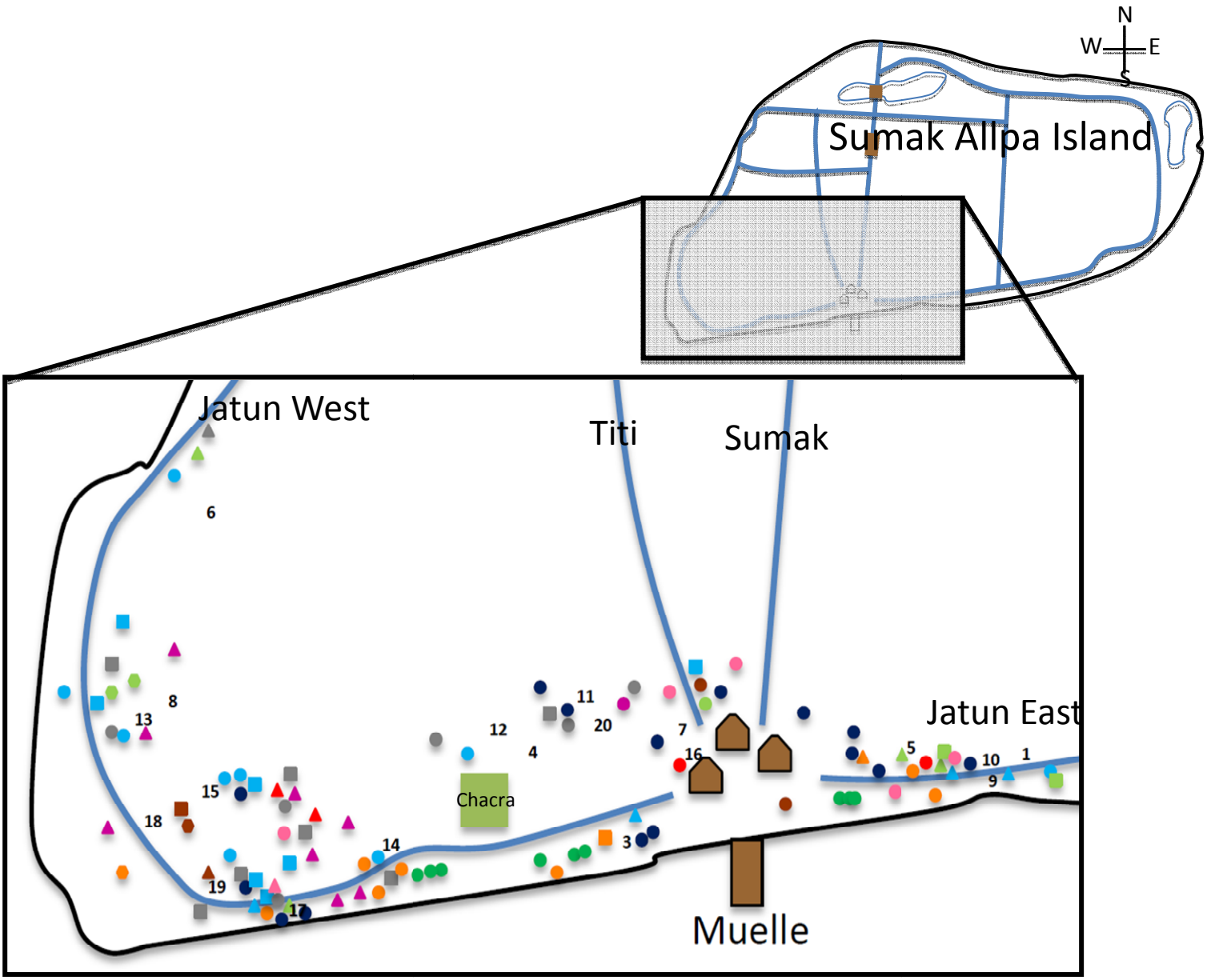
More detailed information on each plant the monkeys were observed eating from is given in Table 2, which lists plant Family, common name, and species name if possible.

Table 2. Family, species, common name, and part eaten of plants from which the woolly monkey troop was observed eating.

Family	Species	Common Name	Part Eaten
Acaranthaceae	n/a	Huarumo	Flower
Annonaceae	*Anona edulis*	Anona/Catarro-muyu	Fruit
Annonaceae	*Annona spp.*	Chirimoya del monte	Fruit
Araceae	n/a	Liana 5	Leaves
Arecaceae	*Iriartea deltoidea*	Pambil	Fruit
Arecaceae	*Philodendrum sp.*	Philodendrum	Leaves and Flower
Arecaceae	*Socratea spp.* or *S. exorrhiza*	Shiquita	Fruit
Bignoniaceae	*Jacaranda spp.*	Jacaranda	Leaves
Bombaceae	n/a	Sapote del Monte 2	Fruit
Bombaceae	*Quararibae cordata*	Sapote del Monte	Fruit
Bombaceae	*Ochioma pyramidale*	White Balsa	Flowers and Leaves
Caricaceae	*Vasconcellea pubescens*	Chamburo/Papayuelo	Fruit
Cecropiaceae	*Cecropia spp.*	Cecropia	Flowers
Combretaceae	*Terminalia oblonga*	Guayabillo/Yuyun	Flowers and Leaves
Euphorbiaceae	n/a	Caucho	Leaves
Fabaceae	*Inga spp.*	Guava/Guaba	Fruit and Leaves
Fabaceae	n/a	Ojo de venado	Leaves
Fabaceae	n/a	Tree 1	Fruit
Fabaceae	n/a	Tocota	Fruit
Lauraceae	*Nectandra spp.*	Quillo ajua/Canelo amarillo	Leaves
Lauraceae	*Ocotea spp.*	Arbol del canelo	Leaves
Malvaceae	*Ceiba spp.*	Ceiba	Fruit
Melastomataceae	*Miconia spp.*	Payasik/Flor de Mayo	Fruit
Melastomataceae	n/a	Liana 7	Leaves

Table 2 (continued)

Family	Species	Common Name	Part Eaten
Menispermaceae	n/a	Sicta/Lechero/Amatiri-caspi	Fruit
Menispermaceae	*Abuta spp.*	Yawatikaspi	Fruit
Moraceae	*Ficus spp.*	Liana del matapalo	Fruit and Leaves
Moraceae	n/a	Wallis	Fruit, Flowers and Leaves
Moraceae	*Artocarpus altilis*	Frutipan	Fruit
Moraceae	*Ficus spp.*	Liana 8	Leaves
Myristicaceae	*Virola calophylla*	Apumpo/Ecuadorian Runa	Fruit
Myristicaceae	*Otoba glycycarpa or parvifolia*	Donsel/Sangre de Gallina	Fruit
Myrtaceae	*Psidium guayaba*	Guayaba	Fruit
Passifloraceae	*Passiflora vitifolia*	Granadilla	Fruit
Passifloraceae	*Passiflora spp.*	Granadilla del monte	Fruit
Poaceae	n/a	Bamboo/Bambu	Leaves
Rubiaceae	*Chimarrhis glabriflora*	Intachic o Moleton	Flowers and Leaves
Rubiaceae	*Calycophyllum spruceanum*	Capirona	Flowers and Leaves
Sapotaceae	*Pouteria caimito or Micropholis venulosa*	Avio/Caimito	Fruit
Sapotaceae	n/a	Avio silvestre	Fruit
Ulmaceae	*Celtis schippii*	Shalipu/Shallipo	Leaves
Vitaceae	*Vitis tiliifolia*	Uva del Monte, Liana	Fruit
n/a	n/a	Liana de cerrakasha	Leaves
n/a	n/a	Liana del tomatillo	Fruit
n/a	n/a	Liana 1	Fruit
n/a	n/a	Liana 2	Fruit
n/a	n/a	Liana 3	Fruit
n/a	n/a	Liana 4	Flower
n/a	n/a	Liana 6	Fruit



Acaranthaceae
1: Huarumo
Annonaceae
Anona
Chirimoya del Monte
Arecaceae
Pambil
Philodendrum
Shiquita
Bignonaceae
2: Jacaranda
Bombaceae
3: White Balsa
Caricaceae
4: Chamburro
Cecropiaceae
Cecropia

Combretaceae
5: Guayabillo
Euphorbiaceae
6: Caucho
Fabaceae
Guava
Ojo de Venado
Tocato
Tree 1
Lauraceae
7: Canelo
8: Canelo Amarillo
Malvaceae
9: Ceiba
Melastomataceae
10, 11: Payasik
12: Vine

Menispermaceae
13, 14: Sikta
15: Yawatikaspi
Moraceae
Frutipan
Liana del Matapalo
Matapalo Blanco
Wallis Muyu
Myristicaceae
Apumpo
Donsel
Myrtaceae
16: Guayaba
Passifloraceae
Granadilla
Granadilla del Monte

Poaceae
Bamboo
Rubiaceae
17: Intachik
18: Capirona
Sapotaceae
Abio
Abio Silvestre
Sapote del Monte
Ulmaceae
19: Shalipu
Vitaceae
20: Uva del Monte Liana
Family Not Identified
Liana
Arbol

Figure 6. Map depicting all trees the woolly monkey troop fed on. Total area utilized by the troop is estimated to be between 25- 30 Ha, 12-15 Ha of which is primary forest. Primary forest is located on the western portion of the map, beginning approximately at the chakra.

The percent time the monkeys spent eating fruit from each plant species and plant Family is shown in Figure 7. Approximately 50% of the monkeys' diet was comprised of fruit from guava, guayaba, abio, donsel, pambil, and granadilla. Guava was the most important fruit species, and monkeys spent 12.5% of the total time eating fruit eating guava. The majority of the fruits eaten were not eaten frequently, and monkeys spent less than 2% of their time on each of 24 of the 37 fruits eaten. Only seven species were eaten from for more than 5% of the total time observed. A similar pattern was observed in the monkeys' consumption of fruit of different plant Families. Fabaceae, Arecaceae, Myrtaceae, Moraceae, Sapotaceae, and Myristacaceae make up approximately two thirds of the plant Families eaten from, with ten other plant Families as well as unidentified Families making up the remainder. However, as with the fruit species, no plant Family makes up a clear majority of the monkeys' diet.

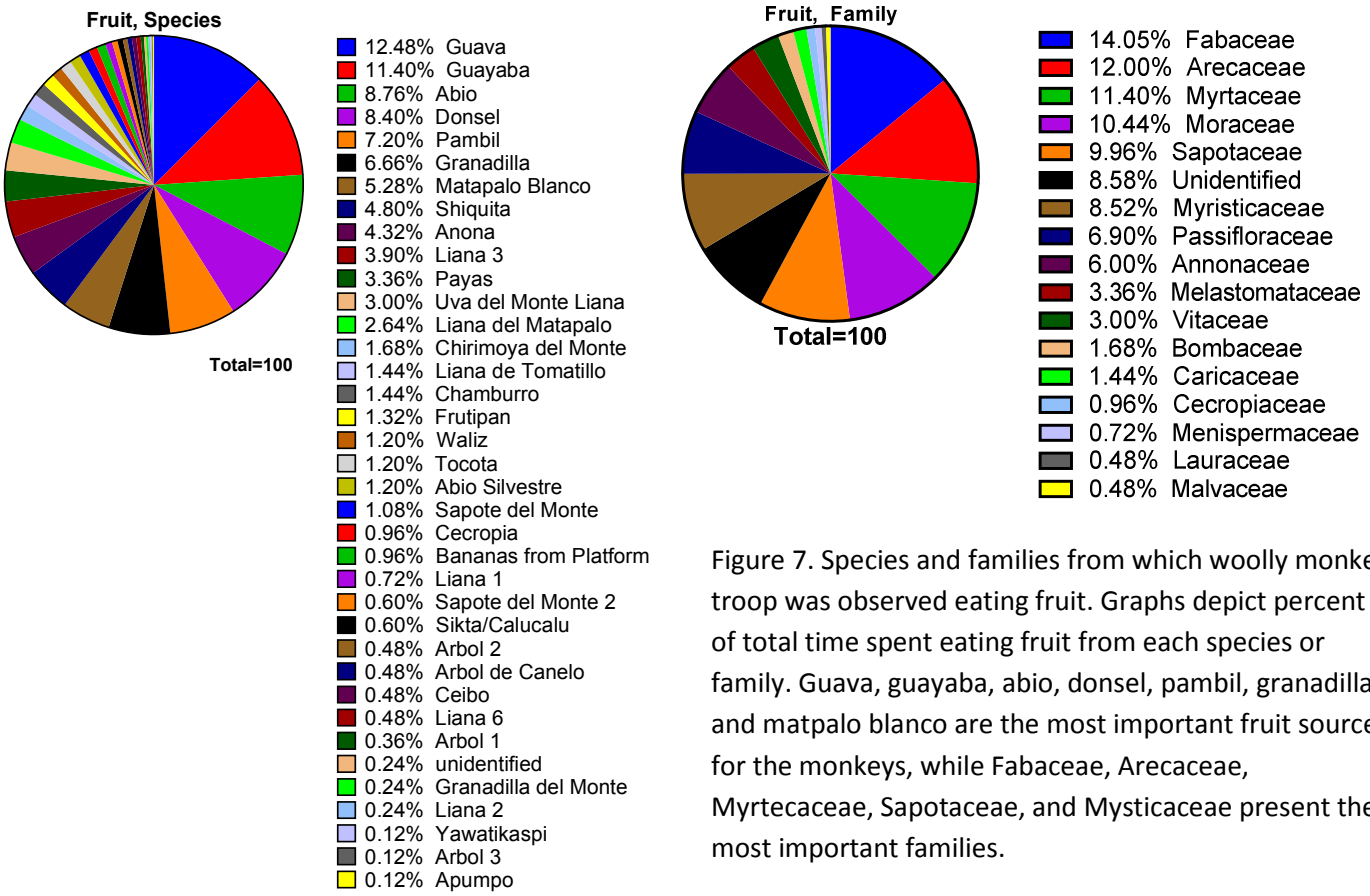


Figure 7. Species and families from which woolly monkey troop was observed eating fruit. Graphs depict percent of total time spent eating fruit from each species or family. Guava, guayaba, abio, donsel, pambil, granadilla, and matpalo blanco are the most important fruit sources for the monkeys, while Fabaceae, Arecaceae, Myrtecaceae, Sapotaceae, and Mysticaceae present the most important families.

The percent time eating from individual species and plant Families for flowers and leaves is presented in Figure 8. The consumption of both flower species and Families is dominated by cecropia of the Cecropiaceae Family, which comprises 68.3% of each (Figure 8A and B). The Moraceae Family, with the Walliz tree, is also an important source of flowers. All other flower species and families combined make up less than 25% of the flowers consumed by the woolly

monkey troop. Bamboo and guava leaves were by far the most frequently consumed leaves (Figure 8C), and all other leaves (16 different species) were each consumed less than 10% of the time. The same is true of the Families the monkeys consumed—Poaceae and Fabaceae make up the majority, with less than 10% of the monkeys' time devoted to eating each of the other 12 Families' leaves.

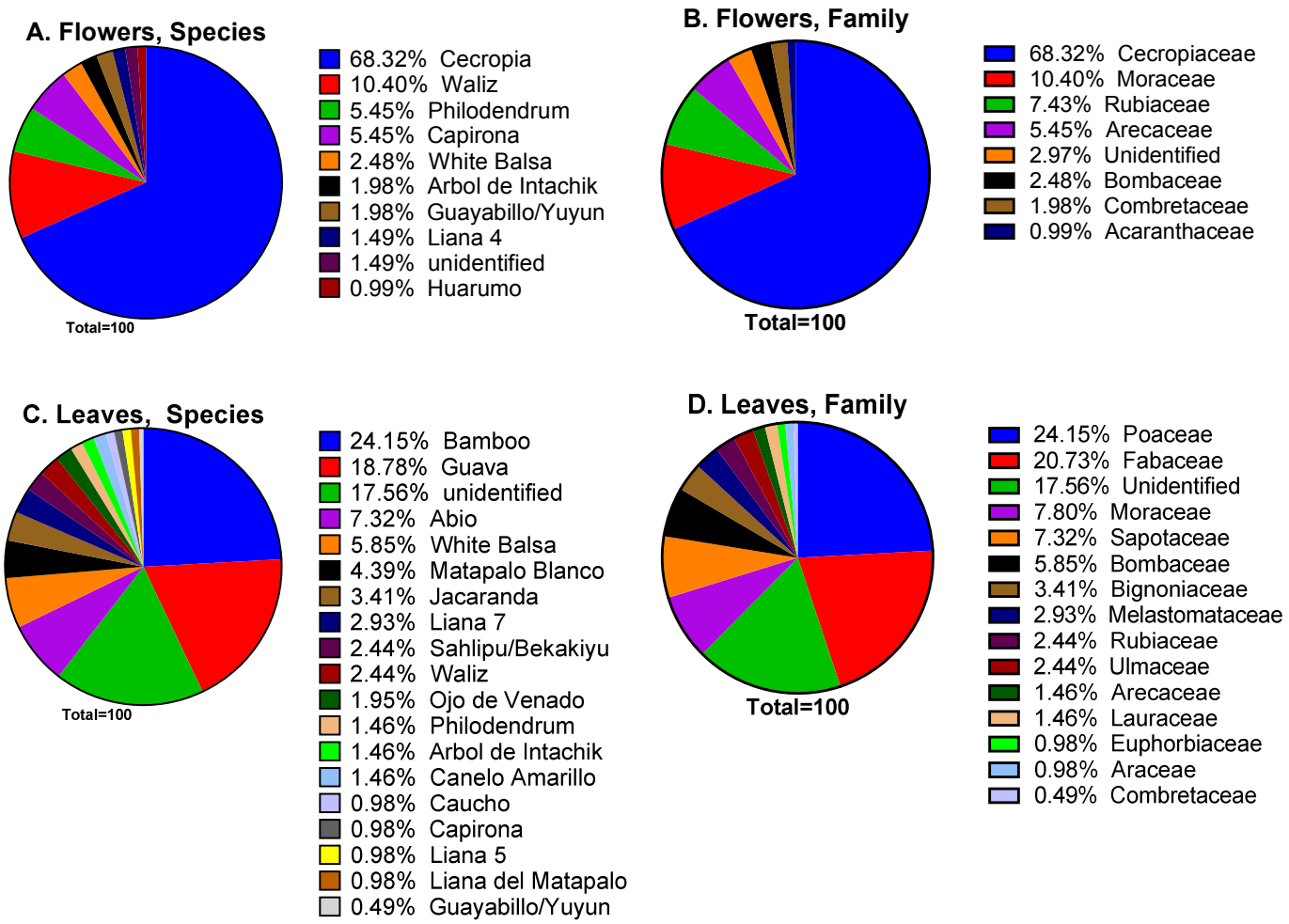


Figure 8. Percent time eating flowers and leaves of each plant species and plant Family. Cecropia species and the Cecropicaceae family represent the majority of flowers eaten by the woolly monkeys (A and B). Bamboo, Guava, and unidentified leaves make up the most important plant species in terms of leaves and shoots, and these correspond with the Poaceae and Fabaceae families (C and D).

On average, the monkeys spent 5.01 minutes at each food source, but overall feeding bouts ranged from one to 18 minutes (Figure 9). Monkeys spent the most time at Wallis, chirimoya del monte, matapalo blanco, capirona, and frutipan, abio silvestre, and tocota; eating bouts at all other plant species were on average less than 10 minutes in length.Less than five minutes were spent at 35 of the 53 plant species, on average.

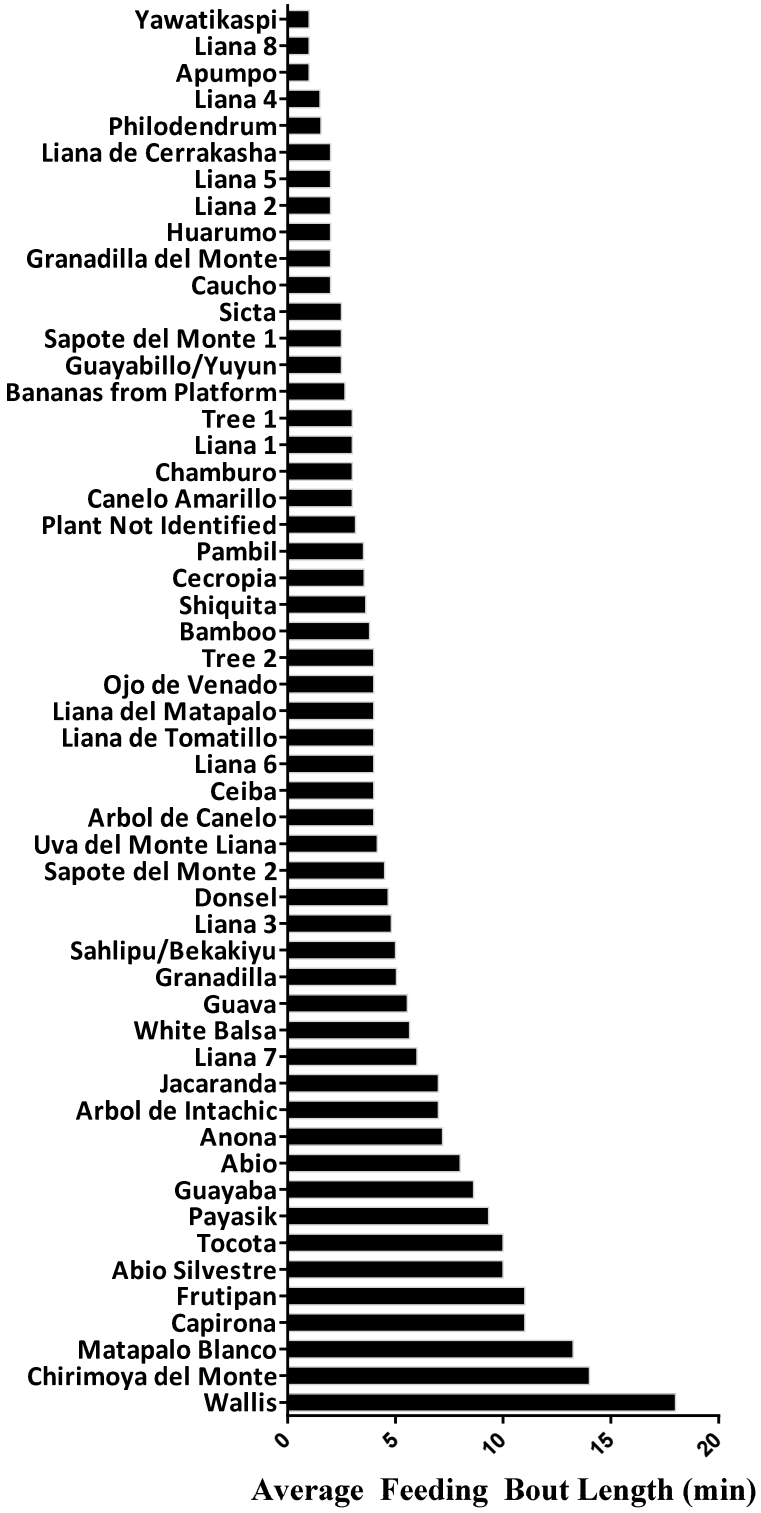


Figure 9. Average feeding bout length for each plant species. In general, monkeys spent an average of 5.01 minutes at each food source, while rarely spending more than ten minutes feeding from the same tree.

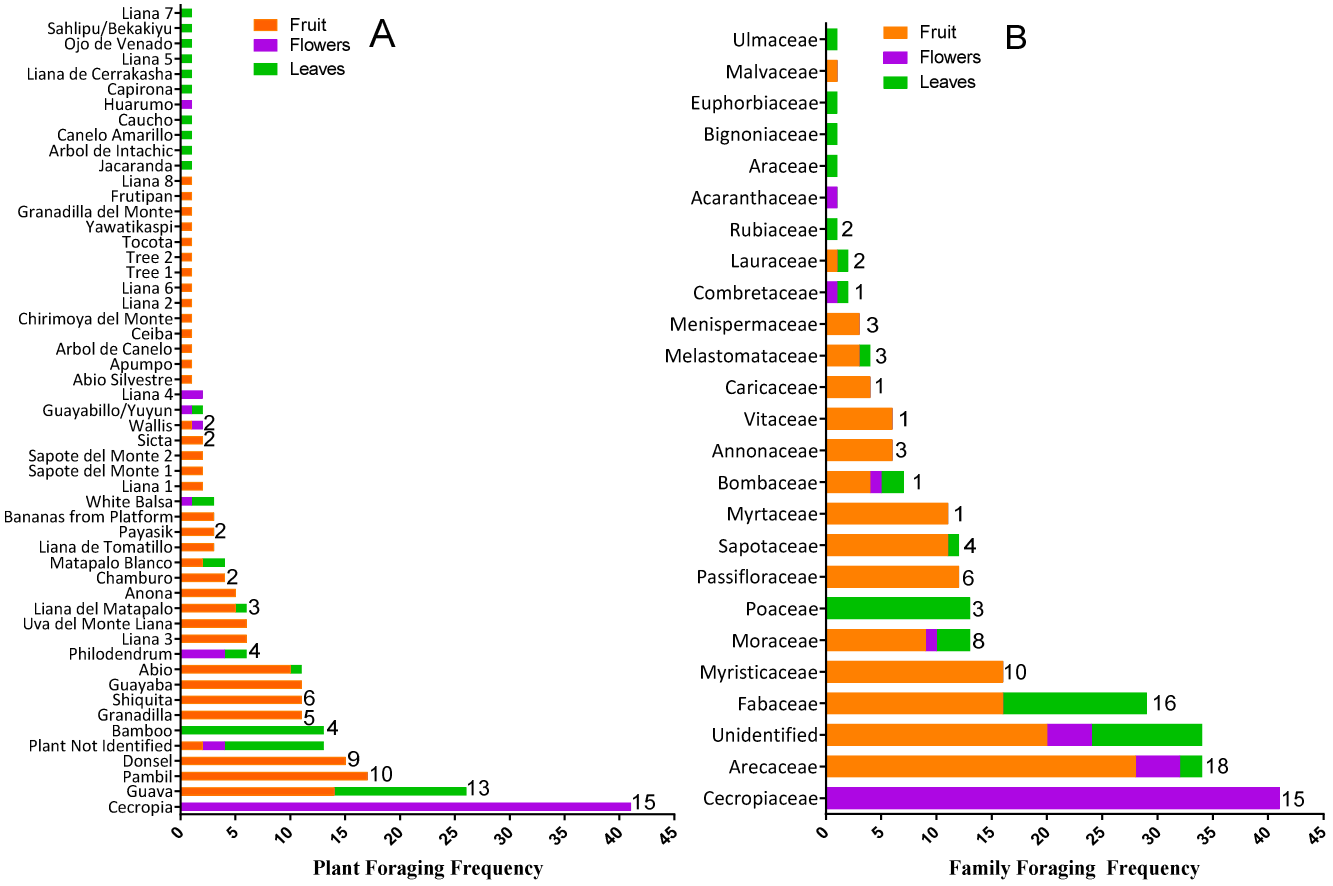


Figure 10. Foraging frequency of leaves, flowers, and fruit of plant species and plant families. Foraging frequency indicates the total number of times monkeys were observed feeding from each plant or family over the course of the study. Numbers at the right tip of each bar represent the number of plants monkeys visited at least once for each species (A) and Family (B). If no number is indicated, only one plant was visited.

The foraging frequency of each plant species shows that monkeys visited the majority of the plants they ate from only a few times (Figure 10A). Twenty-five of the 53 species were only visited once, and another eleven were only visited two or three times. Only cecropia, guava, pambil, and donsel were visited more than fifteen times. In general, the plants visited most often were also the most numerous in terms of how many the monkeys were observed eating from. The most notable exception to this is abio and guayaba, which were both visited eleven times although only one plant existed. In terms of plant Families, only Cecropiaceae, Arecacea, Fabaceae, and Myristicaceae were visited more than fifteen times (Figure 10B). Eleven of the 26 Families were only visited one to three times. In general, as with the plant species, the plant families with more individuals were visited more often. Families that were visited a disproportionate number of times for the number of plants present include Cecropiaceae, Sapotaceae, Myrtaceae, and Annonaceae.

DISCUSSION

Overall, the transition of the juvenile woolly monkey troop from receiving food from humans to being completely dependent on the forest for food was judged to be successful. The monkeys fed from a wide variety of fruits, leaves, and flowers, and this was generally comparable to other studies of the same species in Yasuni National Park. In addition, the monkeys' range includes an important piece of primary forest and the troop is therefore spending less time in human-impacted zones. Because of the monkeys' observed diet and range, this study concludes that they have successfully transitioned into complete independence from humans.

Change in activity

Several important changes were noted in the monkeys' behavior following the removal of all human-provided food sources (Figures 3 and 4). There was a significant decrease in time playing, a response that is typically seen when food sources become limited. For example, Defler (1995) saw an increase in social activity among a troop of woolly monkeys in eastern Colombia when there was an increased food supply. However, monkeys still spent time playing, suggesting that they were not hungry and that they had free time at their disposal to play.

There was also a significant increase in time spent traveling after food was no longer provided to the monkeys. However, although monkey responses to reduced food supply may be highly specific, among nearby woolly monkey populations times of low fruit availability are not associated with greater ranging behavior (Di Fiore 2003). Instead, ranging increases with increased fruit supply, presumably because monkeys have more time to search for insect prey (Di Fiore 2003). Di Fiore and Rodman (2001) also observed that monkeys reduce foraging efforts during times of low fruit abundance, instead spending more time exploiting known food sources (because of the optimal foraging theory). Because increased ranging is generally associated with increased fruit abundance in Ecuadorian *L. poeppigii*, the woolly monkey troop's increased ranging behavior was probably not indicative of increased hunger.

In addition to changes in traveling and playing, a change in feeding behavior was observed. The overall amount of time spent eating did not change, but instead remained constant at 60-61% of total time. Instead, monkeys reduced the amount of time they spent eating insects from 26.7% to 13.4%, essentially cutting the amount of time spent eating insects in half. They increased the amount of time spent eating from plants from 33.8% to 43.8%. This suggests that a reduction in food supply resulted in an increase in feeding on plant matter, possibly because there was less time to forage for insects.

Dietary assessment

In general, the juvenile woolly monkey's diet was determined to be healthy—it comprises a large range of different fruit, flower, and leaf species and plant Families (Figures 7 and 8). Year-long studies of *Lagothrix poeppigii* in the nearby Yasuni National Park have

identified 208 (Di Fiore 2004) and 104 (Dew 2005) separate fruit species from which the monkeys feed. This study identified 37 separate fruit species that were eaten, and 53 plant species in total (including fruit, leaves, and flowers). Although this number is much lower than that of Di Fiore and Dew, the study period was only twenty days as compared to an entire year. Not all plants bore fruit during the study period, and in addition the smaller range of the juvenile monkeys (25 Ha as compared to 100^{+} Ha) may account for lower fruit species diversity.

Interestingly, this study identified more food sources than a similar study conducted on a troop of sub-adult woolly monkeys on Sumak Allpa Island (Mathis 2013). This may be due to a greater number of observation hours (53 as compared to 28), although the observation timelines were similar (20 days; 4/13-5/3 for this study as compared to 23 days; 4/7-4/30). Mathis (2013) observed the adult monkeys feeding from 26 different plant species, while in this study I observed the juvenile monkeys feeding from 53 species. Another possible explanation for the greater overall number of species the juveniles fed on is that they are still learning what is good to eat.

Although the juvenile woolly monkey troop's diet appears to be as varied and diverse as that of other adult *L. poeppigii* in nearby areas, clear differences are seen in the most important plant families consumed (Table 3). The largest differences are seen between this study and that of Mathis, although both were conducted on the same island during the same time frame. Mathis found that monkeys spent almost the majority of their time eating from Moraceae, and although this was also among the most important food sources for the juvenile troop it only comprised 10.4% of their diet. The Moraceae family was of particular importance for the adult troop because almost half their diet was comprised of frutipan and figs. Although the juveniles were observed eating frutipan and figs, these factored less heavily into their diet as a whole and therefore they did not spend as much time eating from Moraceae. Both the adults and juveniles spent similar amounts of time eating from Arecaceae, Myristicaceae, and Bombaceae. However, the adults were only observed eating two of the top five most important families for the juveniles. Again, this might be due to differences in observation times.

Both this study and the studies conducted at Yasuni found that the most time was spent eating from Fabaceae, and most of the important plant families eaten by the juvenile woolly monkeys were also eaten at fairly high levels by the monkeys in Yasuni. Perhaps the most important difference between the adult Yasuni monkeys and the juvenile Sumak Allpa monkeys is the lack of Anacardiaceae, Meliaceae, and Polyganaceae in the juvenile diet. This may be due to seasonal variation or simply a lack of these plants on Sumak Allpa Island. Sumak Allpa Island is comprised of *varzea* forest, which is occasionally flooded, while Yasuni National Park is mainly un-flooded *terra firme* forest. Only fruit typically found in April and early May was documented in this study.

Table 3. Comparison of percent time spent eating fruit from plant families. This study and Mathis (2013) were conducted on Sumak Allpa Island, while that of Di Fiore (2004) and Dew (2005) were conducted at the Yasuni National Park. All studies were conducted on *Lagothrix poeppigii.* Data taken from each author's published paper.

Family	This study	Mathis 2013	Di Fiore 2004	Dew 2005
Fabaceae	14.1%	0	16.0	10.1
Arecaceae	12.0	9	<1	9.5
Myrtaceae	11.4	0	2.6	0.2
Moraceae	10.4	48	10.4	2.9
Sapotaceae	10.0	0	1.4	2.3
Myristicaceae	8.5	6	5.6	4.6
Passifloraceae	6.9	0	<1	<0.2
Annonaceae	6.0	0	1.9	4.8
Melastomataceae	3.4	0	<1	0.4
Vitaceae	3.0	0	2.9	3.3
Bombaceae	1.7	4	2.9	3.7
Caricaceae	1.4	0	<1	<0.2
Cecropiaceae	0.9	4	3.2	3.3
Menispermaceae	0.7	0	<1	<0.2
Lauraceae	0.5	0	<1	1.8
Malvaceae	0.5	0	<1	<0.2
Anacardiaceae	0	0	8.2	11.8
Meliaceae	0	0	5.4	3.2
Polyganaceae	0	0	5.0	1.0
Rubiaceae	0	10	<1	1.0
Combretaceae	0	5	1.2	<0.2

Although there are general similarities in the plant families consumed by the juvenile monkeys and the monkeys studied by Di Fiore and Dew, the composition of the monkeys' diets with respect to percent fruit, flowers, leaves, and insects is substantially different (Table 4). More time was also spent eating flowers as compared to all studies except Stevenson et al (1994). The majority of the flowers they ate were from Cecropia trees (Figure 8A and 8B). This may have been a seasonal variation made apparent by the short study length. The Sumak Allpa juvenile woolly monkey troop spent a comparable amount of time eating leaves as compared to other studies.

The most notable difference in diet was the elevated time spent eating arthropods and other small prey, and the depressed amount of time spent eating fruit. The month of April and early May are known to have sufficient fruit in nearby Yasuni, although fruit levels are declining (Di Fiore 2004). Investigating the abundance of fruit available on Sumak Allpa Island was beyond the scope of this study, but based on the variety of fruit types consumed by the monkeys it is not believed to have been a period of low fruit availability. It is possible that the monkey troop was not accustomed to having to spend large amounts of time foraging for fruit, since a daily supply was provided by humans. This may have freed up time for the monkeys to forage for insects, which are high in protein and fat and may be a preferable food source if enough time

is available to forage for them. In fact, woolly monkeys have been shown to prefer animal prey to fruits (Di Fiore 1997), presumably because of their greater protein and fat content. During times of high fruit abundance, woolly monkeys in Yasuni spend more time foraging for animal prey (Di Fiore and Rodman 2001). This is believed to be an opportunistic response, and the monkeys build up their fat reserves during times of greater fruit abundance by spending more time eating insects.

After removing human food sources, the monkeys spent less time eating insects (Figure 5), which is line with the theory that the monkeys were devoting more time to protein-rich insects during a time of high fruit abundance. However, following the removal of the bananas, time spent eating plant material increased because there was an increase in time spent eating flowers and leaves rather than an increase in time spent eating fruit. The amount of time spent eating fruit actually decreased from 47 to 41%. This may be due to a decline in overall fruit availability. Guava fruit, one of the monkeys' main food sources, was declining and had become largely unavailable by the end of this study (personal observation).

Table 4. Comparison of percent of time spent by *Lagothrix lagotricha spp.* eating from different food sources as observed by different studies. Data taken from Di Fiore (2004) and Dew (2005).

Site	Species	Fruits	Leaves	Flowers	Other plant items & Fungi	Seeds	Arthropods and other prey	Source
Sumak Allpa, Ecuador	Lagothrix lagotricha poeppegii	42.7	10.2	9.43	n/a	n/a	37.7	This study (2014)
Yasuni, Ecuador	Lagothrix lagotricha poeppegii	76.7	7.4	3.5	2.5	0.5	9.3	Di Fiore (2004)
Yasuni, Ecuador	Lagothrix lagotricha poeppegii	73	10	5	n/a	6	6	Dew (2005)
Caparu, Colombia	Lagothrix lagotricha lagotricha	78.9	11.4	[0.5]		4.3	4.9	Defler and Defler (1996)
Urucu, Brazil	Lagothrix lagotricha cana	73.5	16.1	3.1	0.0	7.1	0.1	Peres (1994)
Tinigua, Colombia	Lagothrix lagotricha lugens	60	[17.5]			0	23	Stevenson et al (1994)
Pacaya, Peru	Lagothrix lagotricha	77	7	2		14	0	Soini (1986)

Food Preference

The average feeding bout observed in this study lasted for 5.01 minutes, which is far shorter than feeding bouts seen in other comparable monkey populations. For example, Di Fiore (2004) documented an average feeding bout length of 26.4 minutes, more than five times longer than that seen in the juvenile monkey troop. Many of the species fed from had average feeding bout lengths of just one to three minutes, while few were greater than ten minutes (Figure 9). This suggests that the juvenile monkeys may be testing new fruit to see whether it is palatable, and some of the fruits they were documented eating may not be an important part of their diet. This hypothesis is further supported by the fact that the monkeys were only seen eating from some species one or two times and did not return to the plant (Figure 10).

Table 5. Rank of most important plant species based on multiplying percent time eating, foraging frequency, feeding bout length, and number of plants visited.

Rank	Most Important Food Species	% Time Eating	Foraging Frequency	Feeding Bout length	# of plants visited	Multiplicant
1	Cecropia	11.7	41	3.6	15.0	25661.3
2	Guava	11.4	26	5.6	13.0	21483.6
3	Donsel	5.6	15	4.7	9.0	3539.3
4	Pambil	4.8	17	3.5	10.0	2889.2
5	Granadilla	4.5	11	5.0	5.0	1236.1
6	Bamboo	4.0	13	3.8	4.0	786.6
7	Shiquita	3.2	11	3.6	6.0	770.5
8	Guayaba	7.6	11	8.6	1.0	724.3
9	Abio	7.1	11	8.0	1.0	621.5
10	Matapalo Blanco	4.3	4	13.3	1.0	225.4

Table 6. Rank of most popular plant species based on multiplying percent time eating, feeding bout length, and frequency of visit per plant.

Rank	Most Popular Food Species	% Time Eating	Foraging Frequency	Feeding Bout length	# of Plants Visited	Frequency of visit per plant	Multiplicant
1	Guayaba	7.6	11	8.6	1.0	11.0	724.3
2	Abio	7.1	11	8.0	1.0	11.0	621.5
3	Matapalo Blanco	4.3	4	13.3	1.0	4.0	225.4
4	Guava	11.4	26	5.6	13.0	2.0	127.1
5	Liana 3	3.1	8	4.8	1.0	8.0	118.9
6	Cecropia	11.7	41	3.6	15.0	2.7	114.0
7	Anona	2.9	5	7.2	1.0	5.0	104.0
8	Waliz	2.9	2	18.0	2.0	1.0	52.0
9	Uva del Monte Liana	2.0	6	4.2	1.0	6.0	50.1
10	Granadilla	4.5	11	5.0	5.0	2.2	49.4

The ten most important plants, when the percent time spent eating, foraging frequency, feeding bout length, and number of plants visited are multiplied, are cecropia, guava, donsel, pambil, granadilla, bamboo, shiquita, guayaba, abio, and matapalo blanco (Table 5). It appears

that the ten most popular plants, when the percent time spent eating, feeding bout time, and visits per tree are multiplied, are: guayaba, abio, matapalo blanco, guava, liana 3, cecropia, anona, waliz, uva del monte liana, and granadilla (Table 6).

Assessment of territory

The territory of the juvenile woolly monkey troop was determined to be sufficient to meet their needs, as there is a great variety of fruit-bearing trees to eat from. In addition, approximately half of the monkeys' territory is located within primary forest, the preferred habitat of woolly monkeys (Stevenson et al 2008). However, the juvenile troop still spends a great deal of time near the house and does not appear to fear humans (personal observation). It appears that the juvenile troop is limited by the adult woolly monkey troop also present on Sumak Allpa Island. On May 3rd, the juvenile monkeys were observed eating outside their general territory on Jatun West, almost at Chichico. The adult troop arrived, and upon seeing the adults the juveniles returned very quickly to their normal territory. Following this interaction, the adults and juveniles communicated using territorial vocalizations (see Appendix Table 7). This interaction suggests that the juvenile troop's range is limited by the adult troop.

Limitations to study

As with all studies, there were several important limitations. First of all, the monkeys were only observed from 6-9 and 3-6 each day, leaving the six hours between 9am and 3pm without any observation. Because the monkeys are still juvenile, they are far more active than an adult troop and ate during the day. However, as a single observer it was impossible to follow the monkeys all day long and the monkeys were only observed during their most active periods each day. Secondly, the monkeys were often out of sight and therefore focal observation was not always possible. Because of this, detailed information on foraging versus eating behavior may be misrepresented. When out of sight, eating rather than foraging was assumed. Another limitation is the fact that the monkeys were not always observed for the full three hours of each observation period because the monkeys were not always located where they were left at the end of the previous observation period, and it often took 30-45 minutes to locate them. Rain sometimes also cut observation periods short, since the monkeys are not very active in the rain and are nearly impossible to find.

Information on plant species and families is incomplete, partially because some marked trees were not re-located for identification and partly because, given the resources available, identification was not possible. This gives an incomplete picture of the monkeys' diets. However, the most important tree species were identified. Some important vines were not identified.

One final limitation is the under-representation of the monkeys' activity and diet before the bananas were removed. This was necessary because the time period of the study was short,

but having a full week to observe the behavior of the monkeys before removing their food would have given a more complete picture of their activity and change in behavior.

Conclusions

This study documents the final stages of the successful re-integration of three juvenile woolly monkeys into the wild. The monkeys were gradually transitioned from a state of complete dependence on humans for food to complete independence, and currently occupy a territory of 25-30 Ha. Removing the human-provided food source evoked a response similar to that seen in *L. poeppigii* transitioning into times of less fruit abundance, with less time spent eating insects and less time spent playing. However, monkeys ate from a spread of plant families similar to that of adult *L. poeppigii* in the nearby Yasuni National Park, and differences in diet are probably due to seasonal variation and differences in habitat. The monkeys' most important food sources when the percent time spent eating, foraging frequency, feeding bout length, and number of plants visited were taken into account were cecropia, guava, donsel, pambil, granadilla, bamboo, shiquita, guayaba, abio, and matapalo blanco; the most important plant families in terms of percent time spent eating were Fabaceae (14.1%), Arecaceae (12.0%), Myrtaceae (11.4%), Moraceae (10.4%), and Sapotaceae (10.0%).

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APPENDIX

Table 7. Observed interactions with other species

Date	Species	Interaction
4/24, 15:48-16:40	Adult Woolly Monkeys	Vocalization with adults, intermittent from 15:48 to 16:37
5/3, 16:52-17:41	Adult Woolly Monkeys	Juveniles outside of normal territory on Jatun West Vocalization with adults Interaction with adult chorongos—adult starts climbing the tree the juveniles are in, juveniles go running back to normal territory very quickly, chirping the entire time territory vocalization at 17:41, 17:43, 17:44, 17:46, 17:47, 17:48, 17:50
4/18, 7:51-8:11	Black-mantled Tamarins	Chirp at chichico, run at it, it runs down tree (7:51) Chichico following behind At least two still following behind at 8:03 8:11- still following, vocalization
4/16, 7:52-8:10	Saki	Woolly goes up and chirps in face, pulls on branch, shakes tree. Saki ignores or maybe slightly aggressive. Woolly pulls on branch again. Another woolly comes over, seems slightly aggressive. Saki runs down the tree about 5 meters. Woollies pretend to forage for insects and the saki is still in the tree. The two woollies come up to the saki again, the saki leaves. All three seem to chase the saki or at least follow it until it leaves their area. Saki goes behind them and sits
4/21, 6:49	Saki	With the saki
4/24, 16:44	Saki	With the saki, who is following behind the woolly monkeys
4/25, 6:40-7:00	Saki	Woolly monkeys following saki
4/17, 8:17-8:26	Squirrel Monkeys	Seemed aggressive. Loud chirps and chasing of solitary squirel monkey; squirrel monkey leaves More aggression, this time there are two squirrel monkeys. Probably the same one as a few minutes earlier
4/21, 17:03-17:15	Squirrel Monkeys	2 chorongos above yelling; barizo below yelling loudly and trying to climb up vine/shaking vine. Aggressive body language. At least twelve barizos present. talking at each other more aggressive chirping, choronogos watching barizos from above, barizos follow chorongos. Begin traveling west toward houses, barizos following
4/22, 17:13-17:33	Squirrel Monkeys	barizos yell at chorongos again, in exact same place and same time as yesterday. Not as prolonged or aggressivean interaction as last time
4/23, 16:25	Squirrel Monkeys	Angry barizo sounds on jatun east
4/25, 17:49-17:53	Squirrel Monkeys	barizos surrounding chorongos' tree, same exact spot as before. chorongo chased barizo. aggressive barizo noises
4/27, 17:15-17:31	Squirrel Monkeys	angry barizo sounds, but out of sight no true aggression, making noises at each other. Chorongo slowly follows barizo for about 10 meters thru the canopy leave the tree, very uhappy barizo noises chorongos are running around in trees playing or chasing barizo. In total 5+ barizos
4/29, 16:59-17:16	Squirrel Monkeys	angry barizo noises, then angry barizo and chorongo noises chorongo makes territory scream sound. More angry barizo noises