THE FEEDING AND BEHAVIORAL ECOLOGY OF BLACK SPIDER MONKEY
SUBGROUPS (Ateles paniscus paniscus) IN THE CONTEXT OF ILLEGAL ARTISINAL
GOLDMINING ACTIVITIES IN THE BROWNSBERG NATURE PARK, SURINAME

A thesis submitted
to Kent State University in partial
fulfillment of the requirements for the
degree of Master of Arts

by

Arioene Uncas Naldi Vreedzaam

August, 2013
Thesis written by
Arioene U. N. Vreedzaam
B.A., Kent State University, 2007
M.A., Kent State University, 2013

Approved by

_____________________________________
Dr. Marilyn A. Norconk     Advisor

_____________________________________
Dr. Richard S. Meindl     Chair, Department of Anthropology

_____________________________________
Dr. James Blank     Dean, College of Arts and Sciences
# TABLE OF CONTENTS

**LIST OF FIGURES** ........................................................................................................................................... v

**LIST OF TABLES** ........................................................................................................................................ vii

**ACKNOWLEDGEMENTS** ................................................................................................................................. viii

**CHAPTER 1 INTRODUCTION** .......................................................................................................................... 1

1.1 Primates as seed dispersers and their role in rainforest maintenance ................................. 1
1.2 Small-scale Gold mining: definition, significance, trends worldwide ............................. 6
1.3 General overview of Hg(0) ..................................................................................................................... 9
1.4 The toxicology of mercury and health effects on humans ................................................. 11
   1.4.1 Minamata, Japan .............................................................................................................................. 12
   1.4.2 Iraq .................................................................................................................................................. 14
1.5 Mercury studies in non-human primates ............................................................................ 14
1.6 Research question ............................................................................................................................... 15

**CHAPTER 2 METHODS** ................................................................................................................................. 21

2.1 Background on Suriname and Brownsberg Nature Park (BNP) ......................................... 21
2.2 History of Mining at the Brownsberg ....................................................................................... 24
2.3 Primates of the Brownsberg Nature Park, Suriname ............................................................. 26
2.4 The genus *Ateles*, with emphasis on *A. paniscus paniscus* .............................................. 27
2.5 Sampling Methods ........................................................................................................... 32

2.5.1 Climate ......................................................................................................................... 32

2.5.2 Subgroup data ............................................................................................................. 33

2.5.3 Feeding Data ............................................................................................................... 35

2.6 Determination of the Presence of Mercury ....................................................................... 35

CHAPTER 3 RESULTS ........................................................................................................... 43

3.1 *Ateles paniscus* Ranging and Grouping Patterns ............................................................. 43

3.2 Activity budget ................................................................................................................ 44

3.3 Feeding Ecology ............................................................................................................. 44

3.4 Mercury Concentration in Excretions ............................................................................. 46

CHAPTER 4 DISCUSSION AND CONCLUSIONS .................................................................. 62

4.1 *Ateles paniscus* Ranging and Grouping Patterns ............................................................. 62

4.2 *Ateles paniscus* Activity Budget .................................................................................... 63

4.3 Feeding Ecology ............................................................................................................. 65

4.4 The Mercury Pilot Study ................................................................................................. 66

LIST OF REFERENCES ........................................................................................................... 71
LIST OF FIGURES

FIG. 1.1. ILLUSTRATION DEPICTING A TYPICAL SMALL-SCALE MINING OPERATION............................................................................................................................................................................. 17

FIG. 1.2 COMPOSITE LANDSAT IMAGES OF THE BROWNSBERG NATURE PARK 1987, 1997, 2000 ........................................................................................................................................................................................................ 18

FIG. 1.3 SEVERAL SNAPSHOTs TAKEN DURING VISITS TO THE WK MINING AREA 2005-2008 .................................................................................................................................................................................................. 19

FIG. 1.4 REAL TIME SATELLITE IMAGE OF THE BROWNSBERG NATURE PARK AREA OCTOBER 11, 2008 ................................................................................................................................................. 20

FIG. 2.1 LOCATION OF SURINAME WITHIN SOUTH AMERICA ........................................ 38

FIG. 2.2 NATURE RESERVES IN SURINAME ........................................................................ 38

FIG. 2.3 TOPOGRAPHIC MAP OF BROWNSBERG PLATEAU’S TRAIL SYSTEM........ 39

FIG. 2.4 DISTRIBUTION MAP OF ATELES SPP. IN THE NEOTROPICS ......................... 40

FIG. 2.5 DISTRIBUTION OF ATELES SPP. AND SSP. IN CENTRAL AND SOUTH AMERICA .......................................................................................................................................................... 41

FIG. 2.6 DAILY RECORDED RAINFALL (MM), MINIMUM AND MAXIMUM TEMPERATURE (C) FOR THE BNP PLATEAU (MAY 27, 2008 – JULY 28, 2008) .................. 42

FIG. 2.7 THE HEAVY METALS TEST KIT ............................................................................. 42

FIG. 3.1 DAILY TRAVEL PATHS OF BLACK SPIDER MONKEY SUBGROUPS ALONG THE WITI KREEK TRAIL, BROWNSBERG NATURE PARK, SURINAME .............. 51

FIG. 3.2 TRAVEL PATHS FOR SUBGROUP M ALONG THE WK TRAIL ......................... 52

FIG. 3.4 ACTIVITY BUDGET BLACK SPIDER MONKEY SUBGROUPS ................................ 55
FIG. 3.5 TOTAL ACTIVITY BUDGET FOR BLACK SPIDER MONKEY SUBGROUPS
FROM MAY 28, 2008 – JULY 28, 2008 ................................................................. 56

FIG. 3.6 PERCENTAGES OF TYPES OF FOOD ITEMS CONSUMED BY BLACK SPIDER
MONKEY SUBGROUPS .................................................................................. 57

FIG. 3.7 DISTRIBUTION OF TYPES OF FOOD ITEMS EATEN/INGESTED BY BLACK
SPIDER MONKEYS ..................................................................................... 57

FIG. 3.8 DIET BREADTH IN THE EARLY WET SEASON 2008 ................................. 58

FIG. 3.10 FREQUENCY OF EATING FRUIT FROM DIFFERENT PLANT SPECIES ....... 59

FIG. 3.11 PERCENTAGE OF FEEDING TREES (FRUIT PATCHES) PER GENUS .......... 60

FIG. 3.12 NUMBER OF FRUIT SPECIES EATEN/DAY DURING THE STUDY PERIOD .... 60

FIG. 3.13 DISTRIBUTION OF MERCURY TEST RESULTS ACROSS THREE
POPULATIONS ................................................................................................ 61
LIST OF TABLES

TABLE 2.1. WEATHER DATA FOR THE BNP PLATEAU FROM MAY 28, 2008 – JULY 28, 2008. ............................................................................................................................................... 33

TABLE 3.1 DAILY TOTAL DISTANCE (M) AND AVERAGE DISTANCE/HR (M/HR) TRAVELLED WITH EACH SUBGROUP. ................................................................. 47

TABLE 3.2 MERCURY TEST RESULTS FOR WILD POPULATION, PARAMARIBO ZOO, AND HIRAM INDIVIDUALS .............................................................................. 49

TABLE 3.3 GROUP SCAN DATA PER TWO-HOUR PERIODS DURING THE DAY........... 53

TABLE 4.1 ADAPTED FROM SUAREZ (2006) STUDY ON ATELES BELZEBUTH................. 64
ACKNOWLEDGEMENTS

First and foremost I would like to thank my advisor, Marilyn Norconk, for being so patient with me during my years as a Kent State undergraduate and graduate student. Without her guidance I would have not been able to reach my current goals. I have no way of expressing how truly grateful I am in all that she has done for me. Secondly, I will forever be in debt to Jessica Westin. Without her none of this would be really possible, as she supported me in numerous ways for so many years. Thank you so much.

Many thanks go out to all my fellow graduate students, recent and past, who have been great friends to me during my time at Kent State. Too many to name, you all are awesome. A special word of gratitude to Tremie who has been a great colleague and an even better friend. And of course to the Jessica’s: I miss you guys, thank you for being there for me when I needed it the most. My time in the field would not have been as enjoyable if I had never met Rose Hores. Thank you for helping me get through it all as well. Last, but certainly not least, my dear mother: thank you for everything. I love u so much. My gratitude and love goes out to Chantal my best friend.

Finally, my research would not have been possible with the support of the Graduate Student Senate, support from the Kent State Anthropology Department, and all the professors. Special thanks to Dr. Richard Meindl and Dr. Christopher Vinyard for their patience and insight as well.
CHAPTER 1

INTRODUCTION

“Nature itself is the best guardian of tropical forests, having created and nurtured them over millions of years. It is only when we insist on tampering with nature that diversity is threatened”. – John Terborgh 1992

1.1 Primates as seed dispersers and their role in rainforest maintenance

It is impossible to accurately define the floristic diversity within the tropics. We can only estimate: tropical Africa 30,000, tropical Asia 35,000, and tropical America 90,000 species of flowering plants (Prance 1977). By far, the greatest alpha diversity is found in the Neotropics (Gentry 1988; Gentry 1992; Steege et al. 2000), in Asia it is found in the forests of Borneo and Peninsular Malaysia (Ashton 1977; Gentry 1992), and in Africa it is found along the eastern slopes of the Congo Basin (Gentry 1992). When it comes to woody species that produce fruits dispersed by either birds or mammals we get some sense of the magnitude. In the Guianan region, Van Roosmalen (1985) documented 1,446 species of woody plants that are eaten/dispersed by vertebrates. Most of these plants require vertebrates to disperse their seeds. Galetti et al. (2001) provide a unique perspective, focusing on tapir seed dispersal. Tapirs are especially critical to dispersing particularly large seeds (e.g. palm seeds) over long distances. Galetti et al (2001) estimated that of the 1,380 species of plants with large seeds in the Atlantic Forest of Brazil, 50 of those plant species will be negatively affected by a tapir population decline. Additionally, tapirs can disperse intact large palm seeds up to 2 km away from the parent tree and because they
defecate seeds in large clumps they are the cause for distinctive patches of adult palm trees. They thus influence the forest structure (Fragoso 1997).

Several studies have also shown the importance of birds as primary seed dispersers: Holbrook and Smith (2000) conducted an extensive survey of two species of hornbills in Cameroon and found that they dispersed 80% of seeds from eight tree species more than 500 m from the parent tree. One study compared seed dispersal by birds and monkeys in the same forest, found that birds have a maximal dispersal distance of 473 m, while that of monkeys is 100 m (Clark et al. 2005). In essence, concluding, in the Cameroon forest birds are far better seed dispersers than primates, distance wise. Holbrook and Smith (2000) also emphasize the importance of birds, especially hornbills, as seed dispersers in relation to their extensive home ranges and the loss of large frugivorous mammals.

It is clear that most fruit-bearing trees are dependent on animals for seed dispersal, and in some cases they are completely dependent on primates. Spider monkeys (*Ateles* spp.) play a critical role in seed dispersal as they are widely regarded to be among the most frugivorous primate known (Link and Fiore 2006), incorporating a wide array of fruits in their diet (Di Fiore et al. 2008; Link and Fiore 2006; Van Roosmalen 1981). Furthermore, they are also well known for consuming ripe fruits, which constitutes 55% to more than 90% of their feeding time (Di Fiore et al. 2008). Capuchins and howling monkeys are also known to be effective seed dispersers as well (Simmen and Sabatier 1996).

In the forests of French Guiana, red howlers disperse 95% of plant species from which they eat ripe fruits (Julliot 1996). They disperse seeds from approximately 100 plant species, while in the forests of Manaus 137 plant species were documented as being dispersed by howlers
(Andressen 2002). Furthermore, spider monkeys and howlers are the only arboreal mammal able to effectively ingest seeds 4 x 2 cm without actually damaging them. Thus making them good seed dispersers of large seeded fruit species (Julliot 1996). In terms of being an effective seed disperser Wehncke (2003) argues that Cebus spp. are far better. In the forests of Barro Colorado Island in Panama, two Cebus capucinus groups spent on average less than 10 minutes feeding in individual trees, travelled between 1-3 km/day, and had home ranges greater than 150 ha. They consumed 95 species out of 240 available species, of which 67 species were swallowed and dispersed at a mean distance of 216 m. In addition to their rapid movement and asynchronous defecation patterns within groups, seed deposition sites are widely distributed allowing for effective dispersal of seed species throughout the forest.

Studies in Africa and Asia have documented the frugivorous diet of both apes and monkeys (Lambert and Garber 1998; McConkey 2000). Gibbons for example, who can be categorized into mainly frugivorous to mainly folivorous (Conklin-Brittain et al. 2001), have up to 72% of their diet consist of fruits. Bonobos and chimpanzees incorporate 55% and 64%, respectively, of fruit into their diet (Conklin-Brittain et al. 2001). Within guenons, the largest group of primates in Africa, there is considerable frugivory within the diet albeit with considerable variability among and within species. Data from seven field sites report frugivory within Cercopithecus mitis ranges between 24.5% and 91% (Jaffe and Isbell 2011). Variability within the guenons is primarily due to the fact that they are found in diverse habitats: from sub-Saharan to forested regions in West Africa. Furthermore, studies in Africa have also shed light on how apes and monkeys differ in seed dispersal methods. Chimpanzees, which are generally regarded as “seed swallowers”, are more likely to disperse a cluster of seeds further away from
the parent tree. In contrast, redtail monkeys, which are regarded as “seed spitters”, will disperse single seeds close to the parent tree (Lambert 1999).

It is apparent that seed dispersal by primates involves several different factors: species of fruit, manner of ingestion, distance from parental tree, and density of dispersed seeds. These elements combined make up of what is known as the “seed shadow” (Janzen 1971; Lambert 1999; Lambert and Chapman 2005; Lambert and Garber 1998; Link and Fiore 2006; Russo 2005; Simmen and Sabatier 1996; Stevenson et al. 2002; Valenta and Fedigan 2009; Wehncke et al. 2004; Willson 1993). Additionally, group size, ranging patterns, body size, morphological adaptations (dental or gut), seed predation and mechanical plant defenses (Norconk et al. 1998) influence the manner of seed dispersal, and ultimately the seed shadow.

Ideally, studies of seed shadows created by primates and other frugivorous mammals incorporate both the quantity and quality of seed dispersal (McConkey 2000). Quantity refers to the number of seeds dispersed and quality refers to characteristics of the seeds that enhance their survival (seed size, distance from the parent tree, characteristics of the soil in which the seeds are dropped, etc.). In McConkey’s (2000) study of gibbons, she reported that two gibbon groups dispersed up to 81% of plants they fed on by way of endozoochory (i.e., seeds are swallowed and defecated whole), while in 12% of observations seeds were destroyed. A total of 2,808 seeds (>3mm in length) were extracted from fecal specimens, and with the exception of 53 species, all seeds were matched to tree species wherein gibbons were observed feeding. To put into perspective the scale of seed dispersal by gibbons, the same study calculated that if a single gibbon dispersed 5.6 seeds/day, it would disperse 2,044 seeds/year. Extrapolating to a small gibbon group of 3 individuals, they could disperse 7,300 seeds/group/year. Since data on seedling
survival of dispersed seeds was also collected, McConkey (2000) estimated that a gibbon group was responsible for four seedlings/ha/year or 13 seedlings/ha/group (McConkey 2000).

The aforementioned studies of seed dispersal by primates provide ample evidence in support of the importance of large bodied mammals as key players in maintaining tree diversity in tropical forests. Primates especially, rely on fruiting trees for food while fruiting trees rely on primates as seed dispersers (Chapman and Onderdonk 1998). We must also not forget that a variety of actors play a role in contributing to and in maintaining tropical tree diversity. As Janzen (1970) and Connell (1971) independently postulated, seed and seedling predators play a critical role in determining the “spacing” of seedlings such that it prevents them from being in the immediate vicinity of adult conspecifics.

Seed and seedling predators are classified as being either density responsive or distance responsive: density responsive predators focus their efforts on high density patches of seeds and seedlings, thus killing more with increasing density. Distance responsive predators focus foraging efforts close to the parent tree, disproportionally killing more seeds or seedlings with increasing proximity to the parent tree (Schupp 1992).

Seed dispersers and seed predators, along with the presence of a variety of land mammals, birds, invertebrates, soil composition, and water quality (just to name a few), equate to a well functioning and self-sustaining rainforest ecosystem. As each component is vital to the ecosystem, any disturbance or imbalance could result in harmful impacts to that system. Plant-animal interactions in particular and the resulting dispersion of seeds/seedlings drive forest dynamics. Current anthropogenic factors, such as development and urbanization, deforestation to
develop agricultural or husbandry land, logging, commercial hunting, and of course various mining activities disrupt this self-sustaining ecosystem.

Hunting (both subsistence as commercial) in particular has been shown to negatively impact various mammalian and avian populations directly (Hill et al. 1997; Nunez-Iturri et al. 2008; Peres 2000; Peres 2001; Redford 1992; Thoisy et al. 2005). Native faunal populations decline and as a result seed dispersion is adversely affected. Additionally, mining has a devastating impact on whole ecosystems and humans. Numerous studies have been conducted on the impact of small scale gold mining on the health of local communities and local flora; specifically the impact of methylmercury for aquatic ecosystems and communities living near these areas (Akagi et al. 1995; Cortes-Maramba et al. 2006; de Oliviera Santos et al. 2002; Eisler 2004; Hammond et al. 2007; Heemskerk 2003; Lechler et al. 2000; Miller et al. 2003; Monrroy et al. 2008; Murao et al. 2006; Peplow and Augustine 2007; Tarras-Wahlberg et al. 2001; Vasconsellos et al. 2000; Veiga 1997).

1.2 Small-scale Gold mining: definition, significance, trends worldwide

According to the International Labour Organization (I.L.O.) small-scale gold mining has different meanings based on the following criteria (Jennings 1999): typically fewer than 50 workers that are not formally trained in mining, production output of 15,000 tonnes of ore or mineral to 250,000 tonnes/year, small investment and operating costs, low level mechanization use (simple equipment), typically illegal operations, and hazardous and unhealthy living conditions. In Suriname’s case the gold mining operations at Brownsberg involve fewer than 50
workers, utilize simple machinery in the mining process, and are considered illegal. As such, we can classify the gold mining operations at BNP as small-scale.

Historically, mechanical mining in the Brownsberg area started in 1896 when the company “Goldfields of Suriname” started hydraulicing operations (Buursink 2003; Veiga 1997). Due to improper mining methods, equipment, and the steady decline of the gold industry this venture failed. It was during this time that so called “porcknockers” replaced the larger mechanized companies (Buursink 2003). They exclusively incorporated hand labor, gold pans, sluices, and consisted of a small number of local miners. This industry of small-scale gold miners flourished up until the 1950’s when plans started for developing the hydroelectric dam in the Suriname River valley east of the Brownsberg area. During this time most mining activities in this area stopped and it was not until the 1990’s when resurgence took place; the world market price of gold increased and illegal Brazilian gold miners entered Suriname (Buursink 2003).

Brazilian miners, also known as “garimpeiros” brought with them more effective ways to mine for gold: better machinery and the use of mercury to extract gold. As previously mentioned, gold mining methods employed by the local people involved a lot of manual labor – use of gold pans and sluices. With the introduction of machinery and mercury into the mining process, local people could now increase their profit. The garimpeiros benefited from local knowledge of the location of gold deposits (Buursink 2003). In addition to introducing mechanical means for extracting gold, garimpeiros also changed the way local miners viewed gold mining (Veiga 1997). In the past local miners extracted as much gold as they needed in order to provide for their families. Now, they could mine as much as possible, thereby increasing their profit, without any
regard for the environmental impact of their actions. Thus, the concept of mining for subsistence was replaced with mining for large profit (Veiga 1997).

Since the early 1990’s the Brownsberg Nature Park has been the target of illegal gold mining activities at the base of the mountain along the northern and southern boundaries. These mining activities have primarily resulted in the release of an unknown amount of either liquid mercury or gaseous mercury into the environment, deforestation, soil degradation, and extensive river silting. The devastation as a result of these activities has affected a large area of the park’s primary rainforest and important creeks and streams that run along the periphery and in some instances deep into the park. Composite landsat images of the Brownsberg area from 1987, 1997, and 2000 (Fig.s 1.2) clearly indicate the devastating impact on the landscape as a result of the mining activities. In addition, other researchers and I have personally seen the devastation to the rainforest first hand (Fig. 1.3). A real time satellite image from October 11, 2008 reveals the mining areas to the North, East, and South of the park, and the resulting destruction to the rainforest (Fig. 1.4).

Even though mining in BNP is considered small-scale, it has increased over the past decade via its use of heavy machinery. Through the use of chainsaws and bulldozers an area of forest is cleared surrounding a targeted mining area, which in the majority of the cases is a creek. Once the area is cleared high pressure water hoses (hydraulic monitors), tractors, and bulldozers are used to remove the topsoil layer until the gold-containing bedrock is reached (Peterson and Heemskerk 2001; Veiga 1997). At this point a large suction hose is used, while another hose feeds water into the mining pit, to transport the bedrock to a slurry. At this point the loose bedrock is crushed into finer particles and is diverted to a sluice box, arranged in a Z shape
Elemental mercury is then deposited into the sluice box as the crushed bedrock passes through it. During this process, any gold will instantly bind to the mercury resulting in a gold-mercury amalgam. Finally, the amalgam is collected from the sluice box and brought to a pan where it is heated, as to allow the mercury to evaporate (pers.obs.).

Miners at BNP do not employ the use of a retort during the heating process resulting in the release of mercury vapor into the atmosphere (Veiga 1997). Atmospheric mercury or mercury vapor may either be absorbed by plants/trees in the direct vicinity or continue to rise into the clouds and bind to water molecules eventually coming back down to earth via precipitation (Fisher 2003). A more in depth overview on the affects that this has on the food chain is discussed further on in this document.

Currently, there are no data available on numbers of both legal as well as illegal gold miners in Suriname. Veiga (1997) reported that estimates then were around the 15,000, of which 10,000-12,000 were Brazilian garimpeiros. On a global scale the International Labor Organization (I.L.O.) estimated in 1999 that approximately 13 million people were either employed in or dependent on small scale goldmining (Jennings 1999) activities. In the same report, issues in child labor, prostitution, and sexually transmitted diseases, were also brought up. It was also projected that the number of people involved in small scale mining would gradually increase, and as such, environmental pressures would increase as well.

1.3 General overview of Hg(0)

Mercury is a naturally occurring heavy metal that is found in many different forms in the environment. In its purest form it is known as liquid metal, liquid silver, quick silver, elemental
mercury or colloidal mercury. Its chemical name is hydrargyrum (Hg⁰), with a molecular mass of 200.59, a boiling point of 356.72° C, a melting point of -38.87° C, and a density of 13.534 g/cm³ at 25° C (Fisher 2003; IOMC 2002; NRC 2000). In nature mercury is seldom found in its elemental form and is generally found within compounds and inorganic salts. Due to its molecular structure mercury can be bound to other components as either a monovalent or divalent mercury molecule (Hg (I) or Hg (II)). A composition of mercury with any other molecule, besides carbon, is known as an inorganic mercuric compound. The binding of a carbon to mercury is known as an organic mercuric compound. Several examples of inorganic mercuric compounds are: mercuric sulfide (HgS), mercuric oxide (HgO), and mercuric chloride (HgCl₂) (Clarkson and Magos 2006; NRC 2000).

The mercuric compounds that are of greatest concern to living organisms are those of the organic type. Generally speaking, elemental mercury vapor is released into the atmosphere and is deposited in one of its chemical forms either on land or in water. Microbial organisms, such as bacteria, methylate the elemental mercury into methylmercury. Methylmercury subsequently builds up in e.g. edible freshwater and saltwater fish and marine mammals, up to many thousands of times greater than levels in the surrounding area (Fisher 2003; IOMC 2002). This process is known as bioaccumulation and biomagnification.

Since mercury is a constituent element of earth it cannot be broken down or degraded, it simply changes chemical form. Once it is released into the environment, either anthropogenically or naturally, it changes between different states and species. A study conducted in and around the Great Lakes (Glass et al. 1991) concluded that mercury vapor can travel as far as 2500 km from
its source in just 72 hours. Furthermore, estimates concerning its airborne residency time ranges from one year to six years (Morel et al. 1998; US-EPA 1984).

Mercury is mined from cinnabar ores which are found in some key regions worldwide: Almaden – Spain, Khaydarkan – Kyrgyzstan, Algeria, and China (Goldwater 1972; Hylander and Meili 2003). These key regions all form part of the mercuriferous belt, between the western Mediterranean and central Asia (Hylander and Meili 2003). Hylander and Meili (2003) report that roughly one third of the world’s mercury production is attributed to the Almaden, Spain mine. Hg mining in this region has considerably added to the environmental distribution of this element and its compounds. In addition, the combustion of fossil fuel, cement production, chemical and medical wastes, and its use in small-scale gold mining has added to the major anthropogenic sources of mercury in the environment (Fisher 2003; IOMC 2002).

1.4 The toxicology of mercury and health effects on humans

As previously mentioned the primary concern for the general population (and living organisms) is exposure to methylmercury (MeHg); this can occur either through occupational exposure or incidental exposure. Methylmercury seems to exclusively target the central nervous system, at least in primates (Clarkson and Magos 2006; Clarkson et al. 2003; Gunderson et al. 1986; Risher 2003; Schlabritz-Loutsevitch et al. 2004; Warfvinge and Bruun 2000), and easily passes both the blood brain barrier as well as the placental barrier (Clarkson and Magos 2006; NRC 2000; US-EPA 1984; WHO 2003). This trait of MeHg is of particular concern to expecting
mothers, in addition to the fact that several studies have indicated that lactating mothers exposed to Hg show high concentrations of it in breast milk (Björnberg et al. 2005; Grandjean et al. 1993).

The exact physiological mechanisms involved in the breakdown and absorption of MeHg in the body are not well known (NRC 2000), however, the detrimental effects to humans have been well documented in several mercury poisoning cases that have involved large populations. Two of these cases, one in Minamata, Japan and the other in Iraq, have largely been used as the blueprint for assessing symptoms related to large scale mercury poisoning (Clarkson and Magos 2006; Clarkson et al. 2003; Eto et al. 2002; Fisher 2003; Grandjean et al. 1993; NRC 2000; Rasmussen et al. 2005; Watanabe and Satoh 1996).

1.4.1 Minamata, Japan

The best documented case of (methyl) mercury poisoning occurred during the span of seven years in Minamata Bay, Japan. Starting in December of 1953, several acute cases of a “mysterious” disease were reported at the municipal hospital of Minamata City. Some of the symptoms involved: abnormal gait, dysarthria, ataxia, deafness, and the constriction of the visual field (Watanabe and Satoh 1996). Severe cases involved mental confusion, drowsiness, and stupor. During the course of 1954-1955, more patients were admitted showing several, if not all, of the aforementioned symptoms. In 30% of the cases, fatality was the end result.

It was not until 1959 that the health authority in Japan concluded that the “mysterious” disease was a case of mass mercury contamination. Apparently, a local chemical plant, using mercury as a catalyst in the production of acetaldehyde discharged the byproduct (alkylmercury) into the bay. The alkylmercury eventually accumulated in the shellfish and fish population of the bay, which was a substantial protein source for the local population. As a result, the local
population was exposed to significant amounts of mercury in their diet, resulting in mass acute mercury contamination. Since this time, any form of acute mercury poisoning is known as Minamata disease (Watanabe and Satoh 1996).

Preceding the actual outbreak of Minamata disease, several extraordinary ecological phenomena were observed: floating dead fish, empty shellfish, and birds falling in mid-flight. Even a large number of cats suffered abnormal deaths (Rasmussen et al. 2005; Watanabe and Satoh 1996). Autopsies on those that died of Minamata disease revealed considerable damage to the central nervous system: severe lesions in the cerebral cortex and the cerebellar cortex. The disease particularly targets the calcarine cortex as well, resulting in widespread lesions in this area (Eto et al. 2002). This might explain the sensitivity to sunlight patients displayed. Additionally, mercury levels in organs ranged from 2.6 ppm – 24.8 ppm in the brain, 22.0 ppm – 70.5 ppm in the liver, and 21.2 ppm – 140.0 ppm in the kidneys (Rasmussen et al. 2005).

Additionally, Fetal Minamata disease was first diagnosed in 1958. Several infants manifested disease symptoms similar to cerebral palsy, and were either born in or after 1955. Further examination of these children resulted in diagnosis of: mental retardation, cerebellar ataxia, primitive reflex, and dysarthris. Examinations involving sensory perception could not be conducted due to the severity of the conditions. Since it was a tradition in Japan to keep part of the umbilical cord after birth, researchers were able to analyze these for methylmercury levels; these were extremely high and thus mercury poisoning was confirmed (Rasmussen et al. 2005; Watanabe and Satoh 1996).
1.4.2 Iraq

From 1955 until 1972 three mercury poisoning related epidemics took place in Iraq. The worst took place from 1971 -1972 and resulted in 6530 victims and 459 deaths (Watanabe and Satoh 1996). The epidemic was caused by the consumption of seed grain coated with organic mercury compounds to combat fungus and other pests. Rural people used the grain to make homemade bread and as a result thousands suffered from acute mercury poisoning.

The epidemic in Iraq paved the way for mercury research regarding dose-effect and dose-response relationships. Additionally, research methods were developed regarding Hg concentrations in hair strands; the concentration in hair strands actually summarize the history of the exposure (Watanabe and Satoh 1996). The Iraqi episodes also allowed for further research into the exposure of methylmercury to babies in utero.

1.5 Mercury studies in non-human primates

Extensive studies in captive nonhuman primates with regards to MeHg toxicology have been conducted since the early 1970’s to present (Berlin et al. 1975; Burbacher et al. 1986; Burbacher et al. 1990; Burbacher et al. 2005; Charleston et al. 1995; Charleston et al. 1994; Gunderson et al. 1986; Lind et al. 1993; Rice and Gilbert 1995; Schlabritz-Loutsevitch et al. 2004; Shaw et al. 1975; Vahter et al. 1994; Vahter et al. 1995; Warfvinge and Bruun 2000). In the majority of these studies the study subjects, either Macaca fascicularis or Saimiri sp., were exposed to MeHg orally or through intramuscular injection. The rate of absorption, excretion, and place of absorption were continuously monitored and recorded, while behavioral and sensory tests were conducted pre-exposure, during exposure, and post exposure.
From these behavioral and sensory studies, in addition to necropsies, it is evident that the primary area that is affected by MeHg exposure is the visual cortex region of the brain. In prenatal studies, where the pregnant mother was exposed to controlled doses of MeHg, the infant was born with obvious physical retardation to the eyes. In several cases where it was not evident at birth, behavioral and sensory tests during the infant’s development clearly indicated deterioration of the visual senses. Typical behavioral effects to MeHg included: withdrawal, depression, emotional lability, and sleep disturbances. Additionally, a series of neuromotor effects were observed: tremors, ataxia, and weakness. At the time of this research, there were no known studies conducted on MeHg levels in wild nonhuman primates.

1.6 Research question

Current techniques for assessing levels of organic mercury in primates are limited to studies in captive non-human primates and analysis of hair and blood samples in human populations. These studies show a significant correlation between mercury contamination in the environment and the accumulation of organic mercury in tissues and organs of both humans and non-human primates. However, no such studies have been conducted on free-ranging primate populations.

One of the benefits of captive non-human primate studies is the easy accessibility of high end instrumentation to conduct detailed mercury analyses and easy access to hair/blood samples. There are mercury testers available for the field, these are quite expensive and as such, were not available for this study. Taking into account the need for mercury analyses in free-ranging primates, the high financial investment in field mercury testers, and the invasive nature of acquiring hair and blood samples, this study’s primary goals are to:
1. Collect baseline feeding and behavioral ecology data on black spider monkey subgroups, which have never been studied at the Brownsberg Nature Park.

2. Employ GPS and GIS technology to record daily travel patterns of subgroups in relation to: feeding trees (food patch) and gold mining areas.

3. Develop a simple field method for determining methylmercury levels in fecal and urine samples in wild primates. In addition, this method should also be chemically safe to the researcher and environment, non-invasive to the study animals, and most of all be reliable in measurement.

4. Assess methylmercury levels in fecal and urine samples from captive primates in Suriname and the United States of America, of which I presumed that there would be very limited exposure to methylmercury. Results from these samples would be used as comparison to those samples from wild primates.
Figures and tables

Fig. 1.1. Illustration depicting a typical small-scale mining operation. Source: (Peterson and Heemskerk 2001)
Fig. 1.2 Composite Landsat Images of the Brownsberg Nature Park 1987, 1997, 2000.

Arrows highlight the progression of illegal gold mining in the park (light blue areas = open areas)
Fig. 1.3 several snapshots taken during visits to the WK mining area 2005-2008
Fig. 1.4 Real time satellite image of the Brownsberg Nature Park area October 11, 2008.

Arrows point to gold mining locations to the North, East, and South of the park.
CHAPTER 2

METHODS

2.1 Background on Suriname and Brownsberg Nature Park (BNP)

Suriname is located on the northeastern coast of South America, north of Brazil, between Guyana and French Guiana (Fig. 2.1). The country is 163,270 km$^2$ (Globescope 2005) in area and is part of the Guiana Shield, which includes French Guiana, Guyana, northern Brazil, and eastern Venezuela. Approximately 82% of the country is covered by natural vegetation consisting of tropical rainforests, savannas, coastal swamps, and hills (Department 2009). Suriname has four distinguishable seasons: a short rainy season (December to January), a short dry season (February to March), a long rainy season (April to July), and a long dry season (August to November). Average annual rainfall in Suriname is 2200 mm or 355 km$^3$ per year (Engineers 2001).

The 2005 population of Suriname was estimated at 490,000 with an average annual rate of natural increase of 1.5% (Globescope 2005). The majority of Suriname’s people live along the coast, with the capital city of Paramaribo accounting for 240,000 residents (Globescope 2005). The interior is largely inhabited by small populations of indigenous tribes and maroons (descendants of runaway slaves who now in live in tribal communities).

These areas, totaling 1,959,180 hectares, encompass 11 nature reserves, one Nature Park, and four multiple-use management areas (Fig. 2.2) (Foundation 2010; STINASU 2010). All protected areas fall under the authority of the Secretary of Natural Resources, who has designated management of these areas to the Suriname Forest Service with daily management run by the Nature Conservation Division. The Nature Conservation Division, in collaboration with the Foundation for Nature Conservation in Suriname (STINASU), conducts research projects and nature education programs in the protected areas. STINASU, a semi-governmental organization, also manages Suriname’s only nature park, Brownsberg Nature Park (BNP) (STINASU 2010; Werkhoven and Baal 1995).

In comparison to the rest of South America, the total percent of land protected under IUCN (The World Conservation Union) Categories I and II, in Suriname, is close to 10%. That’s more than twice to that of all other countries on the continent (EarthTrends 2003). Category I refers to protected areas that are managed for science (nature reserves) and areas managed for wilderness protection (wilderness areas) (IUCN 1994). Category II is mainly defined as a protected area mainly managed for ecosystem protection and recreation (Nature Parks) (IUCN 1994). Suriname prides itself in this aspect, in addition to being the first country in the region to establish a nature reserves system (STINASU 2010). The Brownsberg Nature Park is a Category II protected area as defined by the World Conservation Union.

Suriname is home to 180 mammal species, 5,018 plant species, 141 reptile species, 86 amphibian species (EarthTrends 2003), 300 freshwater species, and 674 bird species (Werkhoven and Baal 1995). Seven of the 16 platyrrhine genera are present in Suriname: Saguinus, Saimiri, Cebus, Pithecia, Chiroptes, Alouatta, and Ateles (Norconk et al. 1996). The most common primate species found along the coastal areas and in the interior are Saguinus midas, Saimiri.
sciureus, Cebus apella, and Alouatta seniculus. Pithecia pithecia, Cebus olivaceus, Chiropotes satanas (sagulatus), and Ateles paniscus are found only in the interior.

The BNP protects 12,200 hectares of both disturbed and relatively undisturbed seasonal evergreen rainforest. The park is located 130 km south of the capital city of Paramaribo and can easily be reached within two hours by car or bus transport. Due to its close proximity to Paramaribo, BNP has become a popular destination for both local and international visitors (Fitzgerald 2003; Fitzgerald et al. 2002; STINASU 2010; Westin 2007). In 2001 (Fitzgerald et al. 2002) the park hosted approximately 17,000 visitors, and by 2003 that number increased to 19,700 (Westin 2007). Both these numbers are staggering, considering that they represent about four percent of the Suriname population. The main facilities of the park lie on top of a 500-meter high lateritic plateau where tourist lodges, for both day and overnight guests, are situated in a restricted area with trails running around the area and leading to various waterfalls and scenic vistas.

There is one main dirt road used to gain access to the park itself, and eventually the main facilities on the plateau. This road traverses the main part of the plateau and continues to the southernmost portion of the plateau; along its entire route several forest trails (both research as tourist trails) can be taken to either the Eastern or Western side of the plateau (Fig. 2.3). Two research trails, Jeep Trail and Witi Kreek, each traverse an entire West-East ridge that starts on the plateau (+/- 500 m elevation) and end near the foot of the mountain range at about 78 m asl. All research activities were conducted along the Witi Kreek trail.

The park is commonly regarded as a watershed divide between the Suriname and Saramacca River systems, and is dominated by seasonal evergreen rainforest. A defining trait of the park is the presence of heavily forested, steep slopes and gullies on all sides of the plateau.
Several microhabitats have been identified by Fitzgerald (2003) that make up the ecosystems at Brownsberg: high forest, high palm-dominated forest, high marsh forest, high closed forest, dry forest, mountain savanna forest, moss-covered mountain savanna forest, lowland forest, liana forest, swamp forest, and secondary forest.

Also known as the Brokopondo Reservoir or more commonly Afobaka Lake, the flooded region was home to a dozen maroon villages of the Saramakaans tribe. These people were subsequently forced by the government of Suriname to relocate to several areas, either further south or north, of the Brownsberg area. These “transmigration” villages, such as Marshall Kreek, Tapuripa, and Brownsweg, are thus in fact conglomerates of several maroon villages. Brownsweg is the closest community to Brownsberg, just north of the mountain range, and as such STINASU has employed workers from Brownsweg in the park since the establishment of the Brownsberg Nature Park in 1970.

2.2. History of Mining at the Brownsberg

In 1950, the Brownsberg area was part of an exploration concession of the Suriname Aluminum Company (SURALCO), but since that time the company had no interest in exploitation of the bauxite reserves, it was given to STINASU as part of a long term lease (Fitzgerald et al. 2002). In 1960, the Aluminum Company of America (ALCOA) began the construction of a hydroelectric dam in the Suriname River valley to the east of the Brownsberg area. Construction finished in 1964 with the closing of the dam and by 1965 a total area of 1,566 km² or 600 mi² was flooded, creating one of the largest artificial lakes in the world (Engineers 2001): the Prof. Dr. Ir. W. J. van Blommenstein Lake.
Suriname, French Guiana, northern Brazil, eastern Venezuela and Guyana sit atop the Precambrian deposits of the Guiana Shield (Hammond, 2005). Gold is sourced from greenstone deposits that rim the northeastern portion of the Guiana Shield and Hammond (2005:423) reports that 90% of the major gold deposits are found in the “greenstone belt.” Unfortunately, Brownsberg Nature Park is found squarely in this area and gold mining is the source of current conservation concerns for the Nature Park (World Wildlife Fund, 2012). Gold mining in the deposits around the Brownsberg are dated from the early 20th century. From 1906 to the 1920s, substrates were intensively mined using explosives (De Dijn et al., 2006). Ironically, tourists visit the Park to see the waterfalls, some of which were the result of early excavations in search of gold. Today, small- and medium-sized operations are intruding into the Park along streams draining the mountain. De Dijn et al. (2006) reported that 5% of the Park was destroyed by gold miners mining streams at the base mountain on both the east (lake) side and the west (road) side of the mountain (see Figs 1.2 and 1.3) and the destruction has accelerated since that publication (WWF, 2012). The Guiana Shield leads the world in gold extraction and the source of the gold fever is the accelerating value of gold on the world market (Hammond et al., 2007).

Of particular relevance to this thesis are the extraction methods used by small-scale artisanal mining at locations like Brownsberg (see Fig 1.1). Following deforestation, soil is broken up using hydraulic methods and the stream is diverted through a sluice. Gold particles are amalgamated using mercury contaminating water sources downstream. The contaminated liquid is also aromatized, sending unknown quantities of mercury into the local atmosphere. Following the logic that animals, particularly arboreal animals, may eat contaminated fruit and leaves, this study will pilot a field method to detect mercury excreted by monkeys inhabiting forest uphill of mines.
2.3 Primates of the Brownsberg Nature Park, Suriname

Throughout Suriname’s short history in primate research several studies have been undertaken within the park to assess the primate populations there. Extensive data on primates was primarily collected during the biodiversity monitoring project conducted from 2002 – 2005 (Fitzgerald et al. 2002). Several other reports and studies have also given us a detailed perspective on the composition, behavioral and feeding ecology of these primate communities (Anzelc 2009; Colavita 2005; De Dijn et al. 2007; Gregory 2006; Lim et al. 2005; Neal 2009; Norconk et al. 2003; Westin 2007).

All eight primate species of Suriname can be found throughout the park: black spider monkey (*Ateles paniscus*), red howling monkey (*Alouatta maconnelli*), bearded saki (*Chiropotes chinopeotes*), white-faced saki (*Pithecia pithecia*), wedge capped capuchin (*Cebus olivaceus*), brown capuchin (*Cebus apella*), common squirrel monkey (*Saimiri sciureus*), and golden-handed tamarin (*Saguinus midas*). The most common species seen are the red howlers, bearded sakis, white-faced sakis and the golden-handed tamarins (De Dijn et al. 2007; Fitzgerald et al. 2002; Lim et al. 2005; Norconk et al. 2003; Vanderhoff and Grafton 2009; Westin 2007).

The least common species (*Saimiri sciureus*) seems to prefer the riverine habitats at the foot of the mountain and is rarely seen on the slopes or top of the plateau (De Dijn et al. 2007; Fitzgerald et al. 2002; Norconk et al. 2003). The capuchins (*Cebus apella* and *C. olivaceus*) can be seen on or near the plateau, but remain quite elusive and are sometimes not seen for weeks while at other times they will frequent the plateau several days in a row (personal observation). This can be in part due to the very large home ranges used by capuchin monkeys or availability of food on the plateau.
The black spider monkey, which is the focus of this thesis, is quite often heard in the morning emitting its customary long call over the ridges that run east-west along the berg. Until the present research, no one had ever actively studied the black spider monkey population at Brownsberg. Their presence within the park was noted by sound and the occasional sighting. It is thus the aim of this study to further elucidate the feeding, behavioral, and travel patterns of several *A. paniscus* subgroups, in order to gain some insight into the population of this species in the park.

2.4 The genus *Ateles*, with emphasis on *A. paniscus paniscus*

One of the first field studies of spider monkeys was conducted in Panama on *Ateles geoffroyi* by Carpenter (1935) wherein he assessed that spider monkeys are frugivorous primates, estimating that 90% of their diet consisted of fruits and nuts. He also observed fission/fusion grouping patterns, whereby subgroup composition ranged from male subgroups, female subgroups (with or without young), to mixed subgroups (Carpenter 1935). Similarly, chimpanzees’ diets consist more than 50% of fruits and are considered to be essential in seed dispersal throughout African rainforests (Chapman et al. 1995; Stanford and Nkurunungi 2003; Wrangham et al. 1994; Wrangham et al. 1991). They too employ fission/fusion grouping patterns, but unlike spider monkeys, are composed of larger subgroups (Chapman et al. 1995).

Spider monkeys belong to the Atelinae subfamily which includes the genera: *Ateles, Brachyteles, Lagothrix*, and *Alouatta* (Fleagle 1988). The genus *Ateles* (spider monkey) is distributed throughout parts of Southern Mexico, Central America, and as far south to northern Bolivia (Collins and Dubach 2000; Medeiros et al. 1997). There is some contention on the taxonomic relationships within *Ateles*, as most scientists follow Kellogg and Goldman’s
taxonomy of 1944, which utilizes pelage variation as the defining characteristic. Based on this taxonomy four distinct species are defined: *A. paniscus*, *A. belzebuth*, *A. fusciceps*, and *A. geoffroyi*, and 16 subspecies. Hershkovitz (1969) questioned this taxonomy and proposed various different taxonomies which resulted anywhere from one to six species. This brought on a great deal of confusion among researchers, resulting in the majority of researchers still relying on Kellogg and Goldman’s original classification of 1944.

In the past decade however, through the emergence of genetic studies, others have proposed a slightly different phylogeny. Collins and Dubach (2000) conducted mtDNA comparisons among several recognized subspecies of *Ateles* and proposed four monophyletic species of *Ateles*: *A. paniscus*, *A. belzebuth*, *A. hybridus*, and *A. geoffroyi* (which includes two former species: *A. geoffroyi* and *A. fusciceps*). Their work adds support to previous research that indicated that *A. paniscus paniscus* is indeed genetically different from the other *Ateles* species (Medeiros et al. 1997) and should indeed be classified as a separate species. Medeiros et al. (1997) employed cytogenetic techniques in their analysis and both reports also justify *A. geoffroyi* as a separate species, being mainly distributed throughout Central America and parts of southern Mexico. There are, however, conflicts in the designation of the “in between species”: *A. belzebuth* and *A. fusciceps* (Figs 2.4 and 2.5).

*Ateles paniscus paniscus* is the most geographically isolated of the *Ateles* species, being restricted to the Eastern Guianan Shield and north of the Amazon River (Norconk et al. 1996), which could explain why it is so genetically distinct from the other *Ateles* species. There have been reports of *A. paniscus paniscus* in parts of the Western Guianan Shield/Eastern Venezuela, but recent primate surveys conducted in those regions have provided no evidence for its
occurrence (Urbani 2006). Urbani (2006) does however suggest that it is possible that *A. paniscus*
*paniscus* inhabit small patches of isolated forested areas found throughout this region.

The black spider monkey is primarily found within densely forested regions across
French Guyana, Suriname, and Eastern Guyana. Its restricted range within the Guiana Shield,
along with the difficulty of reaching the field sites where they are found might explain why there
have been so few field studies conducted on this species (Mittermeier and Fleagle 1980; Norconk
and Kinzey 1994; Simmen and Sabatier 1996; Van Roosmalen 1981). By far, the most
comprehensive ecological study of the black spider monkey, and most cited for this species, has
been Van Roosmalen’s (1981) year-long research on several subgroups at Raleighvallen,
Suriname.

Similarly to the other Ateles species, black spider monkeys are strictly arboreal
frugivores, are well adapted to life in the upper canopy, and will rarely descend to the ground to
forage (Campbell et al. 2005). Unlike *Cebus* spp. or *Saimiri* spp. who will often become
terrestrial to forage on insects, spider monkeys have special shoulder joint modifications and
elongated forelimbs hindering any form of terrestrial locomotion (Campbell et al. 2005). In fact,
spider monkeys will actually walk bipedally if terrestrial locomotion is required (pers. obs.).
Spider monkeys rarely ever forage on insects, and thus have no need to descend to the ground to
forage on them. At Raleighvallen, 0.1% of the diet consisted of the occasional eating of small
caterpillars and termites (Van Roosmalen 1981), and these were eaten in the canopy.

Spider monkeys prefer the upper canopy in the Neotropics; this holds especially true in
Suriname where, at Raleighvallen and BNP, *A. paniscus* is mainly spotted in the upper regions of
the forest. At Raleighvallen the forest is typically classified as high forest with emergents
reaching up to 40-50 m in height (Van Roosmalen 1981). Similarly, Brownsberg consists of high
forest, often referred to as cloud forest with trees reaching up to 40 m in height (Alonso and Mol 2007; Fitzgerald et al. 2002; Lim et al. 2005). Both high forest types are typically classified as being found on moist soils, with the Raleighvallen forest being considerably wetter than Brownsberg.

High forests in Suriname tend to be very rich in fruit-bearing species; of the 486 recorded edible fruit species, 331 are found in high forests (Van Roosmalen 1981). This diversity in fruit-bearing trees goes hand-in-hand with the black spider monkey’s diet: during the Raleighvallen study, Van Roosmalen (1981) recorded that 82.9% of feeding observations were fruits. This was followed by flush leaves (7.9%), and flowers (6.4%). Additional food items (all less than 1.7%) that were recorded included: bark, decayed wood, pseudobulbs, aerial roots, honey, termites, and caterpillars. Simmen and Sabatier’s (1996) study on *A. paniscus paniscus* in French Guiana attained similar results: fruits (85.4%), leaves (9.5%), and flowers (2.5%).

Not all Ateles species are found in moist high forests, such as Raleighvallen and Brownsberg. *Ateles geoffroyi* is found in seasonally dry forests in Costa Rica (Chapman and Chapman 1991) and fragmented dry forest in parts of MesoAmerica (Gonzalez-Zamora et al. 2009). *Ateles belzebuth* on the other hand is found in terra firme forest, in areas that typically receive less than 100 mm of rainfall per month (Link and Fiore 2006). Various studies have shown that there is some dissimilarity as well in food choice across field sites. Russo et al. (2005) conducted a study among four field sites in Colombia, Ecuador, Panama, and Suriname: they compared the diet of three *Ateles* spp. and found that among the top 10 plant families represented among the field sites only two were similar (Myristicaceae and Moraceae). On the genus level Brosimum, Cecropia, and Virola were the only three that ranked within the top 20 at all four sites.
Along with Brachyteles and Lagothrix, *Ateles* spp. display an incredible amount of flexibility in grouping pattern within a social unit (Symington 1988): a pattern known as fission-fusion. Within this fission-fusion society, subgroup composition varies in number, age, and sex of the individuals (Carpenter 1935; Chapman 1990; Di Fiore and Campbell 2007). This flexibility in grouping pattern is found in one other non-human primate species, the chimpanzee (Symington 1988). The variation in subgroup composition may be related to the spatial dispersion of food resources (patchiness) within tropical rainforests. Symington (1988) and Shimooka (2003) point out in their study of *Ateles paniscus* and *Ateles belzebuth*, respectively, that a positive correlation exists between subgroup size and fruit abundance. Thus, an increase in fruit production (large fruit patch) allows for larger subgroup sizes. A flexible grouping pattern as expressed in the *Ateles* spp. may allow for more efficient feeding times, energy expenditure, and nutrition intake within the individual (Symington 1988). In disturbed forests where fruit productivity is low due to logging, subgroup size is smaller than average (Link and Jimenez 2007).

In addition to a flexible grouping pattern which is unique for New World primates, *Ateles* spp. also display unusual monkey life history traits: gestation period is on average 7.6 months, while interbirth interval is about 3 years (Campbell and Gibson 2008). Male black spider monkeys weigh on average 7.46 kg and females average a 8.75 kg (Ford and Davis 1992). There is some sexual dimorphism with males being slightly larger than females, though I have seen some very large females. Napier and Napier (1967) report male spider monkeys having a mean head-body length of 545 mm and a mean tail length of 807 mm; females have a mean head-body length of 540 mm and a mean tail length of 814 mm.

Travel and feeding routines are determined by a “dominant” female or by two dominant females (Van Roosmalen 1981). Females will generally emigrate, while males stay in their natal
group. The sex ratio is skewed towards females, with a ratio of 1:2. Due to the dominance of females in subgroup movement, it is very likely that they possess extensive knowledge of fruiting trees within the group’s home range (Van Roosmalen 1981). Subgroups with a female and offspring will therefore utilize certain “core” areas (personal observation; Van Roosmalen 1981), while males will travel together across a much larger area, and routinely “patrol” the boundaries of the group’s home range (Chapman 1990; Symington 1987; Van Roosmalen 1981). Within spider monkey social organization females emigrate while males remain with their natal group (Symington 1987; Van Roosmalen 1981). From my own personal observation I rarely ever followed a subgroup that had more than one male present. It is likely that I conducted most of my follows within the “core” area of the group (see discussion).

2.5 Sampling Methods

2.5.1 Climate

The study period took place from May 28, 2008 until July 28, 2008, which coincides with the peak and the end of the long rainy season. Daily rainfall and temperature data were recorded: both were recorded every morning, rainfall from a rain gauge (mm) and temperature (Celsius) from an outdoor thermometer. Average rainfall was higher during the peak of the rainy season and gradually declined towards the end of the season (Fig 2.6). Aside from minor fluctuations in minimum and maximum temperatures at the end of May, temperatures stayed relatively constant throughout the study period (Fig 2.6). For the entire study period a total of 832.9 mm of rainfall was recorded, with a mean minimum daily temperature of 19.7 C° and a mean maximum daily temperature of 27.2 C° (Table 2.1).

<table>
<thead>
<tr>
<th></th>
<th># Days</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Median</th>
<th>Total for Study Period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Daily Temperature (°C)</td>
<td>40</td>
<td>18</td>
<td>21</td>
<td>19.7</td>
<td>0.76</td>
<td>20</td>
<td>NA</td>
</tr>
<tr>
<td>Maximum Daily Temperature (°C)</td>
<td>40</td>
<td>24</td>
<td>31</td>
<td>27.2</td>
<td>1.12</td>
<td>27</td>
<td>NA</td>
</tr>
<tr>
<td>Rainfall (mm)</td>
<td>40</td>
<td>0.2</td>
<td>107.6</td>
<td>20.8</td>
<td>25.06</td>
<td>11.8</td>
<td>832.9</td>
</tr>
</tbody>
</table>

2.5.2 Subgroup data

A typical day consisted of walking the Witi Kreek (WK) trail by 0700 h to locate a subgroup. Generally speaking, I walked till the WK 2.0 (km) marker and if by then no contact had been made with any subgroup, I would slowly head back to WK 1.0 (km). I continued this process until I was successful in locating a subgroup. The Witi Kreek trail traverses an entire ridge that runs north-south along the eastern side of the Brownsberg mountain range. One of the largest areas mined at the time of the study was on the Witi Kreek below 5.0 trail marker (see Fig 1.3).

Once a subgroup was located information was taken on subgroup composition, i.e., number of individuals, sex, and age category (adult male or female, subadult male or female, juvenile, infant). Waypoints were taken using GPS 60CSx and location was also recorded in my field notebook. The “tracking” feature was turned on during subgroup follows and recorded location in waypoints every 5 minutes. My route was the route taken by the subgroups as I was consistently directly beneath them. GPS waypoints documented the location of:

- Initial contact
- “Feeding patches”
  o I defined a “feeding patch” as any tree wherein half or the entire subgroup was feeding for more than one minute. These included adjacent feeding trees of the same species, as long as members of the subgroup were seen feeding in them. If the subgroup consisted of two individuals, and one was seen feeding, it was recorded as a feeding patch. One minute was chosen as the minimum feeding time because from personal observations, if spider monkeys spend at least a minute feeding on a certain fruit it is most likely a highly regarded food item. It is likely that spider monkeys will ingest the seeds of this item.

- Resting trees
- Foraging on leaves
- Points of interest e.g. sleeping sites, fission/fusion locations.

The following behavioral data were recorded every 10 minutes using group scans:
  o Feeding: as previously mentioned, if half or the entire subgroup were observed feeding, it was recorded as feeding.
  o Resting (includes sitting or lying and unmoving, grooming, playing by juveniles, defecating)
  o Travelling: includes both slow and fast travelling

I confidently identified one subgroup (M) that was followed on 5.16 sample days. The subgroup consisted of an adult female with a male juvenile (c. 2 yo) and occasionally an adult male. Additionally, I followed subgroups which I could not confidently identify on 11 different occasions. As such, these subgroups were recorded as “unknown”. I recorded A total of 71.5 hrs of contact time (duration averaged 4.2 hrs/observation ± = 2.2 hrs; range 1.2 to 8.7 hrs) was recorded with all subgroups over 16 days. I was able to conduct one all-day follow from morning
to night, subsequently camping out at the subgroup’s sleeping site. Shorter duration times were curtailed when a group was lost due to steep terrain.

All GPS data (tracks and waypoints) were downloaded first to MapSource® Version 6.11.6, converted to .gpx format (GPS exchange format), and then imported into ArcMap ® 9.2 for further analysis. All travel data e.g., distance travelled, average speed travelled, were extracted from GPS data. Unless noted, all maps in this thesis were produced in ArcMap ® 9.2.

2.5.3 Feeding Data

Data that were collected as part of the feeding ecology study consisted of fruit identification of foraged fruits. If identification was not possible immediately, a sample was collected and brought back to the research station to be identified later. Since spider monkeys are “seed swallowers” identification of fruits was possible by examining the dropped exocarp, which in most cases remained entirely intact. If feeding on leaves was observed it was also recorded, however, leaf identification was not recorded.

2.6 Determination of the Presence of Mercury

I used the Osumex Heavy Metals Kit, made by Osumex Limited. This “home kit” is initially meant for testing liquid samples (e.g., urine). Since urine is difficult to collect for an animal that typically is 20 meters or higher in the forest, I developed a pre-treatment method for fecal material to use with kit. Prior to field work, in collaboration with Dr. Raghanti and the chemists at Osumex Limited, a modified testing method was developed: 10 ml of 5% HCl was added to 0.45 gr of fresh (or frozen) fecal matter in order to separate any hard/fibrous content in
the feces. Spinning the HCl/fecal solution in a centrifuge sped up this process and eventually separation took place. Subsequently, 6 ml of the natant liquid was then extracted from the test tube and then used in the final process of mercury testing. Since, there were no centrifuges in the field, the test tube was placed in a tube sock and spun over head for at least 5 minutes. The method effectively separated solid from liquid material. Dr. Paul Ouboter, Director of the National Zoological Collection at Anton de Kom University in Paramaribo, Suriname provided the 5% HCl solution. All solutions/chemicals were disposed of properly according to the manufacture’s specifications.

The kit itself consists of an empty test tube (wherein the sample to be tested is placed), and three vials each containing a chemical reagent. One reagent is added to the test tube sample, while the remaining two are combined in effect producing the coloring reagent that will stain whatever mercury ions are present in the sample. Finally, the coloring reagent is added to the test tube sample and allowed time to react, approximately 6 minutes. In time, if the sample contains any significant amount of mercury, the entire solution will start to change color. Determination of mercury levels in the sample was done by comparing the coloration of the entire solution with the provided test kit color chart; measurements are reported in parts per million (ppm). There are eight intervals of ppm measurements used with the test kit, each associated with a different color ranging from light yellow to dark red: 0 – 0.025, 0.025–0.05, 0.05 – 0.1, 0.1 – 0.2, 0.2 – 0.4, 0.4 – 0.8, 0.8 – 1.5, 1.5 – 2.0 (Fig 2.7).

A total of 27 fecal samples and 1 urine sample were collected. Most samples were collected from Brownsberg Nature Park from free-ranging primates that ranged mostly or exclusively in the upper half of the mountain: 9 samples from *Ateles paniscus*; 1 from *Alouatta maconnelli*; and 3 from *Pithecia pithecia*. Eight samples were collected from the Paramaribo Zoo
(1 sample from each of the eight species of monkeys found in Suriname; see Table 3.2). These individuals had been in captivity for some time, but were either collected from the wild or were confiscated pets. All ingested local fruits and vegetables as well as prepared dried chow. The captive platyrrhines (n = 7 fecal samples) housed at Hiram College, OH. All fecal samples were collected fresh, using a wooden Popsicle stick to scoop the sample into a large test tube. If the sample could not be analyzed immediately, it was stored in a Ziploc bag in a freezer. Surgical gloves were used at all times when handling of the specimen to avoid contamination of the fecal sample with any chemical/oil from my skin, and to reduce the likelihood of any disease transmission to myself. A wooden stick was used to prevent any contamination of the fecal sample with any metallic ions.
Fig. 2.1 Location of Suriname within South America.

Fig. 2.2 Nature Reserves in Suriname. The red circle marks the capital city, Paramaribo.

Map legend:
Nature Reserves
1. Hertenrits
2. Coppenname Monding
3. Wia Wia
4. Galibi
5. Brinckheuvel
6. Central Suriname
7. Sipaliwini
8. Boven Coesewijne
9. Copi
10. Wane Kreek
11. Peruvia

Nature Park
12. Brownsberg
Fig. 2.3 Topographic map of Brownsberg plateau’s trail system. Highlighted circle indicates study area.
Fig. 2.4 Distribution map of *Ateles* spp. in the Neotropics:

Fig. 2.5 Distribution of *Ateles* spp. and ssp. in Central and South America. Taken from Collins and Dubach (2000).
Fig. 2.6 Daily recorded rainfall (mm), minimum and maximum temperature (C) for the BNP plateau (May 27, 2008 – July 28, 2008)

Fig. 2.7 The Heavy Metals Test Kit, manufactured by Osumex Limited. Displayed are the three vials with coloring reagents, test tube, and color chart with corresponding ppm levels. Pen is used as scale.
CHAPTER 3

RESULTS

3.1 *Ateles paniscus* Ranging and Grouping Patterns

The majority of initial subgroup encounters occurred between the WK 1.1 km and the WK 2.0 km marker. Even though contact hours with the *Ateles* subgroups varied on a daily basis, most, if not all of the daily travel paths either crossed, ran parallel or ran perpendicular to the trail (Fig. 3.1). The daily path length varied from 83 m up to 1318 m, with a mean of 732 m/day (Std.Dev. = 394.5, median = 644.50). Contact hours with subgroups varied from 1.2 hrs. to 8.7 hrs, with a mean of 4.4 hrs/day. GPS tracking data recorded indicates that the average travel speed/hr to be 424.67 m/hr. The minimum travel speed/hr was 100 m, while the maximum was recorded at 1050 m.

The minimum subgroup size varied between 1 and 3 individuals, while the maximum number of individuals varied between 1 and 7. On several occasions fission and fusion took place between subgroups, up to four times in a day. Some days no fission or fusion took place and on one occasion I followed a single individual all day without any contact from other subgroups. On my last day in the field I observed Martha for several hours as she was travelling without Joey.

As a subgroup, M (Martha + Joey), had a daily path length that varied between 100 m/hr to 400 m/hr (Std.Dev.=134.2, median=300). Contact hours with subgroup M varied from 2.2 hrs to 8.7 hrs, with a mean of 5.62 hrs/day. Subgroup size varied between 1 and 3 individuals, with subgroup composition changing anywhere from one to four times a day. The most frequent encounters with M occurred near WK 2.0 and they seldom travelled far from the trail (Fig. 3.2).
3.2 Activity budget

Activity budget is an expression of the frequency of a recorded behavior (feeding, resting, and traveling) in terms of the total number of 10-minute point scans per two-hour periods for each day. Black spider monkey subgroups foraged 40.68% of total group scans in the first part of the morning, while resting and travelling accounted for 28.81% and 30.51% of the time, respectively, within that same period (Fig. 3.4). By mid morning the time spent feeding decreased to 31.78%, travelling decreased to 27.91%, while resting increased to 40.31% (Fig. 3.4). In the early afternoon, feeding increased slightly to 34.78%, travelling decreased further to 20.87% , as the time spent resting gradually increased to 44.35% (Fig. 3.4). During the mid afternoon hours subgroups spent over half of their time resting at 53.61%, while feeding and travelling time decreased to 25.77% and 20.62%, respectively (Fig. 3.4). For the entire study period May 23, 2008 – July 28, 2008, the total frequency of activities was comprised of 32% feeding, 43% resting, and 25% travelling (Fig. 3.5).

3.3 Feeding Ecology

The majority of the diet consisted of ripe fruits or parts thereof (76%), with the occasional feeding of young leaves (22%) and flowers (2%) (Fig. 3.8). Seeds were swallowed in 61% of samples; whole fruit ingested in 15%; fruit exo/endocarp in 8% of samples (Fig. 3.9). I did not observe any other food item being consumed (e.g., invertebrates, fungus, decayed wood), which may be used in seasons other than the sampling period or may have been rare items that were missed during sampling.

A total of 11 different fruit species were consumed, encompassing seven families, of which the Moraceae family had the most species represented within the diet (3), followed by
Sapotaceae and Tiliaceae each being represented by two species in the diet (Fig. 3.91). On a species level, however, *Virola kwatae* accounted for 35% of the diet (Fig. 3.92) and was consumed on 12 of the 16 observation days (Fig. 3.93).

GPS data were also collected on every feeding patch each subgroup visited per observation period (n = 16). Feeding patches on a daily basis varied between one and nine, with a mean of 2.8 ± 2.3 feeding patches/day (median = 2.5). On a genus level, 32% of feeding patches belonged to *Virola* (Fig. 3.94).

During the second half of the study period (July) subgroups almost exclusively fed on a particular species of fruit: *Virola kwatae*. When feeding on these fruits, individuals ingested the seed whole with mesocarp (or aril) and 2-3 hours later defecated the seeds away from the parent tree. On several occasions I observed a subgroup feeding in a *Virola* tree, move away from the tree for several hours, and travel back to the same tree to feed in. In between these *Virola* feeding bouts they would either feed on a different fruit species, or simply rest. Additionally, subgroups would also travel between *Virola* feeding patches. On three separate days I observed subgroups travel between *Virola* trees during the course of an entire day, resulting in my recording of just a single fruit species for those days (Fig. 3.14).

In the preceding month (June), dietary diversity was higher with some species being fed on only once or twice. The lower diversity in July did not seem to be due to lower availability of those species, but these resources were replaced with *Virola* when it ripened. Thus, the monkeys expressed a clear preference for *Virola* during the samples in July, to the exclusion of other resources. During the month of June, the fruits of this species were not ripe yet and on numerous occasions I noticed subgroups either pass through or pass by a tree with young fruit. Once the
Virola fruits ripened, subgroups exclusively fed on them; this despite other fruit species being available.

3.4 Mercury Concentration in Excretions

**Brownsberg samples:** Two samples from *Ateles paniscus* yielded no definitive results (Table 3.2). Mercury concentration in feces ranged from 0.025 ppm to 0.05 ppm among individuals from three primate species at the Brownsberg. The single urine sample (from a white-faced saki) yielded the highest mercury value (0.1 ppm) (Fig 3.15).

**Paramaribo Zoo:** One fecal sample was collected from eight individuals (one from each platyrrhine species) housed at the Paramaribo Zoo. Samples ranged from trace (0.025 ppm) to moderate (0.1 ppm). The *Alouatta macconelli* sample had the highest result.

**Hiram College:** All samples from the Hiram College had a 0.00 ppm value (Table 3.2). Notable is that within each group at least two samples were not successful; the resulting coloration did not match the color strip. Six samples produced inconclusive results, as the coloration of the samples did not match any color on the mercury indicator strip. The collection of urine samples in the field was extremely difficult; hence, the majority of mercury readings are derived from fecal samples.

An independent t-test was run to test for any significance between sample groups. Between the BNP samples and the Paramaribo Zoo, two-sample t(15) = .733, p = .616, between the BNP samples and Hiram samples, two-sample t(16) = 5.164, p < .000. These results show no statistical significance between BNP and Paramaribo Zoo individuals, however there is a significant statistical difference between BNP individuals and the Hiram College monkeys.
Table 3.1 Daily total distance (m) and average distance/hr (m/hr) travelled with each subgroup. Once every 10 minutes a group (point) scan was taken.

*No GPS tracking data are available for this day.

**Consort pair formed out of previous day’s subgroup. No group scans taken.

***Followed a subgroup away from the study area in the evening. No group scans.

<table>
<thead>
<tr>
<th>Date</th>
<th>Contact hours</th>
<th>Distance trav(m)</th>
<th>Avg Dist/hr (m/hr)</th>
<th># Group Scans</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/5/2008</td>
<td>7.8</td>
<td>1100</td>
<td>* no GPS data</td>
<td>46</td>
</tr>
<tr>
<td>6/21/2008</td>
<td>8.7</td>
<td>1318</td>
<td>300</td>
<td>46</td>
</tr>
<tr>
<td><strong>6/22/2008</strong></td>
<td>1.2</td>
<td>204</td>
<td>200</td>
<td>0</td>
</tr>
<tr>
<td>6/23/2008</td>
<td>3.8</td>
<td>1283</td>
<td>1050</td>
<td>23</td>
</tr>
<tr>
<td>6/26/2008</td>
<td>4.8</td>
<td>1011</td>
<td>300</td>
<td>29</td>
</tr>
<tr>
<td>6/28/2008</td>
<td>4.2</td>
<td>896</td>
<td>300</td>
<td>25</td>
</tr>
<tr>
<td>7/5/2008</td>
<td>4.3</td>
<td>995</td>
<td>570</td>
<td>26</td>
</tr>
<tr>
<td>7/6/2008</td>
<td>2.2</td>
<td>291</td>
<td>130</td>
<td>13</td>
</tr>
<tr>
<td>7/7/2008</td>
<td>5.8</td>
<td>599</td>
<td>340</td>
<td>35</td>
</tr>
<tr>
<td>7/9/2008</td>
<td>4</td>
<td>607</td>
<td>700</td>
<td>24</td>
</tr>
<tr>
<td>7/11/2008</td>
<td>5.2</td>
<td>1206</td>
<td>400</td>
<td>31</td>
</tr>
<tr>
<td>7/13/2008</td>
<td>4.2</td>
<td>192</td>
<td>400</td>
<td>25</td>
</tr>
<tr>
<td>***7/13/2008</td>
<td>1.7</td>
<td>644</td>
<td>500</td>
<td>0</td>
</tr>
<tr>
<td>7/14/2008</td>
<td>3</td>
<td>379</td>
<td>350</td>
<td>18</td>
</tr>
<tr>
<td>7/18/2008</td>
<td>7.2</td>
<td>463</td>
<td>100</td>
<td>38</td>
</tr>
<tr>
<td>7/22/2008</td>
<td>1.3</td>
<td>645</td>
<td>830</td>
<td>8</td>
</tr>
<tr>
<td>7/28/2008</td>
<td>2.2</td>
<td>83</td>
<td>100</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>-------------</td>
<td>-----------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>71.6 hrs</td>
<td>11916 m</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>Average distance</td>
<td></td>
<td>701 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average dist/hr</td>
<td></td>
<td></td>
<td>411 m/hr</td>
<td></td>
</tr>
</tbody>
</table>
Table 3.2  Mercury test results for wild population, Paramaribo Zoo, and Hiram
individuals. Samples 7, 8, 17, 18, 24, and 25 yielded no definitive results. The resulting
coloration of the sample was not in accordance with the color chart for the test.

<table>
<thead>
<tr>
<th>sample no.</th>
<th>sample type</th>
<th>species</th>
<th>ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>Wild Population Individuals</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>fecal</td>
<td><em>Ateles paniscus</em></td>
<td>0.025</td>
</tr>
<tr>
<td>2</td>
<td>fecal</td>
<td><em>Alouatta maconnelli</em></td>
<td>0.025</td>
</tr>
<tr>
<td>3</td>
<td>fecal</td>
<td><em>Ateles paniscus</em></td>
<td>0.025</td>
</tr>
<tr>
<td>4</td>
<td>fecal</td>
<td><em>Ateles paniscus</em></td>
<td>0.025</td>
</tr>
<tr>
<td>5</td>
<td>fecal</td>
<td><em>Ateles paniscus</em></td>
<td>0.025</td>
</tr>
<tr>
<td>6</td>
<td>fecal</td>
<td><em>Ateles paniscus</em></td>
<td>0.05</td>
</tr>
<tr>
<td>7</td>
<td>fecal</td>
<td><em>Ateles paniscus</em></td>
<td>X</td>
</tr>
<tr>
<td>8</td>
<td>fecal</td>
<td><em>Ateles paniscus</em></td>
<td>X</td>
</tr>
<tr>
<td>9</td>
<td>fecal</td>
<td><em>Ateles paniscus</em></td>
<td>0.025</td>
</tr>
<tr>
<td>10</td>
<td>fecal</td>
<td><em>Ateles paniscus</em></td>
<td>0.025</td>
</tr>
<tr>
<td>11</td>
<td>fecal</td>
<td><em>Pithecia pithecia</em></td>
<td>0.05</td>
</tr>
<tr>
<td>12</td>
<td>fecal</td>
<td><em>Pithecia pithecia</em></td>
<td>0.025</td>
</tr>
<tr>
<td>13</td>
<td>urine</td>
<td><em>Pithecia pithecia</em></td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>PARAMARIBOBO ZOO individuals</strong></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>fecal</td>
<td><em>Pithecia pithecia</em></td>
<td>0.05</td>
</tr>
<tr>
<td>15</td>
<td>fecal</td>
<td><em>Cebus apella</em></td>
<td>0.025</td>
</tr>
<tr>
<td>16</td>
<td>fecal</td>
<td><em>Chiropotes sagulatus</em></td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td>Fecal</td>
<td>Species</td>
<td>Quantity</td>
</tr>
<tr>
<td>---</td>
<td>-------</td>
<td>---------</td>
<td>----------</td>
</tr>
<tr>
<td>17</td>
<td>fecal</td>
<td><em>Saimiri sciureus</em></td>
<td>X</td>
</tr>
<tr>
<td>18</td>
<td>fecal</td>
<td><em>Saguinus midas</em></td>
<td>X</td>
</tr>
<tr>
<td>19</td>
<td>fecal</td>
<td><em>Cebus olivaceus</em></td>
<td>0.05</td>
</tr>
<tr>
<td>20</td>
<td>fecal</td>
<td><em>Alouatta maconelli</em></td>
<td>0.1</td>
</tr>
<tr>
<td>21</td>
<td>fecal</td>
<td><em>Ateles paniscus</em></td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Hiram College individuals</strong></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>fecal</td>
<td><em>Saguinus midas</em></td>
<td>0</td>
</tr>
<tr>
<td>23</td>
<td>fecal</td>
<td><em>Saguinus midas</em></td>
<td>0</td>
</tr>
<tr>
<td>24</td>
<td>fecal</td>
<td><em>Saimiri sciureus</em></td>
<td>X</td>
</tr>
<tr>
<td>25</td>
<td>fecal</td>
<td><em>Saimiri sciureus</em></td>
<td>X</td>
</tr>
<tr>
<td>26</td>
<td>fecal</td>
<td><em>Cebus apella</em></td>
<td>0</td>
</tr>
<tr>
<td>27</td>
<td>fecal</td>
<td><em>Cebus apella</em></td>
<td>0</td>
</tr>
<tr>
<td>28</td>
<td>fecal</td>
<td><em>Cebus apella</em></td>
<td>0</td>
</tr>
</tbody>
</table>
Fig. 3.1 Daily travel paths of black spider monkey subgroups along the Witi Kreek Trail, Brownsberg Nature Park, Suriname. The trail markers are at 100 m intervals. Each line represents the travel paths of spider monkey subgroups. Map generated in ArcMap 9.2 from GPS tracking data.
Fig. 3.2 Travel paths for subgroup M along the WK trail. The trail markers are at 100 m intervals. Each line represents the travel path for subgroup M. Map generated in ArcMap 9.2 from GPS tracking data.
Table 3.3 Group scan data per two-hour periods during the day. A group scan is a point scan of the subgroup every 10 minutes.

The data document the following activity patterns: Feed = feeding, Rest = resting, Trav = traveling. Tot = total # of scans

<table>
<thead>
<tr>
<th>Date</th>
<th>(8:00 - 10:00)</th>
<th>(10:00 - 12:00)</th>
<th>(12:00 - 14:00)</th>
<th>(14:00 - 16:00)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feed</td>
<td>Rest</td>
<td>Trav</td>
<td>Tot</td>
<td>Feed</td>
</tr>
<tr>
<td>5-Jun</td>
<td>2</td>
<td>7</td>
<td>2</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>21-Jun</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>23-Jun</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>26-Jun</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>28-Jun</td>
<td>6</td>
<td>0</td>
<td>6</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>5-Jul</td>
<td>7</td>
<td>1</td>
<td>6</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>6-Jul</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7-Jul</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>9-Jul</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11-Jul</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>13-Jul</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Date</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>------------</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>13-Jul</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>14-Jul</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>18-Jul</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>22-Jul</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>28-Jul</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>24-Jul</td>
<td>24</td>
<td>17</td>
<td>18</td>
<td>59</td>
<td>41</td>
</tr>
</tbody>
</table>
Fig. 3.4 Activity budget black spider monkey subgroups. Percentages are the number of each recorded behavior samples (feeding, resting, traveling) divided by the total number of samples for each two-hour period, for the entire study period.
Fig. 3.5 Total activity budget for black spider monkey subgroups from May 28, 2008 – July 28, 2008. Percentages are the total number of recorded behavior samples (feeding, resting, and traveling) divided by the total number of group scans.

**Frequency of activity entire study period**

- Feed%: 32%
- Rest%: 43%
- Trav%: 25%
Fig. 3.6 Percentages of types of food items consumed by black spider monkey subgroups during 16 days of behavioral observations.

Fig. 3.7 Distribution of types of food items eaten/ingested by black spider monkeys.
Fig. 3.8 Diet breadth in the early wet season 2008. Plant families that have fruit species represented within the black spider monkey’s diet across the study period.
Fig. 3.9 Distribution of fruit species in the spider monkeys’ diet (May – July 2008).

Legend:

VIKw: *Virola kwatae*
GuGr: *Guarea glabra*
ApPe: *Apeiba petuoma*
Ficus: *Ficus sp.*
AnRi: *Aniba riparia*
MaSc: *Maquira sclerophylla*
ApGl: *Apeiba glabra*
RhMa: *Rheedia macrophylla*
Brosimum: *Brosimum sp.*

Fig. 3.10 Frequency of eating fruit from different plant species.

Legend:

VIKw: *Virola kwatae*  GuGr: *Guarea glabra*
ApPe: *Apeiba petuoma*  Ficus: *Ficus sp.*
AnRi: *Aniba riparia*  MaSc: *Maquira sclerophylla*
ApGl: *Apeiba glabra*  RhMa: *Rheedia macrophylla*
Brosimum: *Brosimum sp.*
Fig. 3.11 **Percentage of feeding trees (fruit patches) per genus.** The top ranked family (Moraceae) had three genera represented: *Brosimum*, *Maquira*, and *Ficus*. The genus *Virola* (family Myristicaceae) was fed upon most extensively.

Fig. 3.12 **Number of fruit species eaten/day during the study period.** On 07, 13, and 28 July subgroups fed on a single species, every time.
Fig. 3.13 Distribution of mercury test results across three populations: wild monkeys BNP, monkeys at the Paramaribo Zoo, and captive monkeys at Hiram College, OH.
CHAPTER 4

DISCUSSION AND CONCLUSIONS

4.1 *Ateles paniscus* Ranging and Grouping Patterns

There are only three complete all-day follows and other days I followed subgroups between 1.3 hrs to 5.8 hrs. In addition, I was not able to locate a subgroup, or the same subgroup, every time early in the morning. Suarez (2006), Norconk and Kinzey (1994), and van Roosmalen (1981) report average day path lengths of 1393 m, 2300 m, and 2300 m respectively. For the three complete day follows I calculated an average path length of 960 m. My underestimation of average day path lengths could be the result of several factors: lack of multiple all-day follows or the lack of fruiting patches during the rainy season at that time in the park. Additionally, the aforementioned field studies on *Ateles* were long-term, and were conducted in forests with a relatively flat topography. The Brownsberg forest is completely different in that aspect; very irregular mountainous terrain, consisting of numerous ridges and valleys. On several days that I followed subgroup M they stayed within a small core area feeding consistently on *Virola kwatae* fruits, thus shortening the overall average of the daily path lengths as well.

The steep topography along Witi Kreek trail made it quite difficult at times to follow subgroups. Since, I could not always follow a subgroup to a sleeping site it was difficult to predict movements in the morning. The community was seen in its entirety once, and consisted of approximately 16 to 20 individuals. Subgroups that I was able to follow all day (n=3) only “fused” with the community once. On other days, the subgroup had its own sleeping site. Males in subgroups were almost never encountered and subgroups, almost always, consisted of an adult female(s) with dependent offspring. I encountered subgroup M on a regular basis in the same
“core” area, and on several occasions they joined other subgroups in a feeding tree. At one point the subgroup consisted of up to seven individuals. It should be noted that no males were present in this subgroup.

A subgroup was followed on the 13th of July which consisted of a large adult male, two adult females, and three other individuals who we were not able to sex. The large male (who we named Zeus) alarm called and displayed at us the entire time that we followed the subgroup. In the hours that we followed this subgroup, at least one other adult male alarm called/displayed at us. It was very obvious that this subgroup was not habituated to the presence of humans and of particular interest to us was that this subgroup was encountered approximately 2 km away from the usual area where we had followed several other subgroups. It is outside the scope of this study to determine whether or not this subgroup belonged to the “habituated” community that consisted of several subgroups which we had followed many times before. As previously stated, long-term studies have indicated that subgroups of males will “patrol” the boundaries of their home range, while subgroups of adult females with dependents will use a certain “core area”.

### 4.2 *Ateles paniscus* Activity Budget

Even though this was a short study, the behavioral data in terms of activity seems to accord with data from other *Ateles* field studies (Table 4.1). When it comes to resting spider monkeys will spend close to 50% of their time on this activity, followed by feeding, and finally by travelling. The majority of this study was conducted at the height of the rainy season, during which time fruit availability was limited to several fruit bearing tree species, which probably influenced the activity and travelling patterns of subgroups. Further discussion concerning feeding patterns is covered in the feeding ecology portion of this chapter.
During parts of the rainy season it would frequently rain during the night/morning and later in the day, hence deterring my chances of finding subgroups early in the morning. However, when I did find them mid-morning I was able to get a pretty good estimate of activity patterns for the rest of the day. This might explain why my activity budget data (even though short-term) conforms to data from the long-term studies.

As is the case with most non-human primates, early morning feeding activities were comprised primarily of some form of sugar intake. This holds especially true for frugivorous species such as spider monkeys. In the morning hours from 8am to 10 am they would primarily spend their time feeding (41%; see Fig.3.3) on fruits, while as the day progressed fruit feeding decreased. Resting activity increased during the course of the day, as they almost spent as much time feeding as travelling. Resting increased and overall feeding activities decreased in the late afternoon (2pm to 4 pm). Feeding bouts consisted of staying in a single tree eating either fruits or young leaves. On the few instances where I had the chance to camp overnight with the subgroup that I was following, they slept in a tree adjacent to the feeding tree.

<table>
<thead>
<tr>
<th>Species</th>
<th>Location</th>
<th>%feed</th>
<th>%rest</th>
<th>%trav</th>
<th>reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>A. paniscus paniscus</em></td>
<td>Brownsberg</td>
<td>33</td>
<td>42</td>
<td>25</td>
<td>this study</td>
</tr>
<tr>
<td><em>A. belzebuth belzebuth</em></td>
<td>Yasuni</td>
<td>17</td>
<td>58</td>
<td>25</td>
<td>Suarez, 2006</td>
</tr>
<tr>
<td><em>A. belzebuth belzebuth</em></td>
<td>Yasuni</td>
<td>34</td>
<td>44</td>
<td>20</td>
<td>Dew, 2001</td>
</tr>
<tr>
<td><em>A. belzebuth belzebuth</em></td>
<td>La Macarena</td>
<td>22</td>
<td>63</td>
<td>15</td>
<td>Klein and Klein, 1977, 1979</td>
</tr>
<tr>
<td><em>A. belzebuth chamek</em></td>
<td>Manu</td>
<td>26</td>
<td>45</td>
<td>29</td>
<td>Symington, 1987, 1988b</td>
</tr>
</tbody>
</table>
4.3 Feeding Ecology

It is well documented that spider monkeys are primarily ripe fruit consumers (Chapman and Russo 2006; Di Fiore et al. 2008; Gonzalez-Zamora et al. 2009; Link and Di Fiore 2006; Norconk and Kinzey 1994; Russo et al. 2005; Simmen and Sabatier 1996; Stevenson et al. 2002; Suarez 2006; van Roosmalen 1981) and supplement their diet with leaves, fungi, decayed wood, flowers, nectar, and even sometimes invertebrates (Di Fiore et al. 2011; Suarez 2006; van Roosmalen 1981). In the current study, their diet consisted of 84% ripe fruits, of which 61% consisted of seeds that were ingested. Eight percent consisted of exocarp that was eaten (seed was discarded); while in 15% of the cases the entire fruit was eaten. Flowers and leaves make up the remainder of the monkeys’ diet. As previously stated, black spider monkeys supplement their diet with other food items but I was never able to observe feeding on any other food items than the ones listed for my study. This of course does not mean that subgroups I was following never consumed these items. It could just be a matter of that I was not able to see them eating other items than ripe fruits and leaves.

Spider monkeys are excellent seed dispersers and are instrumental in seedling recruitment, hence making them a key element in establishing and maintaining rainforest tree diversity (Chapman and Chapman 1991; Chapman and Russo 2006; Cramer et al. 2007; Di Fiore 2004; Di Fiore et al. 2008; Gonzalez-Zamora et al. 2009; Lambert and Chapman 2005; Lambert and Garber 1998; Link and Di Fiore 2006; Russo et al. 2005; Simmen and Sabatier 1996; Stevenson et al. 2002; Terborgh 1992; Wallace 2005; Wallace 2008; Di Fiore et al. 2011). A key aspect in their role as primary seed dispersers is the fact that spider monkeys ingest whole seeds of ripe fruit, travel
away from the initial feeding tree and then defecate the seeds. Effective seed dispersal depends on
gentle treatment of whole seeds in the gut (van Roosmalen, 1985).

The feeding ecology data not only validates the importance of *Virola kwatae* fruits to the diet of
black spider monkeys at the Brownsberg Nature Park, but also the importance of these monkeys
as primary seed dispersers for this species. This was evident in the distribution of *Virola* trees in
the study area; the day paths before and during the fruiting season of this species almost always
went by these trees.

### 4.4 The Mercury Pilot Study

Mercury is present in any organism’s body and as such this kit will in most cases report
back some kind of result. A “normal” result is any measurement between 0.00 ppm and 0.03 ppm
(NJSDH 2010), while a value of 0.05 ppm indicates that the body is excreting mercury. This is
not a toxic level, but it does indicate that the body is under some stress (NJSDH 2010). Several
international health organizations have adopted different standards concerning what mercury
level is considered to be toxic (Rasmussen et al. 2005). For the current project, I used the 0.05
ppm level as a stress indicator for the body. According to the Environmental Protection Agency
standards (Rasmussen et al. 2005) levels at 0.1 ppm are of health concerns, while the World
Health Organization and the Canada Health Agency employ a level of 0.2 ppm as a health
concern indicator (Rasmussen et al. 2005). Since, the ppm measurements are a result of the
mercury concentration per kg of body weight it was not necessary to control for body weight.
Levels of 0.05 to 1.5 ppm of mercury detected in feather shafts of pheasants was found to result
in reduced chick survival and reduced hatchability (Femreite 1971 cited in Burger and Gochfeld
most levels of mercury leading to low chick survivorship were several magnitudes higher (0.5 to 6.0 ppm, wet weight) (Burger and Gochfeld 1997: 163).

All samples collected from Brownsberg and the Paramaribo Zoo detected measureable mercury, as it is present in all living organisms at various trophic levels (Fisher 2003; Goldwater 1972; Hylander and Meili 2003; IOMC 2002; Morel et al. 1998; NRC 2000; Rasmussen et al. 2005; Renzoni et al. 1998; Risher 2003; US-EPA 1984). However, most of the mercury test results show levels at or below the body burden level of 0.05 ppm for individuals indicating that the animals were unlikely to be stressed excreting the mercury.

**Ateles samples from Brownsberg:** I hypothesized that individuals inhabiting areas that could be affected by mercury aromatization (on the slope above mining areas) would have a higher incidence of mercury exposure either through the atmosphere or their diet. I concentrated observations on a community of spider monkeys that were directly above (albeit several hundred meters above) known active mines. Test results of spider monkeys (fecal samples) were almost uniformly recorded as “trace”. There are several possible explanations of this finding. First, feces may not accurately represent the level of mercury in the body or animals that do ingest mercury on their food excrete it in urine or store it as a heavy metal in the brain or liver. Second, the monkeys may be exposed to mercury, but the concentrations were too low at the time of data collection to be found in feces. Third, mercury, if it is in the atmosphere does not adhere to the fruit. Fourth, leaf eaters might be more heavily affected than monkeys that eat interior portions of fruit. Fifth, the action of mercury in the atmosphere is localized and does not move easily.

**Pithecia samples from Brownsberg:** The only urine sample from a white-faced saki individual that ranged close to the plateau (WK 0.0) had the highest value recorded (0.1 ppm) (Fig. 3.15). This single urine sample may be closer than feces to the ideal medium for indirect
testing. As is the case with humans, individual variation among non-human primates does exist in terms of mercury exposure and intake. Since, I was unable to sample more individuals from that same species I cannot definitively state that the 0.1 ppm count from that individual is alarming. If numerous samples from that species were to show counts in that range then there would be an issue indeed. As is, there are too few samples to evaluate the white-faced saki relative exposure, but on the basis of their location on the top or near the top of the plateau, c. 500 meters from the mines, it suggests that spider monkeys who range closer to the mines may not encounter higher doses.

Monkeys at the Paramaribo Zoo: Results from the Paramaribo Zoo individuals were as I expected, at or below 0.05 ppm, with the exception of one individual red howling monkey from the Paramaribo Zoo. This individual had a 0.1 ppm count of mercury in its feces. Since these individuals were either caught in the wild (from previous owners) or raised in captivity, they are exposed to mercury present in drinking water and food. The high mercury count from the one individual could have several causes: where it originally came from before the zoo and whether or not it already had significant mercury exposure.

Monkeys at Hiram College: The mercury test results from the Hiram College monkeys showed zero levels of mercury. However, it is quite possible that the home testing kit was not able to indicate minute traces of mercury. These individuals live in a controlled environment with regards to food and water, in addition to being born in captivity.

My primary objective in creating a non-invasive method for testing mercury in non-human wild primates was achieved. The coloration of the fecal samples was in accordance with what one might expect if urine were tested (which is what the kit was meant for). Thus, this adjusted mercury test for fecal material can be regarded as reliable. Additionally, this method is
non-invasive as fecal and urine sample were collected. For collecting baseline data on mercury levels in wild monkeys this method is efficient and reliable.

The drawbacks to this method can be found in the difficulty to obtain fresh fecal and/or urine samples from wild monkeys and the possible variability in excretion. I was not able to develop a reliable method in collecting these samples, especially for urine. Tissue or blood samples are more difficult to collect, but may be more sensitive to mercury testing. Ideally, multiple samples per individual could answer questions about variability of excretion, variation among species with different diets, and proximity to the mines.

Overall, my results indicate no alarming levels of mercury exposure in wild monkeys at the Brownsberg Nature Park at the time the samples were collected. If there were any significant recent exposure then it would most certainly be detected by the testing kits. Exposure in previous years would have been excreted naturally. Significant and prolonged exposure to mercury should be evident, but my results show otherwise.

It is beyond the scope of this paper to discuss whether or not these wild monkeys are able to obtain methylmercury through their diet. More elaborate tests would need to be conducted on leaf and fruit samples. I hypothesized that this would be one way wild monkeys, especially frugivores, be exposed to methylmercury. Additional exposure could be through the air. As previously stated, mercury vapor can travel with the wind for several kilometers within a day. This means of course that wild monkeys do not necessarily have to be present in the area of gold mines to be exposed to mercury vapor. A future research project would encompass detailed analyses of soil, air, fruit and leaf tissue samples. Additionally, one would need to collect either hair or blood samples from the wild monkeys.
Interpretation of independent t-test: the first test between the BNP and the Zoo individuals shows no significant difference. This indicates that the mercury levels found in the BNP individuals is comparable to those of the Zoo monkeys. The second t-test between BNP individuals and Hiram College monkeys (captive born) is highly significant. Compared to monkeys that have very minute levels of mercury in their system, the monkeys of BNP have “higher” than normal levels.
LIST OF REFERENCES


Chapman CA. 1990. Association patterns of spider monkeys: the influence of social organization
Behav Ecol Sociobiol 26:409-414.


American Journal of Primatology 45:127-141.

Forest Community Structure. In: Bearder SK, Campbell CJ, Fuentes A, MacKinnon KC,
and Panger M, editors. Primates in Perspective. Oxford: Oxford University Press. p 510-
525.


Determination of Inorganic Mercury Distribution in the Cortex of the Calcarine Sulcus of
the Monkey Macaca fascicularis Following Long-Term Subclinical Exposure to

Increases in the number of reactive glia in the visual cortex of Macaca fascicularis
following subclinical long-term methyl mercury exposure. Toxicol Appl Pharmacol
129(2):196-206.


Bureau of Public Affairs.


Lambert JE. 1999. Seed Handling in Chimpanzees (Pan troglodytes) and Redtail Monkeys (Cercopithecus ascanius): Implications for Understanding Hominoid and Cercopithecine


