Conservation assessment of Taï monkey fauna from two survey methods and a bushmeat market study: How hunting impacts Taï National Park

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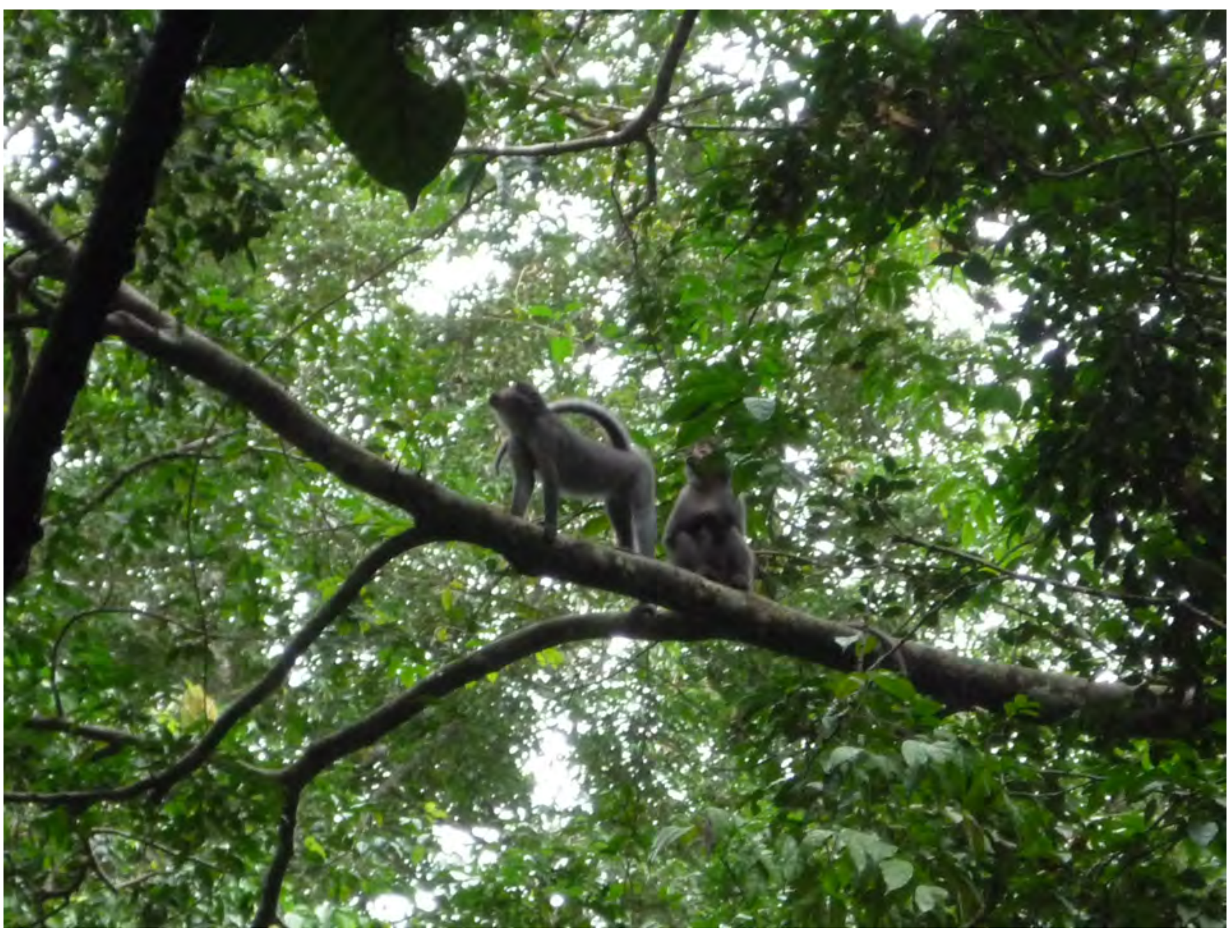

Abstract

Before any informed recommendations for conservation of primate fauna can be made, baseline abundance information is needed. This project uses two survey methods to determine primate densities and distribution adjacent to a protected research area. In addition, I assess the most significant threats facing these primates, and analyze the impact of a local bushmeat market.

Line-transect distance sampling was used to determine group density of eight monkey species living near the research station of the Taï Monkey Project in Côte d'Ivoire's Taï National Park. This method was employed within the main study area which consists of a 2 x 1 sq km grid system. Within this protected grid I walked twenty 500 m transects four times each. In order to obtain comparative data, I walked six 3 km transects three times each outside the research grid. I used occupancy modelling to determine presence/absence of monkey species in the research grid and assess the method's ability in accurately detecting primate presence for future surveys.

My results show that *Cercopithecus diana* (5.84 groups/km^2) and *Procolobus badius* (6.02 groups/km^2) had the highest group density estimates determined from line-transect sampling in the research grid. Outside the protected area, monkeys were detected less frequently and occurred at significantly lower group densities (i.e. *Cercopithecus diana* – 3.4 groups/km^2; *Procolobus badius* – 2.75 groups/km^2). Occupancy modelling accurately reflected the ability to detect species given their ranging and vocal behaviours. The bushmeat survey reveals a high weekly average of monkeys (33) hunted in Liberia, the only large block of forests for primates in Taï National Park to migrate.

I conclude that the decrease in primate density outside the protected area, bushmeat survey results, and observed hunting actions support previous studies' conclusions of primates under extreme poaching pressure and for immediate protection to ensure survival of a diverse primate community.

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1. Introduction

1.1 Use of Surveys

Primates of West Africa, particularly in Côte d'Ivoire, are at risk of being hunted to extinction. Past studies show threats from hunting and forest fragmentation are driving primate populations towards endangered status if they are not already endangered and/or possible extinction (Parren & DeGraaf, 1995; Chatelain *et al.*¸ 1996; McGraw, 1998b; Bowen-Jones & Pendry, 1999; Oates, 1999; Oates *et al.*, 2000; Barnes, 2002; Magnuson, 2002; Herbinger *et al*., 2003; McGraw, 2005; Refisch & Koné, 2005a; Sanderson *et al.*, 2005; Sery *et al.,* 2006; Koné & Refisch, 2007; UNEP, 2007; Campbell *et al.*, 2008). Hunting is illegal in Côte d'Ivoire. Taï National Park is protected by the national park service, yet illegal hunting remains rampant (Refisch & Koné, 2005a; Refisch & Koné, 2005b; UNEP, 2007). In addition to illegal hunting, Taï National Park is affected by other factors which can impact primate populations. Deforestation remains an issue as well as over extended use of a buffer zone surrounding the park; gold panning affects the watersheds of the Hana and Little Hana rivers near the central region of the park; and Ebola and anthrax have affected chimpanzee populations (Formenty, *et al*., 1999; Leendertz, *et al*., 2004; UNEP, 2007). An effective way to measure the impact of various threats to unprotected primate populations is through the use of surveys, particularly if you are able to compare those results to known primate densities within a protected area.

Survey methods for determining primate population densities are numerous and have been used for a variety of reasons. Studies have been conducted to evaluate multiple methods (Whitesides *et al*., 1988; Fashing & Cords, 2000; Marshall *et al*., 2008);

determine distributions of endangered primates (Magnuson, 2002; Campbell *et al*., 2008); locate primates faced with the threat of extinction (McGraw, 1998b; Oates *et al*., 2000); analyze the relationship between primate densities and commercial hunting (Walsh *et al*., 2003; Refisch & Koné, 2005a); and examine densities of primate communities (Fashing & Cords, 2000; González-Solís *et al*., 2002). In determining primate densities and distributions, a wide array of techniques can be used, each with their own benefits and limitations (National Research Council, 1981; Buckland *et al*., 2001; Marshall *et al*., 2008).

For my study I have chosen to use two survey techniques: line-transect distance sampling and occupancy modelling. Occupancy modelling has seldom been used to survey primates and its ability in accurately estimating population density is unclear. This method is primarily used to establish presence of an animal or object over a geographic area. Based on whether sites are occupied by the focal species, management and/or conservation practices can take place (Robbins *et al*., 1989; Cabeza *et al*., 2004; MacKenzie, *et al*., 2006). Occupancy modelling has been used to determine presence of a number of animal species including birds (Robbins *et al*., 1989; Dorazio & Royle, 2005), amphibians (Bradford *et al*., 2003; Bailey *et al*., 2004), and plants (Fertig & Reiners, 2002). Line transect surveys are the most common method employed for censusing primates and can provide accurate assessments of primate populations (Peres, 1999; Fashing & Cords, 2000; González-Solís *et al*., 2002; Refisch & Koné, 2005a; Campbell *et al*., 2008; Marshall *et al*., 2008). Line transects will be used to determine diurnal primate densities within a protected research area and the surrounding unprotected areas. The results from occupancy modelling, employed only within the protected research area, will be compared with those densities and contact rates to determine whether its establishment of presence for each species is accurate.

1.2 Bushmeat Dilemma

The bushmeat crisis occurring presently in Africa is alarming, particularly in West Africa. Many reports have discussed the trade in bushmeat and the consequences it has in endangering primate communities (Anadu *et al*., 1988; Bowen-Jones & Pendry, 1999; Oates, 1999; Caspary *et al*., 2001; Barnes, 2002; Fa *et al*., 2002; Peterson, 2003; Refisch & Koné, 2005a, 2005b). Bushmeat hunting throughout Central and West Africa is primarily for cash and not for protein to ensure survival (Bowen-Jones & Pendry, 1999). Previous studies have analyzed the impact bushmeat markets and hunting have on primate populations around Taï National Park (Caspary *et al*., 2001; Refisch and Koné, 2005a, 2005b). In addition to primate surveys within the park, I will examine a local bushmeat market and its impact on the local primate community.

1.3 Taï Primate Community

Taï National Park contains a diverse array of primate fauna. Twelve species of primates are found in the park: three nocturnal species (*Galagoides thomasi*, *Galagoides demidoff*, *Perodicticus potto potto*); three colobine monkeys (*Procolobus badius badius*, *Procolobus verus*, *Colobus polykomos polykomos*); four guenon monkeys (*Cercopithecus diana diana*, *Cercopithecus campbelli campbelli*, *Cercopithecus petaurista buettikoferi*, *Cercopithecus nictitans stampflii*); one mangabey monkey (*Cercocebus atys atys*); and one ape (*Pan troglodytes verus*). Table I presents the current IUCN status of each species.

Table I. Status of Taï Primates (IUCN, 2008)

Species	*Status*
Galagoides thomasi	Least concern
Galagoides demidoff	Least concern
Perodicticus potto	Least concern
Procolobus badius badius	Endangered
Procolobus verus	Near threatened
Colobus polykomos polykomos	Vulnerable
Cercopithecus diana diana	Vulnerable
Cercopithecus campbelli campbelli	Least concern
Cercopithecus petaurista buettikoferi	Least concern
Cercopithecus nictitans stampflii	Least concern
Cercocebus atys atys	Near threatened
Pan troglodytes verus	Endangered

As Table I indicates, a number of species require immediate conservation protection. In addition to the threatened and endangered primates of Taï, in eastern parts of Côte d'Ivoire subspecies of primates found in Taï (*Cercopithecus diana*, *Procolobus badius*, *Cercocebus atys*) are endangered and facing extinction (McGraw, 1998b; Oates *et al*., 2000). Nocturnal primates found at Taï are currently not under threats from hunting or deforestation and *Pan troglodytes verus* has been the focus of two recent surveys (Campbell *et al*., 2008; Campbell, in prep), therefore my study focuses on the diurnal monkeys found in Taï National Park.

1.3.1 Sooty mangabey, *Cercocebus atys atys*

Sooty mangabeys are large, predominantly terrestrial monkeys found in multi-male, multi-female groups (McGraw & Zuberbühler, 2007). Groups of mangabeys at Taï consist of up to 100 individuals (McGraw & Zuberbühler, 2007), with males an average of 11 kg and females 6.2 kg (Oates *et al*., 1990). Primarily foraging through leaf litter on the forest floor, sooty mangabeys are able to process food items too hard for other fruit eating monkeys to consume (McGraw & Zuberbühler, 2007). Other monkey species are known to associate with sooty mangabeys for their ability in detecting ground predators and will display behavioural patterns not commonly seen in the absence of mangabeys (McGraw & Bshary, 2002). Sooty mangabey vocalizations have been described in detail by Range and Fischer (2004) and include a number of twitters, grunts, and whoop calls. Contact calls can be heard from distances over 500 m (personal observation).

1.3.2 Campbell's monkey, *Cercopithecus campbelli campbelli*

Campbell's monkey is a cryptic, olive-grey coloured monkey capable of utilizing a wide array of habitat types from primary forest to highly disturbed areas (Oates, 1988; McGraw, 1998b; McGraw & Zuberbühler, 2007). Within these habitats they prefer to forage and travel below the main canopy and often come to the ground (McGraw & Zuberbühler, 2007). Frequently associated with other guenon species and particularly with *Cercopithecus petaurista*, Campbell's monkeys live in groups with approximately 11 individuals (McGraw & Zuberbühler, 2007). Males have mean body weights of 4.5 kg while females are much smaller with a mean body weight of 2.7 kg (Oates *et al*., 1990). While most contact calls between Campbell's monkeys are soft and hard to detect from far distances, males make loud boom calls followed by hacks while male lesser spot-nosed monkeys often reply with their loud calls (McGraw & Zuberbühler, 2007).

1.3.3 Diana monkey, *Cercopithecus diana diana*

Diana monkeys are loud, active primates with black coats and white chests (McGraw & Zuberbühler, 2007). Found in groups of up to 20 individuals (Hill, 1994; Zuberbühler & Jenny, 2002), males have mean body weights of 5.2 kg and females mean body weight is 3.9 kg (Oates *et al*., 1990). Diana monkeys rely on high, primary forest (Oates, 1988) while maintaining a diet consisting predominantly of fruits and insects (Oates & Whitesides, 1990). Frequently found in polyspecific associations wherever they inhabit, monkey species prefer to associate with Diana monkeys for their vigilant behaviour in detecting predators such as leopards and chimpanzees (Oates & Whitesides, 1990; Hill, 1994; Bshary & Noë, 1997b; Noë & Bshary, 1997; Zuberbühler *et al*., 1997). In addition to numerous predator specific vocalizations, Diana monkeys have a variety of contact calls and males produce a loud call that carries over great distances (Hill, 1994; Zuberbühler *et al*., 1997; Zuberbühler, 2007).

1.3.4 Stampfli's putty-nosed monkey, *Cercopithecus nictitans stampflii*

Characterized by dark olive fur and a bright white nose, Stampfli's putty-nosed monkeys are large, cryptic, arboreal monkeys found at low densities across Côte d'Ivoire and Liberia (McGraw & Zuberbühler, 2007). Putty-nosed monkey males mean body weight is 6.4 kg and mean body weight for females is 4.1 kg (Rowe, 1996). Found in groups consisting of approximately 11 individuals (Zuberbühler & Jenny, 2002), resource competition with Diana monkeys has effectively displaced putty-nosed monkeys throughout much of their range and yet they still are often found in association with Diana monkeys as a likely adaptation to predator defence (Eckardt & Zuberbühler, 2004; McGraw & Zuberbühler, 2007). Putty-nosed monkeys, particularly males, produce a variety of loud contact and alarm calls (Eckardt & Zuberbühler, 2004).

1.3.5 Western lesser spot-nosed monkey, *Cercopithecus petaurista buettikoferi*

Lesser spot-nosed monkeys are found in various habitats and are able to thrive in degraded habitat (McGraw, 1998b; Oates *et al*, 2000). This fact along with their cryptic behaviour, small body size, and agouti-brown coat make them one of the most common monkeys in West Africa (McGraw, 1998b; Oates *et al*., 2000; McGraw & Zuberbühler, 2007). Average group size for lesser spot-nosed monkeys is 18 individuals (Zuberbühler & Jenny, 2002). Males have mean body weights of 4.4 kg with females' mean body weight being 2.9 kg (Oates *et al*., 1990). Relying on a diet consisting predominantly of fruit and insects (McGraw & Zuberbühler, 2007), they frequently associate with other cercopithecid monkeys. Males produce contact calls consisting of a loud hack followed by a low growling noise (personal observation).

1.3.6 King colobus, *Colobus polykomos polykomos*

King colobus are large, black, arboreal monkeys with a long white tail (McGraw & Zuberbühler, 2007). Males have a mean body weight of 9.9 kg and mean body weight for females is 8.3 kg (Oates *et al*., 1990). Average King colobus group size is 15 individuals although they may have up to 19 individuals in a group (Korstjens, 2001; Zuberbühler & Jenny, 2002). Although found in polyspecific associations at times, they tend to avoid associating with overlapping species (McGraw & Zuberbühler, 2007). A very cryptic species, males produce roaring loud calls heard over distances of 1 km (Walek, 1978; McGraw & Zuberbühler, 2007). Relying on a diet of liana leaves, fruit, and seeds (Dasilva, 1994; Daegling & McGraw, 2001), King colobus monkeys are found in all layers of the canopy and survive well in secondary forest (Struhsaker, 1997; McGraw & Zuberbühler, 2007).

1.3.7 Western red colobus, *Procolobus badius badius*

Western red colobus are loud monkeys found in large groups of up to 90 individuals, though average group size is 53 (Zuberbühler & Jenny, 2002; McGraw & Zuberbühler, 2007). Males have a mean body weight of 8.3 kg and mean female body weight is 8.2 kg (Oates *et al*., 1990). Red colobus primarily feed on leaves, fruit, and flowers (Korstjens, 2001) and prefer foraging and travelling in the main canopy (McGraw, 1996; McGraw, 1998a). Western red colobus are a preferred prey item for chimpanzees (Boesch & Boesch, 1989), and is one of the reasons they are frequently found in polyspecific associations at Taï (Bshary & Noë, 1997a; Bshary & Noë, 1997b; Höner, *et al*., 1997). Western red colobus vocalizations have not been well studied, but contact calls can be heard over distances of 800 m (personal observation).

1.3.8 Olive colobus, *Procolobus verus*

Olive colobus monkeys are extremely cryptic, small, and have greenish olive coats (McGraw & Zuberbühler, 2007). Olive colobus are found in groups of approximately 7 individuals (Korstjens & Noë, 2004) and are the smallest colobines, males have mean body weights of 4.7 kg and females have mean body weights of 4.2 kg (Oates *et al*., 1990). Relying on a diet of young leaves, seeds, and mature plant stalks (Oates & Whitesides, 1990; Korstjens, 2001), they prefer the understory of the forest and are often found in dense vegetation (McGraw, 1996; McGraw, 1998a). Although males produce loud calls (Oates & Whitesides, 1990), olive colobus vocalizations are infrequent and soft when compared with other colobines (Bene & Zuberbühler, 2009). Olive colobus rely on their cryptic behaviour and near permanent association with Diana monkeys for anti-predation benefits (Oates & Whitesides, 1990; Korstjens, 2001; McGraw & Zuberbühler, 2007).

2. Methods

2.1 Study Site

Primate surveys were conducted at the Taï Monkey Project located in Taï National Park, Côte d'Ivoire. Taï National Park is located in the Upper Guinea Forest, and represents the last substantial block of intact rainforest in West Africa (McGraw & Zuberbühler, 2007). Taï National Park covers 330,000 ha with an additional 20,000 ha buffer zone, and is located in the southwest corner of Côte d'Ivoire near Liberia at 6° 20' N to 5° 10' N and 4° 20' W to 6° 50' W (McGraw, 1996). The park was originally a forest reserve in 1927, before obtaining National Park status in 1972. The park was later identified as a Biosphere Reserve by UNESCO in 1978 before joining the UNESCO World Heritage List in 1982. Taï National Park belongs to the West African biodiversity hotspots as defined by Myers *et al.* (2000).

Taï National Park contains 1,300 species of higher plants, 150 of which are endemic, and close to 1,000 vertebrate species (McGraw & Zuberbühler, 2007). The rainy season occurs between June and September and the dry season from December to

February, with average rainfall in the north of the park at 1,700 mm and 2,200 mm in the south (McGraw & Zuberbühler, 2007). The average temperature is 24° C with relative humidity between 85 and 90 per cent (McGraw & Zuberbühler, 2007).

The Taï Monkey Project began in 1989, founded by Ronald Noë and Bettie Sluijter of the University of Zurich. The field site possesses a high density of primates within a 1 km^2 core study area, now approximately 2 km^2, and located in moist, evergreen rainforest (McGraw, 1996). Prior to the Taï Monkey Project's inception, Christopher Boesch had already developed a long-term study site in Taï National Park on *Pan troglodytes verus,* the West-African chimpanzee. Studies from both sites have allowed an entire primate community to be examined. Figure 1 shows the approximate location of the Taï Monkey Project in Taï National Park. Additional information on the study site and Taï National Park can be found in McGraw and Zuberbühler (2007).

2.2 Primate Population Estimates

Primate densities in my project were measured using two methods: line-transect distance sampling and occupancy modelling. The purpose of using two methods was to test the effectiveness of occupancy modelling in determining densities of primates. Occupancy modelling is a relatively new approach to conducting census work, when compared with the often used method of line-transect sampling. Both methods were employed within the research grid of the Taï Monkey Project, but only line-transect distance sampling was used outside the grid. Time constraints prevented me from deploying both methods outside the research grid. Figure 2 is a map of the Taï Monkey

Figure 1: Location of Taï Monkey Project in Taï National Park. (University of Texas Libraries, 2009)

Taï Monkey Project

Project research area. The area outlined in red displays the location of the protected research area and location of transects and occupancy points.

Population numbers of each monkey species located in the research grid are well known from daily observations by four assistants and twenty years of field work at the Taï Monkey Project. Excluding *Cercocebus atys* and *Cercopithecus nictitans,* the other six monkey species have 5-6 groups that frequently range in the Taï Monkey Project's research grid. *Cercopithecus nictitans* is not found in the grid and only two groups of *Cercocebus atys* are found in the grid on a regular basis, with two additional groups found near the western and northern edge of the grid. See Table II for population figures. Having known population data is advantageous as I am able to compare my results to current figures, which will make comparisons of my tested methods more rigorous. However, monkey population densities are not well known outside the research grid. Lacking population figures for this area prevents comparison against known figures, and only allows for comparison between results of the research grid and non-grid surveys. Comparison of data between research grid transects and non-grid transects should indicate whether a significant drop-off in monkey density occurs outside the protected research grid. *Pan troglodytes verus* during the course of my study ranged predominately south of where I was surveying. This offered little chance of detecting them during my census work, and only when they shifted their range back north because of hunting pressures was I able to detect them with either survey method. Since I have little data on *Pan troglodytes verus*, they will be excluded from the analysis in this study. Campbell *et al*. (2008) have estimated densities for *Pan troglodytes verus* in Taï National Park, and Campbell (in prep) recently surveyed a large area surrounding and including both Taï Monkey Project and Taï Chimpanzee Project research grids, which should provide current population figures for *Pan troglodytes verus* and the eight monkey species over a much larger sampling area.

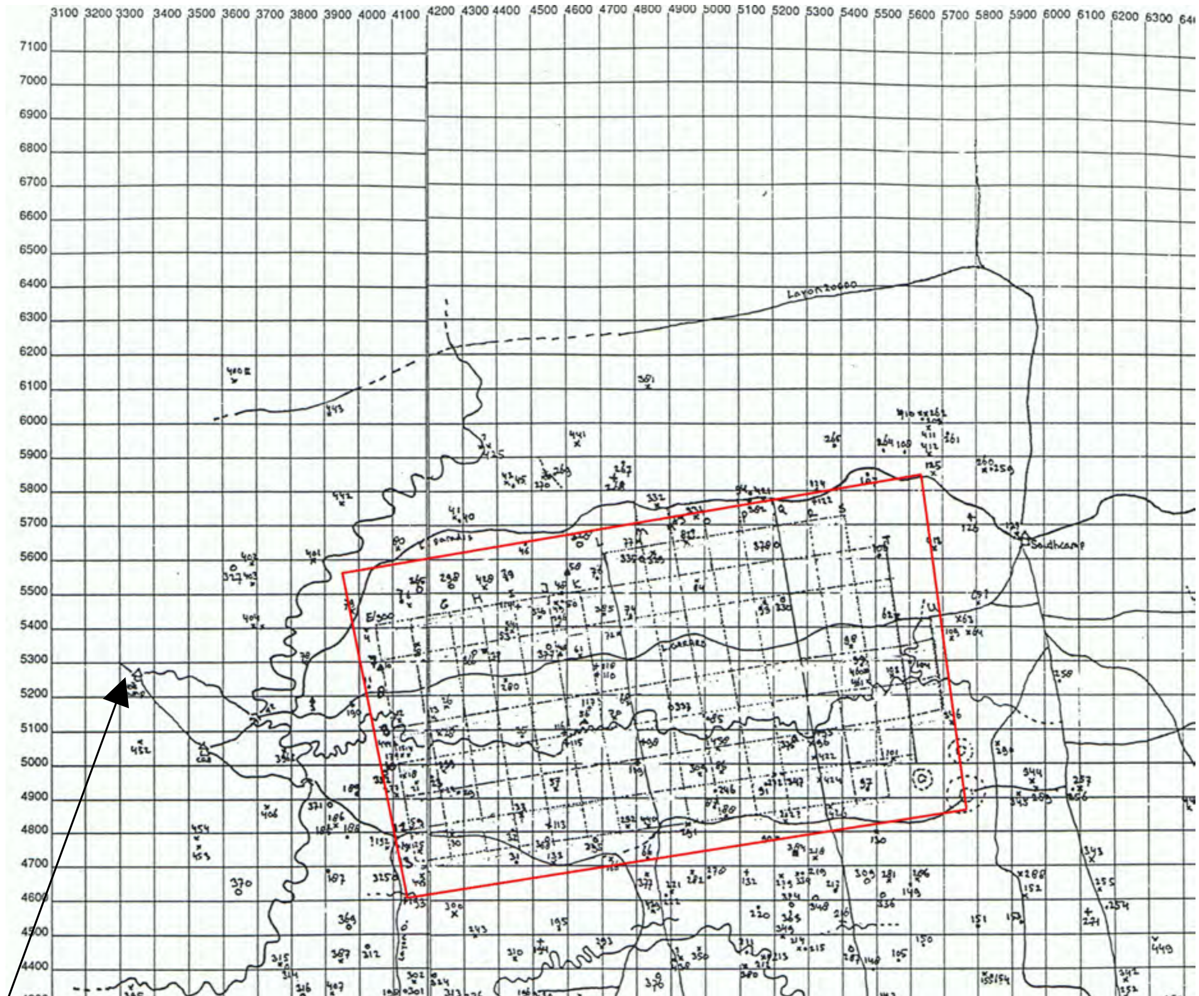

Figure 2: Location of Taï Monkey Project research grid and primary survey area for my study

Taï Monkey Project field camp

Table II. Average Group Size, Density, and Home Range of Taï Monkey Project Research Species

Species	*Group Size*[a]	*Density (ind/km²)*[a]	*Home Range (ind/km²)**
Cercocebus atys	69.7	11.9	4.92
Cercopithecus campbelli	10.8	24.4	0.60
Cercopithecus diana	20.2	48.2	0.63
Cercopithecus nictitans	10.5	2.1	0.96
Cercopithecus petaurista	17.5	29.3	0.69
Colobus polykomos	15.4	35.5	0.78
Procolobus badius	52.9	123.8	0.58
Procolobus verus	6.7	17.3	0.56

[a]Data compiled by Zuberbühler and Jenny (2002)
*Data from McGraw and Zuberbühler (2007)

2.2.1 Line-transect Distance Sampling

Within the research grid of the Taï Monkey Project, I surveyed twenty 500 m transects, walking each transect four times over the course of 42 days. The research grid was divided into two 2000 x 500 m sections, with transects running north to south. Separated by a distance of 200 m, transects ran parallel to each other with the end point of the northern transects 100 m east from the beginning point of the southern transects. Transects were walked between 0700 and 1700 hours at a speed of 1 km/h. Repeat observations of the same individual or group were avoided by surveying transects at least 500 m apart. All transects were walked twice in the morning and twice in the afternoon in order to account for possible differences in behaviour and detection abilities. Each transect was walked twice from both ends. Transects were sampled every other day within the research grid until all had been surveyed four times. Occupancy modelling points were visited on days where I did not conduct transect surveys, so no method was used on two consecutive days.

I sampled six transects outside of the protected research grid. These transects were each 3 km in length and I walked each transect three times. Placed at least 500 m from the research grid edge, transects were placed in pairs separated by a distance of 1 km. One pair was placed north of the research grid, one pair east, and one pair south. Transects north and south of the research grid were walked in a N-S compass direction, and the two transects east of the grid were surveyed E-W. Due to time constraints I could not sample all six transects four times where I could walk each transect twice in the morning and afternoon, however there appeared to be no significant difference in detection abilities between morning and afternoon surveys.

Prior to each walk, specific data were recorded: date; transect identity; and identity of observers. The starting and ending time of each transect walked was recorded as well. When detection occurred during surveys, I recorded: time; species detected; number of individuals; distance from observer to first individual observed; distance from observer to tree; perpendicular distance of tree to transect; type of detection made (audio or visual); direction from observer when detected; GPS location; and location of observer on a transect when detections occur.

There are certain assumptions observers are intended not to violate as discussed in Burnham *et al.* (1980):

1) Monkeys directly on transects were never missed.

2) Monkeys were fixed at the initial sighting position and none were counted twice.

3) Distances and angles are measured exactly in order to avoid measurement rounding errors.

4) Sightings are independent events.

Following Peres (1999) I did not leave transects except to make further observations possible and I did not remain with individuals or groups for more than 10 minutes. Although all primates within viewing distance of transects are hopefully detected, it is understood that all animals in a sample area will not be detected and the further an animal is from a transect, the less likely it will be detected (National Research Council, 1981).

Primate densities and transect strip width were calculated using three methods described by the National Research Council (1981): maximum distance, maximum reliable sighting distance, and maximum perpendicular distance. The maximum distance method uses the maximum distance from observer to individual sighted during the census. Maximum reliable sighting distance determines a cut-off distance within which all animals were likely to be observed. The maximum perpendicular distance method estimates group densities' using the greatest perpendicular distance. This distance is measured by determining where on a transect a 90˚ angle would occur to the individual observed, and then measuring the distance from the transect to the tree. This method assumes all groups detected will be within this distance (National Research Council, 1981). Both sides of the transect are covered by doubling the maximum distance, then multiplied by total transect length to give the area surveyed. The following equation is used to determine primate densities for all three methods (National Research Council, 1981):

$$D = n / 2Lw$$

D is the calculated group density, n equals the number of groups sighted of any particular species, L is the total length of all transects sampled, and w is the width determined by the three methods. Table III provides distances used for calculating species density for Taï monkey species within the research grid. Table IV presents distances for monkey species outside the grid where enough detections occurred to make estimates about group density. For certain species within the research grid, I used the same distance to calculate maximum distance and maximum reliable sighting distance because of few detections and the close maximum observed distance. This is also the case for *Colobus polykomos* in my surveys outside the research grid.

Table III. Distances Used for Calculating Density Estimates Within the Research Grid

Species	*Maximum Distance (m)*	*Maximum Reliable Sighting Distance (m)*	**Maximum Perpendicular Distance (m)**
Cercocebus atys	28	28	**23.2**
Cercopithecus campbelli	50	44	**32.8**
Cercopithecus diana	64	58	**60**
Cercopithecus petaurista	47	29.8	**29.8**
Colobus polykomos	115	57	**85**
Procolobus verus	36	36	**33**
Procolobus badius	65	57	**47**

Table IV. Distances Used for Calculating Density Estimates Outside of the Research Grid

Species	*Maximum Distance (m)*	*Maximum Reliable Sighting Distance (m)*	**Maximum Perpendicular Distance (m)**
Cercopithecus diana	65	55	**55.1**
Colobus polykomos	36	36	**22.1**
Procolobus badius	90	67	**85**

2.2.2 Occupancy Modelling

The purpose of testing occupancy modelling along with line-transect distance sampling was to determine the effectiveness of occupancy modelling as a measure for determining primate densities. Little data currently exists on the use of occupancy modelling in primate census work, compared with the extent of literature on line-transect sampling use in primate censuses. Occupancy modelling is designed to detect species presence within habitats, presence being determined by the proportion of area or sample units that are occupied (MacKenzie *et al*., 2006). Occupancy points are established where detection may or may not occur, with points generally chosen at random or in a way so results are not biased. Surveys should be conducted so that each survey is independent, where the probability of detecting a species in one survey does not depend on the outcome of another survey (MacKenze *et al*., 2006). To determine patch occupancy rates my data were analyzed using Presence 2.0 software (MacKenzie *et al*., 2006). Habitat type, environmental conditions, and outside forces such as hunting remained constant throughout the survey so only one test was run which assumes the probability of detection remains constant during the study.

For my study, two points were placed off of each transect since I did not have a map of the study site prior to my arrival to determine random points. At 100 m from the beginning of each transect I walked 50 m east and at the end of each transect I walked 50 m west to place my occupancy points. A total of 40 points were sampled four times throughout the research grid. Each point was sampled twice in the morning (0700-1200 hours) and twice in the afternoon (1200-1700 hours). Sampling a larger number of sites and varying the times when sampled improves the precision of occupancy estimates and decrease the amount of heterogeneity in the surveys (MacKenzie *et al*., 2006).

Occupancy points were visited for 10 minutes, after which no further detections were recorded. For each occupancy point I recorded: date; occupancy point identity; identity of observers; and time at occupancy point. When detection occurred during surveys I recorded: time; species detected; number of individuals; distance from observer; type of detection; detection direction from occupancy; and GPS location if visible. At each occupancy point each species was given either a 0 or 1: 0 for no detection or 1 for detection. One group may vocalize frequently over the course of a 10 minute sample, but distinguishing between individuals in the group can be difficult. To eliminate chances of error when recording the number of individuals heard from a group, only when we were certain we heard a different individual did we record that individual.

2.3 Bushmeat Survey

Over the course of nine weeks, I visited a bushmeat market located near the town of Taï. The market is located between Liberia and Côte d'Ivoire at the Cavally river near the village of Daobly, only a few kilometres from Taï (Caspary *et al*., 2001). The purpose of this survey was to determine how much meat is coming to this market on a weekly basis from Liberia. The meat is expected to come from Liberia and is then purchased by Ivorian villagers, with the assumption that given the chance to purchase bushmeat in an open, legal market, hunting pressure on Taï National Park would decrease. The market occurs every Friday with vendors crossing the river in canoes to sell bushmeat to Ivorian villagers.

I visited the market seven times and counted all bushmeat being sold by local Liberians. On our first arrival we explained to various buyers and traders why we were there and that any information obtained would not be used to persecute anyone involved in the market. I went with at least two assistants where we walked around the market counting all animals that were smoked and fresh (not smoked). Every attempt was made to identify smoked carcasses, but at times it was very difficult and species identity was made with a best guess. Only primates were identified by exact species. Other animal species were placed into standard categories such as duiker or porcupine. On each visit, I recorded the date, identity of each carcass, and whether each carcass was smoked or fresh. Bushmeat sold by the Liberians was laid out on mats, bags, or often still in bags when we walked around counting. My assistants asked each trader if we were allowed to look in their bags in order to count and identify carcasses. With permission, my assistants were allowed to open the bags and lift up carcasses for identification purposes. After we identified each carcass, we placed the meat back into their bag. Only once were we denied permission to look in a bag because the individual was leaving for her village and did not want to spend the time to have us count her purchased bushmeat. Our presence at the market was tolerated and we never had problems during our survey. Little to no interaction occurred between me and the vendors, any discourse occurred between my assistants and the vendors.

3. Results

3.1 Line Transect Density Estimates

Results for individuals and groups detected within the research grid and estimated group densities are provided in Table V. *Procolobus badius* is most numerous while *Cercopithecus diana* was most frequently detected. *Procolobus verus* was observed least frequently followed by *Cercopithecus campbelli* and *Cercocebus atys.* Although *Cercocebus* monkeys only had eight observations, their large groups and level of habituation allowed for high individual counts. As stated previously, approximately six groups of each monkey species (excluding *Cercocebus*, 2 groups) routinely range throughout the 2 km^2 research grid. Table V shows group estimates for *Cercocebus atys*, *Cercopithecus diana*, and *Procolobus badius* to be well overestimated by all three density estimation methods. *Procolobus verus* density was slightly underestimated by all three methods. Maximum distance was very close in its estimate of group density for *Cercopithecus petaurista* and maximum perpendicular distance was very accurate for *Cercopithecus campbelli*.

Table V. Observed Individuals and Groups, Estimated Group Densities of the Research Grid

Species	*Total individuals observed*	*Total groups observed*	*Maximum distance (groups/km²)*	*Maximum reliable sighting distance (groups/km²)*	**Maximum perpendicular distance (groups/km²)**
Cercocebus atys	140	8	3.57	3.57	**4.35**
Cercopithecus campbelli	20	8	2	1.99	**3.05**
Cercopithecus diana	180	29	5.66	5.81	**6.04**
Cercopithecus petaurista	27	12	3.19	4.19	**5.03**
Colobus polykomos	24	11	1.20	2.19	**1.62**
Procolobus verus	20	7	2.43	2.43	**2.65**
Procolobus badius	266	27	5.19	5.70	**7.18**

Table VI presents data from transects sampled outside the research grid. *Cercopithecus nictitans* was detected in this area from four of the six transects, however no visual observations were made, only audio detections. As Table VI indicates, few observations occurred of all monkey species except *Cercopithecus diana* and *Procolobus badius*. Although only five groups were observed of *Colobus polykomos*, I chose to estimate its group density because of the close distance used for each method and its group estimates were similar to what was found for *Colobus polykomos* groups in the research grid surveys.

Table VI. Observed Individuals and Groups, Estimated Group Densities Outside the Research Grid

Species	*Total Individuals Detected*[a]	*Individuals Observed**	*Total Groups Observed**	*Maximum distance (groups/km²)*	*Maximum reliable sighting distance (groups/km²)*	*Maximum perpendicular distance (groups/km²)*
Cercocebus atys	28	6	1	-	-	-
Cercopithecus campbelli	19	2	1	-	-	-
Cercopithecus diana	214	106	22	3.13	3.37	3.7
Cercopithecus nictitans	10	0	0	-	-	-
Cercopithecus petaurista	20	10	4	-	-	-
Colobus polykomos	37	17	5	1.29	1.29	2.09
Procolobus verus	7	3	1	-	-	-
Procolobus badius	319	196	24	2.47	3.18	2.61

[a]Includes individuals detected through audio and visual observations
*Includes only visual detections

Table VII presents how often monkeys were in polyspecific associations when detected. Polyspecific associations for research grid transects reflect instances where at least two groups were visually detected. Often other groups were present when one monkey species was observed, however these other groups were not observed so data on polyspecific associations when other species were not visually detected were not recorded. All polyspecific associations observed from non-grid transects were noted because I recorded audio detections along with visual observations. As Table VII indicates, monkeys in the Taï Monkey Project research grid are frequently found in polyspecific associations. Within the research grid, *Cercopithecus campbelli* and *Procolobus verus* were only observed while in polyspecific associations. Results from the non-grid survey, which include visual and audio detections to determine mixed-species grouping, also indicate numerous polyspecific associations amongst eight monkey species. *Cercopithecus nictitans*, even though not detected in the research grid, was frequently detected in polyspecific associations where it ranged. Since detections often occurred through vocalizations it is likely many mixed-species associations went unnoticed if the other species involved in the associations did not vocalize. Only *Procolobus badius* was detected less than 50% of the time in mixed-species groups, however given the previous statement and its frequency of polyspecific associations within the research grid in this study and past studies, these results may underestimate how often they were found in polyspecific associations.

Table VII. Number of Polyspecific Associations

	Grid Surveys		*Non-grid Surveys*	
Species	Polyspecific associations	Groups observed	Polyspecific associations	Groups detected
Cercocebus atys	6	8	5	10
Cercopithecus campbelli	8	8	12	17
Cercopithecus diana	23	29	45	85
Cercopithecus nictitans	0	0	5	7
Cercopithecus petaurista	11	12	10	12
Colobus polykomos	7	11	10	15
Procolobus badius	19	27	33	69
Procolobus verus	7	7	3	5

3.2 Occupancy Modelling Results

Table VIII displays data collected during my occupancy modelling survey. As Table VIII indicates, audio detections are the most frequent method for determining presence of an animal at an occupancy point. A total of 873 animals were detected, an average of 5.5 individuals/point for each of the four surveys. The difference between number of sites occupied and number of detections reflects the amount of repeat detections at occupancy points. Diana (66.25%) and red colobus (77.5%) monkeys were detected most frequently during all four surveys; the monkey species detected most after those species were Campbell's monkey at 18.75% of all occupancy points. The low detection rate of Campbell's monkey and the four other species reflect their cryptic nature or in the case of Sooty mangabeys their large home range.

Table VIII. Species Detection from Occupancy Points

Species	*Number of Sites Occupied*	*Number of Detections*	*Audio Detections*	*Visual Detection s*	*Total Individuals Detected*
Cercocebus atys	14	16	13	3	54
Cercopithecus campbelli	19	30	28	2	37
Cercopithecus diana	38	106	89	17	330
Cercopithecus petaurista	18	25	23	2	32
Colobus polykomos	13	16	10	6	42
Procolobus verus	9	10	7	3	16
Procolobus badius	38	124	111	13	361

Table IX present the presence/absence calculations determined by the Presence program. The naïve estimate reflects the proportion of sites occupied by each animal at least once, a standard calculation of sites occupied/total sites (40). Olive colobus have the lowest naïve estimate because they were detected at the fewest amount of occupancy points. The psi value indicates the proportion of sites occupied by the species surveyed as determined by the Program presence. This value reflects the number and location of detections that occurred. Although *Cercocebus atys* and *Procolobus verus* were not detected frequently, it is still possible to have a high psi value and low probability of detection. As Table IX indicates, *Cercopithecus diana* and *Procolobus badius* have the highest detection probability.

Table IX. Presence Occupancy Model of Taï Monkeys

Species	*Naïve Estimate*	*Psi*[1]	*Se(psi)*[2]	*P**	*Se(p)*[a]
Cercocebus atys	0.35	1.00	0.00	0.09	0.023
Cercopithecus campbelli	0.5	0.79	0.1946	0.22	0.063
Cercopithecus diana	0.95	0.99	0.0396	0.55	0.044
Cercopithecus petaurista	0.45	0.79	0.2354	0.19	0.064
Colobus polykomos	0.33	0.73	0.3364	0.14	0.069
Procolobus verus	0.23	0.89	0.79	0.07	0.065
Procolobus badius	0.95	0.96	0.0353	0.67	0.04

[1]Proportion of sites occupied
[2]Standard error of psi
*Detection probability
[a]Standard error of detection probability

3.3 Bushmeat Survey

Over the course of seven visits to the Cavally bushmeat market, I observed 230 primates obtained from hunting, one of which was a live baby *Cercopithecus petaurista* whose mother was likely sold at the market. Including all animals, there were 634 individuals for sale. Table X provides the breakdown of species observed at the bushmeat market. The overall total does not represent all individuals found at the market over the 7 weeks. In the first two weeks, due to our late arrival, we likely missed animals already purchased. On our way to the second survey we witnessed a truck leaving the market, transporting villagers and their purchased bushmeat. Table XI provides weekly totals of animals from the seven surveys. The last five visits to the market we observed many more animals for sale than we witnessed during the first two visits because we arrived earlier in the day. As Table X indicates, duiker and other forest antelope are the most common species hunted, followed by monkeys. On average 33 primates and 52 forest antelope were seen on a weekly basis. If primates are hunted at this level for an entire year 1,716 primates would be killed each year for just one market. I am certain averages would be higher if we had been present earlier on our first two visits to the market. In addition to the bushmeat seen at this market, during my travels between Abidjan and Taï, I often saw hunters standing by the road holding up bushmeat for sale to passing motorists. I observed one Campbell's monkey and one lesser-spot nosed monkey, as well as rats and porcupines, being sold in this way.

Table X. Bushmeat Survey Results

Species	*Fresh (non-smoked)*	*Smoked*	Total
Cercocebus atys	7	22	29
Cercopithecus campbelli	9	15	24
Cercopithecus diana	13	36	49
Cercopithecus nictitans	1	0	1
Cercopithecus petaurista	22	36	58
Colobus polykomos	10	16	26
Pan troglodytes	1	0	1
Procolobus badius	1	21	22
Procolobus verus	7	11	18
Unidentified monkeys	0	2	2
Duiker/forest antelope	67	299	366
Snake	1	1	2
Forest Pig	0	5	5
Porcupine	9	7	16
Rat	2	0	2
Crocodile	1	1	2
Civet	3	7	10
Mongoose	1	0	1
Total	**155**	**479**	634

Table XI. Weekly Bushmeat Survey Results

Species	*Week 1*	*Week 2*	*Week 3*	*Week 4*	*Week 5*	*Week 6*	*Week 7*
Cercocebus atys	2	4	4	3	7	2	6
Cercopithecus campbelli	2	1	1	3	6	9	2
Cercopithecus diana	0	3	11	4	13	8	10
Cercopithecus nictitans	0	0	0	1	0	0	0
Cercopithecus petaurista	4	5	3	11	14	8	13
Colobus polykomos	0	0	1	11	4	7	3
Pan troglodytes	0	0	0	0	0	1	0
Procolobus badius	1	0	1	3	4	8	5
Procolobus verus	0	3	3	6	0	3	3
Unidentified monkeys	2	0	0	0	0	0	0
Duiker/forest antelope	20	17	51	104	36	63	75
Total	**31**	**33**	**75**	**146**	**84**	**109**	**117**

4. Discussion

4.1 Density Estimates

Primate home ranges are not static and it is difficult to know exactly how many groups of each monkey species venture into the research area. As I stated in my methods, there are approximately 3 groups/km² ranging within the protected research area for all species except for *Cercocebus atys* and *Cercopithecus nictitans* (<1 group/km² and 0 groups respectively). Table V indicates high group overestimates for *Cercopithecus diana*, *Procolobus badius*, and *Cercocebus atys* by all three estimation methods. Maximum perpendicular distance most accurately estimated *Cercopithecus campbelli* (3.05 groups/km²) and *Procolobus verus* (2.65 groups/km², 11.7% underestimate) group densities. Maximum distance was most accurate in determining group density for *Cercopithecus petaurista* (3.19 groups/k m², 6.3% overestimate). *Colobus polykomos* (2.19 groups/ km², 27% underestimate) was most accurately estimated by maximum reliable sighting distance. For group densities to be more accurate and reflect current densities, I suggest transects be walked more than four times to increase the number of detections and determine a suitable maximum reliable sighting distance. The National Research Council (1981) and McGraw's (1994) census of monkeys in Zaire found maximum reliable sighting distance to be the most accurate method in estimating primate densities. Fashing and Cords (2000) found observer distances both overestimated and underestimated group densities of their study animals, and other researchers suggest perpendicular distances should be used when calculating primate densities (Buckland *et al*., 2001; Plumptre & Cox, 2006). My results would indicate maximum distance to be most reliable because it overestimated least, however unless additional transects are sampled I hesitate to conclude this is the best method for determining group density from transect sampling. Although the computer program Distance 5.0 (Buckland *et al*., 2001) is a preferred choice in calculating primate densities (Refisch & Koné, 2005a; Campbell *et al*., 2008) and is very accurate, I lacked the minimum number of group observations (40-60) necessary to obtain reliable density estimates for each species.

Group density estimates between grid and non-grid surveys show dramatic differences (see Tables V and VI). Transects outside of the grid covered an area of 9 km^2, much larger than the 2 km^2 research area, yet detection rates outside the research grid were dramatically lower. In three instances, while walking transects outside the protected research area, I made no visual observations of any monkey species and only a few audio detections. Only *Cercopithecus diana* and *Procolobus badius* were observed frequently both inside and outside the grid. It is difficult to determine the accuracy for group density estimates of *Cercopithecus diana*, *Colobus polykomos*, and *Procolobus badius* by each method because we do not have figures on populations outside the research grid. If the level of overestimation is similar between grid estimates and non-grid estimates, then *Cercopithecus diana* and *Procolobus badius* group densities are overestimated and group densities for these species would be lower than known densities within the research grid. *Colobus polykomos* group density might be misleading when compared between Table V and Table VI. Distances used to determine group density for *Colobus polykomos* in grid surveys are much higher than those for non-grid surveys, lowering group density when calculated. Group density for this species outside of the grid is calculated from only five observations. In order to determine true group density of these monkey species in this particular area, more transects need to be walked. Campbell (in prep) has completed a much broader survey which should provide reliable density estimates for these species and will allow for more accurate comparisons between group densities within a protected research area and those groups found in areas that are prone to hunting.

The monkey species for which group density estimates are not given in Table VI are not absent and do not necessarily occur at an extremely low density. My data suggest they do live in much lower densities based on frequency of visual detections, however level of habituation, threat of hunting, and normal behavioural patterns discussed previously may explain why it was more difficult to observe these particular individuals. *Cercocebus atys*, *Cercopithecus diana*, and *Procolobus badius* are very noisy monkeys occurring in large groups that frequently give contact calls (McGraw & Zuberbühler, 2007; personal observation). Other monkey species routinely associate with these species (Oates & Whitesides, 1990; Höner *et al*., 1997; Korstjens, 2001; Eckardt & Zuberbühler, 2004; Buzzard & Eckardt, 2007; McGraw *et al.*, 2007) particularly the Diana monkeys for their predator detection abilities (Zuberbühler *et al.*, 1997; Zuberbühler & Jenny, 2002), as Table VII indicates. During my surveys within the research grid, Diana monkeys or red colobus were primarily detected first with other monkey species observed next. Monkey groups ranging in the research grid are either fully habituated or semi-habituated, making it relatively easy to observe all species even when they appeared nervous around researchers (personal observation). Outside of the grid it was much more difficult observing these monkeys and counting multiple individuals because of their lack of habituation. The added threat of hunting by humans makes it more difficult for human researchers to get close enough to observe and count monkeys from transects because they associate humans with hunting, so they flee and hide. Cowlishaw and Dunbar (2000) mention how primates might adapt their behaviours to pressure from human hunting in order to avoid risk detection and attack in the same manner they respond to other predators. Even in the research grid, colour patterns and cryptic behaviour of *Cercopithecus campbelli*, *Cercopithecus nictitans*, *Colobus polykomos*, and *Procolobus verus* often make them difficult to observe (McGraw, 2007; McGraw & Zuberbühler, 2007; personal observation). If Diana monkeys and red colobus detect the presence of researchers, they vocalize and flee, alerting associated monkey groups to the observers presence making it even more difficult to observe these habitually more cryptic species. *Cercocebus atys* because of their large group size and constant vocalizations are usually easy to see, but their large home ranges makes detecting non-habituated groups who are fearful of hunters much more difficult to observe. Although primate densities appear much lower outside the grid, missed observations can be explained by the above reasons and only after more in-depth surveys take place can accurate estimates about their group densities be made.

4.2 Primate Presence

The presence of primates estimated by the Presence program is fairly accurate. Unlike line-transect sampling, audio detections are used in addition to visual observations when determining presence of a species. This allows for more detections to be made than are observed through line-transect sampling. When comparing Tables V and VIII, all species but two recorded higher individual detections from occupancy modelling than for line-transect sampling. *Cercocebus atys* occur in very large groups and vocalize often, but it is hard to determine how many different individuals are vocalizing and when habituated groups are detected from a transect it is likely you will observe a large number of individuals. *Procolobus verus* vocalize infrequently (Bene & Zuberbühler, 2009), so a method predominantly relying on vocal detections will generally have less individual detection than a method where entire groups can be observed.

The use of occupancy modelling for determining primate presence relies heavily on audio detections (see Table VIII). For animals with large home ranges, visual detections are unlikely to occur. Instead the ability to detect animals through vocalizations or other cues is necessary. The most vocal monkeys were detected most often through this method. *Cercocebus atys* has a large home range making constant detections more difficult. Psi values for *Cercocebus atys* and *Procolobus verus* (see Table IX) show that primates do not need to be detected frequently for them to be present across a survey area. High psi and low p values can indicate a species that can be common across a landscape, but occurs at low density (MacKenzie *et al*., 2006). Both *Cercocebus atys* and *Procolobus verus* are known to occur at low densities (Zuberbühler and Jenny, 2002). Along with the olive colobus monkeys' infrequent vocalizations, these reasons explain why the probability of detection is very low. MacKenzie and Royle (2005) suggest species with high psi values and low p values should be surveyed more than animals with high psi and high p values such as *Cercopithecus diana* and *Procolobus badius*. The frequency in which Diana and red colobus monkeys were detected suggest that in future occupancy modelling studies, visiting an occupancy point four times would be ideal, whereas the other species, particularly sooty mangabeys and olive colobus monkeys, would need additional surveys in order to achieve accurate assessments of their distribution. Originally I planned to estimate densities through my occupancy modelling results, however the density model provided by the program Presence overestimated species density by thousands of individuals. Further research is needed to accurately model this method so it can be determined if its reliable in estimating densities of primate species.

4.3 Conservation Problems of Taï National Park

Hunting across Taï National Park remains a major conservation problem. Past studies have documented the effects of hunting across Côte d'Ivoire and Taï National Park (McGraw, 1998b; Oates *et al.*, 2000; Magnuson, 2002; McGraw, 2005; Refisch & Koné, 2005a; Sanderson *et al.*, 2005; Sery *et al.,* 2006; Koné & Refisch, 2007; Campbell *et al.*, 2008). Hunting is considered the biggest threat to primates outside of complete habitat loss (Oates, 1996). Many primates are able to survive in secondary forest or disturbed habitats, but cannot survive in areas with high hunting pressures (Oates, 1996). During my three month study I witnessed evidence of hunting around but not within Taï Monkey Project's research grid. When conducting my surveys outside the research grid, I found four shotgun shells and one trail cut by hunters. All five signs of hunting were found south of the research area, with one shotgun shell found 250 m south of the research grid on one of our trails. I did not see or hear signs of hunting north or east of the research grid; however this does not eliminate these areas from hunting pressures. Hunting is known to occur north and east of Taï Monkey Project's research area (Koné & Refisch, 2007; G. Campbell, personal communication). Over the duration of my study students and assistants of the Taï Chimpanzee Project heard gunshots in the northern and eastern territories of their chimpanzee groups.

Although overall levels of hunting around Taï Monkey Project have dropped since researchers began studying there in 1989 (Koné & Refisch, 2007; W. McGraw, personal communication), the area is still targeted by hunters. In addition to what was found during my surveys, gunshots were heard from the grid and research camp. On 13/06/09 two gunshots were heard only 200 m from camp at night and on 24/07/09, beginning at 9:05 pm, around ten gunshots were heard over the course of sixteen minutes, the first shots fired within 300 m of our camp. On July 5th I heard a gunshot within the research grid and over the next ten days gunshots were heard daily south of our research grid by Taï Chimpanzee Project researchers. Prior to my arrival, students and assistants from the Taï Chimpanzee Project heard gunshots within 200 m of their study animals (G. Campbell, personal communication). Ignoring initial protests by the researchers, the hunters continued shooting. Students and assistants eventually pursued the hunters in an attempt to find their village and talk with local authorities about the hunting. While in pursuit, they found a hunters camp with a live fire which had been abandoned because the hunters were being followed. At the camp were two bags of bushmeat containing seven red colobus monkeys, one female Campbell's monkey with an infant, one mongoose, one hedgehog, and two snails. The carcasses were taken from the camp and spread throughout the forest so they could not be recovered. In addition to regular hunting for income, an increase in hunting is noticed around holidays and funerals as people want bushmeat for their celebrations.

Although hunting may have decreased slightly in the surrounding areas of the Taï Monkey Projects and Taï Chimpanzee Project's research areas, it is apparent from the evidence given that hunting is still a major threat to at least nine primate species in Taï National Park. Deforestation does not appear to be a problem within the proximity of the research areas or in the majority of Taï National Park, but over the years local villages have encroached further into the forest through the surrounding buffer zone (UNEP, 2007).

The bushmeat market I observed in addition to other markets located along the Liberian/Côte d'Ivoire border (Refisch & Koné, 2005a), creates many problems for primates in Taï National Park. On a weekly basis I observed endangered and threatened animals for sale to local villagers. These markets not only maintain levels of bushmeat consumption for local villagers, but allow tastes to persist for species that are vulnerable to significant population decline because they do not reproduce fast enough to support commercial hunting exploitation (Refisch & Koné, 2005a). Hunting to supply bushmeat markets is considered the most devastating form of trade in primates, when compared with the pet trade or trade in primates for medical use (King, 1994; Cowlishaw & Dunbar, 2000). Villagers often use the bushmeat to make money in addition to it being a food source. Bushmeat is bought at the market by Liberia and then taken to the market in Taï or other local villages where the meat is sold for profit (personal observation).

The market also places pressure on primates in Liberia. Every week hunters in Liberia know they have markets with regular customers where they can sell their bushmeat for a profit. Previous studies of the West African bushmeat trade have shown that increases in individual income for increases demand for bushmeat in both rural and urban settings (Njiforti, 1996). The more money villagers around Taï and surrounding villages earn, the likeliness hunting could increase in Liberia to match demand for bushmeat. Not included in my market study is the amount of bushmeat taken for personal consumption. In addition to a weekly average of 33 monkeys observed at the market, there are likely many more killed for personal consumption and other monkeys that escape but are mortally wounded and die later. It is difficult to determine whether or by how much hunting would increase in Taï National Park if this market was not allowed to continue.

There is hope to establish and maintain an ecological corridor for forest elephants between Liberia and Côte d'Ivoire (CMS/CITES, 2009), which would also benefit the primates of Taï National Park by providing additional forests for which populations can migrate. Grebo National Forest in Liberia has the same monkey species as Taï National Park and would provide an increase in genetic diversity to all monkey species and chimpanzees if this corridor is established and maintained. However, hunting in both Liberia and Côte d'Ivoire would negate these efforts if they are allowed to continue at this level. Hunting detected around the two primate research field sites, along with hunting reported in other parts of Taï National Park (Refisch & Koné, 2005a; UNEP, 2007), and the number of primate carcasses observed on a weekly basis at the bushmeat market (see Table XI), indicate unsustainable hunting is occurring which will lead to a dramatic decline in primate populations unless serious action is taken immediately. McGraw (2007; W. McGraw, personal communication) predicts an order in which monkey species at Taï National Park would disappear based on five criteria if conservation measures are not enacted and maintained: *Procolobus badius*, *Cercopithecus diana*, *Cercopithecus nictitans*, *Cercocebus atys*, *Colobus polykomos*, *Cercopithecus petaurista*, *Procolobus verus*, and *Cercopithecus campbelli*.

5. Conclusions

Group densities of seven monkey species are higher within a protected research area than those found outside of this area. *Cercopithecus diana* and *Procolous badius* occur at the highest density while *Cercopithecus nictitans* remains absent from the research grid and is found in extremely low densities across its range. To further assess the degree to which the densities differ, additional transects should be walked outside of the research area and transects within the research grid should be walked additional times.

Occupancy modelling can be a reliable method in determining primate distributions. This method appears most effective in sampling monkeys that vocalize frequently, i.e. *Cercopithecus diana* and *Procolobus badius*. Monkey species that are more cryptic and utilize polyspecific associations for safety benefits and those with large home ranges are detected less frequently through this method.

Current protection afforded by the presence of researchers has allowed an entire monkey community to prosper over the past twenty years. However outside of this protected area it is evident that monkey densities are lower. The constant hunting that plagues Côte d'Ivoire has lowered primate densities across the country, pushing some species to the brink of extinction. Hunting in Liberia to supply bushmeat markets for

Côte d'Ivoire, along with local hunting in Taï National Park, threatens to diminish primate populations even further across the Upper Guinea Forest. The dramatic decline of primate populations across Côte d'Ivoire raises the priority with which conservation efforts for Taï National Park need to be initiated and maintained.

6. Recommendations

In order to assess and properly monitor primate population densities of Taï National Park, surveys should be conducted annually throughout the park. The surveys need to encompass all areas of the park to determine how primate densities are distributed across the park and to assess where primates face the greatest pressures from hunting. This would help organize conservation efforts by determining which areas are in most need of conservation work and where additional field sites would be most practical. A combined use of occupancy modelling and transect surveys could prove effective. Occupancy modelling is less time consuming and physically less demanding, and would allow for rapid assessments of primate distributions across the park. This is important particularly in areas where primates occur in low densities and line-transect sampling is impractical (Marshall *et al*., 2008). Where primate densities appear relatively high, line-transect sampling can be carried out to accurately estimate primate populations.

The presence of researchers at the Taï Monkey and Chimpanzee Projects has had a positive effect on monkey populations within the research area by protecting them from hunters. The conservation benefits of long-term research presence have been documented previously (Wrangham & Ross, 2008). Hunting is illegal in Côte d'Ivoire, and if hunters are spotted within the research grid they are reported to authorities. An expansion of the current research grid in addition to establishing other field sites should occur to increase the protected areas of primate fauna. Expansion of the research area and/or the addition of new field sites would require the employment of more assistants. The establishment of a larger research area and additional field sites is a short term goal that can be readily achieved if financially supported by conservation NGO's. Our current assistants support many family members from their work with the Taï Monkey Project. The more people that are positively impacted by the conservation of primates, the greater chance you have at changing attitudes towards monkeys. As McGraw (2007) states, "Ultimately, the future of the Taï primate fauna rests on reducing human pressure on wild resources and changing attitudes about local wildlife from one consisting exclusively of "monkeys as food" to one of monkeys as income for food." This idea can work assuming education projects have worked, more jobs are created, and especially if local park police enforces the laws in place against hunting. In the past, conservation projects based around community input and support have failed for a variety of reasons and millions of dollars have been wasted on projects that often led to more problems, leading many to continue to argue for strict protection of conservation areas even where community support is lacking (Oates, 1995, 1999; Noss, 1997; Hackel, 1999; Brockington, 2004; Hill, 2008). Initiatives to increase conservation efforts, particularly those that affect entire communities, are subject to the varying degrees of instability that plague many developing countries, such as internal conflict or fluctuations in currency, where primate habitats and conservation areas occur (Masozera *et al*., 2006). While I believe the future does rely on the changing of attitudes towards local animal fauna, this is an attitude that may take decades to change. Past studies have shown that relying on this change in attitude and to expect it to happen in a few years is naïve and can do more harm than good.

Education initiatives should be formed and continued for adults and school children. Many people, even in the Western world, do not understand the ecological roles animals fulfil with their environment and thus why it remains important to preserve these species. However, given how much money is donated and the level of support for conservation NGO's, most agree that conserving our world's biodiversity is a worthy cause. The challenge is to teach people these ideas who for hundreds of years have relied on these animals for their food and livelihood. Education projects should be part of a long-term conservation process. One education project is currently being carried out by Club P.A.N. through the Wild Chimpanzee Foundation.

Another short term recommendation is the further protection of six classified forests surrounding the park and two other forests, Haute Dodo and Rapide-Gras, which provide ecological corridors for wildlife (UNEP, 2007). Protecting Taï National Park is urgent but without additional forests for animals to migrate to and from, there is the risk of creating genetically isolated populations. Isolated populations are more susceptible to extinction because they have less genetic flexibility to respond to environmental conditions and are affected by the inbreeding depression where deleterious recessive genes are expressed (Cowlishaw & Dunbar, 2000). The protection of these forests can also lead to corridor establishment and protection between Liberia and Côte d'Ivoire, increasing genetic diversity for all species as well as primates.

The final recommendation is an increase in police patrols of the park. Without an effective police presence, laws in place to protect Taï National Park's wildlife will continue to be ignored (McGraw, 2007). Funding would need to be increased in order to hire more police and provide better training and equipment. During my three month study we had problems getting the police to come to the forest and investigate our poaching issues because of a lack of manpower and transportation. Many authors suggest that the most important short term goal for primate protection is effective law enforcement (Walsh *et al*., 2003; Rowcliffe *et al*., 2004; Struhsaker *et al*., 2005; McGraw, 2007). Once poachers are regularly caught and sentenced for their crimes, we will begin to see the benefits of an increased presence by forest police. Benefits from an increased police presence have been observed in other parks (Leader-Williams *et al*., 1990; Cowlishaw & Dunbar, 2000). The police stationed around Taï and in charge of protecting the park frequently sit around at the local office, do not make patrols or enforce the laws, and do not respond to reported activities of hunting (personal observation). Poachers will continue to hunt if they know the chances of being caught and arrested are slim. The main reason attributed to this problem is a lack of funding. With better vehicles, higher wages, and a larger police force, the forest police can perform their job easier and with more enthusiasm. If the proper management and financial incentives can be put into place, anti-poaching patrols can become very effective in curtailing the current unsustainable levels of hunting occurring in Taï National Park.

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