Chimpanzee conservation in light of impending iron ore mining project in SE Senegal

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Chimpanzee conservation in light of impending iron ore mining project in SE Senegal

by

Kelly Morgan Boyer

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

MASTER OF ARTS

Major: Anthropology

Program of Study Committee:
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Iowa State University
Ames, Iowa
2011

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ABSTRACT

Although metal mining is increasing in Africa, little is known about its effects on endangered ape populations. In Senegal, much of the metal mining is located in the southeastern region, where the effects of mining compound existing conservation problems faced by savanna chimpanzees (*Pan troglodytes verus*). As mining and, subsequently, human populations increase in Senegal, chimpanzee populations will likely be displaced from areas of suitable habitat. To understand the effects of human disturbances on chimpanzee populations prior to mining, as well as chimpanzee habitat use and behaviors, I collected survey data at two study sites that have been identified by mining company ArcelorMittal as iron ore mining sites. The sites, located in the Falémé region, were surveyed for chimpanzee nests, behavioral artifacts, habitat types, and areas of human disturbance using reconnaissance and line transect surveys. A total of 184 nests were recorded in and around the 256 km$^2$ Kharakhena (KR) study site and 243 nests at the 64 km$^2$ Bofeto (BO) site. Human disturbances including villages, cultivated areas, mining activities, and tree cutting by herders, were recorded using GIS. Results show that although chimpanzees around KR appear to avoid nesting within areas of human disturbance, at the BO site nesting frequently occurs within disturbed areas. Chimpanzee behavioral data was collected opportunistically through indirect measures during reconnaissance and transect surveys. Indirect data indicate the chimpanzees of KR termite fish using brush-tipped tools and enter caves, behaviors that are relatively rare for this species. Further efforts are needed to understand the balance between shared land occupation of chimpanzees and human around the BO site, as well as reasons for displacement as mining activities and human populations increase.
CHAPTER 1. INTRODUCTION

As anthropogenic habitat disturbances progress across the planet with increasing intensity, primate populations are declining at an alarming rate (Goossens et al., 2006; Cowlishaw and Dunbar, 2000). West African chimpanzees (*Pan troglodytes verus*) are no exception, with population numbers in drastic decline over the past thirty years, to fewer than 55,000 individuals today (Kormos and Boesch, 2003; Campbell et al., 2008). Already extirpated in Benin, Togo, and Burkina Faso, the West African chimpanzee now faces this same risk in Senegal, Guinea-Bissau, and Ghana, where their numbers linger in the hundreds (Kormos et al., 2003). The present study focuses on chimpanzee communities living in Senegal where impending habitat disturbance, degradation and destruction from a proposed iron mine threaten the country’s remaining ape population and intensify the need for conservation efforts in the region.

The Fongoli Savanna Chimpanzee Project (FSCP) is a long-term study of the ecology and behavior of savanna chimpanzee populations in southeastern Senegal (Pruetz, PI) initiated in 2001 (Pruetz et al., 2002; Pruetz, 2006; Pruetz, 2007; Pruetz & Bertolani 2009). As part of the FSCP, this study specifically addresses imminent conservation concerns affecting previously unstudied chimpanzee communities. The study sites are located within the Falémé region of southeastern Senegal where a large-scale iron ore mining operation will be developed. International steel company ArcelorMittal has signed an agreement with the government of Senegal to begin extraction of iron ore at two sites in this region near the villages of Kharakhena and Bofeto. In order to ultimately understand the impacts of mine construction and exploitation

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1 http://www.arcelormittal.com/
on chimpanzees, this study focuses on determining the existing chimpanzee populations, habitat availability and human disturbances in the region prior to mine construction.

**Project Goals and Objectives**

The purpose of this study is to provide an assessment of chimpanzee communities in the Kharakhena and Bofeto areas prior to anticipated habitat disturbances caused by iron ore mining. The results from this study will be used in future research to determine the effects of the iron ore mine and associated activities on chimpanzee population size, density, distribution, behavior and health. Immediate goals include:

1. Estimating chimpanzee population density using nest counts
2. Establishing resource availability and chimpanzee use of habitat
   i. Determining current and proposed areas of anthropogenic habitat disturbance
   ii. Identifying important resources (i.e., water) and potential corridors for chimpanzees
   iii. Establishing use of each habitat type by chimpanzees via nest surveys
3. Collecting preliminary data to determine presence and prevalence of regionally observed behaviors (i.e., cave use, soaking in pools of water) and putative chimpanzee cultural behaviors (i.e. tool assisted hunting, baobab cracking, termite fishing, and ant dipping) using ethoarchaeological and non-invasive methods
(4) Collaborating with ArcelorMittal to avoid critical areas of chimpanzee habitat and travel corridors during the creation of the iron ore mine and associated activities.

CHAPTER 2. BACKGROUND AND SIGNIFICANCE

The study sites lie in the Zone d’Intérêt Cynégétique (ZIC) of the Falémé region of Senegal along the borders of Mali and Guinea (Figures 1 and 2). This region is located within the Mandingue Plateau, an area home to an estimated 1,500 chimpanzees and listed as a priority area of exceptional importance for West African chimpanzee conservation (Kormos and Boesch, 2003). This region defines the northern geographical range of chimpanzees in West Africa, where the habitat is Sudanian savanna and Guinean woodland and has been characterized as a savanna-woodland mosaic (Pruetz and Bertolani, 2009).

Figure 1. Location of study sites within Senegal: Kharakhena, Kedougou, Senegal 12°54’48.69” N 11°31’05.65” W
Figure 2. Kharakhena site (256km$^2$) and Bofeto site (64km$^2$)

The savanna chimpanzees of Senegal differ from forest chimpanzees in that they have adjusted to the extreme stresses of the dry, hot, open environment. Behaviors previously unseen in other chimpanzee communities such as soaking in pools of water, being active at night and using caves, allow apes here to cope with the intense heat of the dry season (Pruetz & Bertolani 2009). Larger home ranges and subgroup or party sizes allow the chimpanzees of Senegal to efficiently access hypothesized dispersed resources (Pruetz and Bertolani, 2009). Conservation of these chimpanzees is necessary in order to continue to understand how apes adapt to the savanna-mosaic environment, providing important implications for the study of early hominins living under similar ecological pressures (Pruetz and Bertaloni, 2009). As large, dynamic and charismatic species, chimpanzees can also be used to encourage habitat and ecosystem
conservation such that a wider array of biodiversity will benefit (Margules and Sarkar, 2007). Ecologically, chimpanzees in Senegal are beneficial to the germination of *Saba senegalensis* seeds, a plant species that is important both to other wildlife species and humans (Pruetz et al., in prep), and they disperse the seeds of numerous other plant species (Pruetz, 2006). However, as savanna chimpanzee habitat decreases, becomes fragmented or disturbed by human activities, valuable information is lost. Southeastern Senegal, home to approximately 300 chimpanzees (Kormos et al., 2003) and a growing mining industry, is now facing this problem.

ArcelorMittal, the world’s largest steel company, plans to develop an iron ore mine in the Falémé region of southeastern Senegal near the villages of Kharakhena and Bofeto (Figure 3). ArcelorMittal proposes an investment of $2.2 billion US for this mining project, which includes 750km of railway and a port in Bargny-Sendou south of Dakar to transport and export the iron ore (ArcelorMittal Press release, February 2007). Over the course of 25 years the mine is expected to produce 25 billion tons of iron annually, generating 75 billion CFA ($168 million US) per year (WTO, 2009). The project, previously expected to begin production in 2011, was postponed temporarily due to the global economic downturn and subsequent crisis in the steel industry (Reuters and MiningMx, July 2009). Presently, the Bofeto mine of the Falémé mining project is projected to begin construction at the end of 2011 (A. Niang, pers. comm.).
Figure 3. Map of Falémé iron ore deposits (Gineste, 2005) Black areas indicate deposits of iron ore in the form of magnetite. Amounts in megatons (Mt) for each deposit are given in corresponding bubbles. The KR study site is outlined in red to the north, and the BO study site is toward the southern border of the map.
The postponement of the ArcelorMittal Falémé mining project allowed me the unique opportunity to establish systematic data on chimpanzees before a known imminent habitat disturbance. Such opportunities are rare and short-lived. Drilling exploration of iron ore deposits has already begun on all three mountains near the village of Kharakhena as well as on the three Koudekkourou mountains adjacent to the village of Bofeto. With the creation of scientific documentation and support from international non-governmental agencies, my goal is to communicate to ArcelorMittal and local governments the importance of the surrounding habitat to the survival of chimpanzee populations and to work towards both environmentally conscious mining practices and the formation of community forests, such that local communities manage and conserve their local resources. It is not possible to consider the elimination of mining in Senegal, as the industry has the potential to not only better the country’s economy but also to reduce poverty at a local level, if managed appropriately. The most viable strategy now is to understand the effects mining has on chimpanzee populations in Senegal and thus mitigate negative impacts. By working with the local communities, national and local government agencies, private mining industries, and conservation organizations to establish sustainable and environmentally sound practices, we can create a systematic conservation plan for chimpanzee populations and encourage community forest programs.

**Conservation Planning and Community Conservation**

Recent trends indicate that the first step to effective conservation planning is identifying stakeholders and encouraging their involvement (Margules and Sarkar, 2007). Although large foreign investing companies and state departments may dominate the field, studies indicated that local community involvement has a significant effect on the success of conservation initiatives.
Community involvement has been shown to increase local acceptance and success of implemented conservation areas (Ban et al., 2009b; Wadley et al., 2010). Creating trust between the local communities and conservationists is key to effective conservation (Berkes, 2007; Wadley et al., 2010).

Setting aside protected areas as reserves for conservation is a concept and practice that has been around for many years. However, past practices have been biased and at times haphazard. Historically, many of the reserves set aside have been in remote and economically invaluable areas and neglected to protect areas targeted for resource extraction (Margules and Pressey, 2000). These reserves were also heavily managed by the state, removing residents from the land and alienating local rights. Today conservationists are looking to improve the method of allocating land for conservation through the use of systematic conservation planning while incorporating Community Based Natural Resources Management (CBNRM) programs. In order to successfully conserve biodiversity, specifically endangered and threatened species, appropriate planning must focus on management of both areas of production and protection as well as community involvement. One of the most important roles of reserves is to represent the biodiversity of a region while protecting the area and inhabitants from threats. Using the CBNRM approach to reserve creation, these areas would not only serve to protect the habitat, but could also continue to serve the local communities through sustainable land use management. Areas targeted for resource extraction, such as the Mining Zone of Senegal, should not be excluded but rather prioritized for community conservation and reserves.

It is also important to link community level conservation programs to the state and international developmental agencies to achieve success (Berkes, 2007). At the state level,
many developing countries are moving toward decentralized administration and management of natural resources such that control of resources falls in the hands of local communities (Alden Wily, 2003). It is becoming imperative to incorporate the needs and idea of these communities. Senegal has been known for its decentralization policies since the 1970s. However, it was not until the 1993 forestry law was passed that local communities were given the right to participate in forest exploitation. They were further empowered in 1998 to fully manage (and conserve) the forests (Ribot, 1995). The 1998 law gave power to the Rural Councils of Rural Communities to create management plans, allow or deny exploitation of resources and collect revenues from the confiscated items (Ribot et al., 2006). Despite the ratification of the 1998 law, as of 2009 these rights have not actually been given to the local communities. The forestry department continues to decide management plans and to reap all benefits from forests across Senegal (Ribot, 2009). Although unequal balance of power in the region remains, it is necessary to include all parties and advocate the rights of the local communities in the creation of local community forest reserves and conservation networks.

International development and environmental organizations should also be integrated in the process of establishing conservation areas and reserves. Specifically related to mining, international policies have been passed by various different organizations to improve the environmental impact of mining. In 2006, the World Bank International Finance Corporation (IFC) created new policies and performance standards to increase social and environmental sustainability by development organizations. The IFC Standard 6 specifically addresses the need “to protect and conserve biodiversity and to promote the sustainable management and use of natural resources through the adoption of practices that integrate conservation needs and development practices” (IFC, 2006). All projects associated with the IFC must assess the
impacts that their project will have on the biodiversity in the project area, focusing on major threats such as habitat destruction and invasive alien species. As both natural and modified habitats can sustain high levels of biodiversity, this standard is applied to all habitats regardless of whether or not they have previously been disturbed and whether or not they are legally protected. Within a given area, critical habitats must be noted and require particular attention. These areas are defined by their importance to endemic, critically endangered and endangered, migratory and congregatory species, as well as their biodiversity value and significance to local communities. An example of such critical habitats would include areas such as woodland and gallery forests of southeastern Senegal, used as critical nesting habitat for the savanna chimpanzees (Pruetz et. al, 2008).

The Mining Zone of Southeastern Senegal

There are two major geological domains that comprise Senegal: the Sedimentary Basin and the Precambian Basement (Figure 4) (Mining Journal Supplement, 2009). The Sedimentary Basin extends from the Atlantic Ocean across 75% of Senegal to the Mauritanides chains in the southeastern region of the country. It is targeted for phosphates, limestone, and attapulgite (Mining Journal Supplement, 2009). The Precambian Basement extends from the western edge at the Mauritanides chain through the southeastern portion of the country and is of great importance to Senegal as it hosts numerous metal deposits. This geological domain is dominated by Paleoproterozoic volcano-sedimentary sequences, which contain most of the country’s metal deposits. Deposits of copper and chromium are found along the western edge in the Mauritanides range, whereas gold, iron, tin, uranium and nickel are found further east.
Figure 4. Geological zones of Senegal: The striated portion to the southeast indicates the Precambian Basement. (USAID/RSI, 1985)

The Department of Kedougou lies entirely in the Precambian Basement of Senegal and is therefore home to all the heavy mineral mining. Kedougou is also one of the poorest, least developed Departments in the country with a low population density (Pison, 1995). An underlying mechanism of many of the environmental threats in Kedougou is the human population increase leading to expanding human habitation and areas of cultivation.

A 2011 estimate by the Central Intelligence Agency (CIA) World Factbook (2011) cites the population growth rate of Senegal as 2.6%, placing the country within the top 10 percent of the highest national growth rates in the world. Over half of the population of Senegal lives in rural areas (CIA, 2011). Unfortunately, within the chimpanzee habitat in the southeastern region
of Senegal, human population estimates are difficult to compile. Numbers are given either for the region of Tambacounda, the more recently subdivided region of Kedougou (as of 2008), or the Kedougou prefecture and are not comparable to one another over time. However, what is known is that the increase in mining, both corporate and artisanal, is causing an increase in the human population across southeastern Senegal (PASMI, 2009; MDL, 2009; Mining Journal Supplement, 2009).

While ArcelorMittal’s incoming iron mine, which boasts the creation of 20,000 direct and indirect jobs in Senegal (Mining Journal Supplement, 2009), will be the first iron mine created in the country, gold mining occurs in Senegal via both large-scale corporate industrial mining companies as well as small-scale informal artisanal miners. Large-scale mining companies have established numerous gold exploration sites in the southeastern region of Senegal, most notably in and around Sabodala. The Sabodala Mining Company is a subsidiary of Australia’s Mineral Deposits Limited, which owns the gold mine here (Mining Journal Supplement, 2009). The corporate mining project in Sabodala, a joint venture between Australia’s Mining Deposit Limited and the Senegalese government, employed around 1400 people for the construction of the mine, the majority of whom were Senegalese (MDL, 2009). In the area surrounding Sabodala, a Canadian mining company, Oromin Explorations Limited, has created the Sabodala Holding Company subsidiary, which is working with two Saudi investment companies. South of Sabodala, the South African company Randgold has discovered another gold deposit, and Canada’s Iamgold mining company is exploring along the Mali border. Both Randgold and Oromin plan to start production in the Kedougou region within the next several years. In total, 20 pockets of gold mineralization have been discovered along with four potential mine sites. There
are currently gold research permits extended to eight foreign companies and nine domestic
companies for exploration (Mining Journal Supplement, 2009; Pasmi, 2009).

Small-scale artisanal gold mining is widespread in southeastern Senegal and also occurs
around the globe. The occupation is estimated to employ 10-15 million miners in 55 countries,
predominately in Africa, Asia and South America. This informal mining process is thought to
make up 20-30% of the world’s gold production (Global Mercury Project, 2007). In Senegal,
artisanal gold mining occurs in pockets across the Kedougou region. There are currently
approximately 10-20,000 artisanal miners working in Senegal with rudimentary extraction
techniques, high occupational hazards and environmental risks and no support or recognition
from the government (Pasmi, 2009). This work is believed to employ approximately 20% of the
region’s population and directly or indirectly affects 50% of the regions inhabitants (WTO,
2009). In Senegal, artisanal gold mining has directly affected the chimpanzee community in
Fongoli, for example. Since 2008, two artisanal mines have been established within the
community’s home range, increasing local human presence and disturbances (J. Pruetz, pers.
comm.).

The increase of mining jobs in southeastern Senegal has also been cited as the cause for
recent local social instability in Kedougou. On December 23, 2008 riots broke out in the town of
Kedougou as a result of biased employment by mining companies in the region (IRIN, 2009).
These riots injured 35, killed at least one and led to the arrest of 26 individuals. Further
instability and population increase in southeastern Senegal could potentially stem from the influx
of immigrants from other West African countries, such as Guinea, Ivory Coast, and Burkina Faso
which have recently suffered from political instability.
In addition to the influx of mining populations across the region, another significant impact on the area is the newly created Bamako-Dakar Corridor roadway. The roadway project known officially as, ‘Road Improvement and Transport Facilitation Programme on the Southbound Bamako-Dakar corridor (Kati-Kita-Saraya-Kedougou-Dakar)’, has created a paved highway running through the Kedougou region from Kedougou to Mali, including a bridge over the Falémé river (ADF, 2005). The roadway, which bisects the KR study site, will ultimately connect Bamako with Dakar, thus opening up the landlocked country of Mali to engage more effectively with coastal export systems. Negative impacts of the roadway include habitat fragmentation and destruction, increased runoff due to asphalited surfaces, increased traffic through the Niokolo-Koba National Park (PNNK) and subsequent potential for traffic accidents, and increased human population in the region (ADF, 2005).

*Falémé Zone d’Interet Cynegetique (ZIC)*

The Mining Zone of Senegal is located within the 1.3 million ha of the Zone d’Interet Cynegetique (ZIC) of Falémé, a protected wildlife area. The area was legislated in 1972 by the Government of Senegal in law 72-11-70 and modified in 1978 by law 78-506. The region is considered a conservation priority by the government and was intended to act as a buffer to the PNNK located to the west (Figure 5) (USFS, 2006).
Although considered a protected area, the Falémé ZIC does not prohibit people from grazing livestock, cultivating, or collecting firewood and other forest resources. The area includes large hunting concession areas owned by the State and managed by large game hunters (USFS, 2006). Hunting in these concessions is primarily by foreign hunters interested in the “African Hunting Experience” (USAID, 2009). Major threats to the Falémé ZIC include cultivation (particularly cotton), mass deforestation, bush fires, logging, cutting fodder for livestock, charcoal production and mining exploration and extraction (USAID, 2008). However, like most protected areas in Senegal, the Falémé ZIC has neither a management plan in place nor the finances to enact enforcement if one were in place. Mining activities are considered most
detrimental to the biodiversity in the Falémé ZIC and are nearly unstoppable due to governmental support and the need for short term financial gain (USAID, 2008).

*Environmental Impacts of Mining Activities*

Natural resource extraction, specifically mineral and metal mining, provides an important source of revenue for many West African countries. In Senegal, mining has been increasing over the past five years due to the rise in mineral raw materials prices (WTO, 2009) and continues to expand as research and exploration permits are extended to foreign and domestic companies (Mining Journal Supplement, 2009). Much of the metal mining is located in the southeastern region of Senegal where the effects of mining will compound the already existing environmental problems faced by the chimpanzee populations. In the past 35 years there has been a decrease in over half of Senegal’s forest cover (Tappan et al., 2004). While natural threats have had an impact on Senegal’s environmental degradation, including climate change, desertification and natural fires, much of the disturbances are anthropogenic and include agriculture, livestock grazing, cutting of plants for livestock fodder, bush fires, logging and charcoal production (USAID, 2008). Savanna chimpanzee populations are already suffering from the effects of these habitat disturbances. Further degradation and disruption to their habitat through mining activities will strain the species and threaten their future survival.

Extractive industries create potential risks for great ape communities through habitat destruction and fragmentation, pollution of natural water sources, behavioral disruption, and disease transmission (Hockings and Humle, 2009). Habitat destruction and fragmentation caused by mining includes clearing vegetation for mining facilities, roads and human settlements such as base camps and relocated villages. As previously stated, mining projects are also directly linked
to an influx of a larger human population. Along with the increased human population, comes the potential for an increase in human-chimpanzee conflict stemming from the creation of roads and human settlements at mining facilities, in conjunction with decreased available habitat (Hockings and Humle, 2009).

Mining operations have wide ranging detrimental effects on the environment, directly causing water, air and noise pollution, deforestation and toxic waste production. Habitat loss, due to the open pit mining system characteristic of iron mines, is marked by overall loss of vegetation and changes in landscape (Akiwumi and Butler, 2008; Kusimi, 2008). Water pollution occurs in both ground and surface water in mining areas, causing sources to be highly vulnerable to heavy metal contamination (He et al., 2006; Yellishetty et al., 2009). Mining areas can also generate potentially toxic waste products in large volumes over time (Williams and Ansley, 2009; Tovar et al., 2009). The environmental effects of airborne contaminants, waste tailings, and acid and metalliferous drainage (AMD) are attributed to hazardous materials involved in the entire process of extraction (LPSDP Hazardous Materials, 2009). The environmental impacts of waste tailings and AMD are generally restricted to the mining site and local environment, whereas airborne contaminants can have an impact throughout the entire process from “pit to port”. Particles are released into the air during facility construction and development, drilling, blasting, exporting, transporting and dumping of ore, beneficiation of materials, power plant operations, wind erosion, rail transportation and ship loading (LPSDP – Airborne Contaminants, 2009). Hazardous materials involved in this process include asbestos, silica, and nitrogen dioxide from blasting, sulfur dioxide and hydrogen cyanide from beneficiation, and emissions of sulfur dioxide and various forms of nitrogen oxides from power
plant operations. Radioactive metals can also be released into the air through the blasting process (LPSDP – Hazardous Materials, 2009).

If human population and corporate industry ventures continue to increase in southeastern Senegal, increasingly fragmenting and degrading the habitat, the chimpanzee populations will inevitably suffer. The critical moment for chimpanzee conservation is now, prior to the major influx of mining operations and population boom. Conserving Senegal’s chimpanzees is not only imperative for ecological and ethical reasons and to maintain genetic viability of the population, but also to preserve the wealth of information that can be understood from the study of their behaviors in a relatively unique chimpanzee environment.

West African Savanna Chimpanzees

West African savanna chimpanzees range across nine to ten countries in West Africa with a total estimated population in the range of 21,000 to 55,000 individuals (Kormos and Boesch, 2003). Even if high estimates are accurate, the population is endangered according to the International Union for Conservation of Nature (IUCN) Red List standards. Such large discrepancies in accuracy for population estimates permeate the data due to the difficulty in assessing the entire chimpanzee range, as well as the constant increase in habitat destruction in West Africa (Butynski, 2003). Many of the surveys contributing to the population database were conducted a decade or more ago, and therefore, do not take into account the current degraded state of the chimpanzee habitat and subsequent population declines.
Previous Surveys in the Mandigue Plateau

In order to successfully conserve chimpanzee populations, as well as evaluate conservation activities, it is important to first accurately estimate population densities. By understanding the baseline population density of an area, one can then understand the impacts of threats on the population. Densities of unhabituated apes are primarily estimated using nest count methods, as apes are known to create a vegetation sleeping platform, or nests, each night (Kühl et al., 2008). There are two types of nest counts, the standing crop nest count method (Tutin and Fernandez, 1984) and marked nest count method (Plumptre and Reynolds, 1996). The standing crop method records all nests in an area during one surveying bout and uses both a nest creation rate as well as a nest decay rate to estimate the population density. The marked nest count method requires repeated surveys of an area and records only the nests that have been created since the previous survey. The method only requires a nest creation rate to calculate population density. Nest creation rates and decay rates vary between sites (Brncic et al., 2010; Marchesi et al., 1995) and should ideally be specifically calculated for each survey area. Calculating these rates, however, is not always possible for projects with economic and temporal constraints; rather, rates are frequently taken from the literature based on similar geographical location, climatic data and habitat structure (Kühl et al., 2008; Pruetz et al., 2002)

Whether using the standing crop or the marked nest count method, there has been debate over whether densities should be estimated using individual nest counts or nest groups (Ghiglieri, 1984; Tutin and Fernandez, 1984). Both methods can provide population density estimates, but both have disadvantages. Individual nest counts assume a random distribution of nests throughout the study area, not taking into account the prevalence of preferred nesting sites and habitats or the fact that chimpanzees nest in groups. This may be especially problematic in areas
where chimpanzees use habitat mosaics and range in cohesive groups. Nest groups, on the other hand, do take into account the fact that chimpanzees primarily nest together. Groups, however, may be difficult to determine as chimpanzees may return frequently to the same nesting site over a series of days resulting in one nesting group being indistinguishable from another. The inability to consistently and accurately determine one nest group from another has resulted in researchers using the individual nest count method, despite its shortcomings (Pruetz et al. 2002; Granier and Martinez, 2004; Fleury-Brugiere and Brugiere, 2010).

In the past ten years, few systematic chimpanzee surveys have been conducted in the Mandingue Plateau. Of those conducted, the most significant to this study are the surveys conducted by Pruetz et al. (2002) in Senegal at Mt. Assirik in Niokolo Koba National Park (PNNK) and surrounding areas, including the current Fongoli field site. The Pruetz et al. (2002) study used both systematic and reconnaissance surveys. The four systematic line transects at Assirik were each 2km long and were surveyed twice, while selective sampling followed water courses through two valleys with transects of 2.8km and 2.9km. The total distance surveyed in the national park was 83.5km. Outside the park a total of 33.2km was walked in reconnaissance surveys. Chimpanzee density at Assirik was determined to be 0.13 individuals/km$^2$ and density at Fongoli was 0.09 individuals/km$^2$.

In the northeast corner of the Mandingue Plateau, located in Mali, the Bafing-Faleme Protected Area (BFPA) was most recently surveyed by Granier and Martinez (2004). The habitat of the BFPA is similar to that of southeastern Senegal as it is dominated by woodland and wooded savannah (35.7% and 18.9%), with gallery forest making up only 5.5% (Granier and Martinez, 2004). Within the BFPA, three study sites were surveyed based on a year of reconnaissance surveying, but only two provided accurate densities (Faragama and Djakoli). At
Faragama eight transects were surveyed totaling 14km and, at Djakoli, seven transects totaling 11.9km were surveyed. Densities at these two sites were 0.30 and 0.39 individuals/km$^2$ respectively. The BFPA had been previously surveyed by Pavy (1993) who, with a greater survey intensity of 100km, found a density of 0.27 individuals/km$^2$.

In Guinea, Fleury-Brugiere and Brugiere (2010) found the highest chimpanzee density in the Haut Niger National Park (HNNP). The habitat of the HNNP is also similar to southeastern Senegal and southwestern Mali with wooded savannah and dry forest dominating the landscape (53.6% and 20.8%) and gallery forest making up 4.2% of the habitat (Fleury-Brugiere and Brugiere, 2010). They surveyed 103.8km of transects, each transect averaging 8.2km long (Fleury-Brugiere and Brugiere, 2010). Transects were placed in 11 randomly selected census blocks in a selected region of the national park. The chimpanzee density found for this area was 0.87 individuals/km$^2$ (Fleury-Brugiere and Brugiere, 2010).

*Regional and Cultural Behaviors*

Chimpanzees have been frequently recognized for their wide variety of behaviors, many of which have been termed cultural (Boesch, 2003; Whiten, 2000; Sapolsky, 2006). As mining and human populations increase in southeastern Senegal, fragmenting and degrading the landscape, the impact may potentially affect the behavior of the Senegal’s chimpanzees. Such habitat disturbance brings about socioecological change for chimpanzee groups in terms of continuity of neighboring territories, which may in turn lead to the complete loss of local cultures (van Schaik, 2002).

Culture can be defined as a distinctive collective practice socially learned from group members and based on shared meanings between members of the same group (Galef, 1992;
Boesch and Tomasello, 1998; Boesch, 2003; Whiten, 2004; Sapolsky, 2006; Whitehead et al., 2004). Boesch (2003) notes that culture is comprised of creativity, diversity, and innovation, and can allow a release from ecological constraint through the transmission of some behaviors. Some behaviors that are recognized as putative cultural behaviors in chimpanzees include leaf clipping (Sugiyama, 1981; Nishida T. 1987; Boesch, 2003), hand clasp grooming (McGrew, 2001), ant dipping (McGrew, 1974; Sugiyama et al., 1988; Boesch and Boesch, 1990; Alp, 1993; Humle and Matsuzawa, 2002; Sanz and Morgan, 2007), termite fishing (Sanz et al., 2004; Bogart and Pruetz, 2008; Sanz and Morgan, 2007) and percussive tool use, such as nut cracking with hammers and anvils (Boesch, 2003). West African chimpanzees have been observed exhibiting all of these behaviors and display a range of cultural variation, with termite fishing and ant dipping behaviors varying between research sites (Mobuis et al, 2007; McGrew et al., 2005; Yamamoto et al. 2008).

Individuals learn certain skills either by innovation or by social learning. Innovation appears to be rare, and it is more likely that new behaviors are learned via social learning and diffusion across populations (van Schaik, 2002). Variations in behaviors may be attributed to ecological, genetic or cultural influences (Langergraber et al., 2011). The loss of connectivity between communities within a population could dramatically influence the loss of behavioral variation by disrupting the both genetic and cultural diffusion process between communities. Where the extinction of a local community would obviously cause the extinction of the local cultures, it is also evident that the fragmentation of habitat would cause the loss of diffusion between communities due to lack of dispersal corridors (Van Schaik, 2002).

Some of the putative cultural behaviors observed in Senegal that have also been observed in other chimpanzee populations across Africa include hand clasp grooming, ant dipping, termite
fishing, leaf clipping, buttress drumming, and rain dances (pers. obs., 2009; McGrew et al., 2005; Bogart and Pruetz, 2008; Pruetz, unpublished data). The chimpanzees of Senegal, however, also exhibit unique behaviors not seen in other chimpanzee populations. For example, at the Fongoli field site, 75km southwest of Kharakhena, the chimpanzees have been observed using caves (Pruetz 2006), soaking in pools of water (Pruetz & Bertolani 2009), systematically hunting mammals with tools (Pruetz and Bertolani, 2007), and performing a ‘fire dance’ (Pruetz and LaDuke, 2010). Further research is needed throughout the southeastern region of Senegal to determine whether other chimpanzee populations are responding to the environment in the same manner as the Fongoli community. The southeastern region is home to a number of other chimpanzee communities living in similar habitat types who likely experience ecological stresses comparable to those of Fongoli apes. One would thus expect to see similar behaviors in the Kharakhena and Bofeto chimpanzee populations. For example, chimpanzees in Mali living in similar ecological condition to those in Fongoli have been observed exiting a cave, indicating that chimpanzee cave usage is perhaps more widespread in the Mandingue Plateau than is currently known (Moore, cited in Pruetz, 2002). Evidence of these behaviors would give further insight into the range of cultural behaviors in Senegalese chimpanzee populations. If conservation efforts are not implemented in the region to compensate for the increasing human population and the habitat degradation, the transfer and future of these behaviors could be lost forever (van Schaik, 2002).

Many of these putative cultural behaviors leave behind material artifacts. Chimpanzees in East, Central and West Africa modify termite-fishing tools by cutting the length of the tool with their hands or mouth and then stripping the tool of extraneous parts, such as other branches or stems. In the Goualougo Triangle, Congo and Fongoli, Senegal researchers have found
termite fishing tools to be modified with fanned or brush-like tips, a modification which aids and increases extraction of insects (Sanz and Morgan, 2007; Gaspersic & Pruetz, in prep.). Researchers studying habituated communities of chimpanzees have thousands of hours of direct observation of tool use. These data provide information of tool use and production that aids in identifying tools used by non-habituated communities. In this way indirect methods can be used to study behaviors of non-habituated chimpanzee communities. By the use of indirect study and artifact recovery, we are able to analyze and interpret some behaviors without actually observing them (McGrew et al., 2003).

Conservation Corridors

In order to best conserve the remaining chimpanzee population in southeastern Senegal, landscape linkages are needed to increase connectivity between populations (Bennet, 2003). Chimpanzee populations may otherwise become isolated due to habitat fragmentation and anthropogenic barriers such as mining activities, highways or human habitations. As noted above, protected areas have already been established in and around the Mining Zone of Senegal such as the Falémé ZIC and PNNK. These areas however are too large to adequately manage with current allocated resources, and chimpanzee conservation may benefit from smaller community based reserves that encompass suitable chimpanzee habitat. Such reserves would act as conservation corridors that either creates contiguous habitat connections or “stepping stones” of habitat between which chimpanzee populations could move (Groves, 2003). Corridors would thus allow for female dispersal from their natal site into other communities. This movement between communities would permit continued genetic and cultural exchanges between communities.
As more and more habitat in southeastern Senegal is disturbed due to mining activities and human habitation, it is important to identify where chimpanzees live, what habitats they use most frequently, and how they react to human disturbed areas. I propose that it is also necessary to begin creating these conservation community reserves to maintain connectivity between the remaining and threatened populations. In this study I have identified two populations whose habitat is under threat of the impending iron mine as well as potential areas of dispersal once the iron mines are constructed.

CHAPTER 3. METHODOLOGY

Study Sites

The study area is located in southeastern Senegal along the Malian and Guinean borders (12°54’48.69” N, 11°31’05.65” W), within the region and department of Kedougou (Figures 1 and 2). Located 83km northeast of the town of Kedougou and 12km from the Mali border, the targeted study area lies within a 65km by 15km belt of supergene enriched iron ore deposits containing nine major and 19 minor ore bodies (Schwartz and Melcher, 2004). It is within this area that ArcelorMittal is expected to develop an iron mine. My project’s two study sites encompass the largest iron deposits. The northern study site is a 256km² area centered on three iron deposits and encompassing the village of Kharakhena (KR) (Figure 4). The three iron deposits in this site total 98 megatons (Mt) of iron ore (Figure 5). The southern site is a 64km² area centered on the mountain of Koudekoounda near the village of Bofeto (BO) (Figure 6). Surveys in the BO area were only conducted in the Senegalese portion of the study site and exclude the northeastern section located in Mali for logistical reasons of working in that country.
The BO study area encompasses one iron deposit of 107Mt (Figure 7). Prior to this study, details of water source and habitat type availability had not yet been determined for these areas and were within the focus of this study.

**Chimpanzee Population Density**

Data used in this study was collected from May through August 2010 and again between December 2010 and January 2011. The study used distance sampling surveys to estimate population density through indirect measures, specifically standing crop nests counts (Plumptre and Reynolds 1997, Kouakou et al. 2009; Kühl et al., 2008). Distance sampling is currently the standard for surveying great ape populations, as it is the most well developed method, can estimate population density, abundance and distribution, and is applicable to various types of habitats (Buckland et al, 2001). Although there are major assumptions associated with distance sampling, (i.e., proper design of transects and survey methods, all objects located above or on the transect will be detected, distances to objects are accurately recorded, and that sightings are independent events), knowledge of these assumptions and careful execution of surveys can assure that data analysis will produce accurate measures of population densities (Kühl et al., 2008). Additionally, counts of objects, such as nests, rather than moving organisms, helps to reduce error associated with some of these assumptions.

In order to reduce bias in establishing line transect locations, I used a stratified systematic sampling method. The 256km$^2$ KR study site was divided into four sectors, each with an area of 64km$^2$. Each sector was then delineated into four strips containing a 6km line transect systematically distributed within the center of each strip, totaling 16 6km transects within the KR
study area (Figure 6). The stratified transect method is also being used by in an African ape population surveillance system to be implemented across Africa (C. Boesch, pers. comm.)

The 64km$^2$ BO study site was divided into four strips because of its smaller size. The northeastern region of the BO study area lying on the Malian side of the Falémé River was not surveyed during this study. One 6km line transect was systematically distributed within each strip, totaling four transects within the BO site (Figure 7). The total number of transects for the entire study area was 20, with a total distance of 160 km surveyed.

Figure 6. 256km$^2$ Kharakhena (KR) study site with 16 6km transects.
Along with a Senegalese field assistant, I walked each transect at a rate of approximately 1.5km per hour (Plumptre, 2000) one time between May 2010 and August 2010. Nests were recorded that were within sight perpendicular to the transect. Perpendicular distance was measured from a point directly below the nest on the ground to the line transect (Plumptre and Reynolds 1997). Effective transect width is determined using the equation \( A = 2 \times ESW \times L \), where \( A \) is the transect area, ESW is the effective strip width, and \( L \) is the length of the transect (Buckland et al., 2001). The ESW of 11.52m for the KR field site was determined by using nests to transect distances and calculated using DISTANCE software.

All night nests seen from the transect line during the surveys were marked and classified according to age. Night nests were distinguished from day nests as being generally larger and more solidly constructed (Brownlow et al., 2001); however, no day nests were seen during data collection. Nest age classes include fresh, recent, old, and rotting (after Tutin and Fernandez,
Fresh nests are characterized by having vegetation that was still green and not wilted and may have feces and urine deposited beneath or within the nest. Fresh nests with feces or urine were distinguished from those without. Fresh feces most accurately indicate the age of a nest. My study recorded fresh nest with feces as well as fresh nests without feces thus allowing me to calculate both a conservative and liberal minimum group size. Recent nests are those that contain wilted green leaves and are assumed to be older than 24 hours. Old nest are those lacking green leaves, and rotting nests contain no leaves at all but only the woody frame of a nest.

Behavioral impacts of habitat disturbance may be indicated by changes in party size over time. Therefore, baseline data on nest clusters of fresh nests were recorded. Fresh night nests were used to estimate minimum party size by counting number of fresh nests within a nest cluster. A nest cluster is defined by Furuichi et al. (2001) as a collection of nests that appear to have been built together on the same day, including all nests of the same age class that are less than or equal to 30m from the nearest of the other nests. In this study I used the parameter of 30m as a guideline to determine a nest cluster and also distinguished fresh nests with feces from those without feces. The former provides a minimum nest cluster size. Data was recorded on a Garmin GPS and analyzed using DISTANCE and ArcGIS software.

Habitat Type and Structure

Habitat type and structure was sampled along the 20 6km transects in the two study areas. The habitat type classification is based on Pruetz et al. (2002), which was modified from McGrew et al. (1981) and includes gallery and ecotone forest (closed habitats), woodland, bamboo woodland, and grassland and open grassland (open habitats). Along transects, every 500m the habitat type was indicated based on the standard definitions for each type such that
gallery forest indicates a tropical semideciduous lowland forest; woodland refers to a drought-deciduous lowland woodland; bamboo woodland indicates a flat-leaved savanna with isolated palms and deciduous trees; grassland refers to a narrow-leaved savanna with isolated deciduous trees, distinguished from open grassland, which is a narrow-leaved savanna with isolated deciduous shrubs; and finally, ecotone forest indicating an area where runoff from a plateau edge produces a strip of evergreen woody vegetation (Bogart & Pruetz, 2011; Pruetz et al., 2002).

Each 500m habitat structure was also sampled by measuring diameter at breast height (DBH) for all trees within a 5m radius from the transect line.

Travel Corridors

Potential travel corridors were identified by sweep surveys of both KR and BO study sites. Sweep surveys followed standards set forth by the IUCN Best Practice Guidelines for Surveys and Monitoring of Great Ape Populations (Kuehl et al., 2008) and were conducted by a Senegalese field assistant and myself walking in the same direction. We recorded all human signs, disturbances, and limits to chimpanzee ranging. It is important to record all human signs and disturbances in order to understand how chimpanzees respond to the changing environment due to human presence (Kühl et al., 2008). Locations of all disturbances or formations likely to inhibit travel by chimpanzees were recorded and mapped with the GPS. Such disturbances included cultivated areas, villages, roads, mining activity, and disturbances due to livestock and/or herders (ie. tree and branch cutting for livestock fodder).
Cultural Behavior Assessment

The presence and prevalence of putative cultural and regional behaviors of chimpanzees were recorded, focusing specifically on cave use, hunting with tools, soaking in water, baobab cracking, termite fishing and ant dipping. All occurrences of direct and indirect evidence within the study sites for these behaviors were recorded. Two camera traps were placed in the KR study site; one was outside caves used by chimpanzees and the other at a frequented water source. One camera was also placed along a chimpanzee path in the BO site to capture chimpanzee activity.

CHAPTER 4. RESULTS

Over the course of this study, I recorded 173 nests in the KR study site and 246 nests in and around the BO study site. The location of each nest was recorded via GPS, as was the surrounding habitat. Using these data, I was able to determine nesting sites and habitats as well as the spatial distribution of nests in relation to potentially influential factors such as human disturbances and permanent water sources. These factors, areas of human disturbance and permanent water sources, along with habitat suitability are also used to predict potential travel corridors, which may become increasingly important as further habitat degradation occurs.

Chimpanzee Population Densities

Between May and August 2010, nest counts were completed along 20 6km transects, totaling 120km total for the KR and BO sites (96km and 24km, respectively). In the KR site, 24 nests were recorded on 16 transects. All 24 nests were found on transect #1 in the northwestern corner of the study site. In KR the maximum perpendicular distance from the transect was 30m.
Using DISTANCE software, the effective strip width (ESW) for KR was calculated first by using the perpendicular distances of all nests recorded along transects. ESW was 11.202 meters with a standard error of 2.3825. However, after removing three outliers with perpendicular distances greater than 20m (and thus reducing the maximum perpendicular distance to 16.1m in 21 observations), the ESW was 11.141m with a standard error of 2.0941. Estimated population density for the KR site was 0.131 with an estimated 34 chimpanzees at the site. A total of 184 nests were found either within or along the outer edges of the Kharakhena study site during reconnaissance walks, although only 24 nests fell along the transect lines. The majority of nests were found just outside the study site and therefore not recorded on transect walks.

The total nest count in the BO site, including both reconnaissance and transect surveys, was 246 nests. Included in the nest count was a fresh nest cluster of 17 nests. This group of fresh nests indicates that the smallest possible party or sub-group size for BO is 17 individuals. If we assume this single sample is average, the actual community group size would be double this estimate based on the average party size at Fongoli chimpanzee (15 individuals) relative to the community size (35 individuals) (Pruetz and Bertaloni, 2009).

Although having more nests overall, only three nests in the BO site fell along the 24km of transects. The maximum perpendicular distance from nests to the transect was 10m. With such a small sample size of observations, it is not possible to calculate a statistically significant ESW or estimated population densities for the BO site using the DISTANCE software. Based on reconnaissance walks, the nest density of the BO site appears to be much greater than the KR sites since 217 nests at the BO site were found in an area one quarter the size of the KR study site. In order to calculate an estimated population density of the BO population, I used the following equation:
Using varying nest decay and production rates from chimpanzee sites across Africa I was able to calculate minimum, maximum and average density estimates. Minimum densities were calculated using Sierra Leone’s nest decay rate of 139 days in woodland savanna nest sites (Brncic et al., 2010) and a nest production rate of 1.23 from Budongo, Uganda calculated by Plumptre and Reynolds (1997). Maximum densities used Tai forest’s decay rate of 73 days (Marchesi et al., 1995), and a liberal production rate of 1 nest per day per chimpanzee. Averages were calculated by using the average nest decay and nest production rates from the varying studies. The proportion of nest builders used in the calculations was 0.83 individuals based on results from Budongo, Uganda (Plumptre and Cox 1996; Brncic et al., 2010). Effective strip width calculated by DISTANCE from the KR data was used for the BO calculations as well.

Using these aforementioned parameters, I found that the estimated population density at BO ranged from 0.04 to 0.09 chimpanzees per km$^2$ with an average of 0.05. When the same parameters were used to calculate an estimated population density for KR, I found a range from 0.08 to 0.19 individuals per km with an average of 0.11, corroborating the density calculated by the DISTANCE program.

**Habitat Type**

Habitat types not previously defined but encountered at the two sites include *river*, and *palm woodland*. *River* habitat was defined specifically as areas completely contained within a
river. *Palm woodland* habitat was defined as woodland areas where *Borassus aethiopum* dominate the landscape.

Available habitat for the KR site, based on data collected every 500m along each of the 16 6km transects, was mainly woodland (50%) and grassland (33.8%), in addition to woodland/grassland mosaic (9.8%), bamboo woodland (2.9%), human impacted (2.5%), and palm woodland (0.5%) (Figure 8). Based on the 173 nests in the KR study area, chimpanzees were found to nest primarily in woodland (49.1%) and gallery forest (38.2%). Other nesting was done in palm woodland (7.5%), bamboo woodland (4%), and ecotone forest (1.2%) (Figure 8).

![Figure 8. Percent available habitat at Kharakhena versus percent of nesting in each habitat](image-url)
The available habitat in the BO site, based on habitat data collected every 500 meters on the four 6km transects, was predominantly woodland (40.4%) and woodland/grassland (25%), as well as grassland (19.2%), human impacted (7.7%), bamboo woodland (3.8%) and river (3.8%) (Figure 9). In the BO site, the percent habitat type used for nesting, based on 246 nests, was found to be almost exclusively in woodland (93.9%), with small the remaining nesting in bamboo woodland (2%), woodland/grassland (2%), gallery forest (1.2%), and palm woodland (0.8%) (Figure 9).

Figure 9. Percent available habitat at Bofeto versus percent of nesting in each habitat

**Travel Corridors**

Anthropogenic habitat disturbances recorded in the KR study site include areas of cultivation, villages, branch and tree cutting for pastoral livestock fodder, and mining activities.
such as artisanal gold mining, diamond drilling for iron ore, past trenching for gold exploration, and gallery tunneling for iron exploration. Another area of disturbance is the newly finished Bamako-Dakar corridor highway that runs from the Mali border to the town of Kedougou. The highway bisects the Kharakhena study site. Currently, this roadway does not appear to be impeding the chimpanzees from traveling in the region. In November 2010, field assistant Seiba Keita observed two chimpanzees feeding on trees within 50 meters of the highway. However upon completion of the highway’s Senegal-Mali bridge, which is located just east of the study site, traffic is likely to increase significantly and may ultimately create a barrier for the chimpanzees.

Travel opportunities appear to be limited in the southeastern quadrant of the study site as there are highly traveled roads and numerous small villages (Figure 10). Most of the traces of chimpanzees were found in the west, and the majority of nests found were north and west of the study site. Although suitable habitat and feeding trees are found in the eastern portion of the study site, few traces of chimpanzee presence were found in this region. Keita reported having seen evidence of chimpanzees nesting in gallery forests in the east in previous years, but since the creation of the artisanal gold mine the chimpanzees no longer appear to nest in the area.

Using ArcMaps to calculate the percentage of nests found within areas of human disturbance (designated as areas within one kilometer from a village or 500m meters from any other disturbance), I found that 31.5% of the nests at the KR study site fell within these buffered areas of human disturbance. Therefore, the majority of nests are located outside areas of human disturbance (Figure 12). Buffer zones around human impacted areas are compliant with buffers used in the USGS habitat map, but buffer areas used around cultivated areas are more conservative in this study, as I used only 500m rather than 1km (USGS/EROS, 2011),
In the BO study site, disturbances also included cultivation, villages, branch and tree cutting for pastoral livestock fodder, and mining activities (Figure 11). Mining activities, however, were limited to the mountain areas, as there were no artisanal gold mines and limited past mining exploration within the study site. Mining activities did include diamond drilling points and temporary road construction for equipment on each of the three mountains.

Nests were also clustered in the northern edge of the BO study site, similar to the KR site. However, in contrast to the KR study site to the north, the majority of chimpanzee nests recorded at the BO site were located within the buffered areas of human disturbance. Of the 217 nests used in this calculation\(^2\) 64.5% were located within a disturbed area’s buffer zone (Figure. 13).

\(^2\) 29 nests located to the south were excluded due to lack of extensive surveying of human disturbances in that area.
Figure 10. Chimpanzee nesting sites in relation to areas of human disturbance and proposed mining sites in the Kharakhena study site. Buffers of 1km were created around villages and mining sites and 500m around all other disturbances.
Figure 11. Chimpanzee nesting sites in relation to areas of human disturbance and proposed mining sites in the Bofeto study site. Buffers of 1km were created around villages and mining sites and 500m around all other disturbances.
Travel corridors in the BO study site are difficult to assess, as the chimpanzees in the area do not appear as currently being displaced due to human presence in an area. Therefore, nearly all areas are currently accessible to the chimpanzee population. However, with the iron ore open pit mine construction plan to start in December 2011, current nesting areas will no longer be accessible. Suitable habitat is located to the northwest of the BO site and may provide the chimpanzees a potential dispersal area.

Cultural Behavior Assessment

In the KR study site, two potential cultural behaviors were recorded. During transect survey data collection, two termite-fishing tools were found in the KR study site that appeared to exhibit ‘brush tips’ (Figure 14). Brush-tipped termite-fishing tools are characterized by a splayed tip created by chimpanzees pulling the tool end through their teeth (Sanz et al, 2009; Gaspersic & Pruetz, in prep.). The split end of the tool was covered with dirt from the termite mound, indicating that this was the insertion end into the termite mound to extract the insects. These two tools, both from the *Terminalia macroptera* tree, were found still resting on the termite mound. Both tools appeared to have been recently used as they were not yet dried and showed visible tooth marks on the plant epidermis.

Evidence of cave use was also observed at the KR site via camera trap photos. A camera trap was placed at the mouth of a cavern located at N 12°51.816 W -11°34.037, which record all activity inside and in front of the cave. The cavern consists of one large chamber approximately 2m tall at the opening, 10m wide and 7m deep. The chimpanzees were recorded spending time in and around the cave from 0800 to 1400 hours during the months of April and May. The Fongoli chimpanzees use caves more frequently during the dry season, which is the hottest time
of the year (Pruetz, 2007). The group at KR was observed grooming, eating, and resting in the caves (Figure 13). Exploration of the cave revealed both fresh and dry remnants of *Borassus aethiopum* fruits, presumed to be transported to the caves by chimpanzees. Photos show the chimpanzees carrying *Piliostigma thonningii* pods into the cave (Figure 14).

At the BO study site, no signs of chimpanzee cultural behaviors were recorded. Caves found in the BO differed from those at the KR site in that the BO caves were below ground. No evidence was found at these caves to indicate that chimpanzees had used them.
Figure 12. Putative brush-tipped termite-fishing tools found in the Kharakhena study site

Figure 13. Cave use at KR site.
CHAPTER 5. DISCUSSION

Population Density

In comparison to other surveyed areas in Senegal, the density at KR is equal to the density found at Mt. Assirik in Niokolo Koba National Park (Pruetz et al., 2002) and slightly higher than the density found at Fongoli using surveys, which was 0.09 individuals per km$^2$ (Pruetz et al., 2002). A site in the region, surveyed in the Bafing-Faleme Protected Area in Mali by Granier and Martinez (2004), showed higher densities of 0.39 individuals per km$^2$ at Djakoli and 0.30 individuals per km$^2$ at Faragama. The Bafing-Faleme Protected Area was surveyed previously and more intensively by Pavy (1993) who found a density of 0.27 individuals per
km². Higher population densities of 0.87 individuals per km² were calculated farther south in the Haut Niger National Park of Guinea (Fleury-Brugiere and Brugiere 2010).

Table 1. Chimpanzee population densities from the Mandigue Plateau

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<thead>
<tr>
<th>Site</th>
<th>Density (ind/km²)</th>
<th>Citation</th>
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<tr>
<td><strong>Senegal</strong></td>
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<tr>
<td>Kharakhena</td>
<td>0.08 to 0.19</td>
<td>this study</td>
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<tr>
<td>Koudeckourou</td>
<td>0.04 to 0.09</td>
<td>this study</td>
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<td>Pruetz et al., 2002</td>
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<td>Fongoli</td>
<td>0.09</td>
<td>Pruetz et al., 2002</td>
</tr>
<tr>
<td><strong>Mali</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Djakoli (BFPA)</td>
<td>0.39</td>
<td>Granier and Martinez, 2004</td>
</tr>
<tr>
<td>Faragama (BFPA)</td>
<td>0.30</td>
<td>Granier and Martinez, 2004</td>
</tr>
<tr>
<td><strong>Guinea</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haut Niger National Park</td>
<td>0.87</td>
<td>Fleury-Brugiere and Brugiere 2010</td>
</tr>
</tbody>
</table>

The encounter of a fresh nest group size of 17 nests allows me to also estimate the community size for the area of Bofeto. In Fongoli, the chimpanzee community was found to be more cohesive than other West African chimpanzee communities, with an average party size of 15 individuals (Pruetz and Bertaloni, 2009). In the wet season in Fongoli, the average party size was larger than the dry season, averaging 17.7 individuals. Pruetz and Bertaloni (2009) also found that the average party size was nearly 50% of the actual community size. If the BO group of 17 individuals is assumed to be an average wet season party size, the actual community group size may be close to 34 individuals. A more conservative method is to assume that 17 individuals is the maximum subgroup size at BO and may account for 60% of the total group size (Yamagiwa et al. 1992). This assumption is based on observations of East African
chimpanzee groups in Budongo, Uganda and Gombe, Tanzania (Yamagiwa et al., 1992). This would estimate the BO community at approximately 28 individuals. This population size would be within the average range for chimpanzee community size as well as above the threshold group size for a sustainable population. Both KR and BO study sites appear to be similar in population density and probable group size as other chimpanzee communities in Senegal and should be considered significant populations in chimpanzee conservation efforts.

In January 2011, I revisited the largest nesting sites found in BO during the summer field season and found that chimpanzees appeared to have been nesting in these areas continuously, as old, recent and fresh nests were found. The center of the BO chimpanzee range appears, thus far, to be located alongside the mountains targeted for the iron mine near the villages of Bofeto, Faramakhono, and Babouya.

Surveying Methods

The surveying methods used in the study follow the Best Practices Guidelines for Surveys and Monitoring Great Ape Populations (Kühl et al., 2008). Line transects were placed systematically throughout the landscape in relation to the proposed mining sites and were not based on habitat coverage or human habitation. Additionally, I based my survey design on previous research in the region. With the understanding that savanna chimpanzees tend to be more dispersed over the landscape and that other survey studies in West Africa used 3km transects (S. Regnaut, pers. comm.; Pruetz et al, 2002) I chose to double this transect length. However, due to fragmented or mosaic habitat in southeastern Senegal, distance transect surveys may not accurately measure chimpanzee populations. Apes do not utilize all habitats equally for nesting and, as seen in both KR and BO, appear to have preferred habitats for nesting sites.
These nesting sites did not fall along the transects, resulting in skewed densities, particularly in the BO site where despite having recorded 217 nests in the study site only four nests were observed from the transects.

Kühl et al. (2008) acknowledges the unequal distribution of surveyed objects due to such variables as preferred habitats and vegetation, feeding sites, and water sources. For accurate measures of abundance, more transects would be needed at both sites so as to assure each transect will encounter nests. However, if time and monetary constraints exist, one must chose between increased accuracy in a smaller area or decreased accuracy but more information for a larger landscape. Ideally, without external constraints, both field sites would incorporate more transects with a smaller inter-transect distance, thus increasing accuracy and the possibility of encountering frequented nesting sites while retaining long transect distances.

**Habitat**

Chimpanzees were found to nest in habitats that make up a very small portion of the habitat available to them. In KR, the chimpanzees nested frequently in gallery forests, which were so rare in the study site that none were recorded along the interval data collection points. Over half of the nests (50.9%) occurred in less than 4% of available habitat. The majority of nests were found in an area of 72km$^2$. While approximately half of the nesting occurred in the woodlands, this does not indicate a significant preference for the habitat type ($X^2=0.0296$, df=1, $p=0.001$). Sample sizes for the other habitats were too small to calculate preferences.

In BO, chimpanzee nests occurred almost exclusively in woodland habitat, which makes up less than half of the available area at the study site. However, the majority of the nests were found only in a specific area of approximately 14.3 km$^2$ in the northern portion of the study site.
The chimpanzee population of Bofeto shows a significant preference for woodland habitat ($X^2=174.286$, df=1, $p=0.001$). Sample sizes for the other habitats were too small to calculate preference.

It is important to note that the study sites examined here may not include the entire home range of the chimpanzees. However, other field studies in Senegal have found that gallery forest habitat is relatively rare in southeastern Senegal comprising only 3% of the habitat at Assirik (McGrew et al., 1981) and 2% of the habitat at Fongoli (Pruetz and Bertaloni, 2009). Woodland habitat at Assirik and Fongoli is also similar to that of the sites in this study, comprising 37% and 46%, respectively (McGrew et al., 1981; Pruetz and Bertaloni, 2009).

It should also be noted that old and rotten nests recorded during May-August are nests that were built during the previous dry season and therefore indicate the habitat preferences of chimpanzees nesting in the dry season. At the Fongoli field site, habitat use changes with the season; forests are used more frequently in the dry season than in the wet season whereas woodland habitat is used more frequently in the wet season (Pruetz and Bertaloni, 2009).

Future research may benefit from more specific habitat classifications as used in Yangambi classification system (Trochain, 1957). This system includes 27 different vegetative classifications, and while many of the classes are not represented in the study sites of this study, the habitat types that are seen in this area are broken down into more specific units than those used in this study. For example, the classification of woodland used in this study includes both the forêt dense sèche (dry forest), forêt claire (woodland), and cordons ripicoles (riparian vegetation) of the Yangambi classification system. Gallery forest as used in this study includes forêt-galerie (riparian and gallery forest) and galeries forestières (gallery forest). While the classification system used in this study suffices for the current research, use of the Yangambi
system of classification may prove more successful for future collaboration and comparative work with The United States Geological Survey (USGS) and the new habitat map of southeastern Senegal (USGS/EROS, 2011).

**Human Disturbance**

Chimpanzee populations in West Africa have been reported to actively avoid areas of human disturbances (Brncic et al., 2010; Garnier 2008; Garnier and Martinez, 2004), but the results of this study indicate that not all chimpanzee communities avoid such areas, at least according to the measures used here. I found a difference in the number of chimpanzee nests located in disturbed areas between the two study sites, with the majority of nests in the KR site outside human disturbed areas and the majority of nests in the BO site within human disturbed areas. The differences between nesting activity in anthropogenically disturbed areas may be related to factors such as changes in human population density, other chimpanzee communities surrounding the study sites, and proximity to permanent water sources.

Changes in human population density in and around the KR site may have already resulted in the displacement of chimpanzee populations. The villages of Kharakhena, Bambadj and Lingeya are relatively old (approximately 25 years). However, newer villages such as Gambagamba, Dialadokhoto, and the ArcelorMittal exploration camp were created in the past eight years. Areas of suitable nesting habitat are located around these newly created villages and, according to local inhabitants, chimpanzees were known to nest previously in these areas and drink at water sources that are now used for human activities. At the BO site, no new villages have been created in the past 10 years. Both Babouya and Feramakhono have been inhabited for over 30 years, and the 10-year old settlement of Bofeto was actually a resettlement
of the same village. The ArcelorMittal mining camp is the only new settlement in the area and was established in 2008. The villages closest to the chimpanzee nesting sites in BO are also much smaller villages than those found in the KR site, with approximately 60 people living in Babouya and 20 people in Feramahono. Comparatively, the villages of Bambadji, Kharakhena, and Gambagamba have approximately 500, 130, and 120 residents respectively (A. Sene – Ankh Consultants, pers. comm.).

The region around Kharakhena has been targeted for gold and iron exploration on and off from 1957 - 1982 by the Bureau de Recherches Géologiques et Minières (BRGM) and Mines de Fer de Sénégal Oriental (MIFERSO) (Schwartz and Melchor, 2004). Gold exploration by multiple mining companies has been continuous in the area since the early 1990s, including AMNERCOSA, Ashanti, AGEM and Randgold (S. Keita, pers. comm.). The BO site has also been targeted for iron ore extraction by BRGM and MIFERSO, but gold exploration has not been as heavy as in the KR site. Gold exploration around Kharakhena has increased the local human population due to the increase in job opportunities from gold exploration companies as well as the influx of artisanal gold miners looking to exploit the newly discovered areas of gold too small or of too poor quality to be exploited by a corporation.

Another possible explanation as to why chimpanzee communities in the BO site are nesting in areas of human disturbance may be the presence of other chimpanzee communities living in neighboring areas. Chimpanzees that live in close proximity to other chimpanzee communities are known to show aggressive territorial behaviors (Goodall et al., 1979; Herbinger et al., 2001). If chimpanzee population density is greater in the southern region of Senegal around the BO site, the population living around the villages of Feramakhono, Bofeto and Babouya may not be able to use available habitat to the north due to the presence of other
chimpanzee groups. Further studies are needed around both study sites to determine whether or not other chimpanzee communities are inhibiting the movement of those living around both the KR and BO sites.

Lastly, the distribution of chimpanzee nests may be independent of human disturbance but dependent on permanent water sources. The majority of nests (63.6% in KR and 93.1% in BO) were located within 2km of a permanent water source. Water sources are valued resources to chimpanzees in the dry season when many smaller water systems dry up (Pruetz & Bertolani, 2009). Proximity to water may be more vital to chimpanzee movement than areas of human disturbance.

Continued monitoring of the areas studied here will be necessary to understand how the current chimpanzee populations living at both sites will react to an increase in human disturbance by the creation of open pit mines. Both study areas have large nesting sites in close proximity (within 1km) of a proposed mining site. Using the Sabodala gold mine in Senegal and Yekepa iron mine in Liberia to estimate disturbed area, it is expected that an open pit mine would directly affect a 25km$^2$ area. Of the nests observed in KR and BO, 72.2% and 88.2% of nests, respectively, are within 5km of the proposed mining sites. With increases in noise, vehicular movement, vibrations and various other disturbances from the mines, many, if not all, of the nearby nesting sites will not be available in the coming years.

It is possible that the buffer sizes used in this study are not optimal in terms of chimpanzee behavior. It is apparent in this study, as well as at the Fongoli field site, that chimpanzee communities are not consistent in their avoidance and use of habitats near human disturbed areas. Nesting sites are found in close proximity to some villages (such as Feramohono and Babouya at the BO site) and areas of cultivation, while other villages
(Kharakhena, Gambagamba and Lingeya at the KR site) and fields are avoided. Chimpanzee communities may respond differently to each village on a case by case basis depending, for example, on the duration of the village or the behavior of the inhabitants.

Seasonality may also play a role in chimpanzee use of disturbed areas, particularly for areas of cultivation and tree cutting by herders. Tree cutting by herders and mining exploration activities occur typically in the dry season, whereas cultivation occurs in the rainy season. The data from this study illustrates nesting locations primarily for the dry season. A year round study should be conducted to identify whether chimpanzees are nesting in these areas throughout the year or avoiding areas during periods when human presence increases.

Cultural behaviors

While most evidence of cultural and behavioral activities in chimpanzees has come from habituated communities (Whiten et al., 2001), it is possible to understand some behaviors without directly observing the animals. This method, however, is limited as few artifacts are left behind. Only two putative brush-tipped termite fishing tools were opportunistically found at the KR study site indicating that further research and focus may be placed on searching for signs of behaviors by targeting ant nests, caves and water sources with camera traps and recurring visits to each site to look for indirect evidence of chimpanzee use.

Camera traps placed around the KR site did capture chimpanzee activity including general behaviors such as eating, drinking, grooming and resting. The putative cultural behavior recorded with the cameras was cave use. Another behavior recorded by the camera traps was nighttime activity. The chimpanzees were photographed visiting a water source at 3am, May 21, 2011, a behavior not observed in other chimpanzee populations outside of Senegal. The
chimpanzees of Fongoli, however, have also been observed leaving their nests during the night to eat, drink, soak in water, and socialize (Pruetz, unpublished data).

Remnants of *Saba senegalensis* fruit found inside the cave suggest that the chimpanzees in the KR may use the caves on Mt. Kharakhena Ndi, but no chimpanzees were captured on camera at these caves. Dry season camera trapping at water sources will increase the likelihood of capturing chimpanzees soaking in pools of water if this behavior is present in the KR and BO communities.

One of the unique behaviors seen only in Senegal’s Fongoli chimpanzee community is hunting bushbabies (*Galago senegalensis*) with tools (Pruetz and Bertaloni, 2007). Hunting behavior was not observed during this field study, but further efforts should be encouraged to study this behavior with non-habituated chimpanzees through indirect methods. Studies of bushbaby ecology and natural history (ie. preferred nesting trees and habitat) coupled with direct observational studies of chimpanzee tool making and hunting will allow researchers to develop an appropriate methodology to study bushbaby hunting indirectly.

**Mine Construction**

In December 2011, construction for the Bofeto Mine near the village Bofeto is expected to begin. Mine construction timelines for the Kharakhena Mountains and Kourou Diakhoma Mountain within the KR study site have not yet been released but are expected to follow the Bofeto mines (A. Niang, pers. comm.). As mine construction begins, dramatic changes to the landscape, habitats, water, air, fauna and human population are expected to take place. Excavation will soon take place on the three peaks of the Koudekourou Mountains. With construction and subsequent extraction of iron, increases are expected in road infrastructure,
vehicular movement, noise, air and water pollution, and human populations. An increase in human presence may lead to increased hunting as immigrants from Guinea and Mali (where chimpanzees are hunted (Kormos et al., 2003)) seek work at the mine, despite the current lack of bushmeat hunting by the local Senegalese populations (Garnier and Martinez, 2004). Available habitat for chimpanzee nesting and feeding is expected to decrease as will access to water sources located near the mines. I expect chimpanzee populations to be displaced from some of their current nesting areas, which are located within 5km of the mountain.

Potential areas of displacement for chimpanzees are based on available habitat seen on the USGS habitat maps of the region (USGS/EROS, 2011) as well as possible deterrents, such as areas of human habitation, cultivation and roads. For the KR chimpanzees, areas to the north and west appear to be the most suitable areas for dispersal with permanent water sources, suitable nesting habitat and few areas of human disturbance. The southwestern region also has suitable habitat without villages or areas of cultivation. This area, however, may become isolated due to the newly paved Bamako-Dakar highway to the north, densely populated area further west (Saraya), human impacted area to the east and road networks to the south.
Figure 15. Potential corridors for chimpanzee dispersal at KR. Red circles indicate current chimpanzee territories. Blue hashed areas indicate possible areas of dispersal. White areas indicate areas of human disturbance including villages, areas of cultivation and roadways.

For the chimpanzee population in the BO site the north and northwestern regions appear to be the most suitable area for dispersal. This area is approximately 100km² and includes the Boboti River, which provides a permanent water source and gallery forests. However, like the region to the southwest of KR, this area may become cut off from other chimpanzee populations in the future. It borders the highly populated areas of Nafadji to the west, a large artisanal gold
mine in the village of Boboti to the east, a transit route from Nafadi to Boboti to the north and proposed ArcelorMittal mine sites to the south.

Figure 16. Potential corridors for chimpanzee dispersal at BO. Red circles indicate current chimpanzee territories. Blue hashed areas indicate possible areas of dispersal. White areas indicate areas of human disturbance including villages, areas of cultivation and roadways.
Conservation Planning

In terms of conservation efforts, regions targeted for resource extraction should not be overlooked simply because they are of economic value. These areas, such as the Falémé region, may be rich in biodiversity and threatened and endangered species. These areas may also be important for creating corridors and links between nationally protected areas. As mining begins in the Falémé region, it is important to set aside land as community reserves to preserve the remaining habitat and travel corridors for wildlife. Community monitored and managed reserves would allow local individuals to continue utilizing forest resources at more sustainable levels.

While species richness has not been calculated for the Mining Zone, it is believed to be similar to that of Niokolo Koba National Park (PNNK) which, when created in 1981, was home to 84 species of mammal, over 330 species of bird, 38 reptiles, 20 amphibians, 60 species of fish and an undocumented number of invertebrate species (UNESCO, 2008). The region is not only home to chimpanzees, an endangered species in Senegal, but also the critically endangered Derby Eland (*Tragelaphus derbianus derbianus*), endangered African wild dog (*Lycaon pictus*), Slender nosed crocodile (*Crocodylus cataphractus*), Dwarf crocodile (*Osteolaemus tetraspis tetraspis*) and vulnerable but regionally endangered African Lion (*Panthera leo*). In the southeastern region of Senegal there are eight species of mammals that are threatened to some degree, two endangered reptiles, two newly identified species of unclassified, endemic snakes and six species of vulnerable birds. Three plant species in the region are listed as vulnerable by the IUCN, four are partially protected, two are fully protected, and one is locally endangered (Table 1).
Table 2. Endangered, threatened and protection status of species in the Mining Zone of Senegal

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Status</th>
<th>Protection status</th>
<th>Comments</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MAMMALS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>African wild dog</td>
<td><em>Lycaon pictus</em></td>
<td>EN</td>
<td>Partial</td>
<td>PNNK</td>
<td>IUCN Redlist</td>
</tr>
<tr>
<td>West African chimpanzee</td>
<td><em>Pan troglodytes verus</em></td>
<td>EN</td>
<td>Full</td>
<td>PNNK</td>
<td>IUCN Redlist</td>
</tr>
<tr>
<td>Hippopotamus</td>
<td><em>Hippopotamus amphibious</em></td>
<td>VU</td>
<td>Females - Full Males – Partial</td>
<td>Populations in West Africa are at highest risk due to fragmentation, PNNK</td>
<td>IUCN Redlist</td>
</tr>
<tr>
<td>Leopard</td>
<td><em>Panthera pardus</em></td>
<td>NT</td>
<td>Full</td>
<td>PNNK</td>
<td>IUCN Redlist</td>
</tr>
<tr>
<td>African Lion</td>
<td><em>Panthera leo</em></td>
<td>VU</td>
<td>Females - Full Males – Partial</td>
<td>Regionally endangered in West Africa, PNNK</td>
<td>IUCN Redlist</td>
</tr>
<tr>
<td>Northwest African Cheetah</td>
<td><em>Acinonyx jubatus hecki</em></td>
<td>CR</td>
<td>Full</td>
<td>May be extirpated in Senegal</td>
<td>IUCN Redlist</td>
</tr>
<tr>
<td>Senegal Hartebeest</td>
<td><em>Damaliscus lunatus korrigum</em></td>
<td>VU</td>
<td>Full</td>
<td>May be extirpated in Senegal; seen in PNNK within the last decade.</td>
<td>IUCN Redlist</td>
</tr>
<tr>
<td>Derby Eland</td>
<td><em>Tragelaphus derbianus derbianus</em></td>
<td>CR</td>
<td>Full</td>
<td>PNNK and Faleme region</td>
<td>IUCN Redlist; Sournia and Dupuy 1990</td>
</tr>
<tr>
<td><strong>REPTILES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Senegal Garter Snake</td>
<td><em>Elapsoidea trapei</em></td>
<td>NL</td>
<td>Full</td>
<td>Endemic species</td>
<td>Mane 1999</td>
</tr>
<tr>
<td>Confusing egg eater</td>
<td><em>Dasypeltis confuse</em></td>
<td>NL</td>
<td>Full</td>
<td>Endemic species</td>
<td>Trape and Mane 2006</td>
</tr>
<tr>
<td>Slender nosed crocodile</td>
<td><em>Crocodylus cataphractus</em></td>
<td>EN</td>
<td>Full</td>
<td>May be extirpated in Senegal</td>
<td>IUCN Redlist</td>
</tr>
<tr>
<td>Dwarf crocodile</td>
<td><em>Osteolaemus tetraspis tetraspis</em></td>
<td>EN</td>
<td>Full</td>
<td>Tentatively observed at KR site</td>
<td>IUCN Redlist</td>
</tr>
</tbody>
</table>
## Table 2. Continued

<table>
<thead>
<tr>
<th>BIRDS</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Black crowned crane</td>
<td><em>Balearica pavonina</em></td>
<td>VU</td>
<td>Full</td>
<td>Around Kedougou</td>
</tr>
<tr>
<td>Beaudouin's Snake Eagle</td>
<td><em>Circaetus beaudouini</em></td>
<td>VU</td>
<td>Full</td>
<td>Throughout Senegal</td>
</tr>
<tr>
<td>Lesser kestrel</td>
<td><em>Falco naumanni</em></td>
<td>VU</td>
<td>Full</td>
<td></td>
</tr>
<tr>
<td>Egyptian Vulture</td>
<td><em>Neophron percnopterus</em></td>
<td>VU</td>
<td>Full</td>
<td>Rarely seen in Kedougou region, including PNNK</td>
</tr>
<tr>
<td>Lapped faced vulture</td>
<td><em>Torgos tracheliotus</em></td>
<td>VU</td>
<td>Full</td>
<td>Rarely seen in Kedougou region, including PNNK</td>
</tr>
<tr>
<td>White headed vulture</td>
<td><em>Trigonoceps occipitalis</em></td>
<td>VU</td>
<td>Full</td>
<td>Rarely seen in Kedougou region, including PNNK</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PLANTS</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>African Mahogany</td>
<td><em>Khaya senegalensis</em></td>
<td>VU</td>
<td>Partial</td>
<td>Targeted by transitory sheepherders; occurs in PNNK and outside park. Chimpanzee nesting tree.</td>
</tr>
<tr>
<td>Shea tree</td>
<td><em>Vitellaria pardoza; Butyrospermum parkii; B. paradoxa</em></td>
<td>VU</td>
<td>Full</td>
<td>PNNK and outside park. Important resource for humans. Chimpanzee food.</td>
</tr>
<tr>
<td>Gueno (Malinke)</td>
<td><em>Pterocarpus erinaceus</em></td>
<td>NL</td>
<td>Partial</td>
<td>PNNK and outside park. Targeted by transitory sheepherders. Important forage resource for humans’ livestock. Chimpanzee food.</td>
</tr>
</tbody>
</table>
Table 2. Continued

<table>
<thead>
<tr>
<th>Jackalberry</th>
<th><em>Diospyros mespiliformis</em></th>
<th>NL</th>
<th>Full</th>
<th>PNNK and outside park. Chimpanzee food.</th>
<th>EIA Sabodala Gold Mine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duguto (Malinke)</td>
<td><em>Cordyla pinnata</em></td>
<td>NL</td>
<td>Partial</td>
<td>PNNK and outside park. Chimpanzee food.</td>
<td>EIA Sabodala Gold Mine</td>
</tr>
<tr>
<td>Sambe (Malinke)</td>
<td><em>Grewia bicolor</em></td>
<td>NL</td>
<td>Partial</td>
<td>PNNK and outside park. Chimpanzee food.</td>
<td>EIA Sabodala Gold Mine</td>
</tr>
<tr>
<td>Hallea stipulosa</td>
<td><em>Hallea stipulosa</em></td>
<td>VU</td>
<td></td>
<td></td>
<td>IUCN Redlist</td>
</tr>
<tr>
<td>Bindura bamboo</td>
<td><em>Oxytenanthera abyssinica</em></td>
<td>NL</td>
<td></td>
<td>Only native bamboo species to Senegal; Regionally endangered</td>
<td>CBD action plan, 1994</td>
</tr>
</tbody>
</table>

CR – Critically endangered; EN – Endangered; VU – Vulnerable; NT – Near threatened; NL – Not listed

* Protection status for all animals come from Senegal’s Hunting and Wildlife Protection Code of 1986 (IUCN Environmental Law Centre. 1986).
While biodiversity data are scarce in Senegal, systematic conservation planning incorporates more than simply data on species, taxa and biodiversity to create protected areas. Analyses may also include land use practices, as seen in modeling for the proposed Biosphere Reserve plan in Bioko, Equatorial Guinea (Zafra-Calvo et al., 2010) or hunting pressures and anthropogenic influences when designating protected areas (Buckingham and Shane, 2009). Furthermore, allocation of land for protected areas is more successful when the support and knowledge of local communities is included in the process (Wadley et al., 2010; Ban et al., 2009a; Ban et al., 2009b; Henson et al. 2009). As southeastern Senegal faces increased human populations and anthropogenic changes, each of these parameters is necessary to develop a successful conservation plan.

All stakeholders in the region including members of rural communities, local department governments, Water and Forestry Department (EFCCS), NGOs, international mining companies and research organizations should be included in the creation of a systematic conservation plan. Each stakeholder has in investment in the land and needs that must be met. In order to be successful in creating a sustainable management plan for the region all partners must be involved and the process must be transparent.

In order to prioritize conservation areas, areas of critical habitats for endangered and threatened species, such as gallery forest and woodland for chimpanzees, including permanent water sources must be identified. Areas of cultivation and resource exploitation, such as mining, must also be delineated, and appropriate buffer zones for anthropogenic disturbance should be established. Finally, all protected areas and existing conservation area networks must be identified, e.g. the Zone d’Interet Cynegetique of Falémé and local community reserves. After having identified these areas, a network of community conservation reserves may be established.
Decreasing human activity in these areas to sustainable levels, such as minimizing cultivation, deterring transient herders, and establishing limits for resource extraction, should be encouraged. As chimpanzees are able to live within and near areas impacted by humans, it is not necessary to completely stop local human populations from entering and utilizing the forests. However, it is important that sustainable practices be put into place. Ultimately this network would create ecological corridors that will link chimpanzee communities to one another and provide dispersal opportunities for migrating females.

Conclusions

The data collected from this study will ultimately help the conservation community better understand the effects of mining on chimpanzee populations. To effectively evaluate changes once the iron mine is created and in production I will continue to study the distribution and behavioral responses of the chimpanzee communities in these study areas. Specific conservation action plans for Senegal’s West African chimpanzees, and perhaps those elsewhere, can then be created with reference to metal mining and human disturbances.

Collaboration with mining companies is imperative to chimpanzee conservation efforts. In January 2011, I was able to meet with chief geologist Abdoulaye Niang, who is directing all environmental aspects of the ArcelorMittal project in the Faleme region. Mr. Niang was very supportive of my project, and I look forward to sharing information and collaborating throughout the course of this project with him. Final results of this project will be presented to the local communities around the two study sites and to ArcelorMittal. Results will include critical areas of use and travel corridors necessary for dispersal and movement of the local chimpanzee
groups, such as the areas to the north and southwest of KR and to the north of BO, as well as potential areas for future research.

The project also increases awareness and educates the local Senegalese communities on chimpanzees through researcher presence in the area, employment of local individuals and initiating community education projects. Future endeavors in the region will include environmental and conservation education programs at schools and villages. Local human populations are generally unaware of the importance of and level of threat to chimpanzees in the area (Carter et al., 2003); it is therefore necessary to encourage their involvement and to promote education. Recent findings show that the sheer presence of researchers in a wildlife region results in a decrease in wildlife poaching around the research station (Campbell et al., 2011). Research presence in the area can also provide a voice for the environment and for chimpanzee communities. Environmental impacts by large-scale mining operations on the habitat and indigenous species must not be overlooked during organizational meetings and conferences such as the Senegalese Mining Conference. This conference was last held in Dakar in 2010, but my request to present my current research on chimpanzees living in mining concession zones was denied.

Finally, the data collected on population demographics and abundances will be contributed to the APES database\(^3\) of chimpanzee populations. Researchers from the Max Planck Institute are compiling data from across Africa to produce an ape surveillance system. Data collected during the proposed project will be added to the database upon analysis.

\(^3\) http://apes.eva.mpg.de/eng/index.php
**BIBLIOGRAPHY**

African Development Fund (ADF) 2005. Road rehabilitation and transport facilitation programme on the southbound Bamako-Dakar corridor. Department of Infrastructure Central and West Regions.


Pruezt JD and T LaDuke 2010. Reaction to fire by savanna chimpanzees (Pan troglodytes verus) at Fangoli, Senegal: Conceptualization of “fire behavior” and the case for a chimpanzee model. American Journal of Physical Anthropology 141 (4) 646-650.


USAID. 2008. Senegal Biodiversity and Tropical Forests Assessment: Prosperity, livelihoods and conserving ecosystems, (“Senegal 118/119 Assessment”) IQC Task Order #1


United States Forestry Service (USFS). 2006. Rapid Assessment of Existing Social, Economic and Biological Conditions within the Zone d’Interet Cynégétique de Falemé and Recommendations for Future Management. USDA Forest Service International Programs Technical support to USAID/Sénégal and the Wula Nafaa Project.


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