POPULATION ESTIMATE AND DISTRIBUTION OF THE WESTERN CHIMPANZEE (*Pan troglodytes verus*) IN SAPO NATIONAL PARK, LIBERIA

BY

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DECLARATION BY THE CANDIDATE

This thesis is my original work and has not been presented for a degree in any other university or any other award.

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DEDICATION

This work is dedicated to my beloved mother, Christina M. Tweh, my inspiration, the late Mr. Edison B. Tweh and my dear friend Jessica Junker.

Thanks for your unfailing support in ensuring that I always achieved what I desired in Life and for setting the stage that challenged me to achieve further education.

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LIST OF ACRONYMS AND ABBREVIATIONS

BZ	Buffer zone
FDA	Forestry Development Authority
FFI	Fauna Flora International
IUCN	International Union for the Conservation of Nature
LEP	Local Empowerment Program
NTFP	Non Timber Forest Product
OHA	Other Human Activities
SNP	Sapo National Park

ABSTRACT

The western chimpanzee (*Pan troglodytes verus*) has recently been uplisted from endangered to "Critically Endangered category" in the IUCN Red List. It is therefore key to monitor population status and trends of the remaining chimpanzee populations in the region, which is frequently done by counting sleeping nests of individuals along line transects. In tropical forests, permanent line transects can facilitate the passage of surveyors, but may also cause avoidance by animal species, which complicates data analysis and may yield erroneous estimates. In this study, surveys were conducted in Liberia's Sapo National Park (SNP) and its buffer zone along clear-cut ('permanent') and uncut ('temporary') line transects to estimate chimpanzee abundance and compare chimpanzee densities inside and outside the park and determine the impact of human activities on the survival of the chimpanzees. All indirect signs of chimpanzee presence and human activities were recorded on 16 permanent transects in SNP and six temporary transects within the surrounding buffer zone. The analysis of this study revealed a population density of 0.83 individuals/ km^2 (CV= 0.29) across the park and its buffer zone. Compared to previous estimates, this suggests a relatively stable population of roughly 1,000 chimpanzees over the past eight years and represents 15% of the total population of about 7000 chimpanzees in Liberia. Despite the presence of human threats in and outside the park, it appears that poaching and habitat encroachment, which has been persisting in the area since the first chimpanzee survey in 2009, did not have a significant negative affect on population growth over time. Possible reasons for this include the existence of local taboos against killing chimpanzees, poachers not targeting chimpanzees directly, and chimpanzee behavioral flexibility. Nest encounter rate inside the park was considerably lower than in the buffer zone and significantly fewer nests were found on or near permanent transect lines (19%) than temporary transects (44%), indicating an avoidance effect of chimpanzees towards the former. The study also shows that permanent transects were frequently used as passageways by illegal miners and poachers, providing direct evidence of the impact that humans have on chimpanzee habitat use and the potential negative implications of cutting permanent transect lines on wildlife in the park. There is a need for an increase in conservation and law enforcement efforts to prevent humans from accessing the park. Furthermore, it is also necessary for the legal enforcement of the park's buffer zone in order to effectively protect wildlife against poaching, habitat destruction and disease, and ensuring the continued survival of chimpanzees in Liberia's oldest national park.

Keywords: Chimpanzees, hunting, Sapo National Park, line transect, buffer zone, conservation planning

CHAPTER ONE

1.0 INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Chimpanzees (*Pan troglodytes verus*) are often used as an indicator species in studies related to biodiversity and improving our understanding of the environment (Francais *et al.,* 2001). The species have been widely studied because of their high sensitivity to changes in the environment and their ecosystem functions (such as seed dispersal) (Richard *et al.,* 1994). Often, chimpanzees are a significant component of forest ecosystems by contributing to seed dispersal, regeneration of forests and ecosystem health (Estrada *et al.*, 2017). Like most animals, they also serve the function of predator-prey in the food web hence influencing the way in which an ecosystem works (Lonsdorf, 2006). When selecting their habitats, chimpanzees often use ultimate and proximate factors such as food availability, space, shelter (free from predators), habitat structure and other animals (to avoid competition) (Pruetz *et al*., 2008). As a result, success in the study and conservation of chimpanzees depends on deeper understanding of their habitat requirements (Anne *et al.*, 2007). For instance, chimpanzees have evolved physical structures and behavioral patterns that represent their unique characteristics as well as those that enable them to select particular habitat types and high quality niches to enhance their fitness (Koops *et al.,* 2007; Stewart & Pruetz 2013). Variations in these underlying ecological factors may cause population fluctuations and changes in composition of the populations. These evolutionary processes have been accelerated by human alteration of forest ecosystems that offer habitats to wildlife through habitat destruction and fragmentation hence causing rapid loss of biodiversity, (Myer *et al.*, 2000; Primack, 2010).

Loss of biodiversity is now evident in tropical forests (world's richest terrestrial ecosystems) that are rapidly disappearing due to pressure from increasing human activities such as, intensified agricultural, logging, mining, urbanization and over-exploitation of natural resources (Brooks *et al.*, 1999; Primack, 2010; Fuller, 2012). Due to habitat loss, direct hunting, poor enforcement of law/policies, poaching due to high demand for bushmeat, and illegal pet trade (Tweh *et al.*, 2014; Brugiere *et al.*, 2003), the Western chimpanzee (Pan *troglodytes verus*) has become one of the most endangered of the four current recognized subspecies of the chimpanzee (Brugiere *et al.*, 2003). In relation to the pet trade, adults are often killed so their young can be taken (Kabasawa, 2009), with animal welfare being compromised to some extent at all stages of the exotic pet trade (Bush *et al.*, 2014).

Chimpanzees have a range of environmental conditions under which they can survive, grow and reproduce. Many studies in tropical forest have shown that the forest structure, tree canopy, tree density and understory are strong determinants of wild chimpanzee species richness, community composition, and distribution (Torres *et al.*, 2010; Bortolamiol *et al.*, 2014). The fragmentation of their habitats also affect rare forest specialist species that are usually sensitive to changes in the habitat (Sesink-Clee *et al.,* 2015). In spite of the many challenges facing the conservation and protection of tropical habitats in West Africa through human activities, the region has remained one of the last strong holds of the remaining chimpanzee populations. The combination of threats currently facing the remaining population of the great apes requires immediate conservation action at all scales (Bush *et al.*, 2014). However, conservation and management of chimpanzees in the wild requires adequate knowledge of their distribution and population size (Ancressnaz *et al.*, 2004b). The study was conducted for five months at Sapo National Park (Liberia) and its buffer zone. These areas represent the largest remaining proportion of rain forests in West Africa that offer a habitat to a large population of the Western chimpanzee. The study to estimate the density of the Western chimpanzees was therefore conducted through identification of signs of their presence (nests, dung, and calls) along line-transects (Burnham *et al*., 1980; Koster & Hart, 1988; Kühl *et al.,* 2008).

1.2 Literature Review

1.2.1 Abundance and distribution of the Western chimpanzee

The western chimpanzee has a wide and discontinuous distribution across Africa's landscape. The distribution of the species range in various countries is poorly known, with only few accurate estimates of the population size (Kormos *et al*., 2003). In addition, in the entire African continent, chimpanzee populations have been declining with the population in their known habitats been estimated to be less than 20,000 (Kormos *et al.,* 2003). The Republic of Guinea and Liberia are considered to be the last major stronghold habitats of this sub species. This was after nationwide surveys in these countries in 2010 and 2012 that yielded a conservative estimates of 12,000 individuals in Guinea and 7,000 in Liberia (WCF, 2012; Tweh *et al*., 2014).

Liberia has about 42 % of the last remaining Upper Guinea Forest (Allport, 1991; Brottem & Unruh 2009; Boafo & Massalatchi, 2011). This is part of the biodiversity hotspot (that extends from Ghana through Cote D'Ivoire and Liberia to Sierra Leone to Guinea) listed as endangered among the global 200 critical ecosystems. These forests provide habitats to several rare and threatened species, one of the species being the West African chimpanzee. In spite of this, Liberia has remained a biological "blind spot" on the map due to the 14 years of political instability resulting from civil war (1989- 1997 and 2003-2004). This made the country largely devoid of scientific data. Although the country appears to have experienced drastic decline in quality of habitats for the ape since 1990s, a recent study by Junker *et al.,* (2012) has confirmed that the rainforest in Liberia is a potentially suitable habitat for the Western chimpanzee.

1.2.2 Evolutionary history, ecology and behavior of the Western chimpanzee

Chimpanzees are considered to be closest living relatives of the humans given that they share a significant large number of human genetic code (98.4 % DNA similarity with the humans (Ciccarelli *et al.,* 2006). Furthermore, they have much resemblance of morphological and physiological similarities with the humans (Lonsdorf, 2007). In the current human society, they play a unique role in human culture and religion and provide insight into evolutionary origin of humans.

Chimpanzees live in troops of an organized group where the alpha male is the head. They are organized into distinct linear structure of dominance in which males usually dominate females within their social structure (Goldberg & Wranghan, 1997). The groups may also contain smaller sub groups for a shorter period (Boesch, 1998), that may not be stable (Goodall, 1986). This characteristic of group living enables them to protect their territory and allow them to have a better chance of winning competitions against other groups. The males tend to remain in their biological community while the females emigrate (Nishida *et al.,* 2003). Although the male chimpanzees are often related to each other, maternal kinship tends to lack strong influence on their social behavioral patterns. For example, males compete highly with one another for hierarchy of dominance or position of an alpha male (Goldberg & Wranghan, 1997). Their feeding ecology and pattern of geographical distribution have been linked to angiosperm, although they also feed on flowers, seed, honey, duikers and other monkeys (Goodall, 1986; Pacheco & Simonetti, 2000). Although chimpanzees are considered to be pollinators (Heymann, 2011), their role as consumers of different plants may affect plant reproduction and mortality rate (Chapman *et al.*, 2013).

In relation to behavioral patterns among chimpanzees that have been studied, behavioral ecologists have argued on benefits associated with group living. For example, Boesch (1996) asserted that the social structure of the chimpanzee may be affected by pestilence and the need to defend resources. The social cooperation within the group may have greater significant effects given that it often protects them from being attacked by predators (Goldberg & Wranghan, 1997). It has clearly been reported that the close relationship between chimpanzees serves two purposes; inter-community interaction and intra-community interaction (Boesch, 1996; Estrada *et al.*, 2017). Inter community interaction is best seen during hostile attacks by an adjacent group of male and cooperative boundary lines patrols. Intra-community interaction is characterized by domination by males when the resources are scarce or during foraging in groups (Goldberg & Wrangham 1997). It is therefore not surprising that during social cooperation, the young animals learn survival techniques from experienced parents to ensure that they are proficient in dealing with their society and environment when they grow up (Estrada *et al.*, 2017).

1.2.3 Threats facing survival and reproduction in chimpanzee

According to the IUCN, there have been huge declines in chimpanzee population size across their natural habitats. The most up to date information on the population size of primate species by Estrada *et al.* (2017) estimates about 60% of the species to be threatened with extinction due to unsustainable human activities. Some of the threats affecting regional and global population dynamics include habitat destruction due to agriculture, logging and wood harvesting (Estrada *et* *al.*, 2017), livestock farming, mining and hunting. However, there are other emerging potential threats such as pollution and climate change that cannot be ruled out. At the global scale, the greatest threat to the survival of chimpanzees is habitat destruction with secondary threats varying across the regional scale (Estrada *et al.,* (2017). Globally**,** high market demand for arboreal/non-arboreal crops and hardwood in tropical regions has led to rapid deforestation across Africa with the wood industries playing a key role in worsening the situation (Laurence *et al.*, 2009). For example, over the 10 years period of between 1990 and 2000, agricultural driven expansion in countries with chimpanzee habitats was estimated at 1.5 million km^2 (an area that triples the size of France) (Estrada *et al.*, 2017). The increase in demand for global agricultural products is a key driver of the current rapid decline of chimpanzee population and increases the possibility of having large segmented population existing outside the protected areas (Wich *et al.*, 2014; Tweh *et al.*,2014); Lanjouw *et al.*, 2015; Vijay *et al.*, 2016). Moreover, future oil palm production activities are likely to threaten forested areas across Africa (Vijay *et al.*, 2016). This is projected to have negative implications on chimpanzee population in those regions (Estrada *et al.*, 2017). Similarly, deforestation due to established rubber plantations across countries with chimpanzee habitats has serious impact on their populations (Mazumder, 2014; Fan *et al.*, 2014). An assessment of the overlap between agricultural land and chimpanzee distribution within the 21 century predicts that the habitat range of chimpanzees is expected to undergo the largest agriculture expansion over the next 10 years (Wich *et al.*, 2014; Estrada *et al.*, 2017).

The population of chimpanzees has been threatened by habitat loss to create land for agriculture, especially due to shifting cultivation that promotes forest clearance (Humle & Kormos, 2001). For instance, although the ban on timber export was lifted in 2006, the Ministry of Planning and Economic Affairs in 2010 reported that more than 20,000 km^2 of forest had been assigned as forest concessions awarded to international and local investors. Since this concession came to effect, it has been impossible to quantify the impact of the threat on Liberia's chimpanzee populations because accurate and up-to-date information on their distribution and abundance is either insufficient (Barrie *et al.,* 2007), or discontinuous due to unsystematic field observation (Coe, 1975; Anderson *et al*., 1983; NGoran *et al.*, 2010).

The globalization of financial institutions and commodity production has led to increased demand for tropical timber and expansion of logging industries. This has resulted to deforestation on a larger scale as development of potent economic impetus of road construction network in forest regions increase (Malhi *et al.,* 2014). Countries within which primate range falls are positively responding to worldwide demand for timber by increasing logging activities to maximize their economic potential (Barrett *et al.,* 2010; Estrada *et al.,* 2017). Although deforestation in Liberia was fairly low between 1980s and 2000 (Christie *et al*., 2007), the long term effect and implication of legal and illegal logging has been the loss of natural forest habitat and extinction of important tree species used for food and shelter by chimpanzees (Lewis *et al.*, 2013).

Extraction of minerals is another growing threat to tropical forest ecosystems that affects the chimpanzee ecological habitat (Barrett *et al.,* 2010; Estrada *et al.*, 2017). Both small and large scale mining in the forests often contributes to deforestation, water pollution and soil infertility (Alvarez-Berrios & Aide, 2015). Lanjouw (2014) reported that population densities of apes decreased in the mined forest than sites where mining activities were absent. For instance, in Madagascar, many protected areas have been affected by illegal mining (Duffy, 2007), leaving the primates vulnerable. In March 2005, the United Nations Mission in Liberia (UNMIL) reported that an estimated 5,000 illegal miners lived in the park. By 2010, this number increased to 18,000. By October 2010, the government of Liberia responded to this problem by evicting people from the park (Vogt, 2012). Currently, the impact of the miners on the chimpanzee population of Sapo National park is unknown. Due to its rich natural habitat, Sapo Nation Park has been facing the problem of illegal mining, consequently resulting to the cutting down of large trees that may be used as sleeping platforms and feeding sites by the chimpanzees. Furthermore, the presence of illegal miners is a threat to the survival of chimpanzee by facilitating commercial hunting supported by those who are willing to pay excess amount of money for a small quantity of bush meat.

Hunting has become a major threat to the decline of chimpanzee population in Africa (Gouveia *et al.,* 2014). Population growth and increasing per capita income have led to increased commercial hunting and bush meat consumption (Abernethy *et al.*, 2013; Tweh *et al.*, 2014). Although bush meat is difficult to be detected, reports have indicated that 150,000 primate carcasses are traded annually from West Africa (Fa *et al.,* 2015). Due to the relatively small number of chimpanzee living inside the protected areas (Hickey *et al.,* 2013; Tweh *et al.,* 2014; IUCN, 2014), populations outside the areas are undoubtedly at higher risk of experiencing rapid declines (Tweh *et al.,* 2014; Estrada *et al.,* 2017). Hunting of chimpanzees in the Sapo National Park is forbidden (Nisbett *et al.*, 2003), and is therefore not supported by the local people. However, decrease in chimpanzee population increases demand for bush meat and raises the price of chimpanzee meat, making it key target for poachers who risk intruding into protected areas (Junker, 2008; Rovero *et al.,* 2012). For instance, wildlife survey conducted by Amstey (1991) reported poaching of about 15,000 tons of wildlife in Liberia. This was one of the highest offtake per capital in Africa. According to CEEB (2000-2001), recent survey of bush meat sale revealed that Liberia generated about 8,000,000 USD during a period of less than 1 year from the sale. It has been reported that hunting is one of the major threats to the survival of chimpanzees near Sapo National Park (Greengrass, 2011).While qualitative and quantitative data on chimpanzee's off-take rates across Liberia is scarce, the species appear to be hunted by individuals specializing as chimpanzee's hunters (Lormie *et al. in Prep).*

1.3 SAPO- National Park

The Sapo National Park (SNP) is an important center for biodiversity that represents Liberia's first fully protected park. It is also a regional center of endemism that offers habitat to about 1,517 chimpanzees (N'Goran, 2009). SNP permits environmentally compatible scientific, educational and recreational activities as has been recommended by the IUCN (Dudley, 2008). The park is a site of global conservation concern given that it holds one of the three remaining large blocks of the Upper Guinea rainforests, and represents one of the most-if not the most intact ecosystem in Liberia (Vogt, 2012). Since its establishment in 1983, SNP has been facing numerous threats in its efforts to conserve biodiversity, especially the primates. It is therefore a key area to conduct a study on distribution/population size of the Western chimpanzee (one of the most endangered and endemic primates in West Africa).

1.3.1 Protected areas: a tool for conservation

The conservation of biodiversity has been an issue of global concern since the 20th century. This concern still continues to be expressed among scientists, politicians and pro-nature groups of the world today. There are over 100,000 protected areas worldwide that now cover about 12% of the Earth's land surface (Chape *et al.*, 2005; Primack, 2010). Several studies have reported the successful use of protected areas in the conservation of biodiversity (Bruner et al., 2001; Nagendra *et al.*, 2004; Singh and Gibson, 2011). For example, in their assessment of over 90 protected areas worldwide, Bruner *et al.* (2001) found protected areas to be very effective in stopping forest clearance in the tropics. However, they argued that the efficiency of protected areas as an effective biodiversity conservation tool in the tropics would be more when proper management practices such as law enforcement, boundary demarcation and direct compensation of surrounding local communities are ensured. The International Union for Conservation of Nature (IUCN) defined a protected area as "a clearly defined geographical space (includes land, inland water, marine and coastal areas), recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (Dudley, 2008). Naughton-Treves *et al.* (2005) argued that in addition to an emphasis on biodiversity loss, protected areas policies should also pay attention to poverty and unsustainable land–use in developing countries. This approach has been adopted by Birdlife International under their Local Empowerment Programme (LEP) which seeks to work with local people in the conservation of biodiversity (BirdLife, 2014).

1.3.2 Buffer zones around protected areas

The establishment of buffer zones has become a common practice in protected areas worldwide. Buffer zones play significant role in protecting species with high mobility like hornbills, elephants, etc and also in reducing edge effect on protected areas (Shafer, 1999; Barzetti, 1993; Martino, 2001). Sayer (1991) defined buffer zones as areas "peripheral to a national park or equivalent reserve, where restrictions are placed upon resource use or special development measures are undertaken to enhance the conservation values of the area". A buffer zone may be established inside or outside a protected area (Ebregt and Greeve, 2000). According to Ebregt and Greve (2000), there are two views about buffer zones from nature conservationists: for the 'hard-core' conservationists, the buffer zone serves only to avoid negative human impact on the core area, while socio-conservationists see the buffer zone as a part of the socio-economic development of the entire area comprising conservation and non-conservation sub-areas. Buffer zones have been used as important conservation strategies for a wide variety of sites of biodiversity importance, including World Heritage Sites, Biosphere Reserves and IUCN Protected Area categories. However, the success of buffer zone management depends very much on the participation and support of local communities around the protected area (Ebregt and Greeve, 2000). A recent study in the Chitwan National Park, Nepal showed how the use of buffer zones improved tiger conservation in Nepal with the participation of local stakeholders (Carter, 2012).

1.4 Justification of the Study

Many years of civil war (1989-2003) left Liberia largely devoid of biological data. Furthermore, previous data that had not been stored in a database system was eventually lost during the civil war. There is still limited baseline data on the distribution and abundance of chimpanzee population in Liberia. This paucity of data prompted Komos *et al.*, (2003) to recommend nationwide chimpanzee survey and continuous research as one of the priority action plans in the conservation of chimpanzees in Liberia. It's has therefore become necessary to fill the existing data gaps in relation to the abundance and distribution of chimpanzee population.

In order to restore Liberia's remaining chimpanzees and wildlife population, it has become necessary to investigate the population status and distribution of the species within protected areas, such as the SNP. This will assist the government to put into place a strong and effective management and conservation strategies to protect wildlife populations. With increasing human population and unlimited needs, chimpanzees will continue to face huge challenges over the next decade. The findings of this study were expected to play a critical role in ensuring the protection and conservation of the Western chimpanzee and its habitats in the SNP.

1.4.1 Main Objective

The overall objective of this study was to estimate the population and distribution of western chimpanzees in Sapo National Park and its buffer zone, as well as to assess the impact of human threats on survival of the chimpanzee.

1.4.2 Specific Objectives

i) To determine the abundance and distribution of chimpanzees in the SNP and its buffer zone

ii) To investigate the anthropogenic threats affecting chimpanzee nest distribution in SNP and buffer zones

iii) To determine the effect of habitat variables on chimpanzee nest site selection

1.5 Hypotheses

i) Abundance and distribution of chimpanzees did not vary significantly between its habitat in SNP and buffer

ii) Human presence did not affect chimpanzee distribution and within SNP and buffer zone

iii) Habitat variables did not vary significantly between vegetation characteristic in SNP and its buffer zone and nesting plots across habitat types.

CHAPTER TWO

2.0 THE STUDY AREA, MATERIALS AND METHODS

2.1. Geographical Location

The study was carried out in Sapo Nation Park (SNP) and surrounding buffer zone (located in the South-eastern part of Liberia) and lies between latitude 5°-6°N and longitude 8°-9°W (Figure 2.1). It is approximately 180,356 hectares (ha) surrounded by 3km stretch of buffer area in size (Vogt, 2012). The park is about 500km from the center of Monrovia at the bearing of 102°.

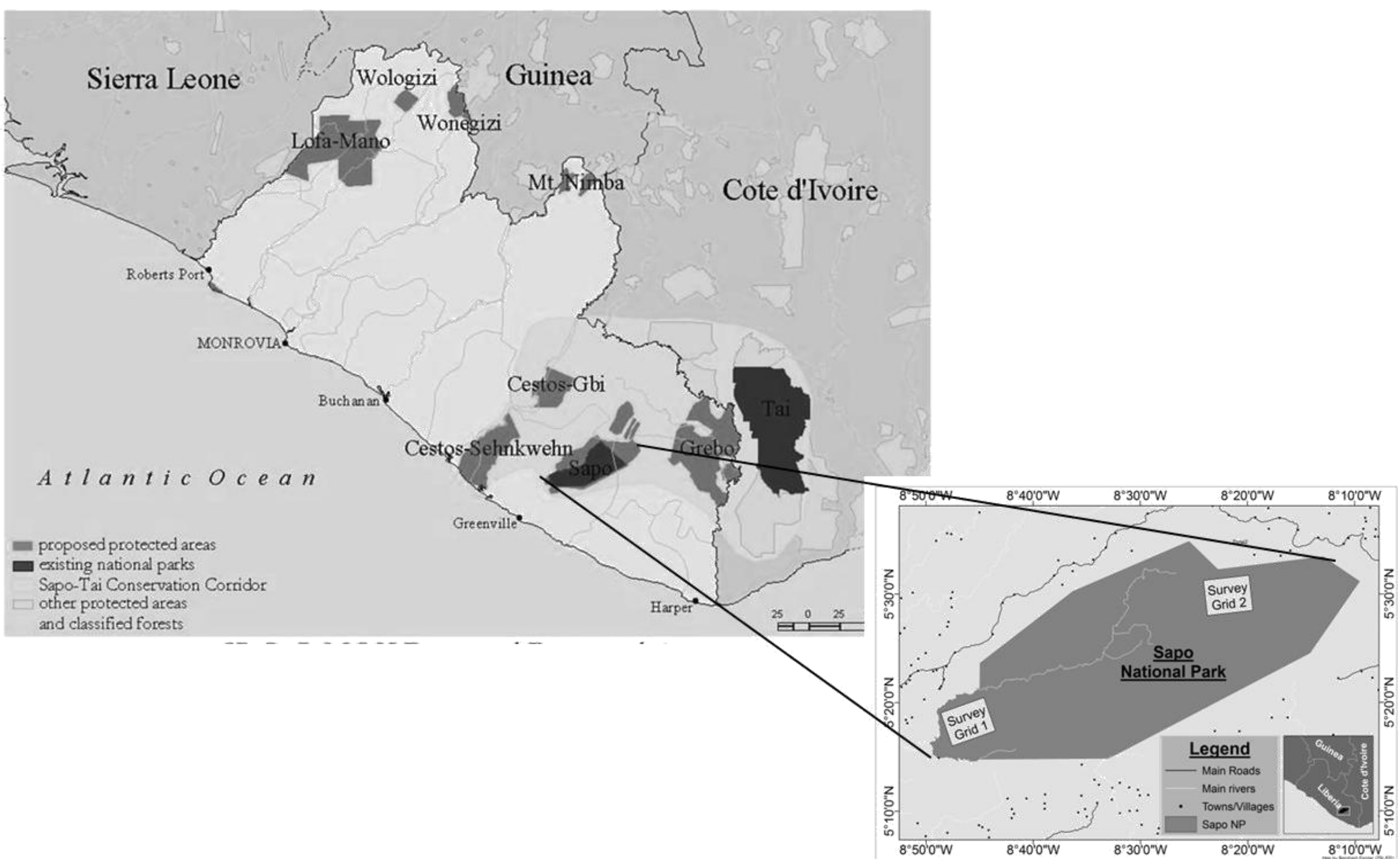

Figure 2.1: Map of Liberia showing the location SNP and buffer its zone (FFI)

2.1.1 Conservation status of SNP

The Forestry Development Authority (FDA) of Liberia was established through an Act of Legislation in 1976 to manage and preserve Liberia's forest resources (Peal, 2007). In 1977, Division of Wildlife and National Park was created under the supervision of Alexander Peal, who served as head of the institution until 1990 when the Liberia Civil War erupted. In 1982, the government of Liberia proposed creation of seven protected areas, including three national parks. Of these three national parks, Sapo National Park was formerly created in 1983. The original park boundaries were set up and its management plans put together by the Wildlife Division and National Park in collaboration with the International Union for Conservation of Nature and Natural Resources (IUCN), World Wildlife Funds (WWF) and Peace Corps. Throughout its history, SNP has been facing several threats (illegal farming, logging, mining and hunting activities (Vogt, 2012)), "All accelerated by Liberia grinding poverty" and social-political conflicts. By early 1990s, UNEP's World Monitoring Center for Conservation reported that community rural development projects undertaken around SNP to embrace conservation had assisted in reducing potential rising conflicts.

2.1.2 Climate

Sapo National Park has tropical with temperatures ranging between 22–28 °C (72–82 °F). The average relative humanity of the forest is 91%. Yearly precipitation at Basin town, 2 mile (4 km) to the south of the park's head quarter averaged 100 inches (2596mm) in the 1980s. The dry season occurs between November and April and the wet season between May and October (UNEP, 1989). January and December are the driest months while May to August are the wet months. July is considered as a mid-dry period of decreased rainfall which sometimes extends into August. During the dry season, many of the smaller streams dry up and their sand and rocky stream beds are exposed. Large rivers also shrink in size, exposing waterfalls and sandbars. In the rainy season, river levels rise up to 4 m (13 ft) in a night, this causes flooding of forest near rivers (UNEP, 1989).

2.1.3 Soil, natural vegetation and topography

The park is quite homogenous, flat with marshy topography supporting a large area of uninhabited forest (Riley & Riley, 2005). The southeastern area has lower elevation of approximately 100 m (328 ft) with gentle hills. Areas with high elevations of about 400 m (1312 ft) are characterized by steep ridges in the north. The soil ranges from weakly developed muds and hydromorphic clays along the flat plans with the inland swamps having shallow soils on the plateaus and ranges and lateritic hills and terraces in the north (Riley & Riley, 2005). The soil patterns are determined by differences in parent material, physiography and present and past climatic conditions. Latosols are the most widespread soil type, followed by lithosols, regosols and alluvial or swamp soils respectively. Loamy-peaty organic materials with high humus content and 'half-bog' soils provide good conditions or cultivation of swamp rice and similar crops (Riley & Riley, 2005).

2.1.4 Flora

The park has one of the richest diversity of plant species in the country, with many endemic species (Vogt, 2012). A 1983 survey of the park indicated that it composed of 63% primary and mature secondary forest, 13% swamp forest, 13% inundated forest and 11% young secondary forest (Peal, 2007). The forest is luxuriant with trees that can grow up to a height of 70 m (230 ft). The forest canopy height ranges from 12-32 m (39-105 ft), with an average height of 25 m (82 ft). The primary forest is dominated by high forest trees of Canarium (*Canarium schweinfruthii*), Sacoglottis (*Sacoglottis gabonensis*), Cotton tree (*Ceiba petendra*), Danoma

(*Piptadeniastrum africanum*), Calpocalyx (*Calpocalyx aubrevillea*), Wild nut (*Cola edulis*), Azobe (*Lophira alata*), Niangon (*Tarrietera* utulis) and Parinari (*Parinari excels*).

The mature secondary contains smaller swamps dominated by plant family Marantaceae and trees, such as Parkia (*Parkia* bicolour), Diospyrus (*Diospyros sansameneca*), Fagara (*Fagara microphalla*), Limbali (*Gilbertiodendron pursuii*), False rubber (*Funtumia elastic*) and Tetra (*Tetraberlinia tubmaniana*). Unlike the mature secondary forest, the young secondary forest is dominated by young trees of Flat crown (*Albizia adianthifolia*), lianas and thick bushes.

2.1.5 Wildlife

The park is a regional centre of endemism and biodiversity, at one time hosting around 125 mammalian species and 590 types of birds (Peal, 2007). This includes a number of threatened bird species such as, White brested guinea fowl (*Guttera pucherani*), Crown eagle (*Stephanoaetus coronatus*), The grate blue turaco (*Corythaealo cristata*) and African pied hornbill (*Lophoceros fasciatus*). Some important mammal species are Forest elephant (*Loxodanta African cyclotis*), Golden cat (*Felix aurata*), Leophard (*Panthera leo*), Pygmy hippo (*Clorosis liberiansis*) and Bongo (*Tragelaphus euryceros*). The reptiles of SNP are represented by Crocodile (*Osteolamus tetripis*), African rock python (*Python sebae*), Forest cobra (*Naja melanoleuca*) and Gaboon viper (*Bitis gabonica*). There are also several insects which include Ciliate blue butterfly (*Anthene georgiadisi*), Dragon fly (*Neodythemis campioni*), Bug (*Recilia dex*), Praying mantis (*Sphodromantis aurea*) and Carpenter bee (*Xylocopa Africana*).

2.2 Materials and Methods

2.2.1 Research design

The study was conducted at the Sapo National Park and its buffer zone between November 2016 and March 2017. Sampling was undertaken within three classified vegetation types: primary forest, mature secondary forest and young secondary forest (Figure 2.2). The primary forest comprised mainly of tall forest trees and intact vegetation, it is visible more than 10m, unlike the mature secondary forest where forest understory is dominated by lianas and not visible up to 10m. Logging and settlement might have existed here long time ago. The young forest consisted of thick vegetation of bush and shrub that was difficult to penetrate. The study was conducted based on systematic sampling design developed by the Forestry Development Authority (FDA) and the international non-governmental conservation organization of Fauna Flora Internationally (FFI) in 2012. Based on the design, ninety (90) line transects were placed systematically using Arc GIS 2.4 to specifically determine and monitor population dynamics of primates, mammals, birds; and address changes in ecological pattern and anthropogenic threats affecting population and its distribution of the species (Figure 2.3). The transects were 2 km in length with a regular distance interval between, maintained at 2km. The pattern of regular space allows for accurate estimates of abundance and spatial distribution of large mammal species. Using the same design to sample large mammals and vegetation, as well as assess the effects of human activities in the SNP has been recommended in order to reduce disturbance and allow for comparison of monitoring of population trends (FFI, 2012; unpublished report). This was the design therefore used in this study.

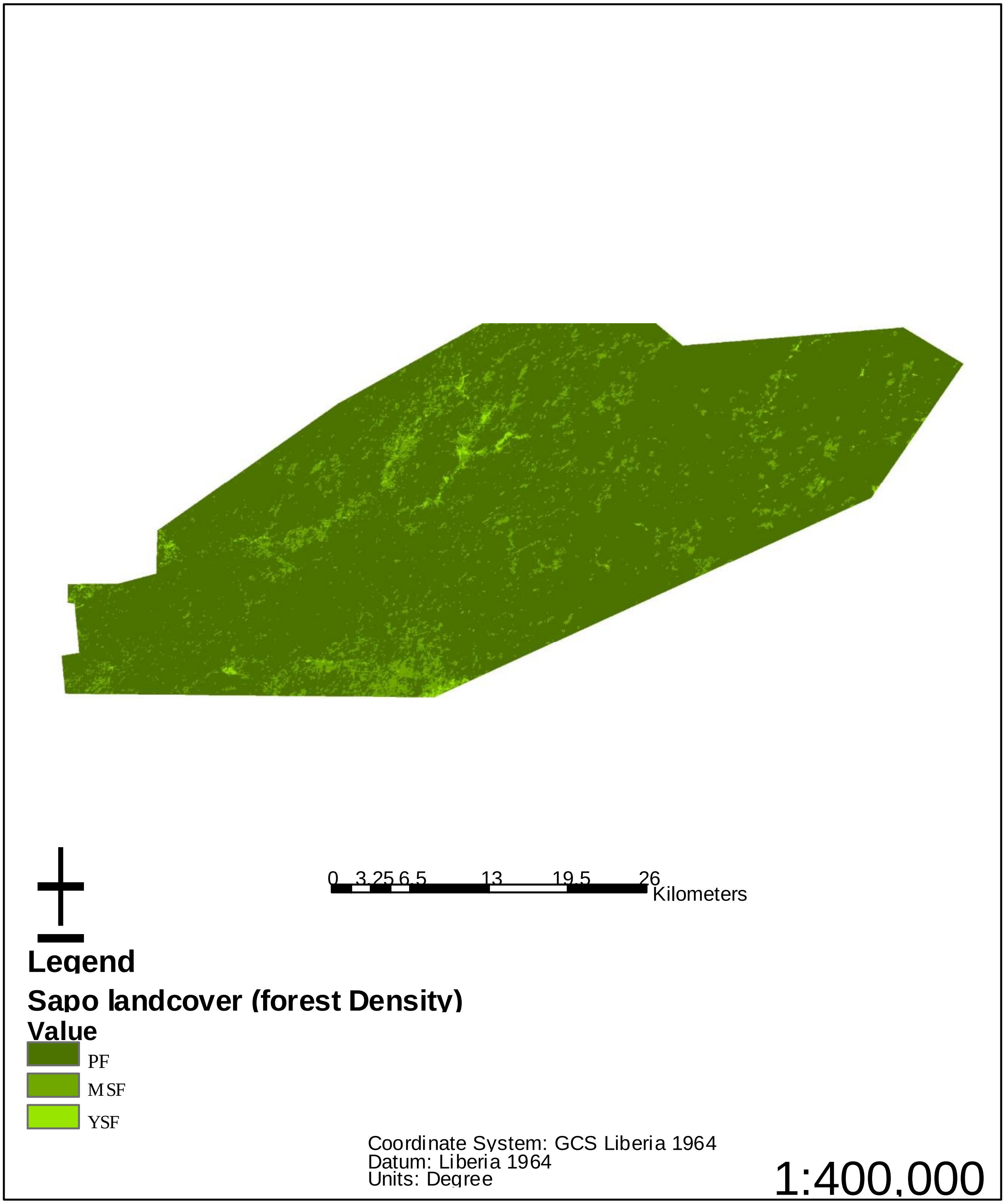

Figure 2.2: Land cover map of SNP showing forest cover of the primary forest (PF), mature secondary forest (MSF) and the young secondary forest (YSF): Retrieved from FFI.

About six (6) line transects of equal length were strategically placed using Quantum GIS version 2.14 technology along the 3km buffer zone of the park excluding the southern part. The southern part was excluded in the sampling due to threat from influx of armed illegal miners and hunters. The decision to place transects strategically was also due to limitation of time and the need to avoid FDA reconnaissance patrol aimed at evacuating illegal miners from SNP, an activity that would have greatly affected the results of this study. Apart from the SNP study area, sampling was also conducted in the buffer zone (demarcated area adjacent to the park boundary): (Figure 2.3).

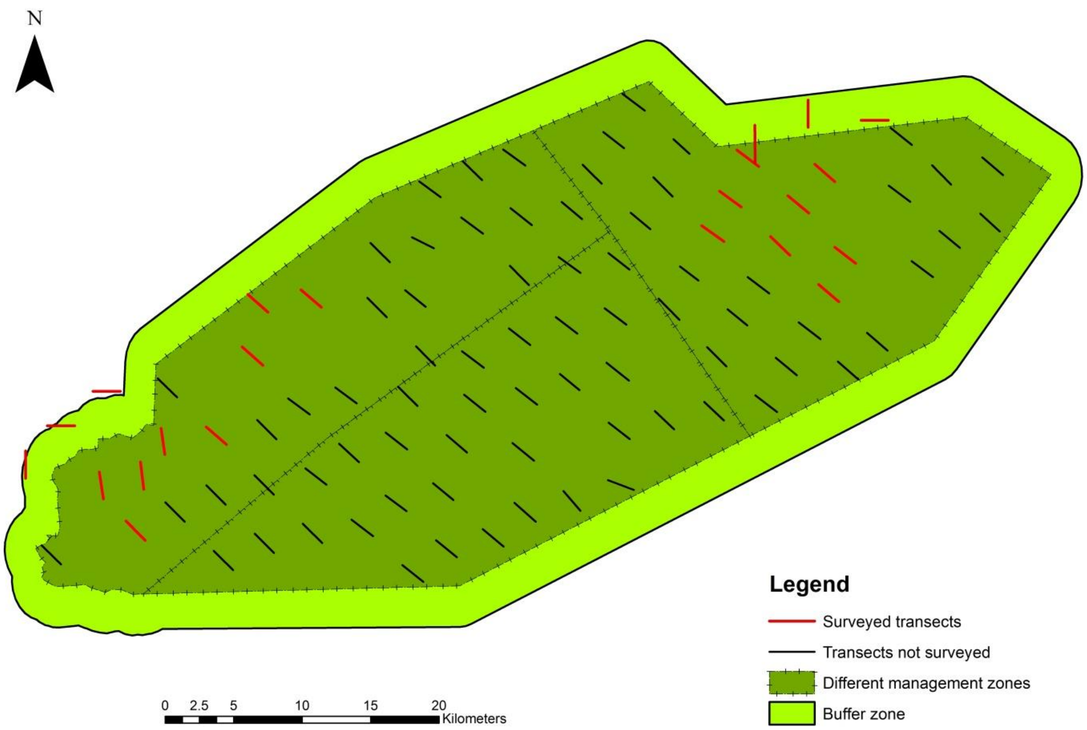

Figure 2.3: Map showing survey transects in SNP and buffer zone

2.2.2 Vegetation Classification

Vegetation classification was based on land-cover map that was derived from Landsat TM imagery capture in 2012, courtesy of Fauna and Flora International database for Sapo National Park. An extensive field inventory was undertaken in 2012 using GPS and compasses to locate systematic points for establishment of permanent cut line transects. These points were used to evaluate consistency of land-cover types from Landsat imagery using Arc GIS computer program, by interpolating GPS data of physical vegetation observations and Landsat imagery of SNP.

2.2.2.1 Vegetation sampling

Random selection of 16 out of the 90 systematically placed permanent line transects in SNP, and 6 temporary line transects in the buffer zone was done. Survey was carried out to assess the effect of vegetation variables (percent canopy cover at every stratum, canopy diameter, nest height, nesting tree height and DBH) on chimpanzee nests, population estimate, density and distribution of chimpanzees.

2.2.2.2 Vegetation types measurement

During this study, vegetation was measured on two instances along every transect. The first occasion was at every 500 m distance of each 2km transect, where a quadrat of 20 by 20 m was placed on either side of the transect (Manu & Cresswell, 2007) using a 50 m measuring tape and string to establish the quadrat. Every quadrat at 500 m was considered to be a regular quadrat or transect plot. Trees in regular plots were classified into four vegetation variables, sapling (smaller trees less than 5m), lower canopy cover (trees >5m<10m), middle canopy cover (trees>10m<20m) and upper canopy cover (trees >20m) (Jones *et al.*, 1995)}. The percent canopy of every vegetation type was estimated due to limited time and resources, and the lack of an experienced botanist in the survey team.

The second instance was whenever chimpanzee nest was spotted at every 60 m interval on every transect within the three vegetation types, quadrats of similar size (20m by 20m) discussed in regular quadrat or transect plot above was also established. These quadrats were referred to as nesting quadrats or nesting plots. Vegetation variables within nesting quadrats were classified into, nest height within a tree, nesting tree height, DBH, nest diameter and number of trees counted within quadrat. A measuring tape was used to measure DBH of nesting trees in centimeters, and diameter of nest in meters. To obtain nest, the measuring tape was carried under the nest by two team members from two cardinal directions [(north and south) and (east and west)] located by using a compass and the mean of the measurements computed.

However, nest height and nesting tree height were measured in meters using a cytometer. The data collected in nesting plots were used to assess the effect of vegetation variables (nest height, tree height, DHB, and nest diameter, and number of trees within nesting quadrat) on chimpanzee nest site choice in all habitat types. All sampling points were located using a GPS, compass and a map.

2.3 Chimpanzee Nest Density

Chimpanzee nest density was estimated along 18 transects established in various vegetation types across SNP. This method was adopted from IUCN best practice guideline for surveying apes in forested habitats using nest count (Kuehl et al., 2008). The method is based on key principles and a number of considerations derived from distance sampling methodologies (Buckland *et al.*, 2001). The method requires that: (a) objects, namely animals or signs of their presence (e.g., dung or sleeping nests), directly on the line transect, presence is always detected with certainty; (b) objects are detected at their initial location prior to any movement in response to the observer; (c) distances are measured accurately; (d) probability of detecting an object decreases as distance increases from the transect centerline.

Once a nest(s) was identified by the observers walking along the transect line, its distance $\mathbf{X_i}$ from the centerline was measured using a measuring tape. The $\mathbf{X_i}$ distance was referred to as the perpendicular distance, with an angle of 90^o. The X_i distance from all of the nests observed was used to find the detection probability function (**Pa).** This is the probability that a randomly chosen nest within the survey area (a) is detected from the centerline at a measurable frequency. The (Pa) was calculated from Distance 6.2 software program (Thomas et al., 2010) since it is impossible to obtain a manual detection probability frequency graph. The estimate of nest density was calculated using the formula.

$$Dn = n/2wLPa$$

Where ***Dn*** is the estimated nest density: n was the number of nest detected in the survey area (***a***), with ***a*** = ***2wL***: ***L*** was the total length of the transect or the survey effort and ***w*** was the distance from the transect line beyond where no nests were detected: Pa was the probability that a randomly chosen nest within the survey area (a) was detected from the centerline at a measurable frequency.

2.3.1 Chimpanzee population density

Chimpanzee population count was carried out from November 2016 to March 2017. The method of nest enumeration was adopted from Buckland *et al* (2001), Kuehl *et al* (2008), and White & Edwards (2000). Twenty two transects measuring 2km were established in various habitat types.

Eight transects were established in primary forest, eight in mature secondary forest and six in young secondary forest. Four observers walked slowly along the center of the transect line and two observers on either side of the transect line within 5m distance. They scanned the habitat for for chimpanzee nests, dung, nut cracking site, vocalizations, direct observations of chimpanzees and natural factors such as streams and fruiting trees. During the observations, the following was recorded;

- distance travelled from the beginning of the transect line using topofil
- the perpendicular distance $\mathbf{X_i}$, of nest or direct observation of chimpanzee from the transect line
- Stage of decomposition of nest, dung pile or nut cracking site
- measurement of compass degree and estimated distance at which chimpanzee was detected
- vegetation type and other features(such as rivers or streams)
- the height at which nest was seen and whether nest is sheltered by canopy or not

Wild Chimpanzee Foundation (WCF, 2012 unpublished) method of grading nests by their state of decomposition was adopted as follows:

- **Stage I:** Very fresh nest, all the leaves in the nest are green with dung and traces of urine under the nest (Figure 2.4).

Figure 2.4: Chimpanzee nest in stage I

- **Stage II:** Fresh nest, the majority of the leaves are still green but there are no traces of dung or urine under the next (Figure 2.5).

Figure 2.5: Chimpanzee nest in stage II

- **Stage III:** Old nest, there is no longer green leaves, but the nest has still kept its general form (Figure 2.6).

Figure 2.6: Chimpanzee nest in stage III

- **Stage IV:** Very old nest, there are no longer green leaves, and the nest has lost its shape.
- **Stage V:** All leaves have completely disappeared.

The nest decay rate used in this study was assumed to be 100.69/day, which was calculated from previous study by N'Goran *et al.*, (2009) done in SNP. The decay rate was established by observations of a total of 178 fresh nests. These nests were revisited after five months period if they passed stage IV to V (when they are deemed to have disappeared). The decay rate was calculated by plotting the formula by Laing *et al,* (2003) using logistic regression model as a function of time in *R* statistical software.

$$P\ (xi) = 1/1+\exp[-(\beta_o + \beta_1 X_1)]$$

Where,

P(*xi*) = is the probability that sign *I* survive until the revisit

β_o and **β_1** = are coefficient to be estimated

X_1= represents the time of revisit or the life span determines at zero

Chimpanzee population size was estimated based on i) a nest production rate (number of nest built during the day) of 1.143 {calculated from observations of habituated chimpanzees in Taï National Park in Ivory Coast (Kouakou *et al.*, 2009)} ii) a proportion of nest builders of 0.83 (Plumpter and Cox, 2006) which is the number of chimpanzees from different communities that build the nest. These variables were used to calculate the density of chimpanzees from the formula developed by Kuehl *et al.*, (2008) below:

Population density = D *nest/ PRT*

Where,

D *nest* = density of nest calculated above

P = the proportion of nest builder

R= the production rate

T= time or decay rate of nest

2.3.2 Assessment of anthropogenic activities

The anthropogenic activities assessed included agricultural activities, hunting, farming, logging and mining. As observers walked along the transect lines that were selected across primary forest, mature secondary forest and young secondary forest in the SNP and buffer zone, all human activities found were identified and marked using a GPS. The presence or absence of signs was used to confirm anthropogenic activities as follows; farming (plantations, cleared forest patches), mining (gold mining camps), hunting (gunshots, empty cartridges, snares, hunting camps, poacher trails, human direct observation), other human activities (human path/ rangers patrol path, human track, human vocalization, old touch light, extraction of non-timber forest products- NTFP) and logging activities (logging camps, old logging road, log tree stumps).

Each human activity was assigned a score ranging from "1" to "3", where a score of "1" indicated that the sign was "fresh" (occurred within a period of two to three months), while a score of "2" denoted that the activity had occurred more than three months but less than six months prior, were considered "recent". All signs that were more than six months old were assigned a score of "3" and considered "old" or "abandoned". Additionally, all cartridges found along transects were removed, which follows procedures of previous studies conducted in SNP (Kouakou *et al.,* 2009), also (FFI, 2014-2016; unpubl. data) to determine trend in human activities that may positively or negatively affect chimpanzee population in future. The parameter provided using the categories was meant to show occurrence of most recent threats in SNP. Data of all human signs collected from our study area were compared with most recent previous bio-monitoring data (FFI, 2016; unpubl. data) for SNP. These data were collected to show the influence of human activities on the long term survival of chimpanzees in SNP and buffer zone.

2.4 Data Analysis

All data were entered and organized in Excel spreadsheets, and managed using MS- Excel for Window Vista, SPSS (Statistical Package for Social Sciences version IBN 20), Distance Program version 6.2 and R Statistic (version 3.0.2) were used for statistical analyses. All tests, unless otherwise stated, were considered significant at $p < 0.05$.

2.4.1 Analysis of vegetation data

A one way ANOVA test was used to determine whether the three forest types used by chimpanzees differed in percent canopy cover at every stratum in regular plot, and variable measurement within nesting plot in SNP and buffer zone.

2.4.2 Estimate of population size, density and distribution

Distance Program version 6.2 was used to estimate chimpanzee abundance and density. QGIS with the Geographic Resources Analysis Support System (GRASS) v. 7.0.4 (GRASS Development Team 2017) was used to plot the distribution and to model inverse-distance weighted density of chimpanzee nests. Here, a half-normal model with simple polynomial adjustment was fitted to the frequency distribution of perpendicular distances. Furthermore, the data were not left truncated but normalized, and pre-defined distance group intervals were not set. This model was identified as the model with the best fit from a set of alternative models, using Akaike's Information Criterion (AIC) (Akaike H, 1973 & Sakamoto *et al.*, 1986). To test for the potential presence of or avoidance effect of permanent transects by chimpanzees, the frequency distributions of perpendicular distances measured to nests encountered were compared on both permanent transects in SNP and temporary transects within the buffer zone.

2.4.3 Anthropogenic activities

A Spearman's correlation test was run in R Statistics to test the influence of human signs on chimpanzee distribution and abundance. All direct and indirect signs of chimpanzee and human presence encountered on line transects in SNP and the associated buffer zones were interpolated using the inverse-distance weighted method in ArcGIS.

CHAPTER THREE

3.0 RESULTS

3.1 Variation in vegetation variables within different vegetation types

3.1.1 Vegetation within the transect plots

Sampling of vegetation was conducted in various transect plots within three vegetation types (primary forest, mature secondary forest, young secondary forest). A one way ANOVA to examine differences for the various vegetation variables (% upper canopy cover, % middle canopy cover, % lower canopy cover, % sapling) sampled in transect plots within the three vegetation types was conducted. Although there was significant difference for the % upper canopy cover ($F_{0.05, 2, 73} = 4.57$, $p < 0.05$(0.013)) and % middle canopy cover ($F_{0.05, 2, 73} = 11.82$, $p < 0.05$ (0.000), there was no significant differences for % lower canopy cover ($F_{0.05, 2, 73} = 1.022$, $p > 0.05$(0.28)) and % of sapling cover ($F_{0.05, 2, 73} = 1.455$, $p > 0.05$ (0.21): (Figure 3.1).

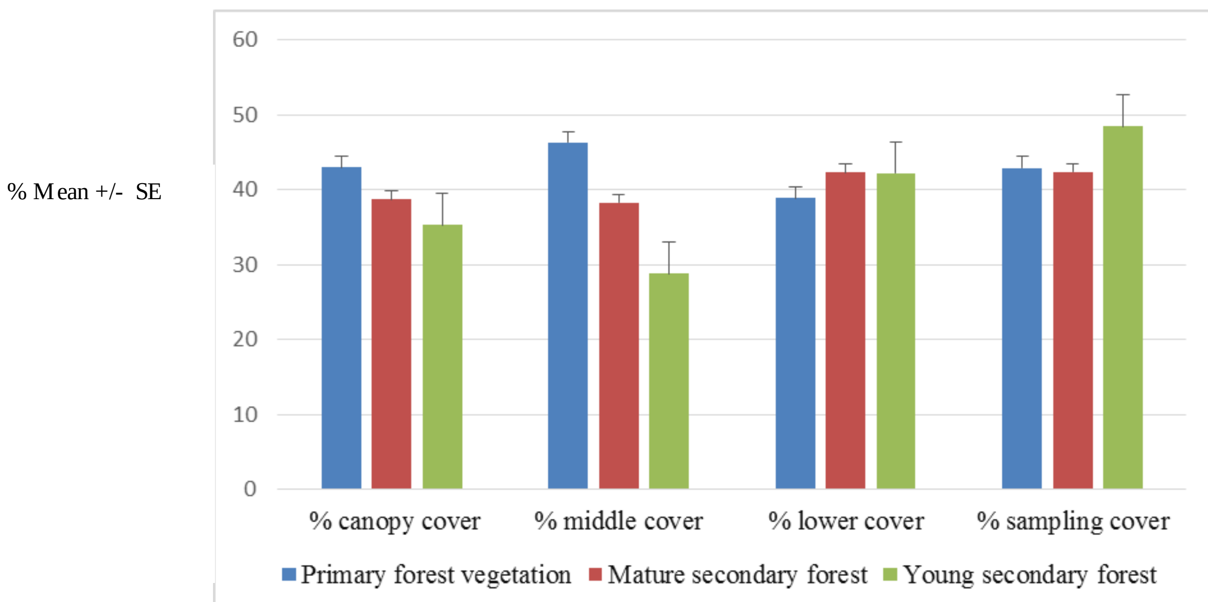

Figure 3.1: The % mean± SE cover of vegetation at different height levels in the forest

The Tukey Post hoc test was conducted to examine significant differences in vegetation variables for different vegetation types. Results from the post hoc test showed that there was no significant differences for high canopy cover for mature secondary forest vs. primary forest, percent middle canopy cover for young secondary forest vs. mature secondary forest; mature secondary forest vs. primary forest (Tukey Post hoc $P > 0.05$. The high canopy cover in young secondary forest was (63.6%), and percent mid canopy cover in primary forest (74.8%), mature secondary (66%) and young secondary (56.4%). For percent lower canopy cover and sampling cover, there was significant variation observed in all vegetation types. The lower canopy cover was (66.5%) in primary forest, (70.1%) in mature secondary forest, and (70.6%) in young secondary forest. The percent sampling cover was (100%) for primary forest, (70.7%) for mature secondary forest and (70.6%) for young secondary forest.

3.2 Vegetation within the Nesting Plots

Vegetation sampling was conducted in plots where nests were found within the three different vegetation types. A one way ANOVA to examine differences for the various vegetation variables (height of the nesting tree, nest height, nest diameter, DBH of nesting trees, number of trees per nesting plot) between nesting plots was conducted. Results revealed that there was significant difference for the DBH ($F_{0.05, 2, 19} = 4.8$, $p < 0.05$). However, there were no significant differences for height of the nesting tree ($F_{0.05, 2, 19} = 0.96$, $p > 0.05$, nest height ($F_{0.05, 2, 19} = 0.95$, $p > 0.05$), nest diameter ($F_{0.05, 2, 19} = 2.04$, $p > 0.05$ and number of trees per nesting plot ($F_{0.05, 2, 19} = 1.43$, $p > 0.05$) (Table 3.1).

The mean nest diameter was (3.07 m) within young secondary forest, (12.15 m) within mature secondary forest, (4.95m) within primary forest, and trees counted in nesting plot were (19.93m) for primary forest, (19.58m) and (10.08m) for mature secondary forest and young secondary forest respectively. The height of nest within primary forest was (12.48 m), mature secondary forest (12.17 m) and young secondary forest (6.85 m), while the height of nesting trees was (13.36 m) for primary forest, (13.68 m) mature secondary forest and (7.53 m) young secondary forest. A *post hoc* test was also conducted in nesting plots to examine differences in nest diameter, nesting tree height, height of nest and DBH of nesting tree in various vegetation types. There were no significant differences for DBH between young secondary forest and primary forest or mature secondary forest, (Tukey post hoc $P > 0.05$).

Table 3.1: The mean± SE of various vegetation variables measured at the site where chimpanzee nests were encountered in the three habitat types studied in SNP.

Vegetation variables		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
diameter of nest (m)	PF	9	4.9587	4.26403	1.42134	1.6810	8.2363	0.00	13.49
	MSF	7	12.1543	14.47377	5.47057	-1.2317	25.5403	0.00	38.56
	YSF	6	3.0683	3.63665	1.48466	-.7481	6.8848	0.00	8.64
	Total	22	6.7326	9.21481	1.96460	2.6470	10.8183	0.00	38.56
Nesting tree	PF	9	19.9300	9.65499	3.21833	12.5085	27.3515	0.00	34.00
	MSF	7	19.5886	13.94493	5.27069	6.6917	32.4855	0.00	32.00
	YSF	6	10.0833	12.73198	5.19781	-3.2781	23.4447	0.00	28.92
	Total	22	17.1359	12.21599	2.60446	11.7196	22.5522	0.00	34.00
Height of nest_ (m)	PF	9	12.4844	5.96749	1.98916	7.8974	17.0715	0.00	20.50
	MSF	7	12.1757	11.14296	4.21164	1.8702	22.4812	0.00	30.00
	YSF	6	6.8517	7.56538	3.08855	-1.0877	14.7910	0.00	14.72
	Total	22	10.8500	8.30468	1.77056	7.1679	14.5321	0.00	30.00
Nesting tree height (m)	PF	9	13.6211	6.37969	2.12656	8.7172	18.5250	0.00	21.57
	MSF	7	13.6843	12.56331	4.74849	2.0652	25.3034	0.00	34.50
	YSF	6	7.5333	8.28147	3.38090	-1.1575	16.2242	0.00	15.71
	Total	22	11.9809	9.20338	1.96217	7.9004	16.0615	0.00	34.50
DBH of nesting trees _cm	PF	9	8.2372	4.26234	1.42078	4.9609	11.5135	0.00	12.97
	MSF	7	43.6157	35.61290	13.46041	10.6793	76.5522	0.00	86.02
	YSF	6	17.7117	21.47836	8.76850	-4.8285	40.2518	0.00	51.79
	Total	22	22.0780	26.85696	5.72592	10.1702	33.9857	0.00	86.02

3.2.1 Overall difference of chimpanzee nests and vegetation types

Chimpanzee nests in different stages of decay were encountered in all three forest types. A chi-square test was conducted to determine whether the distribution of various stages of nest decay were independent of the forest types. The results confirmed that indeed the stages of nest decay were independent of forest types (Primary forest $\chi^2_{0.05, 6} = 16.65$, $p < 0.05$, Mature secondary forest ($\chi^2_{0.05, 6}$ = 14.45, $p < 0.05$) and young secondary forest ($\chi^2_{0.05, 6}$ = 14.12, $p < 0.05$(0.0027) as shown in (Table 3.2).

Table 3.2: Data used to perform χ^2 on the decay of chimpanzee nests and vegetation types

Forest Type	Nest stage I	Nest stage II	Nest stage III	Nest stage IV
PF	5	12	23	1
Mature SF	2	12	15	0
Young SF	0	1	19	5

3.3 Chimpanzee abundance estimate

Based on 95 nest observations in zones 1 and 2 of SNP and its buffer zone, we estimated the chimpanzee population at 1,055 individuals (95% CI = 595–1,870, CV = 0.29) with a density of 0.83 chimpanzees/ km^2 (95% CI = 0.47–1.47, Table S2). This represents approximately 15% (9-27%) of the total chimpanzee population in Liberia as estimated by Tweh *et al.* (2014). The estimate was based on the total survey effort L = 38.38 km, the average transect length l = 1744.5 m, the effective strip width ESW = 15.665 m, and the study area A = 1275.65 km^2. A total of 16 km was surveyed in each zone inside SNP and 6.38 km in the buffer zone surrounding zones 1 and 2. The majority of nests were seen in zone 1 (N = 41), followed by zone 2 (N = 29) and then the buffer zone (N = 25) (Figure 3.2), resulting in a nest encounter rate (no. of nests encountered/ km surveyed) for the three areas of 2.56 (zone 1), 1.88 (zone 2) and 5.80 (buffer zone).

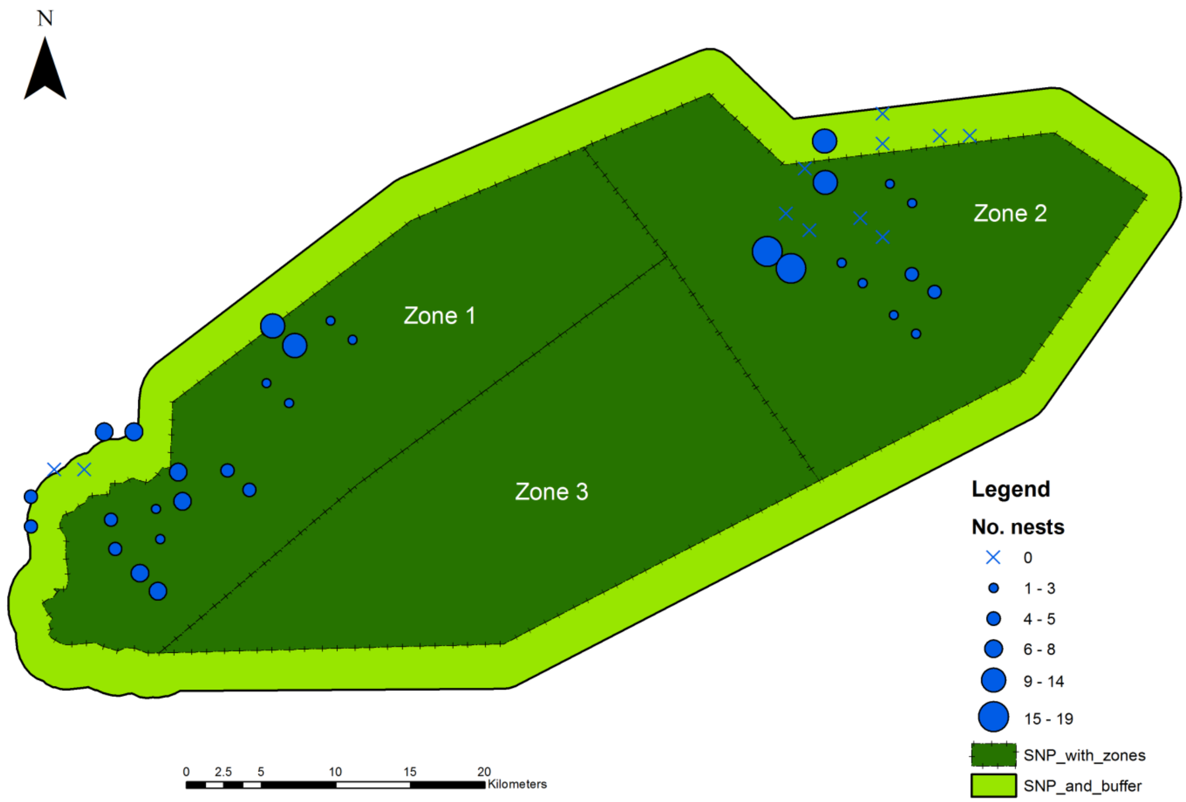

Figure 3.2: Map showing the distribution of chimpanzee snests found in permanent transects in zone I and II in SNP. Zone III was not sampled and temporary transects were used for sampling nests in the bufer zone around the park.

In relation to nest decay stages, in the young secondary forest, stage II accounted for 4% (n= 1) of total observations made, stage III (76%; n= 19) and stage IV (20%; n= 5). For mature secondary forest, stage I accounted for (6.89%; n=2), stage II (41.37%; n= 12) and stage III (51.72%; n= 15). In the primary forest, stage I represented 12.19 % (n= 5) of observations, stage II (29.27%; n= 12), stage III (56.09%; n= 23) and stage IV (2.2%; n= 1).

3.3.1 Nest placement in relation to human disturbance

Chimpanzee placed their nests away from permanent transects and foot paths used by humans. In order to compare the perpendicular distances of nests from the sources of human disturbance in the park and its buffer zone, a two sample t-test was conducted. The test confirmed that there was significant difference in the distances at which chimpanzees built their nests in SNP and the buffer zone ($t_{(2), 69} = 0.000128$, $P < 0.05$). Eighty-one percent of the chimpanzee nests were spotted more than six meters away from permanent line transects in SNP, as compared to forty four percent of the nests placed away from the temporary transects in the buffer zone.

3.3.2 Distribution of signs of chimpanzee and human effects

The distribution of chimpanzee nests across the survey area differed only slightly among the three surveyed areas (Figure 3.3), with the majority of chimpanzee nests observed in zone 1. One hundred and fourteen signs of chimpanzee presence were encountered in total, of which 38% (N = 43) were observed in primary forest (zone 1), and 39% (N = 44) and 24% (N = 27) within (mature secondary forest (zone 2) and the buffer zone (young secondary forest), respectively (Table 3.3).

Table 3.3: Number of chimpanzee signs and hunting activities detected in SNP (management zone 1 & 2) and in the buffer zone surrounding these, respectively.

Area	Category transect	Survey effort (km/ day)	Number of hunting signs	No. of other signs of human presence	No. of chimpanzee Nests	No. of other signs of chimpanzee presence
Zone 1	Permanent transects	16	20	5	41	3
Zone 2	Permanent transects	16	33	5	29	14
Buffer zone	Temporary transects	6.38	10	10	25	2

3.4 Presence of anthropogenic activities in SNP and buffer zone

A total of 83 human signs were observed on all transects together, of which 30% were recorded in primary forest (N = 25), 46% (N = 38) in mature secondary forest, and 24% (N = 20) in the young secondary forest. There was no mining signs encountered on either permanent or temporary transects. However, mining signs during this study were only encountered in the buffer zone while navigating between transect lines. Hunting signs (N = 63) were the most frequently encountered human threats, accounting for 75.9% of all human signs detected and ranging from 1–3 observations per transect (Figure 9.3). Hunting sign encounter rate for SNP and the buffer zone was 1.7 and 1.6, respectively. The most frequently encountered hunting signs during this survey were poacher trails (N = 33), followed by empty cartridges (N = 20) and snares (N = 2). While empty cartridges were only observed on/from permanent transects, snares were seen only in the buffer zone. Poacher trails were recorded on both, permanent (N = 23) and temporary transects (N = 10). All poacher trails were probably in use, as the markings on trees along these trails, typically made by the poachers to mark their way, were still fresh. Of the empty cartridges found, 70% (N = 14) were new (0-3 months), and 20% (N = 4) were recent (3-6 months). Signs of farming (N = 2), logging (N = 3), NTFP (N = 3), and OHA (N = 12) accounted for only 2.4%, 3.6%, 3.6%, and 14.5% of all human signs, respectively. Encounter rates for farming-, logging-, NTFP- and OHA signs were 0.06, 0.08, 0.08 and 0.31, respectively. Evidence of logging and farming was only recorded in the buffer zone, but not inside the park. Signs of NTFP were observed only in SNP, whereas signs of OHA's were recorded in both SNP (N = 9) and its buffer zone (N = 3).

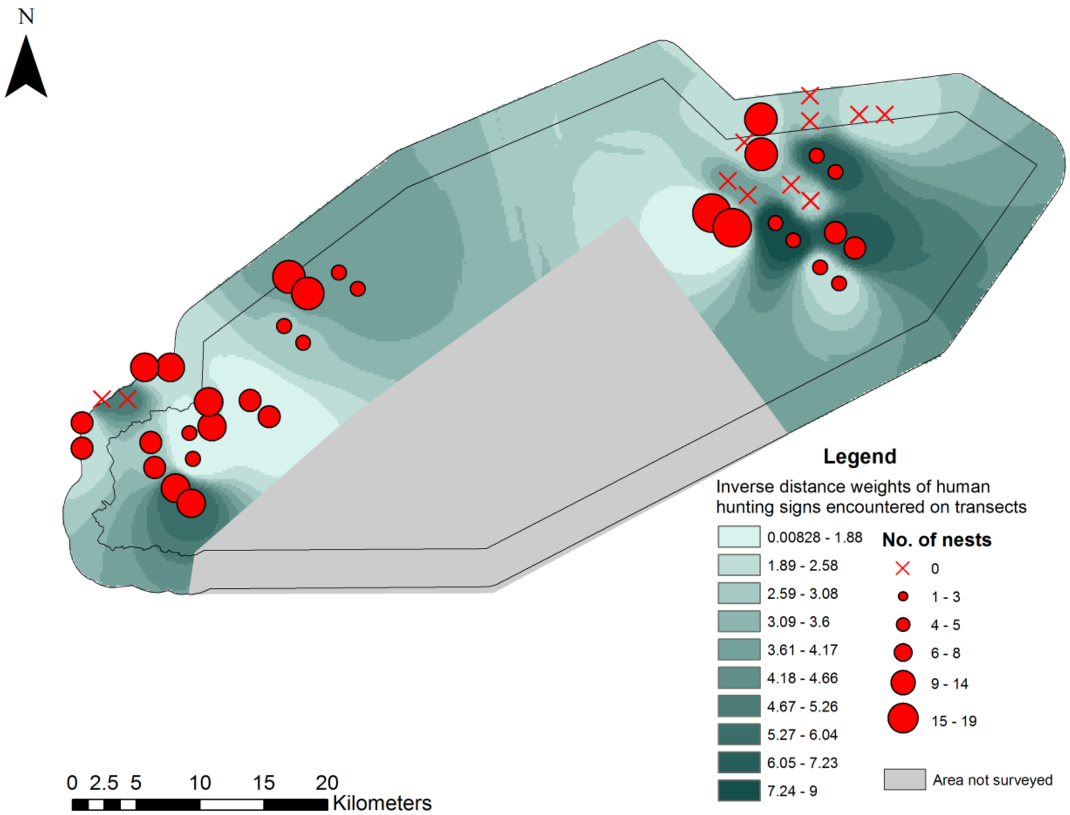

Figure 3.3: Distribution and density of wildlife hunting signs and the number of chimpnzee nests encountered in SNP and its buffer zone.

The results of the Spearman's correlation analysis showed that there were no significant positive relationship between abundance of chimpanzee nests and human signs recorded on transects (rho = 0.00130, p-value =0.564). There were non-significant positive relationship between abundance of all chimpanzee signs and all human signs (rho = 0.0865006; p- value = 0.7019), chimpanzee nests and all hunting signs (rho = 0.2454765; p- value = 0.2708) and all chimpanzee and all hunting signs (rho = 0.31042; p- value = 0.1597). This indicated that chimpanzees avoided areas frequented by humans. Specifically, results showed that within primary forest, percentage frequency of anthropogenic activity encountered included 4% for cartridges, 12 % for gunshots, poacher trails (60%), human tracks (12%), OHA (4%) and HumDO (4%). For mature secondary forest, cartridges accounted for 50%, gunshots (10.5%), poacher trails (21.1%), human tracks (5.3%), NTFP (5.3%) and OHA (2.6%). However, there were only four human activities encountered within the young secondary forest with logging accounting for 15 %, poacher trails (50%), trap (10%), human path/ ranger trails (15%) and farming (10%) (Figure 3.4).

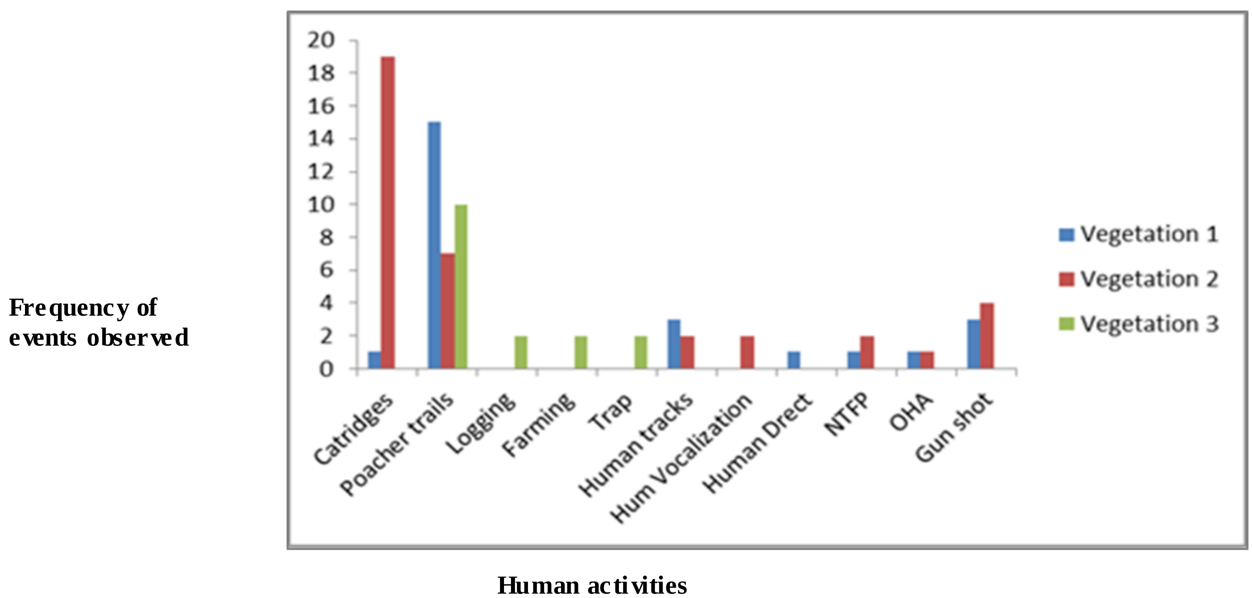

Figure 3.4: The frequency of various human activities encountered in SNP (Zone I & II) and the buffer zone. See also figure 8 for vegetation zones.

4.0 DISCUSSION, CONCLUSION AND RECOMMENDATIONS

4.1 Discussion

4.1.1 Variation in vegetation characteristics

The percentage of high canopy and middle canopy cover varied among the primary forest, mature secondary forest and young secondary forest. However, there were more similarities for percent high canopy and middle canopy cover in the primary and mature secondary forest. One major factor could be attributed to the similarities of high and middle canopy structure in the primary and mature secondary forest could be similarity within the physiochemical property of soil as both primary and secondary forests are classified within the locality of SNP, and shared potential natural factors such as streams and fruiting trees. Furthermore, the estimated percentage of sampling and lower canopy cover across primary, mature secondary and young secondary were similar. Perhaps, competition by tall trees within primary and mature secondary forest is higher than young secondary forest. This tends to affect the undergrowth of lower canopy and sampling cover within every vegetation type.

4.1.2 Nest size variation among forest types

Nest diameter varied across the three vegetation types. It was higher in mature secondary forest than primary and young secondary forest. This may possibly due to variation in size of chimpanzee sleeping platforms. Chimpanzees within the mature secondary forest of SNP may have bigger sizes which required them to build wider nests than chimpanzees in primary and young secondary forest. However, the possibility of cultural variations within different groups of chimpanzees may be another potential factor. Chimpanzees in mature secondary forest may have been adapted to such a tradition from their ancestors. The mean nest height was generally higher and similar in primary and mature secondary forest than young secondary forest. Human activities and threats evident in the permanent transects established in SNP could account for the differences in nest size and site selected since chimpanzees possess high cognitive ability to detect and respond to risk factors within their immediate environment.

There were more signs of poaching (such as cartridges and gunshots heard) along permanent transects within the primary and mature secondary forest of SNP than in the temporary transects in young secondary forest established in the buffer zone. Nesting tree height and DBH of nesting trees were higher and similar in the primary and mature secondary forest than in the young secondary forest. This was likely due to the young secondary forest being affected by farming and mining activities which was also shown in similar study by (Moreira and Russo, 2017). Furthermore, trees in the young secondary forest are undergoing regeneration process, and hence were shorter than those in the primary forest (Gibson *et al*, 2001; Ansell *et al.*, 2011).

The number of trees identified and counted in the nesting plot within the primary and mature secondary forest was similarly higher. Since the establishment of SNP in 1983, an act of legislation was passed into law forbidding all illegal activities including logging for timber. The establishment of this act is attributed to the increased number of trees counted in nesting plot in the primary and secondary forest. The chimpanzees in SNP could prefer more dense vegetation with many trees due to food availability and avoid being exposed to danger. Unlike the primary and mature secondary forest, young secondary forest in the buffer zone was exposed to farming and settlements, until recently when the area was expanded and demarcated for protection by the Forestry Development Authority of Liberia.

4.1.3 Relationship between nest decay and vegetation types

Stages of nest decay were different in all vegetation types sampled. This variation could be explained by factors of temperature, time and nesting tree species. Temperature in young secondary forest may tend to be very high due to exposure to sunlight unlike in primary forest and secondary forest. However, the time of nest construction and leaf texture of the nesting trees may also have a great impact. For example (N'Goran *et al.*, 2010) mentioned that softer tree leaves used to build nests in cold temperature for a longer time will decay faster than coarse tree leaves used to build nests in hot temperature condition. The nest decay rate used during this study was estimated during a short-term nest decay study in SNP during the rainy season from June to October 2009 (N'Goran *et al.*, 2010). However, this survey was conducted mostly during the dry season (November to March), during which nests may have actually decayed at a slower rate than the one previously estimated for SNP. Also, short-term studies of decay time for orangutan nests have confirmed enormous amounts of variation in nest decay time (Laing *et al.*, 2003). Although studies on the variation of chimpanzee and orangutan nest decay have shown that factors, other than climate (such as tree type, tree size and nest height) may considerably influence nest duration (Kouakou *et al.*, 2009; Laing *et al.*, 2003). This did not affect our estimate because the area for which nest decay time was estimated by (N'Goran *et al.*, 2009), overlapped considerably with ours.

4.1.4 Chimpanzee abundance, density and distribution

This study revealed that chimpanzees are found across every habitat type and the population estimate for SNP and its buffer zone (excluding management zone 3) was 1,055 chimpanzees with an average density of 0.83 individuals/ km^2. Previous studies conducted in the same park by (N'Goran *et al.*, 2010) reported a population of 1,079 chimpanzees in SNP (excluding mining areas) with a density of 0.86/ km^2. The marginal decrease of 24 individuals implies that the population has remained relatively stable over the past eight years. In a recent study, Kuehl *et al.*, (2017) found that the chimpanzee population in SNP underwent a significant decrease in size from 2009 to 2014. This stands in contrast to our results presented here. Several factors may explain this discrepancy. First, temporal variation in nest decay due to variation in climatic conditions, which was not considered in this study, may have resulted to a biased estimate of chimpanzee population size (Laing *et al.*, 2003). Secondly, the sampling strategy of the two survey events used to estimate the population size for SNP by Kuehl *et al.*, (2017), differed substantially with that used in the 2009 study surveyed temporary transects, whereas the 2014 study surveyed permanent transects. The spatial distribution of nest observations recorded in this study is very similar to that recorded during the 2009 survey in (N'Goran *et al.*, 2010). However, nest encounter rate was more than two times higher in the buffer zone (young secondary forest) than in either of the two vegetation type inside the park. This may be attributed to the observation that the percentage of chimpanzee sleeping nests (19%) detected on/near (0-6 m) permanent transect lines was more than two times lower than on/near temporary transects (44%).

4.1.5 Effect of human disturbance

The findings of this study have shown that chimpanzees seem to avoid cut permanent transects in the primary and secondary forest. This could have resulted in an underestimate of the nest encounter rate in this study. This was also observed in 2014 survey data of SNP (Kuehl *et al.*, 2017). Although the areas of the two surveys overlapped substantially, it is possible that the difference in location of transects during the two survey events influenced nest detection and thus estimation of population size. Chimpanzee signs were found across both SNP (primary and mature secondary forest) and the buffer zone (young secondary forest). The recent Ebola outbreak in West Africa in 2014/2015 may have discouraged hunters from killing chimpanzees, because significantly less bush meat was purchased and consumed during the Ebola crisis in Liberia out of fear of contracting the disease (Ordaz-Nemeth *et al.*, 2017). This is likely to have had a positive impact on the distribution of chimpanzees. However, human threats to chimpanzees and other species, including poaching for bush meat (Greengrass, 2011), habitat destruction and disturbance caused by illegal mining activities (Kayjay, 2010) continue to exist.

It is quite clear that hunting is a potential future threat to wildlife population in SNP compared to farming, logging and mining, with increased rate of encounter (2.9/km) observed from same transects in this study surveyed by FFI in early 2016 (yielded an encounter rate of 1.8/km with an increased in 38% of hunting sign less than a year). Compared to the most recent previous study done by (FFI, 2016; unpubl. data), hunting sign encounter rate was 3.14/km from 8km of transects surveyed in SNP. Also, (N'Goran *et al.*, 2009) reported hunting sign encounter rate in SNP to be 0.43/km with total survey effort of 44km. Results from this study also demonstrated that 80% of empty bullet cartridges, which were only found on/near permanent transects established in primary and mature secondary forest but not on temporary transects in young secondary forest, were new or recent. This suggested that poachers made use of permanent transects to access bush meat from inside the park, thereby jeopardizing the long-term survival of wildlife populations inside the park. The majority of hunting signs were found to be in the mature secondary forest, and young secondary forest in the buffer zone. Although the mature secondary forest found within SNP, hunting activities tended to be increasingly high. This may be due to inadequate or ineffective patrols due to shortage of the forest rangers.

The stability of the chimpanzee population in SNP over the past eight years despite the persistent threats may be explained by chimpanzees not directly being targeted by hunters, as seems to be the case in some areas elsewhere in Liberia (Junker *et al.,* 2015), and other countries (e.g. Equatorial Guinea: (Rist *et al.,* 2009; Brncic *et al.,*2010), Sierra Leone: Ragnaut & Boesch, 2012), Guinea: (McCarty *et al.,* 2015), Uganda: (Mathewson *et al.,* 2008). In addition, many Liberian villages practice taboos against eating and killing chimpanzees (Junker unpubl. data), including those situated near the south-western border of the park (Greengrass, 2009; Greengrass, 2011).

4.2 Conclusion

Considering that the Western Chimpanzee is currently critically endangered, SNP is an important refuge for these primates in Liberia and West Africa. The park host more than 1,000 chimpanzees, which represents 15% of the national population. Because of increasing human encroachment and disturbance, the distribution range of these primate is shrinking. SNP is a stronghold for chimpanzees and one of the few viable chimpanzee populations in West Africa that has been relatively stable in size over the past eight years. However, the survival of this and other populations in Liberia is threatened by hunting and the rapidly growing mining, forestry and agricultural sectors (Tweh *et al.* 2014, Junker *et al.* 2015a). This study demonstrates the importance of carefully-planned and robust monitoring designs that yield reliable biomonitoring data for effectively informing conservation strategies.

The implications of using inaccurate population status and trend estimates for conservation decision-making are manifold. For example, if a population decreases despite having implemented intensive conservation efforts to prevent population declines, funders may discontinue financing such conservation actions. Secondly, investors may prioritize populations that are viable in the long-term over those that are declining. Furthermore, with economic development in Africa being on the rise (e.g. Edwards *et al.* 2014, Wich *et al.* 2014), biased population status or trend estimates can play into the hands of resource extraction firms who may have an economic interest in the area.

As this study has shown, establishing permanent, clear-cut transect lines in a protected area may facilitate access to illegal miners and poachers, which is counterproductive from a conservation point of view. Continuing to improve the accuracy and precision of monitoring methods is crucial if conservationists are to most effectively use limited resources and offer chimpanzees in West Africa the best chance of long-term survival.

4.3 Recommendations

4.3.1 Recommendation for further studies

- Further studies of chimpanzees in SNP should be conducted during both the dry and rainy seasons.
- There is also need to conduct more surveys to cover those areas that were not covered by this study including detail vegetation study in the chimpanzee foraging ranges so as to establish its structure and composition.
- A comprehensive collection of plants in SNP should be established at the park headquater for use by researcher and park managers.
- Data collection must involve camara trapping to be able to identify different family groups of chimpanzees and establish their group sizes and age composition.

4.3.2 Recommendation for management action

To achieve the effective management of SNP and its surrounding buffer areas, the following measures are recommended

- Stepping up law-enforcement measures to more effectively control poaching by increasing rangers especially in the mature secondary forest and young secondary forest regions.
- Change from using permanent transects to temporary transects that are not cut to avoid creating pathway or routes used by poachers and miners.
- Increase community awareness and involvement in monitoring chimpanzees and detrimental human activities (threats)
- Transects used should be permanently marked to ensure that they are accurately relocated during consecutive surveys.
- Future surveys should continue in the buffer zone and possibly beyond, because it is important to be able to pick up on any disturbance (e.g., human encroachment) before it reaches the park and because it is advisable to have a survey design that allows for detecting spatial population- or community expansion into the buffer zone.

4.3.3 Recommendation for policy interventions

- Policy makers should put into place unique legislations that will enable coordination among government institutions and conservation agencies in SNP and other protected areas in Liberia. For instance, the Ministry of Land, Mines and Energy should collaborate and coordinate their activities with those of Forestry Development Authority to avoid overlapping of mining concession agreements and the conservation priorities.

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APPENDICES

Appendix 1: Measured perpendicular distances from the center of the transect line in SNP and buffer zone (BZ)

Management Area	Transect id	No. of nest	Perpendicular distance
SNP	T-67	1	4.3
SNP	T-72	1	10.4
SNP	T-72	1	10.72
SNP	T-72	1	11.1
SNP	T-72	1	9.64
SNP	T-72	1	10.36
SNP	T-72	1	15.7
SNP	T-72	1	15.4
SNP	T-72	1	16.8
SNP	T-72	1	0
SNP	T-72	1	9.2
SNP	T-72	1	8.3
SNP	T-72	1	7.51
SNP	T-72	1	6.9
SNP	T-72	1	18.1
SNP	T-82	1	12.4
SNP	T-82	1	16.6
SNP	T-82	1	0.59

SNP	T-89	1	5.2
SNP	T-89	1	15.2
SNP	T-89	1	9.3
SNP	T-89	1	10.2
SNP	T-89	1	14.3
SNP	T-95	1	14.2
SNP	T-95	1	16.2
SNP	T-95	1	9.3
SNP	T-95	1	5.3
SNP	T-95	1	13.6
SNP	T-95	1	5
SNP	T-98	1	8.1
SNP	T-98	1	16.3
SNP	T-99	1	15.3
SNP	T-99	1	17.8
SNP	T-99	1	19.7
SNP	T-99	1	16.05
SNP	T-100	1	12.9
SNP	T-100	1	13.4
SNP	T-100	1	13.9
SNP	T-100	1	0
SNP	T-100	1	10.1
SNP	T-100	1	9.8

SNP	T-10	1	8.2
SNP	T-10	1	10.2
SNP	T-17	1	0.5
SNP	T-17	1	3
SNP	T-17	1	7.2
SNP	T-17	1	7.8
SNP	T-17	1	8.1
SNP	T-17	1	8.9
SNP	T-17	1	9
SNP	T-17	1	8.5
SNP	T-17	1	9
SNP	T-17	1	8.7
SNP	T-17	1	7.9
SNP	T-17	1	9.6
SNP	T-17	1	6.8
SNP	T-17	1	5.3
SNP	T-17	1	4.7
SNP	T-17	1	7.1
SNP	T-17	1	5.9
SNP	T-17	1	15
SNP	T-17	1	4.6
SNP	T-18	1	12
SNP	T-18	1	12

SNP	T-19	1	7.3
SNP	T-19	1	5.7
SNP	T-23	1	12
SNP	T-23	1	4.19
SNP	T-23	1	5.2
SNP	T-23	1	11.1
BZ	BZ1T1	1	5
BZ	BZ1T1	1	8.2
BZ	BZ1T1	1	2.1
BZ	BZ1T1	1	11.2
BZ	BZ1T1	1	10.7
BZ	BZ1T4	1	6.2
BZ	BZ1T4	1	7.1
BZ	BZ1T4	1	0
BZ	BZ1T4	1	4.3
BZ	BZ1T4	1	9.4
BZ	BZ1T4	1	10
BZ	BZ1T4	1	8.4
BZ	BZ1T4	1	2.5
BZ	BZ2T1	1	7.3
BZ	BZ2T1	1	5.2
BZ	BZ2T1	1	4.8
BZ	BZ2T1	1	5.1

BZ	BZ2T1	1	5.8
BZ	BZ2T1	1	6.7
BZ	BZ2T1	1	3.6
BZ	BZ2T1	1	8.4
BZ	BZ2T1	1	7.1
BZ	BZ2T1	1	5.9
BZ	BZ2T1	1	8
BZ	BZ2T1	1	10.4

Appendix 2: Number of chimpanzee nests detected on permanent (PMNT) and temporary transect (TMP) lines in SNP and in the buffer zone (BZ) surrounding these, respectively.

Transect id	Area	Type of transect	Transect length	No. of nest detected	No. other chimp signs
T-67	SNP	PMNT	2000	1	0
T-72	SNP	PMNT	2000	14	0
T-82	SNP	PMNT	2000	3	0
T-89	SNP	PMNT	2000	5	1
T-95	SNP	PMNT	2000	6	0
T-98	SNP	PMNT	2000	2	0
T-99	SNP	PMNT	2000	4	2
T-100	SNP	PMNT	2000	6	0
T-10	SNP	PMNT	2000	2	0
T-11	SNP	PMNT	2000	0	0
T-12	SNP	PMNT	2000	0	3
T-13	SNP	PMNT	2000	0	0
T-17	SNP	PMNT	2000	19	2
T-18	SNP	PMNT	2000	2	7
T-19	SNP	PMNT	2000	2	0
T-23	SNP	PMNT	2000	4	2
BZ1T1	BZ	TMP	1179	5	1
BZ1T3	BZ	TMP	2000	0	0
BZ1T4	BZ	TMP	1000	8	0

BZ2T1	BZ	TMP	760	12	1
BZ2T2	BZ	TMP	1000	0	0
BZ2T3	BZ	TMP	440	0	0

Appendix 3: Category of anthropogenic activities and status recorded permanent transect in SNP and temporary transect in the buffer zone (BZ)

Transect	Area	Type of transect	Human action	N0. detected	Status
T-67	SNP	PMNT	Poacher trail	2	Active
T-67	SNP	PMNT	Human direct	1	
T-67	SNP	PMNT	Human track	1	Recent
T-72	SNP	PMNT	Poacher trail	2	Active
T-72	SNP	PMNT	Human track	2	Recent
T-72	SNP	PMNT	Old touch light	1	Old
T-82	SNP	PMNT	Poacher trail	3	Active
T-89	SNP	PMNT	Poacher trail	1	Active
T-95	SNP	PMNT	Poacher trail	2	Active

T-95	SNP	PMNT	Tree back extraction	1	Recent
T-99	SNP	PMNT	Poacher trail	3	Active
T-100	SNP	PMNT	Poacher trail	2	Active
T-100	SNP	PMNT	Gun shot	3	Live
T-100	SNP	PMNT	Cartridge	1	Recent
T-10	SNP	PMNT	Poacher trail	3	Active
T-10	SNP	PMNT	Cartridge	4	Recent
T-11	SNP	PMNT	Cartridge	2	Recent
T-12	SNP	PMNT	Poacher trail	1	Active
T-12	SNP	PMNT	Human nut cracking site	2	New
T-12	SNP	PMNT	Human Vocalization	1	Active
T-13	SNP	PMNT		4	New

			Cartridge		
T-18	SNP	PMNT	Poacher trail	1	Active
T-18	SNP	PMNT	Gun shot	4	Live
T-18	SNP	PMNT	Cartridge	4	New
T-19	SNP	PMNT	Poacher trail	1	Active
T-19	SNP	PMNT	Human track	1	New
T-19	SNP	PMNT	Cartridge	1	New
T-23	SNP	PMNT	Cartridge	4	New
T-23	SNP	PMNT	Human Vocalization	1	Active
T-23	SNP	PMNT	Human track	1	New
T-23	SNP	PMNT	Poacher trail	2	Active
T-23	SNP	PMNT	Old touch light	1	Abandoned
BZ1T1	BZ	TMP	Old log road	1	Abandoned

BZ1T1	BZ	TMP	Poacher trail	2	Active
BZ1T3	BZ	TMP	Snares	2	Active
BZ1T3	BZ	TMP	Poacher trail	2	Active
BZ1T3	BZ	TMP	Human path	1	Active
BZ1T4	BZ	TMP	Poacher trail	1	Active
BZ1T4	BZ	TMP	Old log road	2	Abandoned
BZ2T1	BZ	TMP	Poacher trail	2	Active
BZ2T2	BZ	TMP	Poacher trail	2	Active
BZ2T2	BZ	TMP	Plantation	1	Abandoned
BZ2T2	BZ	TMP	Forest clearing	1	New
BZ2T3	BZ	TMP	Human path	2	Active
BZ2T3	BZ	TMP	Poacher trail	1	Active

Appendix 5: Category of natural factors (fruiting trees and streams) recorded on permanent transect in SNP {primary forest (PF) and mature secondary forest (MSF)} and temporary transect in the buffer zone {young secondary forest (YSF)}.

No. Nests	**Fruiting tree**	**Stream**	**Veg. Type**
3	4	9	PF
1	1	3	PF
14	2	2	PF
4	2	1	PF
5	6	4	PF
6	4	7	PF
2	1	1	PF
6	1	2	PF
2	0	1	MSF
0	2	2	MSF
0	1	0	MSF
2	5	2	MSF
4	2	1	MSF
0	0	2	MSF
2	1	1	MSF
19	3	2	MSF
12	2	3	YSF
5	1	1	YSF
0	0	1	YSF
8	2	1	YSF
0	0	1	YSF
0	1	0	YSF

Appendix 6: Perpendicular distance interval, distance at which each distance interval starts, observed and expected number of nests, and $\chi2$-values for the data collected during the study and analyzed with the Distance software.

Distance interval	Cut points for distance intervals (m)	No. of observed nests after truncation	No. of expected nests after truncation	χ^2
1	2.86	8	17.32	5.019
2	5.71	7	17.27	0.004
3	8.57	24	16.98	2.903
4	11.4	23	16.08	2.983
5	14.3	9	14.00	1.787
6	17.1	11	10.03	0.095
7	20.0	3	3.32	0.031

Total Chi Square = 12.2817; DF = 4

Appendix 7: Summary of best-fit model results in Distance.

Model	# of parameters	Effective Strip Width (ESW)	Probability of nest detection (P)	AIC	# of observations
Half-normal, simple polynomial adjustments	2	15.66	0.78	357.62	95

Appendix 8: Detection function fitted to the frequency distribution of detected nests.