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Use of Gallery and Non-Gallery Forest by Ungulates Inhabiting the Loma Mountains Non-Hunting Forest Reserve, Sierra Leone, West Africa

Aaron Peter Kortenhoven
University of Miami, kortenha@gmail.com

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UNIVERSITY OF MIAMI

USE OF GALLERY AND NON-GALLERY FOREST BY UNGULATES INHABITING THE LOMA MOUNTAINS NON-HUNTING FOREST RESERVE, SIERRA LEONE, WEST AFRICA

By

Aaron Peter Kortenhoven

A THESIS

Submitted to the Faculty
of the University of Miami
in partial fulfillment of the requirements for
the degree of Master of Science

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Aaron P. Kortenhoven

Approved:

________________ Steven M. Green, Ph.D. Professor of Biology	________________ Terri A. Scandura, Ph.D. Dean of the Graduate School
________________ David Janos, Ph.D. Professor of Biology	________________ Michael Gaines, Ph.D. Professor of Biology
________________ John F. Oates, Ph.D. Professor of Anthropology Institution	

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This 11-month study examined rates of encountering dung pellet groups, dung piles and ungulates in gallery forests and non-gallery forests during diurnal surveys in the Loma Mountains Non-Hunting Forest Reserve (LMNHFR) in Sierra Leone, West Africa. These indices of relative abundance were then used to infer relative habitat use by the seven ungulate species on which data were collected.

This study also examined the differences in rates of encountering duikers during nocturnal surveys with rates of encountering duikers during diurnal surveys to determine which time of day produces higher rates of encounter, and thereby a more accurate estimate of duiker abundance.

The dung of four of the seven species, namely *Cephalophus niger*, *Philantomba maxwelli*, *Tragelaphus scriptus*, and *Potamochoerus porcus* is encountered at a higher rate in gallery forest than in non-gallery forest. Rates of encountering the dung of three species, *C. silvicultor*, *C. dorsalis* and *Syncerus caffer nanus,* do not differ between forest types. Rates of encountering four species, namely *C. niger*, *P. maxwelli*, *T. scriptus,* and *C. silvicultor* are higher in gallery forest than in non-gallery forest. Rates of encountering

three species, namely *C. dorsalis*, *S. caffer nanus,* and *P. porcus* do not differ between forest types.

Rates of encountering duikers ranged from three to six times higher during nocturnal surveys than during diurnal surveys for *C. niger* and *P. maxwelli* and 20 times higher for *C. dorsalis.* Survey timing did not affect the rate of encounter for *C. silvicultor.*

Forest ungulates in the LMNHFR utilize gallery forests regularly. Possible reasons for the higher rates of encounter for six of the species in gallery forests compared with non-gallery forests are access to water, readily available browse resulting from annual fire damage on the periphery and interior of gallery forests, and easy access to cover for ungulates when foraging in adjacent grassland.

Given the current rate of forest loss in West Africa, studies examining how forest mammals are able to persist in small forest fragments should be high priority for both government and conservation groups. The findings here give evidence that forest ungulates can and do use small areas of forest. Most importantly, the findings from this study show the global value of the LMNHFR for the conservation of large mammals endemic to the Upper Guinea Forests.

To

Bamba Konkoro Koroma

1950-2008

Na kurɛ wuleŋ tɛgɛ Karamɔgɔ

Kumandi, i kana kassi.

You opened my eyes and taught me to think about the African bush “Lahawalakolɔŋ”
from the inside looking out. My point of view has never changed.
Thank you.

Acknowledgments

This thesis has been a collaborative effort that would not have been possible without the guidance, support, and perseverance of many people. First, I thank my committee: Steven Green, David Janos, Michael Gaines, and John F. Oates, for their comments and advice at various junctures in the research and preparation of this manuscript. This project was funded by the Tropical Biology Fellowship and Summer Research Grant from the University of Miami.

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I could not have done any of this work without the support of my family. My parents, Paul and Mary Kortenhoven, gave me the freedom to explore the African bush and introduced me to a world of wonder. Finally, I thank my wife, Emily Loeks. She sacrificed more than any wife ever should for the sake of her husband. She supported me through every step of this research and continues to give me courage each day. She must love me.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Appendix Figure List

LIST OF TABLES

Appendix Table List

Chapter 1.

INTRODUCTION

Ungulates are an integral and often poorly known component of African forest ecosystems (Wilson 2001; Lwanga 2006), but they fulfill a crucial ecological role as seed dispersers for forest plants (Gautier-Hion, Emmons and Dubost 1980; Dubost 1984; Dubost and Feer 1988; Bodmer 1991; Feer 1995; Wilson 2001) and as prey for forest predators (Hart, *et al.* 1996; Henschel *et al.* 2005; Jenny and Zuberbühler 2005; Shultz 2008). Forest ungulates are under increased pressure from habitat loss and hunting throughout Africa (Wilkie and Finn 1990; Muchaal and Ngandjui 1999), and a decrease in ungulates could have deleterious effects on the ecosystems they inhabit. As expansive forested habitats throughout Africa are becoming ever more threatened and fragmented due to human activities (Tutin *et al.* 1997; Walsh *et al.* 2003; Poorter *et al.* 2004), knowledge concerning forest use by ungulates is needed for conservation.

In West Africa, savannas are widespread, as are the gallery forests found in these savannas. These gallery forests are strips of closed canopy forest situated along streams and headwater basins (Beard 1955). With the current rate of forest loss in West Africa it is essential to understand how large mammals utilize gallery forests, as their future habitat will likely be forest fragments that are similar to gallery forests in both size and floral diversity. The key role gallery forests play in species survival is emphasized by Fay (1988) and Tutin *et al.* (1997), but few studies have documented the use of gallery forests by ungulates in West Africa (Mühlenberg *et al.* 1990). In order to adequately examine ungulate forest usage, it is necessary to conduct research in areas with minimal human disturbance.

The Loma Plateau, located in the north-central portion of the Loma Mountains Non-Hunting Forest Reserve (LMNHFR) in northeastern Sierra Leone, contains gallery forests that have escaped the effects of farming and firewood gathering common to gallery forests in more populated areas. The Loma Plateau is situated above the escarpment of the Loma Mountains. It ranges between the elevations of 1000 and 1600 meters. The plateau is characterized by montane grasslands interspersed with numerous streams along which gallery forests occur. The western and northern limits of the plateau are marked by escarpments, whereas the eastern and southern borders of the plateau have a more gradual slope to the surrounding lowlands. A common feature of the Loma Plateau is its many granite rock formations. The combination of limited human pressure**,** little fragmentation, and a large assemblage of forest ungulates in the LMNHFR provide ideal conditions in which to examine forest usage by ungulates in a natural setting.

The broad aim of this study was to assess whether gallery forests in the LMNHFR are vital for species survival as reported for other regions containing gallery forests (Fay 1988; Mühlenberg *et al.* 1990; Tutin *et al*. 1997a). This study provides baseline data on forest ungulates in the LMNHFR, explores the use of encounter rates in assessing differences of relative habitat use, and determines the relative use of gallery and non-gallery forest by the seven investigated ungulate species. Surveys were undertaken regularly over a single study period from April 2007 to February 2008.

Based on dietary and habitat preferences reported in earlier studies, I expected rates of forest ungulate encounters to be higher in non-gallery forests than in gallery forests, given that non-gallery forests in the LMNHFR are more expansive and harbor a higher diversity of trees than gallery forests. I predicted that three of the seven species would have higher rates of encounter in non-gallery forest, three would have higher rates of encounter in gallery forest, and one would not differ in rates of encounter between forest types (Table 1.1).

Table 1.1. Diet, habitat preference, and predictions for rates of encounter for each species based on its natural history.

Species		Diet	Habitat	Prediction	Reference
Bay duiker	*Cephalophus dorsalis*	Fr, Br, C	CF	↑ ER in non-gallery forest	1, 2, 5
Black duiker	*C. niger*	Fr, Br, C	F/SF	↑ ER in gallery forest	2, 3
Yellow-backed duiker	*C. silvicultor*	Fr, Br, C	F/EV/S	↑ ER in gallery forest	1, 2, 6
Maxwell's duiker	*Philantomba maxwelli*	Fr, Br, C	F	↑ ER in non-gallery forest	2, 3
Bushbuck	*Tragelaphus scriptus*	Br	EV	↑ ER gallery forest	4
Forest buffalo	*Syncerus caffer nanus*	Grazer	S/F	Gallery = non-gallery forest	4
Red river hog	*Potamochoerus porcus*	Omnivore	F	↑ ER in non-gallery forest	4

1. Dubost 1984; 2. Newing 2001; 3. Hofmann and Roth 2003; 4. Bodmer 1990; 5. Hart 1986; 6. Lumpkin and Kranz 1984; Fr = fruit; Br = browse; C = carrion; CF = closed canopy forest; F = forest; SF = secondary forest; EV = edge vegetation; S = savanna; ER = Encounter rate.

In this thesis, I compare rates of encountering dung and animals during diurnal and nocturnal surveys of ungulates in gallery forests to rates of encounter in adjacent non-gallery forests. I also compare differences in rates of encountering duikers during nocturnal surveys with rates of encountering duikers during diurnal surveys. I then discuss some of the potential factors that may be underlying reasons for the differences in encounter rates reported in this research.

METHODS

Study Site

The LMNHFR is located in northeastern Sierra Leone (9° 12’46.16” N, 11° 08’39.26”W) on the northern border of the Upper Guinean forest block (Figure 1.1). The reserve covers 33,201 hectares (ha) and is a mosaic of wooded savanna, montane grassland, montane forest, tropical evergreen forest and gallery forest (Cole 1974).

Elevation in the reserve ranges from 500 to 1945 meters (m) above sea level. Temperatures range from 10º to 33º C (Morton 1986). Annual rainfall during this study was seasonal, with six months of dry season and six months of rainy season during which there was a total precipitation of 3,650 mm at an elevation of 1350 m (Figure 1.2). Data were collected on the Loma Plateau within an approximate area of 5,000 ha (Figure 1.3).

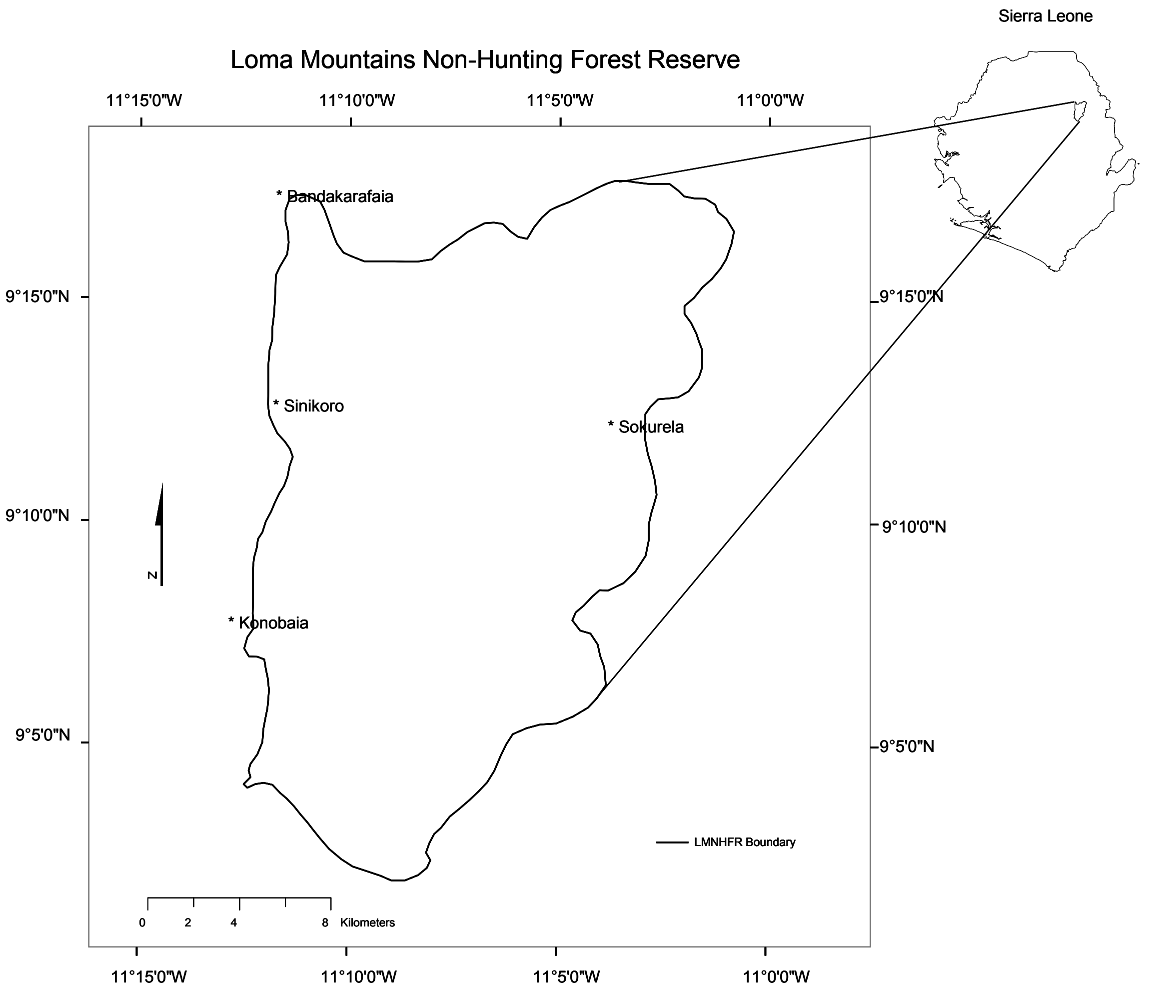

Figure 1.1 Location of the LMNHFR in Sierra Leone, West Africa.

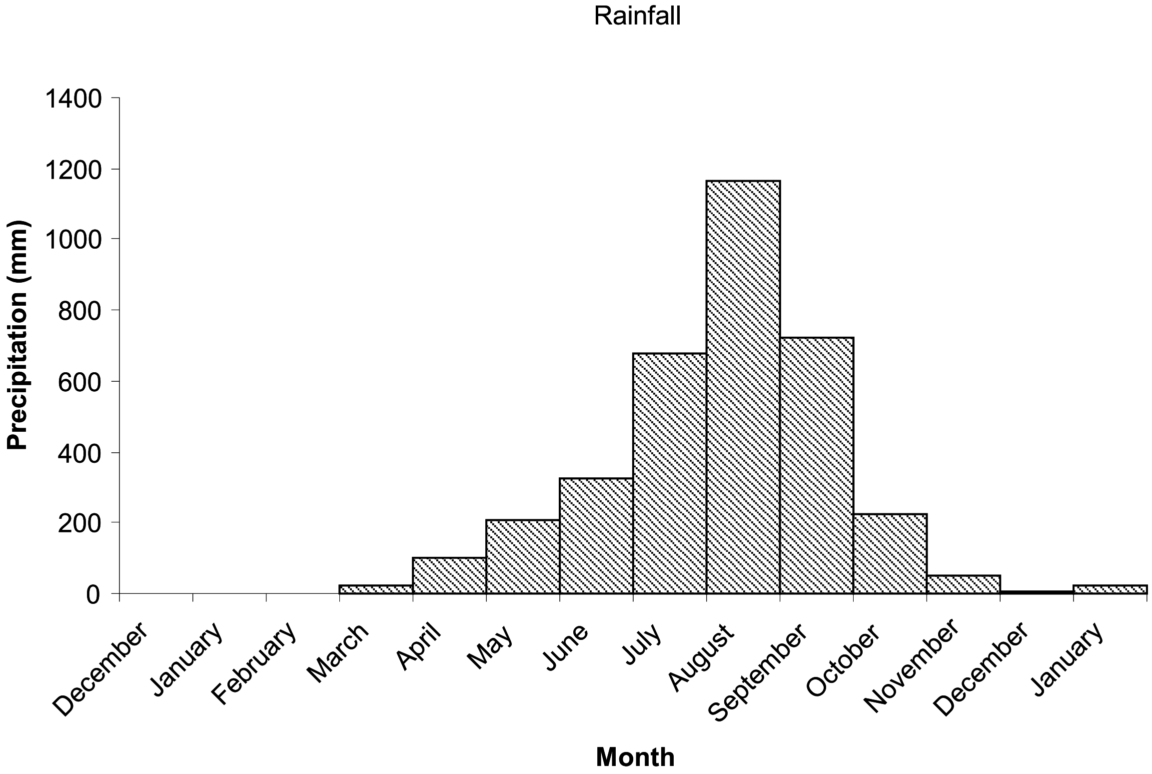

Figure 1.2. Monthly patterns of rainfall in the LMNHFR from December 1, 2006 to January 31, 2008 taken at 9°12'45.10"N, 11° 8'37.40"W at an elevation of 1,350 meters.

Habitats Surveyed

For this study, any forest forming a corridor of trees along a watercourse projecting into a landscape otherwise sparsely populated by trees was considered a gallery forest. Data were collected in gallery forests that formed corridors along watercourses and headwater basins within the grasslands of the Loma Plateau. Annual brush fires in these grasslands are the likely reason gallery forests do not colonize some grassland areas. The sun-exposed tree composition in these gallery forests is less diverse than the sun-exposed tree composition of forests not projecting into grasslands (referred to as non-gallery forest). Twenty-four sun-exposed tree species were recorded in sampled gallery forests (Appendix 1, Table A1.2). In nearby non-gallery forest seventy-two sun-exposed tree species were recorded (Appendix 1, Table A1.3). *Parinari excelsa* is the dominant sun-exposed tree in gallery forest with an importance value index (IVI) of 142 and a basal area of 20 m^2/ha. No tree family was represented by more than three different canopy species in gallery forest (Appendix 1).

Non-gallery forest was defined as any forest currently contiguous with the surrounding lowland forest and not surrounded by grassland. In non-gallery forests where systematic surveys were conducted, *P. excelsa* is the dominant sun-exposed tree with an IVI of 65 and a basal area of 12 m^2/ha. A striking difference in sun-exposed tree species composition between gallery and non-gallery forests is that the latter harbors 10 different Sapotaceae species with a combined basal area of 3 m^2/ha and 12 different Fabaceae species with a combined basal area of 16 m^2/ha (Appendix 1.).

Study Animals

Fourteen species of artiodactyls occur within the LMNHFR (Table 1.2). Data analysis was carried out only on species that were encountered during systematic surveys, namely bay duiker (*Cephalophus dorsalis*), black duiker (*C. niger*), yellow-backed duiker (*C. silvicultor*), Maxwell's duiker (*Philantomba maxwelli*), bushbuck (*Tragelaphus scriptus*), forest buffalo (*Syncerus caffer nanus*), and red river hog (*Potamochoerus porcus*). These species, with the exception of bushbuck and buffalo, are generally considered forest specialists (Tutin *et al*. 1997; Blake 2000; Newing, 2001). The bushbuck is a forest-edge species that favors transitional vegetation (Estes 1991). Buffalo utilize forests regularly for cover but acquire the majority of their food in grassland (Blake 2000; Korte 2008).

Table 1.2. The Artiodactyls recorded in the LMNHFR from 2006-2008.

Family	**HIPPOPOTAMIDAE**		
	Pygmy hippopotamus *Hexaprotodon liberiensis*	rare	N
Family	**SUIDAE**		
	Common warthog *Phacochoerus africanus*	common	D/N
	Red river hog *Potamochoerus porcus*	common	D/N
Family	**TRAGULIDAE**		
	Water chevrotain *Hyemoschus aquaticus*	rare	N
Family	**BOVIDAE**		
Sub-family	**Antilopinae**		
	Royal antelope *Neotragus pygmaeus*	rare	N
Sub-family	**Bovinae**		
	Forest buffalo *Syncerus caffer nanus*	common	D/N
	Bongo *Tragelaphus eurycerus*	rare	Unknown
	Bushbuck *T. scriptus*	common	D/N
	Waterbuck *Kobus ellipsiprymnus*	rare	D/N
Sub-family	**Cephalophinae**		
	Maxwell's duiker *Philantomba maxwelli*	common	D/N
	Bay duiker *Cephalophus dorsalis*	common	N
	Black duiker *C. niger*	common	D/N
	Yellow-backed duiker *C. silvicultor*	common	D/N
	Red flanked duiker *C. rufilatus*	rare	D/N

D = Diurnal; N = Nocturnal

Hours of Observation

The author and six field assistants conducted this study. Encounter rates and animal observations presented in this research were collected over approximately 717 hours from April of 2007 through February of 2008 (Table 1.3). Vegetation data were collected over 100 hours. Hours were not logged for work done at the base camp or for constructing the base camp. The hours recorded here are actual hours, not man-hours. During the course of research, there was a minimum of four people conducting field work at all times.

Table 1.3. Hours of effort between April 2007 and January 2008

Activity	Hours of Effort
Walking survey trails	314.8
Vegetation surveys	100.0
ad lib observations	401.8
Total	816.5

Survey Techniques

We cut twelve minimum impact trails, six in gallery forest with a total length of 2.8 kilometers (km) and six in non-gallery forest with a total length of 6.6 km (Table 1.4; Figure 1.3). These trails were cut through the forest removing vegetation only as necessary to allow for ease of movement. Extra care was taken not to cut lianas, and, when possible, saplings were bent rather than cut. By preserving saplings and lianas, we hoped to reduce potential browse along trails and speed forest recovery so that our trails would not become hunting trails used by poachers.

Table 1.4. Trail identification, number of walks on each trail and total distance covered on each trail for gallery and non-gallery forests for both diurnal and nocturnal surveys.

Gallery Forest				Non-gallery Forest			
Trail	Length (km)	Number of surveys	Distance (km)	Trail	Length (km)	Number of surveys	Distance (km)
gBereh	0.5	28	14	Camp	1.4	28	39.2
Sankan	0.39	21	8.19	Pig lake	1.3	21	27.3
Fulon	0.39	17	6.63	Semeh	1.1	22	24.2
Salt lick	0.38	24	9.12	No name	1	24	24
Bintumani	0.38	18	6.84	Lappeh	1	20	20
Nonkeh	0.75	23	17.25	Merreh	0.8	21	16.8
Total	2.79	131	62.03		6.6	136	151.5

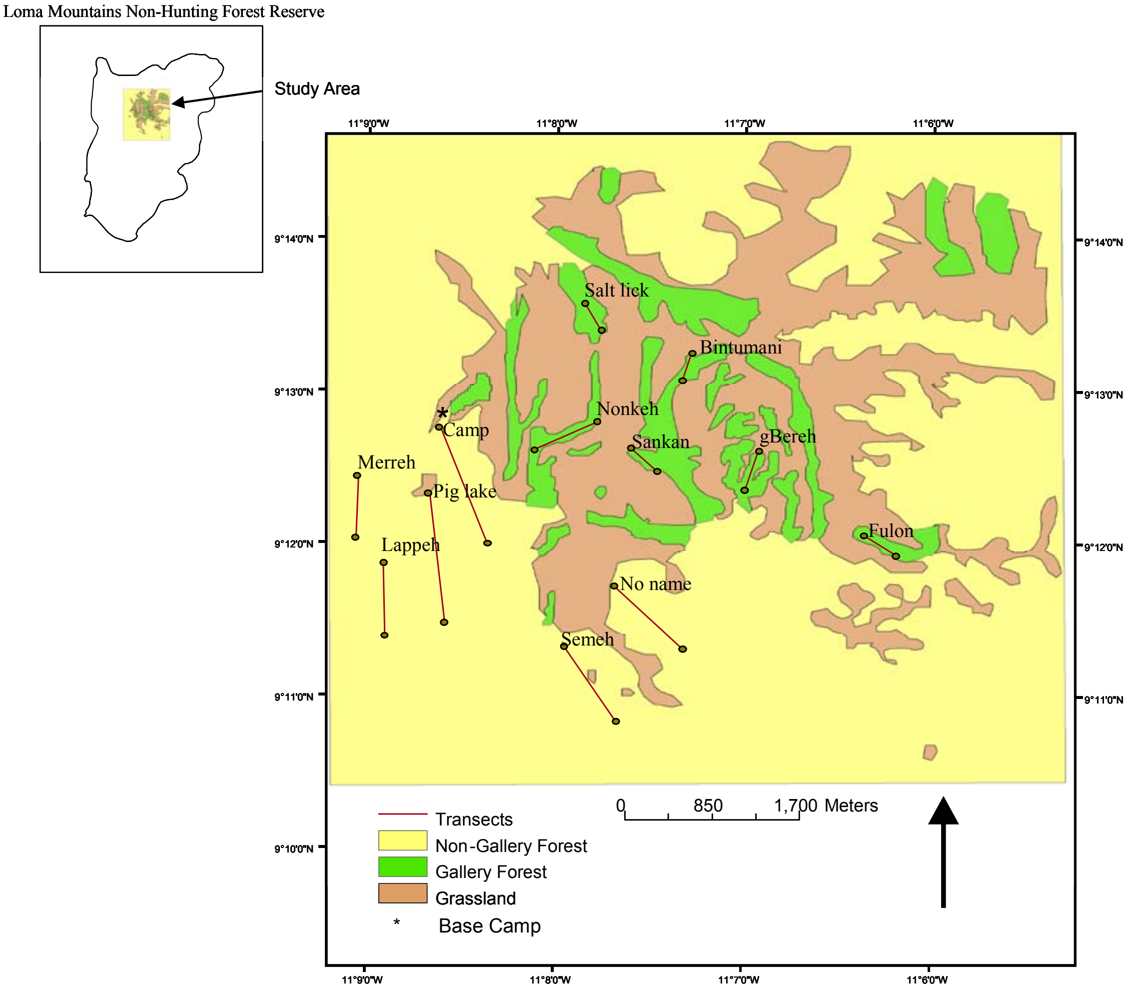

Figure 1.3. Location of survey trails and study area in the LMNHFR.

Each survey trail followed a single compass bearing through the forest and was marked every 25 meters with orange taping. Individual trails were walked multiple times, with individual walks separated by at least seven days. Each day that survey walks were conducted, two different trails were walked, each by a separate team and each in a different forest type.

In gallery forest, 131 survey walks were completed on the six trails for a total distance of 62 km. In non-gallery forest, 136 survey walks were completed on the six trails for a total distance of 151.5 km (Table 1.4). Survey walks were abandoned when rain fell for more than fifteen minutes because rain affects animal behavior and detection probability (White 1994).

Diurnal Surveys

I used line-transect sampling methods as described by Whitesides *et al.* 1988 and by McCoy 1995. Survey walks were conducted between 0700 and 1100 hrs and were walked at a rate of 0.70-1.0km/hr, with periodic stops to listen and look for animals. During survey walks all dung pellet groupings, dung piles, and animal encounters were recorded.

In order to determine if habitat influenced detection distance, the perpendicular distance from the survey trail to each dung pellet grouping, dung pile or animal was measured. When groups of animals were encountered, perpendicular distance was recorded for only the first individual seen. When an animal was detected, its location was noted. Its perpendicular distance from the survey trail was measured from the point on the trail closest to the animal's location upon detection. Distances were measured to the nearest meter using a Nikon Prostaff® laser 440 range finder. Often when an animal was detected, it had already been disturbed and was fleeing. In such cases, we attempted to identify the point where the animal was located before flight was initiated. This point was identified by the scattered dirt and debris resulting from the animal having been startled.

When a dung pellet grouping or dung pile was encountered, the species, the age of the dung deposit, and its perpendicular distance from the survey trail were recorded. Perpendicular distances were measured to the nearest centimeter. Dung pellet groupings were then spread out so the grouping would not be recorded on subsequent survey walks. Dung piles were left intact since they have a fast rate of decomposition and are easily cross-referenced with data sheets from previous surveys. The presence of dung was recorded only during diurnal survey walks. Only field workers with extensive experience as hunters identified the species that deposited the dung. Species identification from dung was possible because all ungulate species within the study area had distinctly different dung morphology as described below.

Dung Morphology

Bay duiker dung pellets are oblong spheroids approximately 10 mm in diameter with a dimpled surface. The difference in diameter between the major and minor axis is barely noticeable. Dung pellet groupings contain in excess of 200 pellets and have a spread of 10-20 cm.

Black duiker dung pellets are oblong with the major axis 10-15 mm long and a minor axis approximately 25% less than the major axis. The pellet's surface is smooth without dimpling. Dung pellet groupings contain in excess of 200 pellets and have a spread of 10-20 cm.

Maxwell's duiker dung pellets are the smallest of the duiker dung pellets and are prolate spheroids. The major axis is approximately 6-8 mm long and the minor axis is approximately 25% less than the major axis. Dung pellet groupings contain in excess of 200 pellets and have a spread of 10-20 cm.

Yellow-backed duiker dung pellets are spheroids with an approximate diameter of 15 mm. One end of the dung pellet is truncated and the other end is somewhat pointed. Dung pellet groupings contain in excess of 100 pellets and have a spread of 20-40 cm.

Bushbuck dung pellets are prolate spheroids with the major axis approximately 10-15 mm long and a minor axis approximately 25% less than the major axis. One end of the major axis always exhibits a small point and the other end is rounded. Dung pellet groupings contain in excess of 100 pellets and have a spread of 15-30 cm.

Buffalo dung is best described as an amorphous pile the size of a large dinner plate, about 20-25 cm in diameter. There are no individual pellets.

Red river hog dung is comprised of poorly formed pellets of various shapes and sizes that clump together. They are easily distinguished from all other ungulate dung in the study area by their extremely pungent odor.

Mean Group Size

Several of the study species were often encountered in groups. Each group encounter was recorded as a single encounter, but all individuals in a group that were seen were noted. Mean group size was obtained by dividing the total number of animals recorded for a particular species by the total number of encounters with that species.

Nocturnal Surveys

During this study sunset was no earlier than 1830 hours and no later than 1910 hours. Sunrise was no earlier than 0630 hours and no later than 0645 hours. Nocturnal survey walks were conducted between 2000 and 2300 hours and between 0300 and 0600 hours at a speed of 0.70 -1.0km/hr, stopping only when animals were detected. Survey walks were abandoned when it began raining or became excessively windy. Light-emitting diode (LED) head lamps were used to locate animals by their eye shine. Species were identified by sight after setting the headlamps to the high intensity beam. Perpendicular distances were measured as during diurnal survey walks.

Encounter Rates

The aim of line transect studies is to estimate and compare animal densities (Buckland *et al.* 2001, Whiteside *et al.* 1988). Models used to obtain density estimates, however, depend on core assumptions rarely attainable in tropical forests (Rovero 2004, Lwanga 2006). Three of these core assumptions are as follows: all animals on the census trail are detected, all animals are detected at their initial location, and census trails are placed at random with respect to animal distribution (Buckland *et al.* 2001). Because some animals and dung along survey trails were likely to have gone undetected, and in many instances it was not possible to determine if animals were recorded at their initial locations, data collected during this study probably violate these assumptions. Given the above limitations, I compare relative abundances of animals in the form of animal or dung detections per kilometer and do not compare densities. Relative abundance measures are robust even in a rainforest environment. I present dung and sighting records as encounter rate (ER) per kilometer. Encounter rates were calculated individually for each survey trail using the number of dung piles and sighting records of each species per kilometer walked on that survey trail. Encounter rates were calculated separately for dung and animal sightings. Using the number of sightings and number of dung pile records of each species recorded per kilometer as an index of abundance, I compared the rates of encounter for each species in gallery forests with rates of encounter for each species in non-gallery forests.

Examining the Use of Nocturnal Surveys for Duikers

I examined the rates of encountering each duiker species during nocturnal surveys with rates of encountering the same species during diurnal surveys to determine if nocturnal surveys yield rates of encounter that differ from diurnal surveys. Data were analyzed separately for each species.

Opportunistic Observations of Ungulates

All ungulates seen in grassland during this research were recorded. When an animal was seen, its species, distance from observer, and behavior state (feeding, vigilant, moving/not moving) were recorded. The wind direction in relation to the observer (up-wind, down-wind, or cross-wind), weather condition, and the location of the animal were also recorded. If animals were in a group, all individuals that were seen were noted.

Observations of duikers were also conducted at known food sources to determine the time of day different species came to feed. These observations were made beneath several trees whose fruit is known to be eaten by duikers, namely *Parinari excelsa,* *Milicia excelsa, Ficus craterostoma, Parkia bicolor, Chrysophyllum pruniforme,* and *Samanea dinklagei*. Observations were made between 1500 and 1900 hrs and again between 2000 and 2300 hrs. Observations during daylight were made from elevated blinds or from tree branches and nighttime observations were made during nocturnal visits to each tree by an observer slowly approaching the tree from a down-wind direction. Nocturnal observations were only to determine if and which species of duikers were present.

Statistical Analyses of Data

Statistical analyses were carried out with the MYSTAT ® and SYSTAT 10.2 ® statistical analysis software packages, with the exception of the randomization test (Siegel 1956) which was done by hand. The criterion for statistical significance was $p < 0.05$ for all analyses and all tests were two-tailed. Sighting and dung count data do not conform to normality (Lilliefors test, $p < 0.05$). For this reason, the non-parametric randomization test was used to determine if encounter rates for each species differ between habitats. To accomplish data analysis with the randomization test, a single encounter rate for each species was calculated for each survey trail by dividing the total number of records of that species on a given trail by the total distance walked on that trail. The result was six encounter rates for dung, diurnal animal sightings, and nocturnal animal sightings for each species in each habitat, one for each data set for each trail. These encounter rates were then tested with the randomization test to determine if there was a significant difference between the two habitats. The protocol was carried out separately on dung, diurnal sighting records, and nocturnal sighting records.

Variation in visibility between habitats can cause differences in detection distance that create biases that can compromise survey results (Struhsaker 1997). Detection distances of individual animals and dung piles from the survey trail failed to meet normality (Lilliefors test, $p < 0.05$). The Mann–Whitney U test was used to examine both dung and sighting detection distances to determine if either differs in stochastic size. I also examined sighting distances with the two-sample Kolmogorov–Smirnov test to determine if there is any difference in the distribution of perpendicular distances between gallery and non-gallery forests.

RESULTS

Detection Distance

To determine if detection distances in the two forest types differ, perpendicular sighting distances of animals, dung pellet groupings, and dung piles were examined. The combined sighting distances for all species are not different between gallery and non-gallery forest (Mann-Whitney U test, $p > 0.05$; gallery forest, median = 8.25 m, interquartile range (IQR) = 4.5–12.5 m, n = 93; non-gallery forest, median = 8.0 m, IQR = 4 – 12 m, n = 65), nor are dung pile sighting distances (Mann–Whitney U test $p > 0.05$; gallery forests, median = 1.0 m, IQR = 0.30–2.2 m, n = 901; non-gallery forest, median = 1.2 m, IQR = 0.40–2.4 m, n = 748). Furthermore, to determine if sighting distances differed in distribution between the two forest types, the sighting distances were examined using the Kolmogorov–Smirnov test.

The distributions of combined sighting distances for all species are not significantly different for gallery and non-gallery forest (K–S, $p > 0.05$; Figure 1.4), so any visibility differences between forest types do not bias encounter rates between habitats.

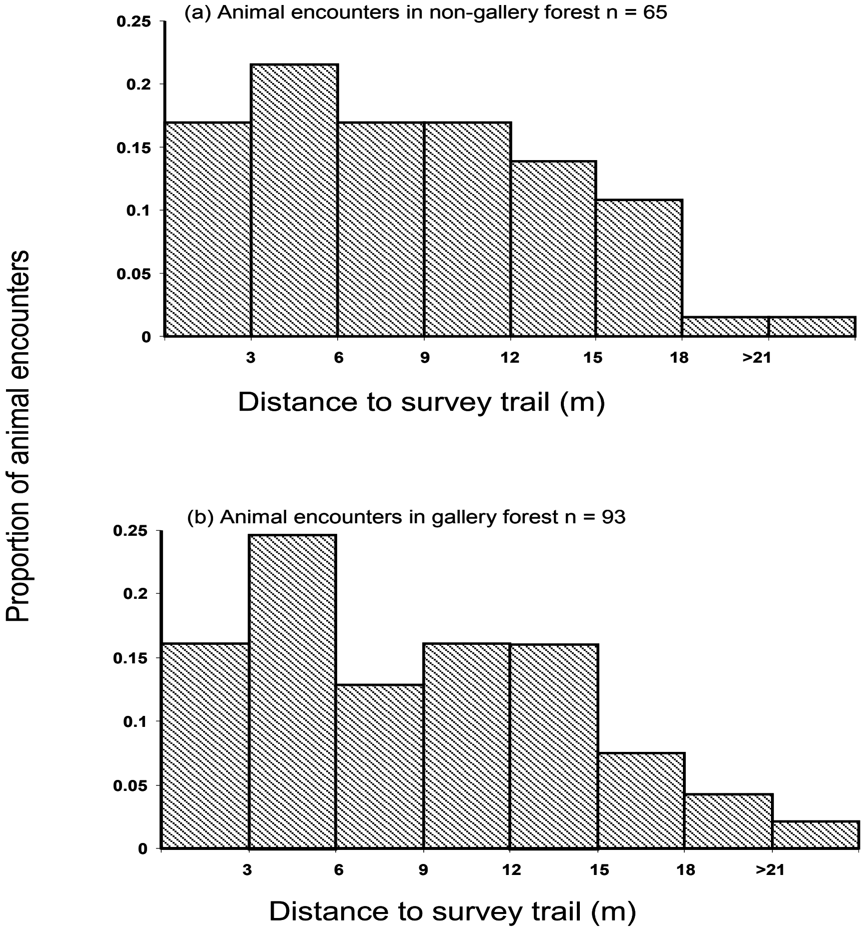

Figure 1.4. Distribution of perpendicular distances from animal to survey trail for diurnal surveys conducted in gallery and in non-gallery forests.

Nocturnal vs. Diurnal Sighting Distances

Sighting distances were also pooled by time of day across both habitats to determine if they differed for nocturnal and diurnal sampling. Nocturnal sighting distances are greater than diurnal sighting distances (Mann-Whitney U test, $p < 0.05$; nocturnal, Median = 10 m, IQR= 6–12 m; diurnal, Median = 7.5 m, IQR = 4.5–11.5 m). The distributions of sighting distances for all species are also different for nocturnal surveys compared to diurnal surveys (K-S, $p < 0.05$; Figure 1.5).

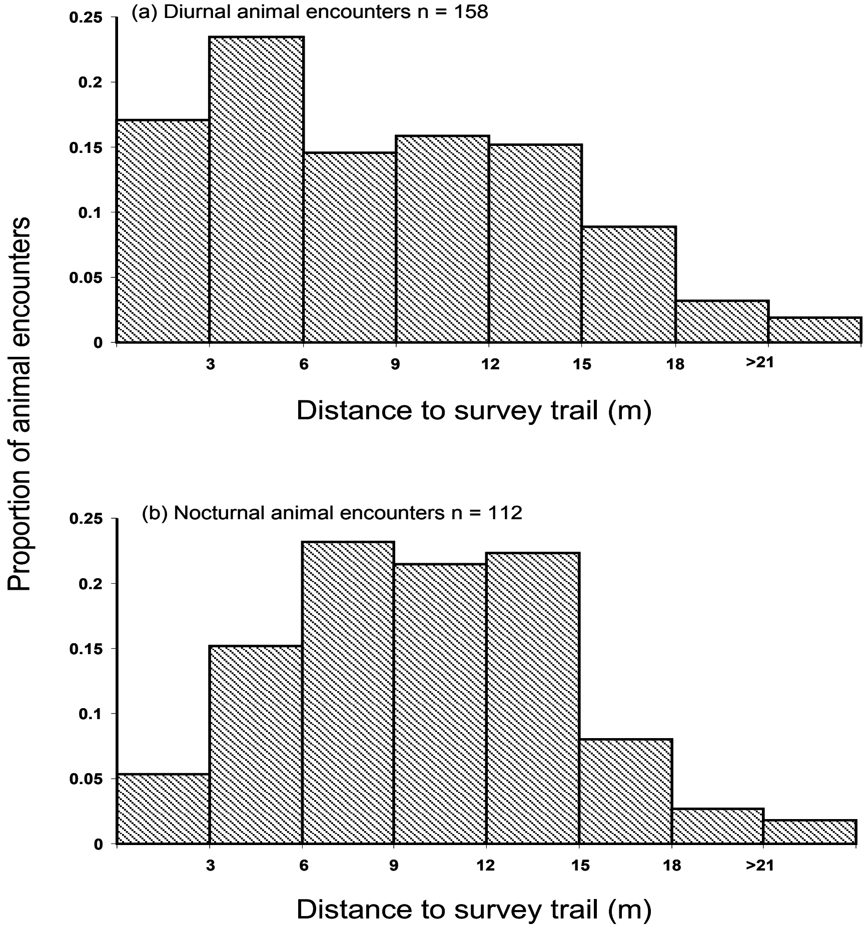

Figure 1.5. Distribution of perpendicular distances from animal to survey trail for diurnal and for nocturnal surveys regardless of forest type.

Dung Pellet Grouping and Dung Pile Data

During this study, 837 dung pellet groupings and 64 dung piles were recorded during 119 survey walks covering 130.2 km along the 6 trails in non-gallery forest, and 664 dung pellet groupings and 84 dung piles were recorded during 115 survey walks covering 54.5 km along the 6 trails in gallery forest. Rates of encountering dung pellet groups are higher in gallery forest than in non-gallery forest for black duikers, Maxwell's duikers, bushbuck, and red river hogs (randomization test, $p < 0.05$; Table 1.5; Figures 1.7a, 1.8a, 1.10a 1.12a). Rates of encountering dung pellet groups do not differ between forest types for bay duikers or yellow-backed duikers (Table 1.5; Figures 1.6a, 1.9a). Rates of encountering buffalo dung piles do not differ between forest types (Table 1.5, 1.11a)

Table 1.5. The number of dung pellet groups, dung piles, and their rates of encounter per kilometer for each of the seven study species in gallery and non-gallery forests in the LMNHFR.

		Gallery Forest		Non-Gallery Forest	
	Species	Dung records	ER/km	Dung records	ER/km
Bay duiker	*Cephalophus dorsalis*	104	1.91	209	1.61
Black duiker	*C. niger**	204	3.75	263	2.02
Yellow-backed duiker	*C. silvicultor*	32	0.59	40	0.31
Maxwell's duiker	*Philantomba maxwelli* *	190	3.49	224	1.72
Bushbuck	*Tragelaphus scriptus**	106	1.95	45	0.35
Forest buffalo	*Syncerus caffer nanus*	64	1.18	84	0.65
Red river hog	*Potamochoerus porcus**	48	0.88	36	0.28

* Significantly different between forest types (randomization test; $p < 0.05$); ER = encounter rate

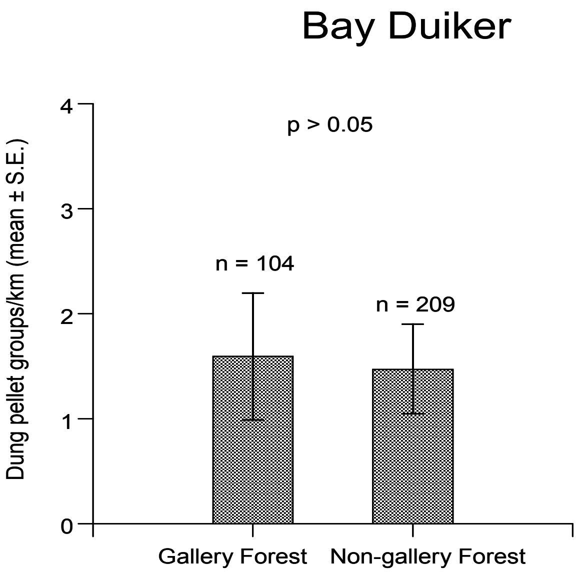

Figure 1.6a. Rate of encountering bay duiker dung pellet groups in gallery and non-gallery forests in the LMNHFR.

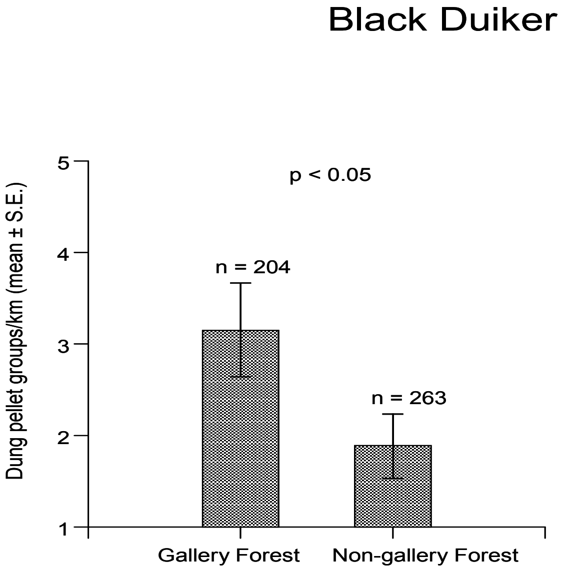

Figure 1.7a. Rate of encountering black duiker dung pellet groups in gallery and non-gallery forests in the LMNHFR.

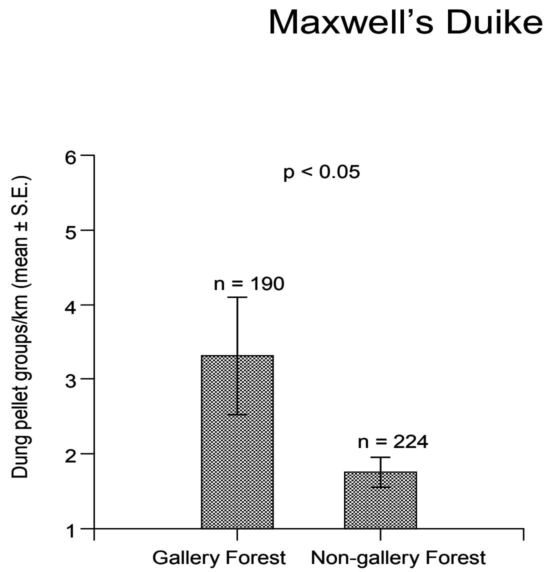

Figure 1.8a. Rate of encountering Maxwell's duiker dung pellet groups in gallery and non-gallery forests in the LMNHFR.

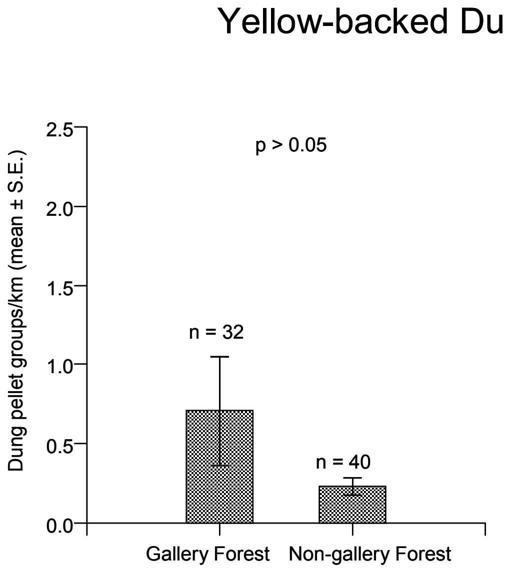

Figure 1.9a. Rate of encountering yellow-backed duiker dung pellet groups in gallery and non-gallery forests in the LMNHFR.

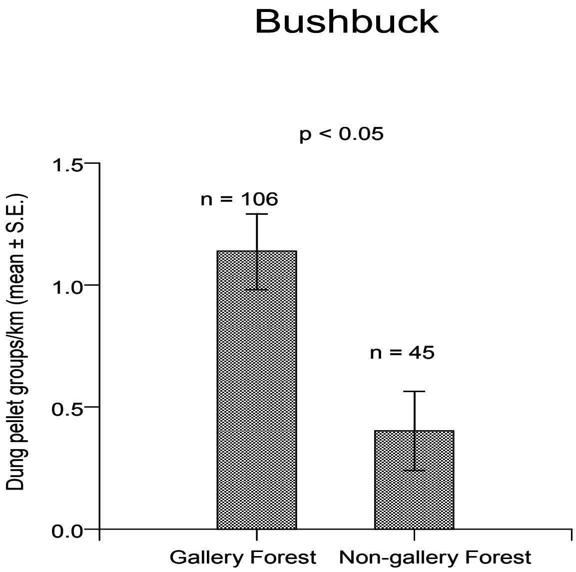

Figure 1.10a. Rate of encountering bushbuck dung pellet groups in gallery and non-gallery forests in the LMNHFR.

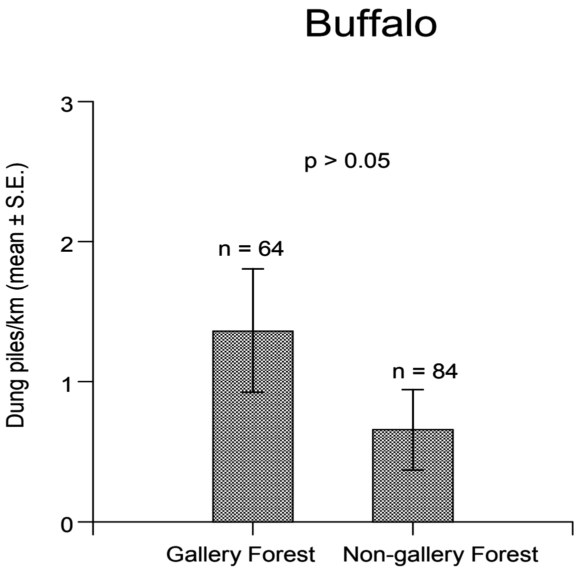

Figure 1.11a. Rate of encountering forest buffalo dung piles in gallery and non-gallery forests in the LMNHFR.

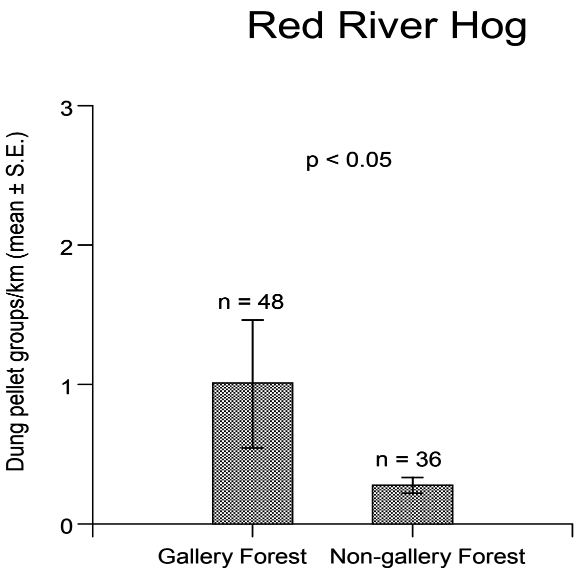

Figure 1.12a. Rate of encountering red river hog dung pellet groups in gallery and non-gallery forests in the LMNHFR.

Diurnal Sighting Data

During diurnal surveys over the same trails and distance on which dung counts were made, 65 ungulate sightings were recorded in non-gallery forest, and 93 ungulate sightings were recorded in gallery forest.

Encounters with black duikers, Maxwell's duikers, yellow-backed duikers, and bushbuck during diurnal surveys occur at a higher rate in gallery forest than non-gallery forest (randomization test, $p < 0.05$; Table 1.6; Figures 1.7b, 1.8b, 1.9b, and 1.10b). Rates of encountering bay duikers, buffalo, and red river hogs during diurnal surveys do not differ between forest types (randomization test, $p > 0.05$; Table 1.6; Figures 1.6b, 1.11b, and 1.12b).

Table 1.6. The number of animal sightings per kilometer, mean group size, and rates of encounter for each of the seven study species in gallery and non-gallery forests during diurnal survey walks in the LMNHFR.

		Gallery forest			Non-gallery forest		
Species		Sightings	Mean group size	ER/km	Sightings	Mean group size	ER/km
Bay duiker	*Cephalophus dorsalis*	2	1	0.04	6	1	0.05
Black duiker	*C. niger**	26	1	0.50	26	1	0.20
Yellow-backed duiker	*C. silviculto*r*	7	1	0.13	0	0	0.00
Maxwell's duiker	*Philantomba maxwelli* *	39	1.14	0.72	27	1	0.20
Bushbuck	*Tragelaphus scriptus**	10	1	0.19	1	1	0.01
Forest buffalo	*Syncerus caffer nanus*	4	5.2	0.08	4	9	0.03
Red river hog	*Potamochoerus porcus*	5	5.25	0.10	2	10.5	0.02

* Significantly different between forest types (randomization test; $p < 0.05$); ER = encounter rate

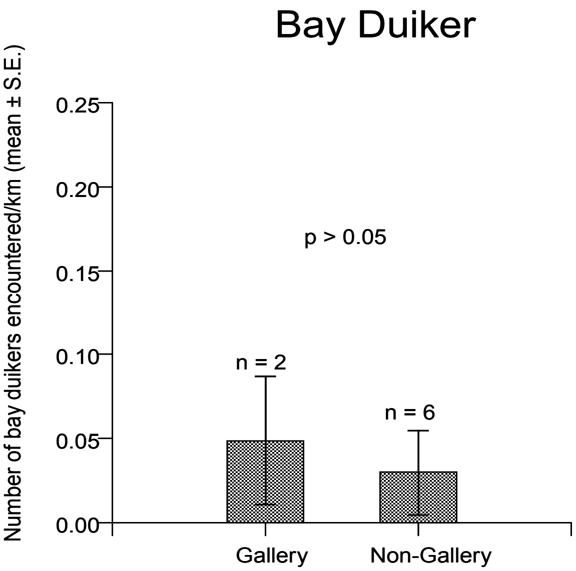

Figure 1.6b. Rate of encountering bay duiker during diurnal survey walks in gallery and non-gallery forests in the LMNHFR.

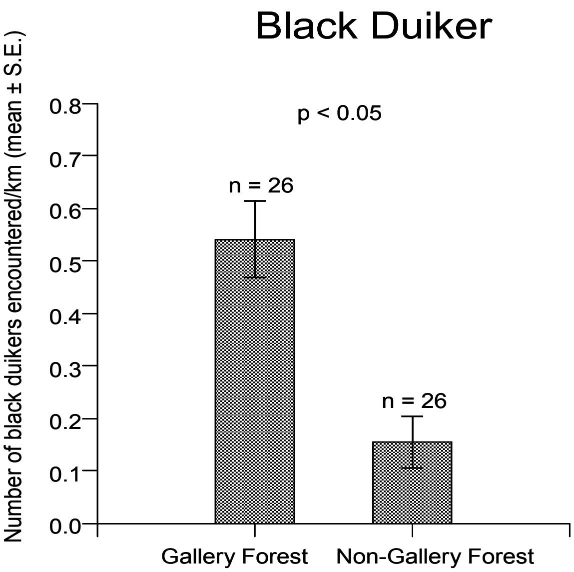

Figure 1.7b. Rate of encountering black duiker during diurnal survey walks in gallery and non-gallery forests in the LMNHFR.

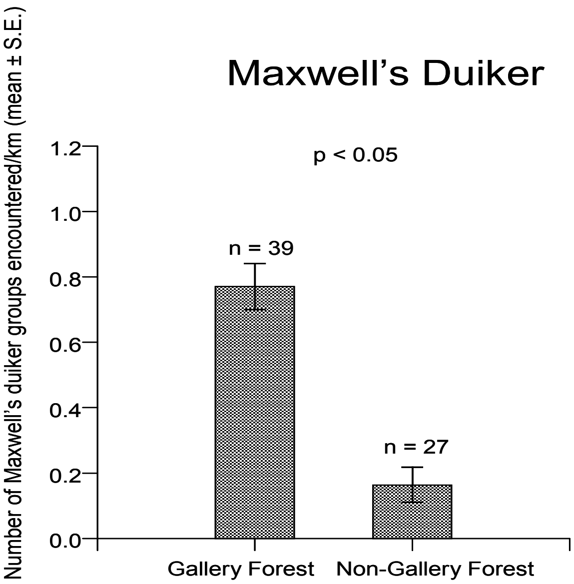

Figure 1.8b. Rate of encountering Maxwell's duiker groups during diurnal survey walks in gallery and non-gallery forests in the LMNHFR.

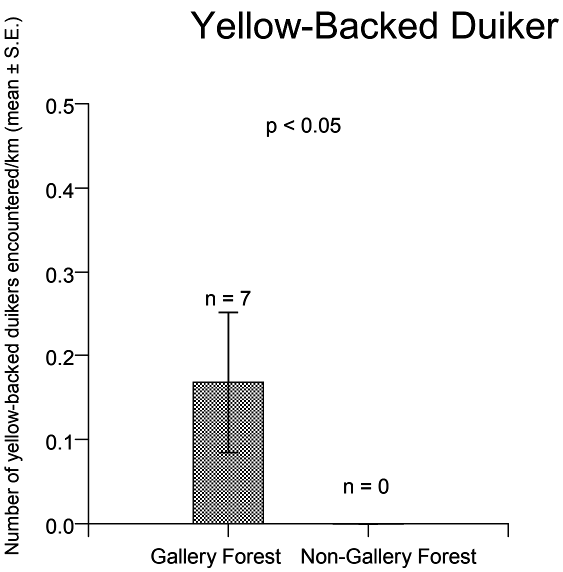

Figure 1.9b. Rate of encountering yellow-backed duiker during diurnal survey walks in gallery and non-gallery forests in the LMNHFR.

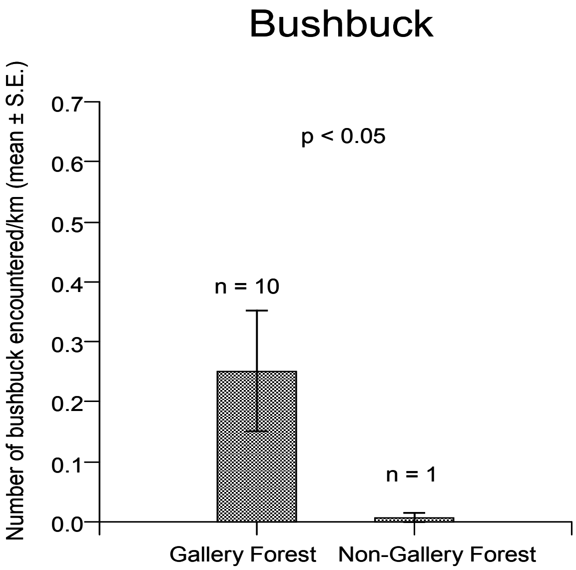

Figure 1.10b. Rate of encountering bushbuck during diurnal survey walks in gallery and non-gallery forests in the LMNHFR.

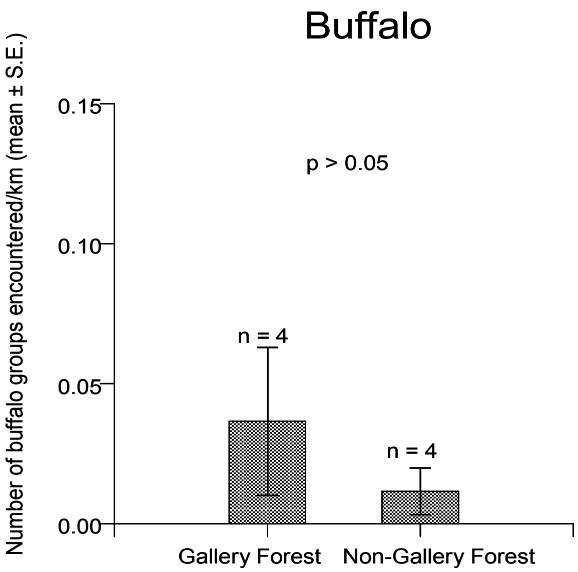

Figure 1.11b. Rate of encountering forest buffalo groups during diurnal survey walks in gallery and non-gallery forests in the LMNHFR.

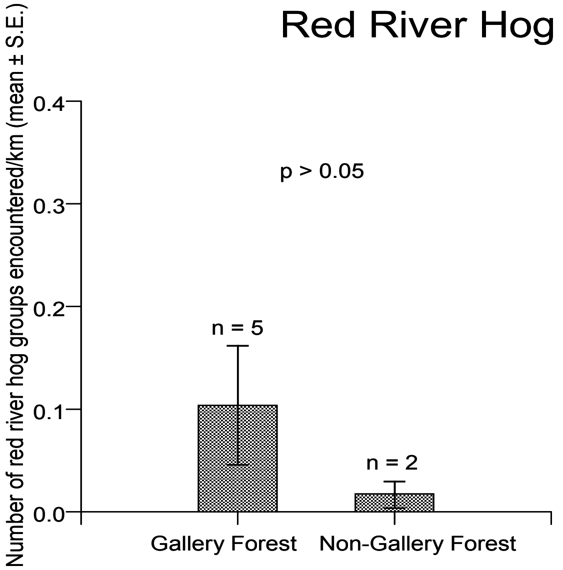

Figure 1.12b. Rate of encountering red river hog groups during diurnal survey walks in gallery and non-gallery forests in the LMNHFR.

Nocturnal Sighting Data

During nocturnal surveys a total of 21.3 kilometers were walked in non-gallery forest, and a total of 7.6 kilometers were walked in gallery forest, yielding 63 and 49 sightings respectively.

Encounters with black duikers and Maxwell's duikers during nocturnal surveys occur at a higher rate in gallery forest than non-gallery forest (randomization test, $p < 0.05$; Table 1.7; Figures 1.14 and 1.15). Encounters with bay duikers, yellow-backed duikers, bushbuck, and red river hogs during nocturnal surveys do not differ between forest types (randomization test, $p > 0.05$; Table 1.7; Figures 1.13, 1.16, 1.17 and 1.18). Buffalo were not recorded in either forest type during nocturnal survey walks and were excluded from analysis.

Table 1.7. The number of animal sightings per kilometer, mean group size, and rates of encounter for each of the seven study species in gallery and non-gallery forests during nocturnal survey walks in the LMNHFR.

		Gallery forest			Non-gallery forest		
Species		Sightings	Mean group size	ER/km	Sightings	Mean group size	ER/km
Bay duiker	*Cephalophus dorsalis*	9	1	1.19	21	1	0.94
Black duiker	*C. niger**	11	1	1.46	10	1	0.47
Yellow-backed duiker	*C. silvicultor*	3	1	0.4	6	1	0.28
Maxwell's duiker	*Philantomba maxwelli**	24	1.46	4.37	24	1.31	1.17
Bushbuck	*Tragelaphus scriptus*	2	1	0.26	0	0	0
Forest buffalo	*Syncerus caffer nanus*	0	0	0	0	0	0
Red river hog	*Potamochoerus porcus*	0	0	0	2	8	0.1

* Significantly different between forest types (randomization test; $p< 0.05$); ER = encounter rate

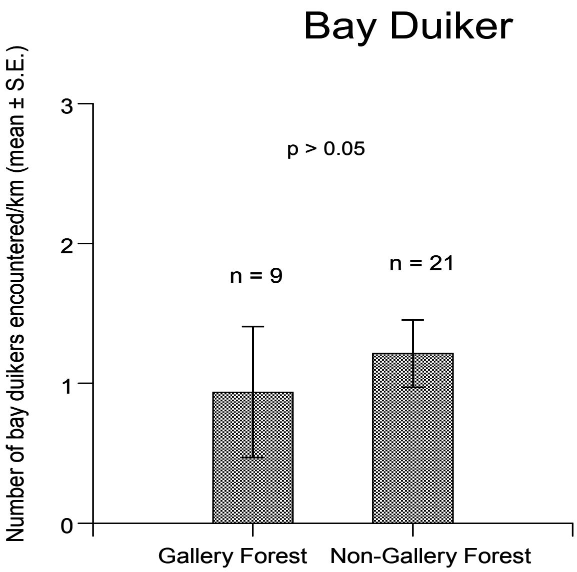

Figure 1.13. Rate of encountering bay duikers during nocturnal surveys in gallery and non-gallery forests in the LMNHFR.

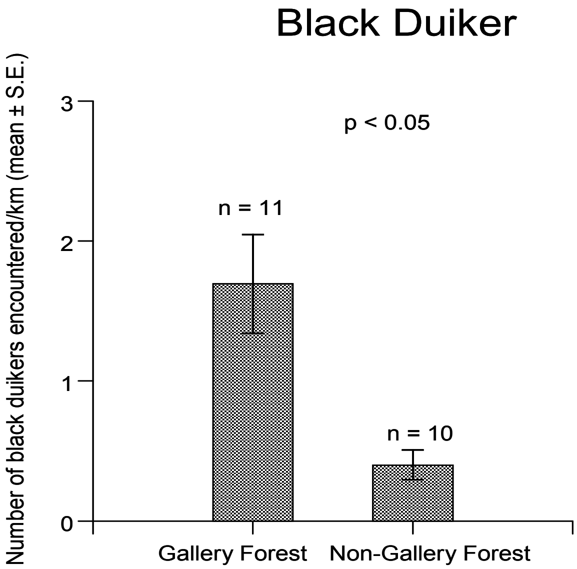

Figure 1.14. Rate of encountering black duikers during nocturnal surveys in gallery and non-gallery forests in the LMNHFR.

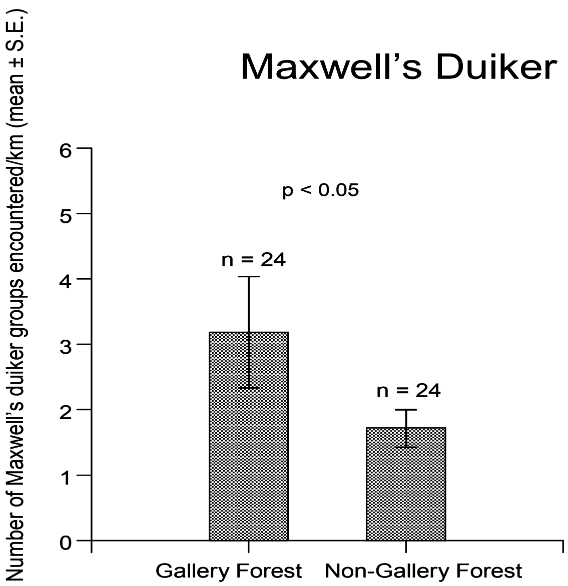

Figure 1.15. Rate of encountering Maxwell's duiker groups during nocturnal surveys in gallery and non-gallery forests in the LMNHFR.

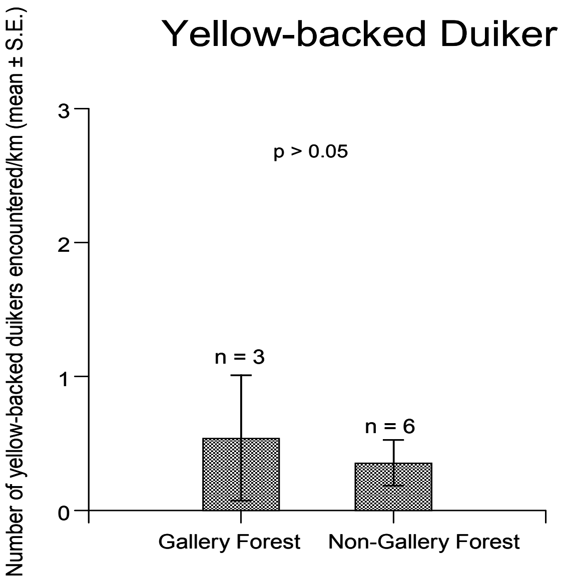

Figure 1.16. Rate of encountering yellow-backed duikers during nocturnal surveys in gallery and non-gallery forests in the LMNHFR.

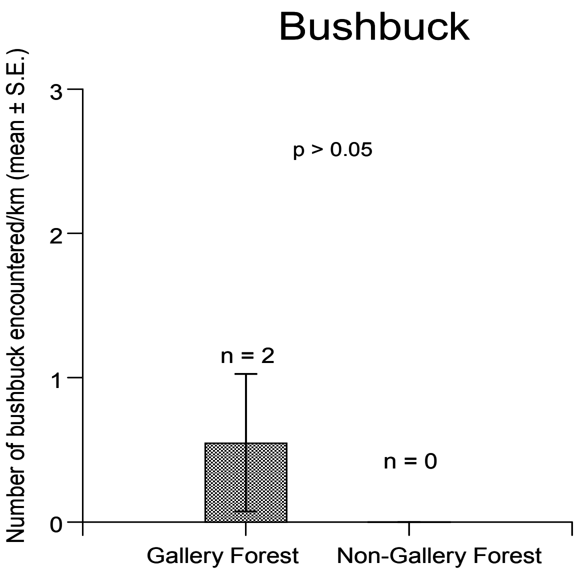

Figure 1.17. Rate of encountering bushbuck during nocturnal surveys in gallery and non-gallery forests in the LMNHFR.

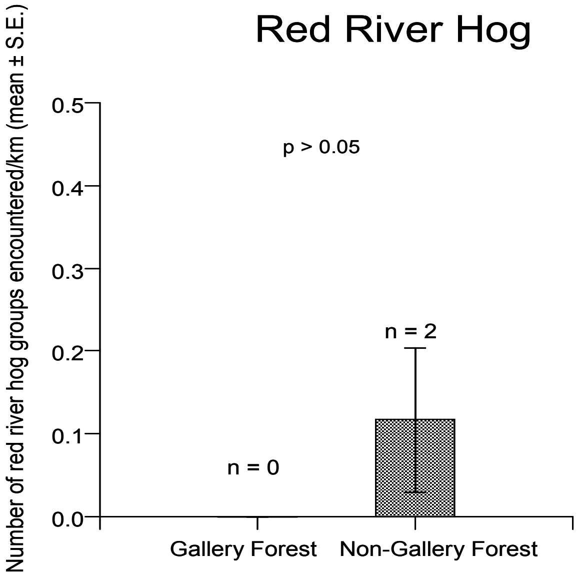

Figure 1.18. Rate of encountering red river hog groups during nocturnal surveys in gallery and non-gallery forests in the LMNHFR.

Nocturnal vs. Diurnal Encounter Rates of Duikers

Encounters with duikers were pooled by time of day across habitats to determine if rates of encounter differed between diurnal and nocturnal sampling. Encounters with bay duikers, black duikers, and Maxwell's duikers are higher during nocturnal survey walks than during diurnal survey walks (Mann-Whitney U test, $p < 0.05$, Table 1.8; Figures 1.19, 1.20, 1.21). Encounters with yellow-backed duikers do not differ between nocturnal or diurnal surveys (Mann-Whitney U test, $p > 0.05$, Table 1.8, Figure 1.22).

Table 1.8. Comparisons of diurnal and nocturnal encounters with duikers in the LMNHFR.

Species		Time	Median ER/km	IQR (ER)	p-value
Bay duiker	*Cephalophus dorsalis*	Diurnal	0	0.00 –0.07	< 0.05
		Nocturnal	0.89	0.61 – 1.61	
Black duiker	*C. niger*	Diurnal	0.31	0.14 – 0.54	< 0.05
		Nocturnal	0.65	0.51 – 1.50	
Yellow-backed duiker	*C. silvicultor*	Diurnal	0	0.00 – 0.04	> 0.05
		Nocturnal	0.13	0.00 – 0.55	
Maxwell's duiker	*Philantomba maxwelli*	Diurnal	0.45	0.20 – 0.74	< 0.05
		Nocturnal	2.39	1.30 – 3.30	

IQR = interquartile range; ER = encounter rate

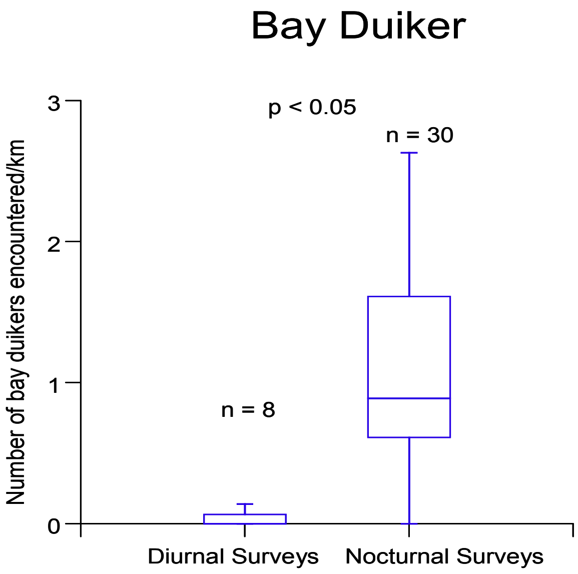

Figure 1.19. Rate of encountering bay duikers during diurnal and nocturnal surveys. Boxes represent quartiles above and below medians. Whiskers of boxes represent the minimum and maximum values. Outliers are not shown but were included in statistical analysis.

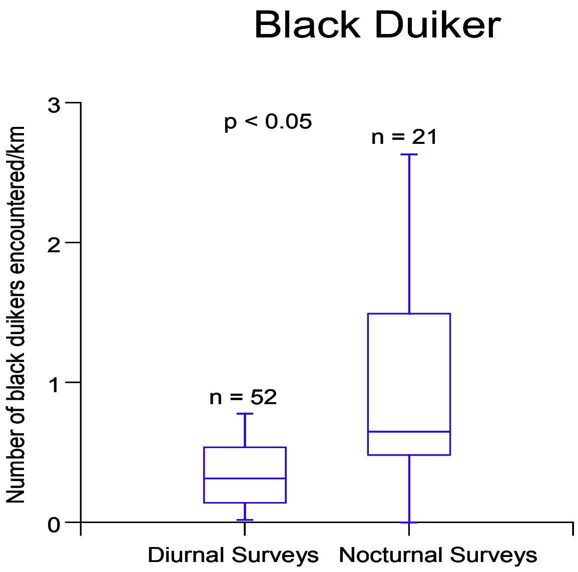

Figure 1.20. Rate of encountering black duikers during diurnal and nocturnal surveys. Boxes represent quartiles above and below medians. Whiskers of boxes represent the minimum and maximum values.

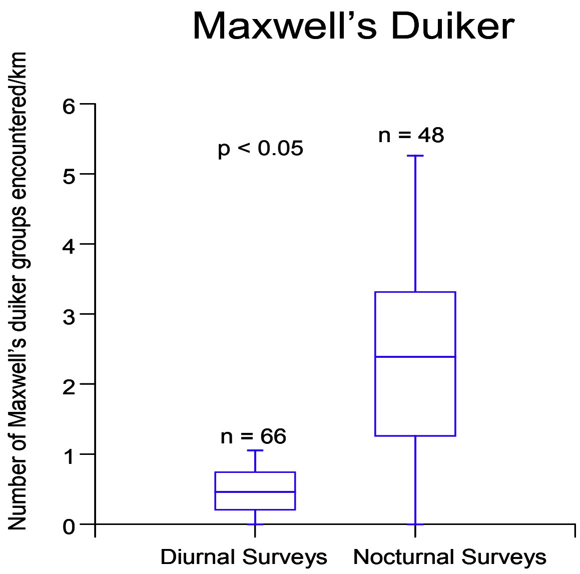

Figure 1.21. Rate of encountering Maxwell's duiker groups during diurnal and nocturnal surveys. Boxes represent quartiles above and below medians. Whiskers of boxes represent the minimum and maximum values.

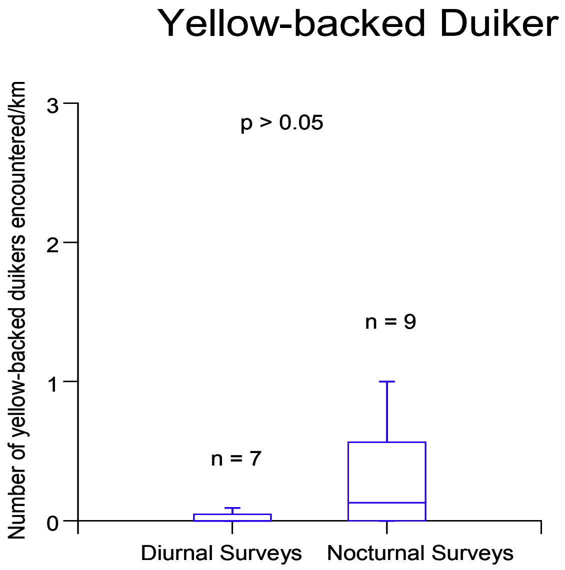

Figure 1.22. Rate of encountering yellow-backed duikers during diurnal and nocturnal surveys. Boxes represent quartiles above and below medians. Whiskers of boxes represent the minimum and maximum. Outliers are not shown but were included in statistical analysis.

Summary Grassland Observations of Ungulates

Table 1.9. Summary of ungulate observations in grassland from September 2006 to February 2008.

	Sightings	Group size				Obs. time	
Species	N	Mean	Min	Max	SD	AM	PM
Common warthog *Phacochoerus africanus*	56	2.83	1.00	9.00	2.50	38	18
Red river hog *Potamochoerus porcus*	13	8.46	1.00	16.00	4.80	12	1
Maxwell's duiker *Philantomba maxwelli*	8	1	1.00	1.00	0	7	1
Bay duiker *Cephalophus dorsalis*	0	-	-	-	-	-	-
Black duiker *C. niger*	104	1.03	1.00	2.00	0.17	57	47
Yellow-backed duiker *C. silvicultor*	5	1.4	1.00	2.00	0.56	5	0
Red flanked duiker *C. rufilatus*	2	1	1.00	1.00	-	0	2
Forest buffalo *Syncerus syncerus nanus*	71	6	1.00	12.00	3.91	43	28
Bongo *Tragelaphus eurycerus*	0	-	-	-	-	-	-
Bushbuck *T. scriptus*	75	1.23	1.00	3.00	0.45	52	23
Waterbuck *Kobus ellipsiprymnus*	0	-	-	-	-	-	-
Total	334						

Observations of Duikers at Fruit Trees

During approximately 40 hours of diurnal observations at fruit trees, there were 26 duiker visits, fifteen by Maxwell's duikers, eight by black duikers, and three by yellow-backed duikers. On 25 nights during the same fruiting season, I recorded nine bay duikers and five Maxwell's duikers at the same fruiting trees. Eight animals fled from beneath the trees before these animals could be identified.

DISCUSSION

The Use of Animal Encounter Rates

Several studies have attempted to produce reliable density estimates in tropical rainforests for a wide variety of species (Koster and Hart 1988; Whitesides *et al.* 1988; Plumptre and Harris 1995; Plumptre 2000). The secretive nature of forest ungulates and low visibility on the forest floor make accurate density estimates of forest ungulates difficult (Plumptre and Harris 1995; Struhsaker 1997; Lwanga 2006; Rovero 2004). Models used to estimate densities from line transects depend on several underlying assumptions that are difficult to meet in rainforests (Struhsaker 1997) and require a large number (60+) of sightings (Chiarello 2000; Buckland *et al*. 2001).

The use of encounter rate as an index with which to assess relative abundance of forest ungulates has proven useful, however, in addressing questions related to habitat preference, population change, impact of hunting, and response to conservation practices (McCoy 1995; Struhsaker 1997; Lwanga 2006). Moreover, this method does not have assumptions that are easily violated (Struhsaker 1997; Lwanga 2006). I found comparing encounter rates between forest types and between survey times to be an effective method that is easily replicated. While using actual animal densities for such comparisons would be ideal, the error associated with their calculation, as well as the number of samples needed to reduce error, make their use inefficient for short-term studies.

Comparison of Gallery and Non-Gallery Forest Usage

I compared gallery and non-gallery forest usage by the seven study species using rates of encountering dung and animals. Black duikers, Maxwell's duikers, yellow-backed duikers, and bushbuck are encountered more frequently in gallery forests than in non-gallery forests. The dung of black duikers, Maxwell's duikers, bushbuck, and red river hogs is encountered more frequently in gallery forests than in non-gallery forests. Encounter rates do not differ for bay duikers and buffalo, or for their dung, between the two forest types.

The higher rate of encountering black duikers in gallery forests than in non-gallery forests concurs with reports that black duikers were more common in secondary forest than in closed canopy forest in the Tai National Park, Côte d'Ivoire (Newing 2001). Black duikers are known to exploit a wide range of non-fruit food items (Newing 1994; Newing 2001; Hofmann and Roth 2003). The findings of my study may be attributed to annual savanna fires that penetrate gallery forests, causing damage that permits pioneer plant species to establish themselves. The result is a patchwork of herbaceous and pioneer plant species. This regrowth is reminiscent of secondary forest and offers more abundant browse than is found in non-gallery forests where fire damage is minimal. Regrowth vegetation also offers more palatable foliage (Ewel 1980) with a higher nutritive value than much of the foliage found growing near the forest floor in non-gallery forests (Davies *et al*. 2001). Similar conditions allowing for abundant browse accessible to terrestrial herbivores are reported for the Parc National des Volcans, Rwanda (Plumptre and Harris 1995).

During this study black duikers were also regularly observed (n = 104 animals[1]) in grassland browsing on the inflorescence of the sedge *Afrotrilepis* sp. No other duiker species was observed foraging outside of the forest. The large numbers of black duiker sighted in grassland show that black duikers utilize grassland for obtaining food and that their use of grassland in the LMNHFR is not restricted to movement to and from forests. On the Loma Plateau, the behavior of black duikers was more comparable to the non-related bushbuck than to the other duikers studied. I have not observed such behavior by black duikers elsewhere in Sierra Leone. I have most commonly seen black duikers in

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[1] A single black duiker was observed on the hillside approximately 400 meters from Base Camp nearly every day in March, April, and May of 2007 and is the reason the number of black duiker observations in grassland are high.

Sierra Leone in secondary forest and remnant forest blocks but rarely in savannas (pers. obs.). The behavior of utilizing grassland in the LMNHFR suggests that where human pressure is low, black duikers readily venture into open areas. Black duikers foraging in open grassland often retreat to gallery forests for cover because gallery forests protrude into grassland and are nearer to where they forage than are non-gallery forests.

Like black duikers, Maxwell's duikers exploit a wide range of food items and are encountered at higher rates in gallery forests than in non-gallery forests. These results are contrary to reports from southern Sierra Leone, where studies did not show a difference in the use of closed canopy and secondary forests by Maxwell's duikers (Fimbel 1994). The abundance of ground vegetation in gallery forests possibly provides cover for foraging duikers. This cover is particularly important to smaller species prone to aerial predators. Maxwell's duikers, smallest of the duiker species, are preyed upon by crowned hawk eagles (*Stephanoaetus coronatus*) that hunt regularly in non-gallery forests in the LMNHFR. Crowned hawk eagle kill remains (n = 4) of Maxwell's duikers were recorded only in grassland and all kill remains were greater than 100 meters from the forest's edge. No kill remains were recorded under the forest canopy. All Maxwell's duiker kill remains appeared to be sub-adult or adult animals. Given that the weight of a Maxwell's duiker is greater than the weight of a crowned eagle it is unlikely eagles carried their prey far from the kill site as they are known to do for smaller primate prey (Mitani *et al.* 2001). During this study I regularly made duiker distress calls to lure in duikers in order to obtain video footage. In December of 2007, while I was imitating a duiker distress call in non-gallery forest, a crowned eagle made two passes over my head before taking perch less than 10 meters from my position. I did not observe crowned eagles hunting in gallery forests during this study.

I frequently observed buffalo, bushbuck, black duikers, yellow-backed duikers, and red river hogs using the network of grassland game trails linking different forest blocks. Movement between forest types was documented for yellow-backed duikers, black duikers, and red river hogs. These species were observed regularly moving to and from the two forest types, suggesting they utilize both, but are not obligate residents of either. Individual recognition of animals was beyond the scope of this study, but anecdotal evidence suggests some duikers, particularly Maxwell's duikers, were resident in gallery forests. The blue duiker (*Philantomba monticola*), a duiker species very similar to the Maxwell's duiker, but found east of the River Niger, occupies a home-range of 2-5 ha (Tutin *et al.* 1997a). Given the Maxwell's duikers' similarity to the blue duiker in size, habitat and behavior (Ralls 1973), it is likely they inhabit similarly sized home ranges.

Given the high diversity of fruit trees found in non-gallery forest compared to gallery forest during this study, I would have expected bay duikers to have higher rates of encounter along survey trails in non-gallery forests than in gallery forests, but I did not find any difference. Bay duikers are highly adapted for large fruits and low nutrient browse (Hart 1986; Dubost and Feer 1988; Newing 2001; Wilson 2001). Foliage found in non-gallery forests is less nutritive than the foliage found in gallery forests where fire has created large gaps allowing for fresh regrowth vegetation. Feer (1988) contended that bay duikers reduced competition with sympatric duikers by their nocturnal behavior and by being more efficient than other duikers in their utilization of poor quality fruits and foliage. Further research is needed to understand why bay duikers do not differ in relative abundance between forest types, as this species is particularly prone to habitat loss and finds much of its food in primary forest.

All published research examining bay duiker ecology has been conducted where sympatric red duikers also occur. The red duiker complex is a group of sympatric red duikers that includes Brooke's duiker (*Cephalophus brookei*), Peters' duiker (*C. callipygus*), bay duiker (*C. dorsalis*), white-bellied duiker (*C. lecogaster*), black-fronted duiker (*C. nigrifrons*), and Ogilby's duiker (*C. ogilbyi*). Previous research has shown that these species partition niches by habitat preference, food selection, and activity patterns (Dubost 1984; Feer 1989a, Feer 1989b; Hart 1986). This study is the first to examine bay duikers in an ecosystem where sympatric red duikers are absent, but where black duikers are present. It is likely that in West African forests black duikers occupy a niche similar to Peter's duikers in Central Africa.

Photographs taken with camera traps in gallery and non-gallery forests indicate bay duiker movement in gallery and non-gallery forests was exclusively at night, and movement for black duikers was almost entirely diurnal (Appendix 2). Furthermore, observations of these same species feeding at fruit trees also noted that black duiker visits were during the day and bay duiker visits were at night.

Bushbuck and forest buffalo, which are active both day and night, do not find the range or abundance of suitable food items in continuous forest that they would in grassland or transitional vegetation (Tutin *et al.* 1997; Plumptre and Harris 1995; Blake 2002; Dankwa-Wiredu and Euler 2002). Frequent sightings of these species in grassland areas during morning hours and overcast days provide evidence that these animals use forests primarily to escape the heat of the day. When heat is not an issue, these animals often stay in open areas throughout the day, bedding in grassland rather than forest. These two species depend on both forest types for cover, though bushbuck evidence was not recorded in the interior of non-gallery forest during this study. Bushbuck find abundant browse along gallery forest edges and where fire damage has occurred. Forest buffalo evidence was recorded along all survey trails in gallery and non-gallery forest, and it is evident forest buffalo will move through large areas of forest to access grasslands off the Loma Plateau.

Rates of encountering red river hog dung are higher in gallery forest than in non-gallery forest, but this was not the case for sightings. Red rivers hogs are extremely wary animals (Ghiglieri *et al*. 1982) that favor dense habitats and normally only venture into open areas at night or during rainy days (pers. obs.). We did not conduct surveys during rainy days because of the decrease in activity for the other study species, probably resulting in an under-sampling of red rivers hog sightings compared to red river hog dung.

The Role of Nocturnal Surveys in Obtaining Abundance Estimates for Duikers

Given that visibility is greater during the day, one would expect detection distance and encounter rates of duikers also to be greater. The greater detection distances and higher nocturnal encounter rates found for bay duikers, black duikers and Maxwell’s duikers during this study contradict this notion and point to the need for conducting surveys during the night to obtain more accurate results, as first reported by Payne (1992) and later by Waltert (2006).

Duikers often avoid detection by remaining completely still while concealed in dense cover (Lumpkin and Kranz 1984). This behavior coupled with their cryptic coloration makes them difficult to detect (Wilson 2001). With the aid of a flashlight at night, however, the highly reflective *tapetum lucidum* of their eyes can be detected more readily than their cryptic pelage. In fact, their habit of freezing when approached, which aids their concealment during the day, makes them more detectable at night. I found greater detection distances and encounter rates for duikers at night than during the day. While no survey method will make it possible to detect all animals within range of detection, the use of headlamps to catch an animal's eye-shine greatly increases the probability of detecting well-concealed individuals.

Heydon and Bulloh (1997) also report that rates of encountering mousedeer (*Tragulus javanicus klossi* and *T. napu borneanus*) at night were 7-8 times higher than rates of encounter during the day. The encounter rates calculated from records of Maxwell's and black duikers during nocturnal surveys during this study were 3 to 6 times higher than encounter rates from diurnal surveys. Bay duikers were encountered at night at 50 times the rate they were encountered during the day.

CONCLUSIONS

The findings of this study substantiate the evidence from Fay (1988) and Tutin *et al.* (1997), that gallery forests, in spite of their relatively small size, can play a vital role in meeting the habitat requirements of large mammals. The abundance of browse year round in gallery forests may help explain the higher encounter rates in gallery forests for three of the four duiker species. Because fruit availability is seasonal (Tutin *et al*. 1997) and there is little browse to be found in non-gallery forests, encounter rates in non-gallery forest may be less than in gallery forest. To determine if forest usage is seasonal, future research should examine whether use of gallery and non-gallery forest by duikers changes with fruit availability.

Another explanation for large mammal use of gallery forests is their connection to water. Because gallery forests follow waterways that extend to headwater basins, gallery forests provide a year-round water supply. In contrast, the lower reaches of streams located in non-gallery forests are often seasonally intermittent. Access to water in gallery forests is essential for large mammals during the height of the dry season when water is scarce in non-gallery forests.

Gallery forests in the LMNHFR have not remained static over the last 20 years. Several areas of gallery forest observed in the reserve during the early 1990's are currently grassland. Only one 10 ha area of grassland was colonized by forest during this same period. Observations during this study indicate that whenever grassland fires penetrate gallery forests, additional forest is converted to grassland. While these fires create abundant browse in the short term, active management is imperative to curb the severity of fire damage, or the long-term impact could be a drastic loss of gallery forest in the LMNHFR. The most effective prevention of excessive fire damage would be controlled grassland burning soon after the rains stop in November.

This study has provided baseline data for future monitoring of ungulate populations in the LMNHFR. Until the completion of this research, very little data were available for the mammalian fauna of this remote remnant of the Upper Guinean Forest, resulting in a gross underestimation of the value of LMNHFR for large mammal conservation in the region (East 1990; Kormos 2003).

Some of the differences between gallery and non-gallery forests found during this study can be explained by differences in forest structure and food availability, but many questions remain. Before the underlying reasons for differences can be understood fully there is a need for long-term studies at the community level. Considering the current rate of habitat loss for large mammals in Sierra Leone, and throughout Western African, such studies should be considered top priority. The survival of many rainforest species depends on the ability of biologists and policy makers to evaluate these critically endangered ecosystems.

Appendix 1

VEGETATION QUANTITATIVE ANALYSIS OF GALLERY AND NON-GALLERY FORESTS IN THE LOMA MOUNTAINS NON-HUNTING FOREST RESERVE

METHODS

The point center quarter method (PCQM) for vegetation quantification (Cottam and Curtis 1956) was used to determine species composition, basal area, tree density, and frequency of sun-exposed trees found along survey trails in gallery and non-gallery forests in the Loma Mountains Non-Hunting Forest Reserve (LMNHFR). The data obtained from PCQM surveys were used to calculate the importance value index (IVI) for different tree species. At a sample point in each quadrant, I recorded data for the first tree encountered of which the uppermost leaves were exposed to direct sunlight and which, if the forest were viewed from above, would be visible to an aerial observer. The rationale for choosing which trees to record was related to remote sensing classification of vegetation types. Such classification rests upon the reflectance properties of trees visible in a satellite image. Different vegetation types often differ in reflectivity. My initial plan was to create a forest classification map of my study site from satellite images, and so I chose to sample trees that likely would be visible in such an image. After an initial attempt at GIS classification, however, it was apparent that mapping gallery and non-gallery forests from a LANDSAT image was not possible because of the abundance of *Parinari excelsa* in both forest types.

By following my protocol for choosing which trees would be recorded as sun-exposed, I sampled trees belonging to different strata of the forest. Some of them were emergent trees, some canopy trees, some sub-canopy, and others, understory trees because the forests of the LMNFHR are very heterogeneous in vertical structure. In both gallery and non-gallery forests, gaps occur wherein trees are sparse and often short in stature. Gap areas contain vegetation regenerating after tree falls, not after fires. Because fire did not create these gaps, small trees that are usually understory trees, remained intact and were recorded as sun-exposed.

Because data were collected only on sun-exposed trees, they do not reflect species composition of all the woody plants along survey trails beneath the canopy. For a detailed description of the woody plants of the Loma Mountains, refer to Jaeger (1966). Vegetation surveys were conducted in July, August, and September of 2007 for each survey trail along which systematic ungulate surveys were conducted.

These survey trails were sampled at intervals of 25 meters. At each sampling point an imaginary line was made perpendicular to the survey trail line. This imaginary line divided the surrounding area of that sampling point into quarters (Figure 1.1). In gallery forest, there were 103 sampling points and in non-gallery forest, there were 256 sampling points.

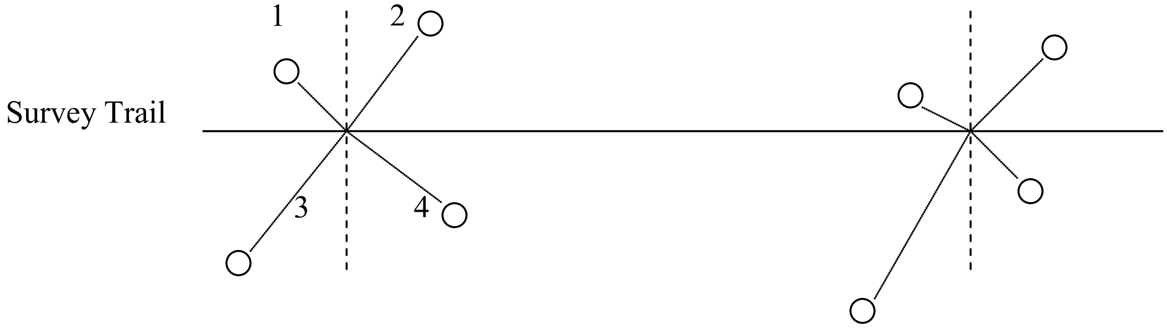

Figure A1.1. Sample points along a survey trail with the nearest sun-exposed tree in each quarter.

Setting a distance limit beyond which trees are not measured is generally discouraged when using the PCQM (Dahdouh-Guebas and Koedam 2006). Calculations of absolute tree density must be corrected to account for vacant quarters if a distance limit is adopted. I adopted a distance limit of 25 meters for two reasons, both to make data collection efficient and also to avoid sampling the same tree twice. If a tree was not located within 25 meters of a sample point, this quarter was recorded as being vacant, and the possible cause for its vacancy was noted. Vacant quarters were recorded only in gallery forests. To account for these vacant quarters a correction factor following Dahdouh-Guebas and Koedam (2006) was applied when calculating sun-exposed tree densities in gallery forest.

Distance Measurements

The nearest sun-exposed tree was located in each quarter. Once located, the distance was measured from the sample point to the nearest side of the tree at a height of 1.5 meters. The radius of each tree was added to all distance measurements to obtain the distance to the center of each tree. Measurements were made to the nearest 0.5 meter. For trees less than six meters from the sampling point, distance was measured with a 30 meter Keson® open reel fiberglass tape measure. Distances greater than six meters were measured using a Nikon Prostaff® 440 laser range finder.

Diameter at Breast Height Measurements

Diameter at breast height (DBH) for each tree was measured to the nearest 0.1 centimeter (cm) using a Forestry Suppliers metric diameter tape. Measurements were taken above root buttresses whenever possible. DBH measurements for trees without buttressed roots were taken 1.5 meters above the ground.

Basic Analysis

The next four sections outline how estimates of density, basal area, frequency, and importance value index were calculated for each sun-exposed tree species along survey trails. All calculations were carried out separately for gallery and non-gallery forests.

Before any further analysis could be undertaken, mean distance to the nearest tree ($\bar{r}$) was calculated by dividing the sum of the distances to each sun-exposed tree in each non-vacant quarter by the number of non-vacant quarters sampled.

Density Calculations

Absolute Density

Absolute density of trees is defined as the number of trees per unit area. The absolute density of trees per hectare is calculated as $(1/(\bar{r})^2)$ x 10,000 (Cottam and Curtis 1953).

Absolute Density of Each Species

The absolute density of each species is the number of trees of that species per hectare (Mitchell, 2007). Absolute density of a single tree species is calculated by dividing the number of quarters in which that species was observed by the total number of quarters in which trees were found, then multiplying by the absolute density of all trees (Table 1.2 and Table 1.3).

Relative Density of a Species

The relative density (RD) of a particular species is the total number of quarters where that species was recorded divided by the total number of quarters sampled and then multiplied by 100 (Mitchell, 2007; Table 1.2 and Table 1.3). A high relative density indicates that a species was recorded in a large number of quarters.

Basal Area Calculations

Absolute Basal Area of a Species

The basal area (BA) of a tree is calculated using the recorded DBH of that tree (Mitchell, 2007). Basal area is expressed as m^2/hectare in this paper. The basal area of a particular species is the sum of all the basal areas of that species (Mitchell, 2007). To obtain the BA of each sun-exposed tree species, the mean basal area for that species is multiplied by the absolute density of that species.

Relative Basal Area of a Species

The relative basal area (RBA) (also referred to as relative dominance) for a particular species is a metric of species dominance. A species with a high RBA is considered more dominant because it covers a greater area (Mitchell, 2007). RBA is calculated by dividing the absolute basal area of a given species by the sum of the basal area for all species and then multiplying by 100 (Table 1.2 and Table 1.3).

Frequency Calculations

Absolute Frequency of a Species

The absolute frequency (F) of a species is the percentage of sample points at which that species is present. The absolute frequency provides an estimate of distribution of a species. A high absolute frequency indicates a uniform distribution and a low absolute frequency indicates a clumped distribution. Low absolute frequency can also indicate the species is scarce in the area sampled (Mitchell, 2007). The absolute frequency of a species is calculated by dividing the number of sampling points in which a particular species was present by the total number of sampling points, then multiplying by 100 (Table 1.2 and Table 1.3).

Relative Frequency of a Species

Absolute frequencies add up to more than 100%. To normalize absolute frequency, the relative frequency is calculated (Mitchell, 2007). The relative frequency (RF) of a species is calculated by dividing the absolute frequency of one species by the sum of the frequencies for all tree species, then multiplying by 100 (Table 1.2 and Table 1.3). Like absolute frequency, a species with a high RF is well distributed in the sampled area and a species with a low RF either has a clumped distribution or is scarce.

Importance Value Index of a Species

The importance value index (IVI) of a species is the sum of the three relative measures, relative density + relative basal area + relative frequency (Table 1.2 and 1.3, Figure 1.2 and 1.2).

Tree Height Measurements

Height of trees was measured using two methods. For the first method, I used a Suunto® Tandem Compass/Clinometer that gives a reading that is expressed as a percent of the horizontal distance. To measure tree height with this method, I first located a horizontal baseline distance (D) from the tree at which both the top and bottom of the tree could be seen. I next sighted the top of the tree and took a percentage reading (X), then sighted the base of the tree and took a percentage reading (Y). When a tree is on level ground or located below the point from which measurements are taken the two percentages are added. The sum is multiplied by the baseline distance for the total tree height. If a tree is located above the point from which measurements are taken the bottom reading is subtracted from the top reading. The difference is multiplied by the baseline distance for the total tree height.

In the second method, a Nikon Prostaff® 440 laser range finder was used to measure tree height. This method was employed when dense vegetation made the first method impractical. The recorder would simply stand at the base of the tree, point the range-finder at the highest point of the tree and take multiple readings. The tree's height was recorded as the highest reading plus 1.6 meters to account for the height at which the range finder was held.

Tree Identification

The species of a tree was identified with the aid of Fox and Savill (1967) and Hawthorne and Jongkind (2006) using characteristics of the tree's leaves, fruit, and slash. Either a field assistant or I established the tree's vernacular Kuranko name. The vernacular name was then located in Fox and Savill's (1967) appendix of vernacular names with corresponding scientific names. I cross-checked our identification with the description for that species in Fox and Savil (1967). When a tree could not be identified this way, it was identified with the dichotomous key in Hawthorne and Jongkind (2006). When the tree could not be identified in the field then, leaf, bark, and fruit samples were collected for later identification at base camp. If a tree remained unidentified it was labeled "unknown" and given a numeric value. Nomenclature was used in accordance with Hawthorne and Jongkind (2006) and the African Flowering Plants Database (2009).

Fire Damage

In 1993 and 2002, I had visited the LMNHFR. I was able to use information from these prior visits during this study to estimate when fires had occurred in certain forested areas. Fire damage was qualitatively assessed based on the succession of pioneer vegetation and recorded as "fire damage late succession" or "fire damage early succession." "Late" was defined as having occurred between 1993 and 2002 and "early" was defined as having taken place since 2002.

RESULTS

In total, 76 different sun-exposed tree species were recorded during systematic PCQM surveys (Table A1.1). In gallery forest, 24 species were recorded, four of which were not recorded in non-gallery forests (Figure A1.2). In non-gallery forest, 52 species were recorded that were not recorded in gallery forests (Figure A1.2). The two forest types had an overlap of twenty sun-exposed tree species.

Table A1.1. Checklist of sun-exposed tree species recorded during vegetation surveys using the point center quarter method along survey trails in gallery and non-gallery forests in the LMNHFR.

Family	*Species*	Kuranko name*
Annonaceae		
	Xylopia quintasii	bGɛsiɛ †‡
	Xylopia acutiflora	
Anacardiaceae		
	Trichoscypha smythei	Bɛsɛ †
Apiaceae		
	Polyscias fulva	
Apocynaceae		
	Funtumia sp.	Bandaparɛ †
	Alstonia boonei	Doŋkaŋ †
Boraginaceae		
	Cordia platythyrsa	Salaŋ †‡
Burseraceae		
	Canarium schweinfurthii	Dɔlɛ †
	Santiria trimera	
Chrysobalanaceae		
	Parinari excelsa	Kurɛ †‡
Cyatheaceae		
	Cyathea manniana	Loma saŋkaŋ †‡
Euphorbiaceae		
	Uapaca guineensis	Dɔmbɛ †‡
	Bridelia grandis	Firɛ bɛmbɛ †‡
Gentianaceae		
	Anthocleista sp.	Samakombɛ †‡
Hypericaceae		
	Harungana madagascariensis	Suŋgbalɛ †‡
Clusiaceae		
	Garcinia smeathmannii	Sagbɛ yoŋ †‡
Lauraceae		
	Beilschmiedia mannii	Lappɛ †
Fabaceae		
	Albizia ferruginea	Saŋsaŋ †‡
	A. zygia	Tuŋbgɛnɛ †‡

	Anthonotha macrophylla	Bumbusɛ †‡
	Cryptosepalum tetraphyllum	Maŋkɛ ‡
	Gilbertiodendron preussii	
	G. splendidum	
	Hymenostegia afzelii	Maŋkɛ †‡
	Newtonia duparquetiana	
	Piptadeniastrum africanum	Mɛlɛ †‡
	Xylia evansii	Yalɛ †‡
	Samanea dinklagei	Woŋkɛ † / Woŋgɛ‡
	Parkia bicolor	Kulanɛrɛ †‡
Sterculiaceae		
	Sterculia tragacantha	Deinkiranafuŋ ‡
	Heritiera utilis	Denɛrɛnafa ‡
	Cola lateritia	Wurɔlatɔgɔlɛ †/gBiŋgbaŋ ‡
Meliaceae		
	Carapa procera	Kuɛ †‡
	Entandrophragma cylindricum	bGɔŋwɛ ‡
	Guarea cedrata	Tolotawulɛŋkɔŋ ‡
	Turraeanthus africanus	
Moraceae		
	Milicia excelsa	Semɛ †‡
	Morus mesozygia	
	Trilepisium madagascariense	
	Ficus craterostoma	Noŋkɛ †‡
Myristicaceae		
	Pycnanthus angolensis	gBɔŋsɔŋ
Myrtaceae		
	Syzygium rowlandii	gBuluti †‡
Olacaceae		
	Strombosia pustulata	
Rubaceae		
	Psydrax subcordata	Mɛnɛmɛnɛkɔŋ †‡
	Nauclea diderrichii	Firɛdundi †Yadundi‡
Rutaceae		
	Vepris suaveolens	
	Fagara macrophylla	Waɛ †‡
Sapotaceae		
	Chrysophyllum africanum	
	C. albidum	
	C. perpulchrum	
	C. pruniforme	Kɔnikuruwɛ †‡
	C. subnudum	
	Synsepalum afzelii	
	S. cerasiferum	
	S. dulcificum	
	S. passargei	Firɛ tulaŋ †‡
	Omphalocarpum pachysteloides	gBelinɛ †‡
Simaroubaceae		
	Hannoa klaineana	Dogorɛ †‡
Unknown		

Species 1	KarasinikƆŋ †
Species 2	MƆgƆsibuɛ †
Species 3	
Species 4	
Species 5	
Species 6	
Species 7	
Species 8	
Species 9	
Species 10	
Species 11	
Species 12	KonakƆŋ †
Species 13	
Species 14	
Species 15	
Species 16	Korobolɛ †
Species 17	
Species 18	BulaŋkƆŋ †
Species 19	YɛgɛkolokƆŋ †

Kuranko has numerous regional dialects in Sierra Leone. Tree names are often dialect specific and often the same names are different species in different dialects. I have included names for two dialects; † = Diaŋ Kuranko; ‡ = Wolley Kuranko; Ŋ = ng sound, ɛ = eh sound; ɔ = oh

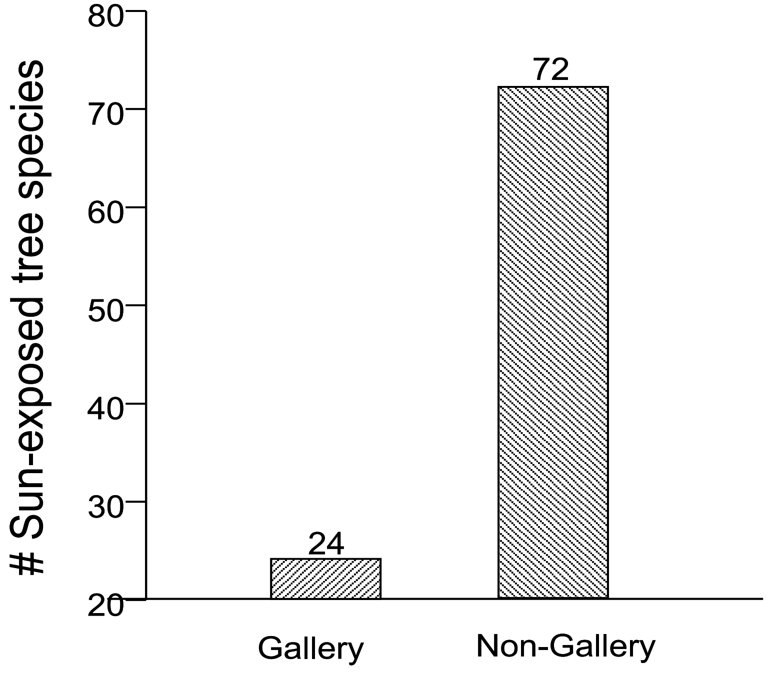

Figure A1.2. The total number of sun-exposed tree species recorded in gallery and non-gallery forest in the LMNHFR.

Gallery Forest

In gallery forest, 24 sun-exposed tree species were recorded at 103 sampling points (Table A1.2). At these sampling points, the species of 338 trees was identified. Nine additional trees were of two unidentified species. These two species were assigned identification numbers. The absolute density of sun-exposed trees /ha was 103.3, giving a total basal area of 28.6 m^2/ha (Table A1.2). The mean height of sun-exposed trees in those gallery forests where data were collected was 15 meters with a standard deviation of 5 meters, and a median of 15.6 meters. Sun-exposed trees along survey trails ranged in height from four to 26 meters.

The most important sun-exposed tree by basal area in sampled gallery forests was *Parinari excelsa,* with an importance value index (IVI) of 142.4 and a total basal area of 20 m^2/ha (Table A1.2, Figure A1.3). *P. excelsa* was the only tree recorded in gallery forest with a total basal area greater than 2 m^2/ha. The second most important tree, *Trichoscypha smythei,* had an IVI of 23.7, approximately one sixth of that calculated for *P. excelsa* (Table A1.2). Because *P. excelsa* was so abundant, when gallery forest was observed from high rocky out-croppings the patches appeared to be mono-dominant.

Fire damaged areas were recorded only in gallery forest. Fire damage was recorded in 65 quarters at 19 sampling points. Early succession fire damaged areas consisted of low-lying vegetation populated by pioneer species including *Adenopodia* sp., *Strychnos* sp., *Caesalpinia benthamiana*, *Lepianthes peltata*, *Combretum racemosum*, and *Urera rigida.* Pioneer trees sparsely populated late succession fire damaged areas. These included *Harungana madagascariensis, Albizia zygia,* and *Samanea dinklagei*.

Table A1.2. Quantitative analysis of sun-exposed tree species in those gallery forests where point center quarter method data were collected in the LMNHFR ranked in order of their IVI.

	Species Name	D (trees/ha)	RD (%)	BA (m2/ha)	RBA	F (%)	RF (%)	Mean Ht. (m)	IVI
1	*Parinari excelsa*	42.58	41.21	19.88	69.52	66.02	31.63	17.51	142.36
2	*Trichoscypha smythei*	10.12	9.8	1.17	4.08	20.39	9.77	12.06	23.65
3	*Synsepalum passargei*	6.55	6.34	0.93	3.26	16.5	7.91	12.71	17.5
4	*Albizia zygia*	6.55	6.34	1.11	3.88	13.59	6.51	15.05	16.74
5	*Samanea dinklagei*	6.25	6.05	0.53	1.85	13.59	6.51	12.15	14.41
6	*Syzygium rowlandii*	3.87	3.75	1.17	4.1	11.65	5.58	14.29	13.42
7	*Polyscias fulva*	4.17	4.03	0.78	2.73	10.68	5.12	13.49	11.88
8	*Harungana madagascariensis*	4.76	4.61	0.16	0.57	12.62	6.05	9.23	11.22
9	*Synsepalum cerasiferum*	2.68	2.59	0.6	2.11	6.8	3.26	17.93	7.96
10	*Psydrax subcordata*	2.68	2.59	0.43	1.51	4.85	2.33	13.43	6.42
11	*Ficus craterostoma*	2.38	2.31	0.39	1.36	3.88	1.86	9.83	5.53
12	Sp. 2	1.79	1.73	0.18	0.62	5.83	2.79	9.43	5.14
13	*Parkia bicolor*	1.49	1.44	0.33	1.14	4.85	2.33	13.49	4.9
14	*Vepris suaveolens*	1.19	1.15	0.18	0.63	1.94	0.93	10.93	2.72
15	*Xylopia acutiflora*	1.19	1.15	0.12	0.41	1.94	0.93	15.1	2.49
16	Sp. 1	0.89	0.86	0.3	1.04	0.97	0.47	17.77	2.37
17	*Trilepisium madagascariense*	0.6	0.58	0.04	0.13	2.91	1.4	16.1	2.1
18	*Strombosia pustulata*	0.6	0.58	0.09	0.32	1.94	0.93	16.1	1.83
19	*Synsepalum dulcificum*	0.6	0.58	0.06	0.21	1.94	0.93	15.1	1.71
20	*Cyathea manniana*	0.6	0.58	0.01	0.02	1.94	0.93	9.6	1.52
21	*Hannoa klaineana*	0.6	0.58	0.04	0.13	0.97	0.47	9.6	1.18
22	*Garcinia smeathmannii*	0.6	0.58	0.01	0.05	0.97	0.47	16.1	1.09
23	*Albizia ferruginea*	0.3	0.29	0.05	0.18	0.97	0.47	15	0.94
24	*Turraeanthus africanus*	0.3	0.29	0.04	0.15	0.97	0.47	16.1	0.9
	Total	**103.31**	**100**	**28.59**	**100**	**208.74**	**100**		**300**

D = density, F = frequency, BA = basal area, RD = relative density, RF = relative frequency, RBA = relative basal area, IVI = importance value index

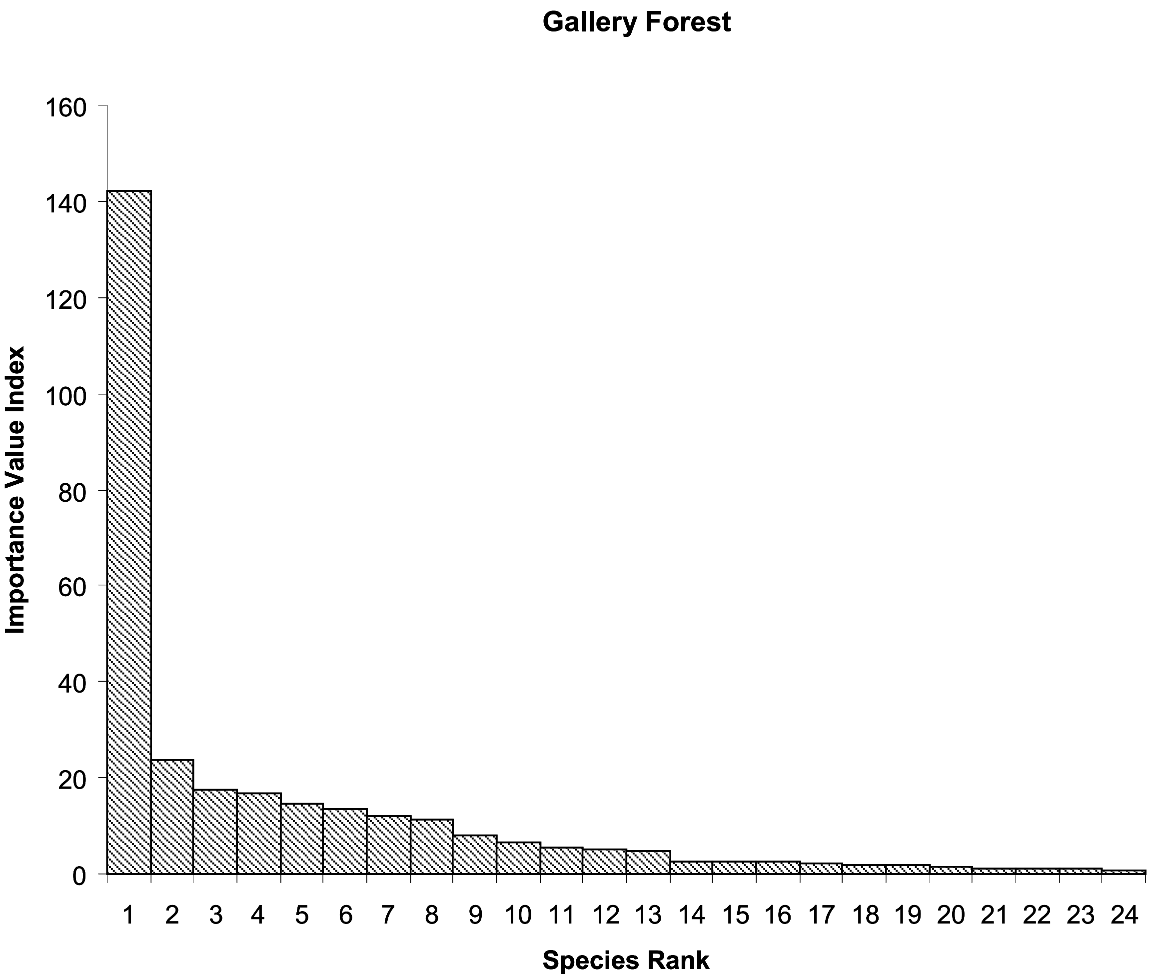

Figure A1.3. Dominance diversity curve for sun-exposed tree species in gallery forests in the LMNHFR; species names are given in Table 1.2.

Non-Gallery Forest

In non-gallery forest, 72 sun-exposed tree species were recorded at 256 sampling points (Table A1.3, Figure A1.4). At these sampling points, the species of 993 trees was identified. For one tree, only the genus was identified. An additional 30 trees were of 17 unidentified species. These 17 species were assigned identification numbers. The absolute density of sun-exposed trees was 149/ha, with a total basal area of 42.4m^2/ha (Table A1.3). The mean canopy height in those non-gallery forests where data were collected was 19 meters with a standard deviation of 8 meters, and a median of 19 meters.

Sun-exposed trees measured along survey trails ranged from four to 43 meters tall. The tallest tree recorded in non-gallery forest that was not on a survey trail was a *Ceiba pentandra,* measuring approximately 70 meters tall with an estimated diameter of 3 meters above the buttresses. *C. pentandra* of this size were common in certain areas of non-gallery forest.

The most important sun-exposed tree by basal area in non-gallery forests was *P. excelsa* with an IVI of 65 and a total basal area of 12.4 m^2/ha (Table A1.3). Six tree species in non-gallery forest, namely *Cryptosepalum tetraphyllum, Samanea dinklagei, Parkia bicolor, Piptadeniastrum africanum,* and *Guarea cedrata*, were recorded to have basal areas greater than 2 m^2/ha (Table A1.3). The two family groups with the highest representation were the Sapotaceae and Fabaceae. Sapotaceae accounted for 13% of all canopy species and had an IVI of 26. Fabaceae accounted for 17% of all canopy species and had an IVI of 110. The latter family was the most represented along survey trails in non-gallery forest.

Table A1.3. Quantitative analysis of sun-exposed tree species in those non-gallery forests where point center quarter method data were collected in the LMNHFR ranked in order of their IVI.

	Species Name	D (tree/ha)	RD (%)	BA (m^2/ha)	RBA (%)	F (%)	RF (%)	Mean Ht. (m)	IVI
1	*Parinari excelsa*	29.7	19.92	12.43	29.28	44.53	15.97	19.94	65.17
2	*Cryptosepalum tetraphyllum*	16.45	11.04	3.01	7.08	26.56	9.52	20.48	27.64
3	*Samanea dinklagei*	15.72	10.55	2.01	4.74	22.27	7.98	14.06	23.27
4	*Parkia bicolor*	4.37	2.93	3.69	8.69	14.45	5.18	26.78	16.81
5	*Piptadeniastrum africanum*	3.49	2.34	4.12	9.7	12.5	4.48	31.79	16.53
6	*Albizia zygia*	7.28	4.88	1.73	4.08	12.5	4.48	18.54	13.45
7	*Guarea cedrata*	5.39	3.61	2.54	5.97	11.72	4.2	29.11	13.79
8	*Cola lateritia*	6.41	4.3	1.63	3.85	11.33	4.06	23.01	12.21
9	*Carapa procera*	5.39	3.61	1.23	2.89	10.55	3.78	16.13	10.29
10	*Synsepalum cerasiferum*	5.1	3.42	1.08	2.54	10.16	3.64	20.11	9.60
11	*Ficus craterostoma*	5.1	3.42	0.92	2.17	8.98	3.22	10.51	8.81
12	*Hannoa klaineana*	2.91	1.95	0.8	1.89	7.03	2.52	20.48	6.36
13	Sp. 19	4.08	2.73	0.29	0.69	5.47	1.96	9.01	5.39
14	*Synsepalum dulcificum*	2.33	1.56	0.79	1.85	5.08	1.82	20.98	5.23
15	*Newtonia duparquetiana*	2.77	1.86	0.49	1.16	5.08	1.82	20.31	4.84
16	*Albizia ferruginea*	2.47	1.66	0.23	0.55	4.69	1.68	13.98	3.89
17	*Synsepalum passargei*	1.75	1.17	0.31	0.73	4.3	1.54	15.73	3.44
18	*Trichoscypha smythei*	1.89	1.27	0.17	0.39	3.91	1.4	14.72	3.06
19	*Polyscias fulva*	1.75	1.17	0.31	0.72	3.52	1.26	16.06	3.16
20	*Chrysophyllum subnudum*	1.46	0.98	0.49	1.16	3.13	1.12	25.80	3.26
21	*Alstonia boonei*	1.02	0.68	0.47	1.1	2.73	0.98	28.17	2.76
22	*Xylia evansii*	1.02	0.68	0.53	1.25	2.73	0.98	29.17	2.91
23	*Xylopia quintasii*	1.75	1.17	0.14	0.32	2.34	0.84	20.68	2.33
24	*Chrysophyllum pruniforme*	1.31	0.88	0.14	0.33	2.34	0.84	21.61	2.05
25	*Fagara macrophylla*	1.02	0.68	0.21	0.51	2.34	0.84	19.96	2.03
26	*Trilepisium madagascariense*	0.87	0.59	0.3	0.7	2.34	0.84	24.02	2.13
27	*Uapaca guineensis*	1.31	0.88	0.1	0.24	2.34	0.84	13.27	1.96
28	*Milicia excelsa*	0.87	0.59	0.15	0.36	1.95	0.7	23.17	1.65
29	*Anthonotha macrophylla*	0.87	0.59	0.05	0.12	1.56	0.56	10.02	1.26
30	*Cordia platythyrsa*	0.58	0.39	0.14	0.33	1.56	0.56	17.98	1.28
31	*Chrysophyllum perpulchrum*	0.73	0.49	0.09	0.21	1.56	0.56	23.10	1.26
32	*Beilschmiedia mannii*	0.44	0.29	0.18	0.43	1.56	0.56	18.77	1.28
33	Sp. 2	0.58	0.39	0.04	0.09	1.56	0.56	9.35	1.04
34	Sp. 4	0.58	0.39	0.03	0.07	1.17	0.42	11.10	0.89
35	*Cyathea manniana*	0.87	0.59	0.04	0.1	1.17	0.42	8.40	1.11
36	*Pycnanthus angolensis*	0.44	0.29	0.11	0.25	1.17	0.42	29.77	0.97
37	*Nauclea diderrichii*	0.44	0.29	0.14	0.33	1.17	0.42	31.77	1.04
38	*Chrysophyllum africanum*	0.44	0.29	0.06	0.14	1.17	0.42	22.43	0.85
39	*Gilbertiodendron preussii*	0.44	0.29	0.11	0.26	0.78	0.28	21.10	0.84
40	Sp. 13	0.44	0.29	0.04	0.1	0.78	0.28	20.10	0.68
41	*Harungana madagascariensis*	0.44	0.29	0.01	0.03	0.78	0.28	5.77	0.6
42	Sp. 1	0.58	0.39	0.02	0.06	0.78	0.28	5.85	0.73
43	*Anthocleista* sp.	0.29	0.2	0.1	0.24	0.78	0.28	22.60	0.72
44	*Bridelia grandis*	0.44	0.29	0.02	0.05	0.78	0.28	14.77	0.62
45	*Morus mesozygia*	0.15	0.1	0.14	0.33	0.78	0.28	33.10	0.70

46	Sp. 3	0.29	0.2	0.03	0.08	0.78	0.28	19.30	0.56
47	*Syzygium rowlandii*	0.29	0.2	0.03	0.08	0.78	0.28	18.60	0.55
48	Sp. 11	0.29	0.2	0.02	0.05	0.78	0.28	7.60	0.52
49	*Psydrax subcordata*	0.29	0.2	0.02	0.04	0.78	0.28	11.30	0.52
50	Sp. 15	0.29	0.2	0.02	0.04	0.78	0.28	4.10	0.52
51	Sp. 12	0.29	0.2	0.02	0.04	0.78	0.28	7.10	0.52
52	*Omphalocarpum pachysteloides*	0.15	0.1	0.11	0.27	0.39	0.14	27.10	0.51
53	*Vepris suaveolens*	0.29	0.2	0.01	0.02	0.39	0.14	6.10	0.36
54	Sp. 5	0.29	0.2	0.07	0.16	0.39	0.14	11.10	0.49
55	*Chrysophyllum albidum*	0.44	0.29	0.02	0.05	0.39	0.14	16.93	0.49
56	*Entandrophragma cylindricum*	0.15	0.1	0.08	0.19	0.39	0.14	33.10	0.43
57	*Canarium schweinfurthii*	0.15	0.1	0.07	0.16	0.39	0.14	28.10	0.40
58	Sp. 6	0.15	0.1	0.07	0.16	0.39	0.14	28.60	0.40
59	Sp. 7	0.15	0.1	0.06	0.13	0.39	0.14	24.60	0.37
60	Sp. 14	0.15	0.1	0.03	0.07	0.39	0.14	28.10	0.30
61	*Gilbertiodendron splendidum*	0.15	0.1	0.02	0.05	0.39	0.14	16.90	0.29
62	*Hymenostegia afzelii*	0.15	0.1	0.02	0.05	0.39	0.14	12.10	0.29
63	*Funtumia* sp.	0.15	0.1	0.02	0.05	0.39	0.14	24.10	0.29
64	*Heritiera utilis*	0.15	0.1	0.02	0.04	0.39	0.14	8.10	0.28
65	Sp. 17	0.15	0.1	0.02	0.04	0.39	0.14	5.60	0.28
66	*Synsepalum afzelii*	0.15	0.1	0.01	0.03	0.39	0.14	20.10	0.27
67	Sp. 16	0.15	0.1	0.01	0.03	0.39	0.14	9.10	0.27
68	*Sterculia tragacantha*	0.15	0.1	0.01	0.02	0.39	0.14	6.10	0.26
69	Sp. 18	0.15	0.1	0.01	0.01	0.39	0.14	13.10	0.25
70	Sp. 8	0.15	0.1	0	0.01	0.39	0.14	6.10	0.25
71	Sp. 9	0.15	0.1	0	0.01	0.39	0.14	10.10	0.25
72	Sp. 10	0.15	0.1	0	0.01	0.39	0.14	6.10	0.25
	Total	**149.08**	**100**	**42.44**	**100**	**278.91**	**100**		**300**

D = density, F = frequency, BA = basal area, RD = relative density, RF = relative frequency, RBA = relative basal area, IVI = importance value index

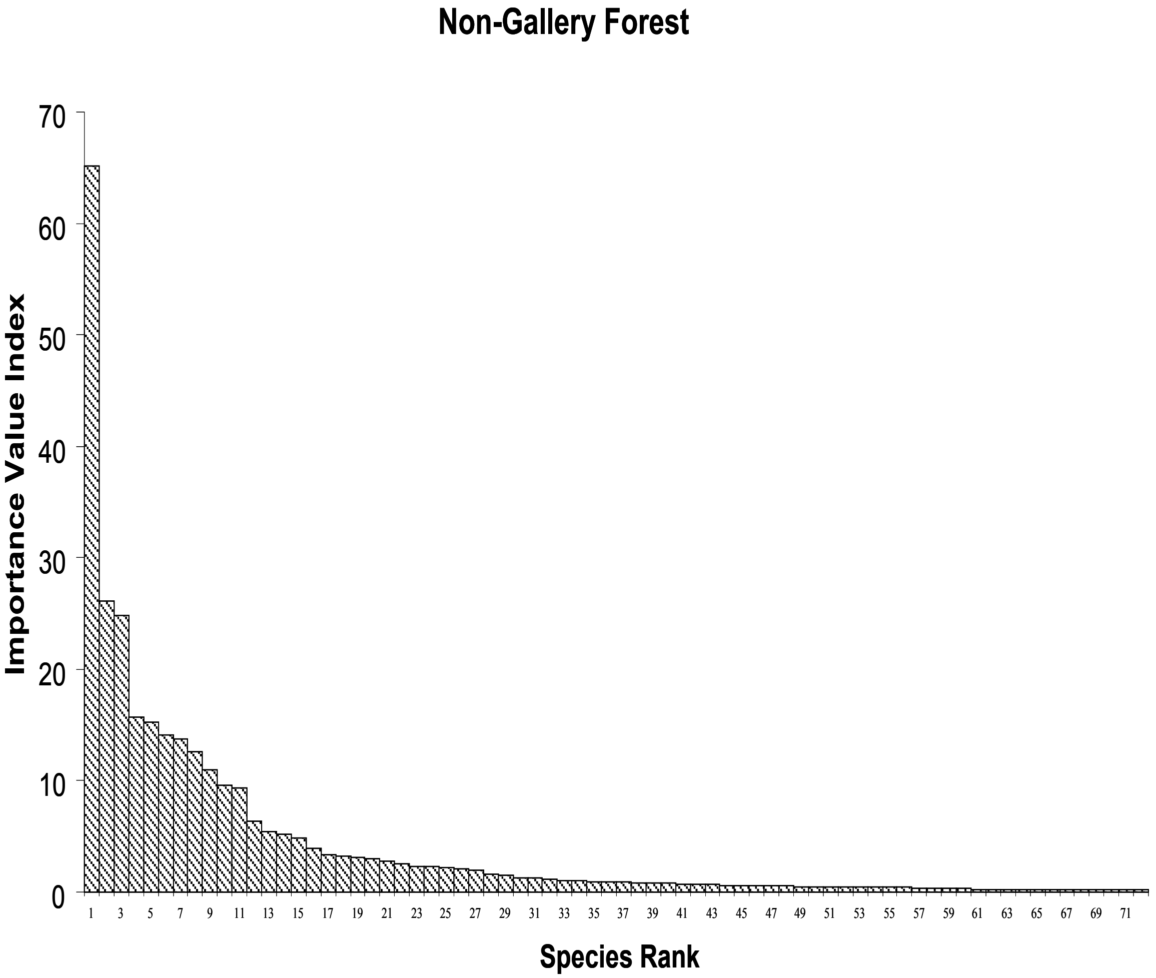

Figure A1.4. Dominance diversity curve for sun-exposed tree species in non-gallery forests in the LMNHFR; species names are given in Table 1.3

DISCUSSION

The forests of the LMNHFR are diverse. Jaeger (1983) recorded over 1550 species of vascular plants within the reserve. A recent short-term survey of vegetation in the LMNHFR recorded over 700 species of plants (Kouassi *et al.* 2009). Koussi *et al.* (2009) also noted that in general, trees from the Fabaceae family accounted for more than 140 species and dominated the forests of the LMNHFR. Their research also reported an IVI of 58 for *P. excelsa* in upland forests that were defined by them as any forest above 1000m elevation. *P. excelsa* was the most important tree in upland forest.

Corresponding to my results, they report Fabaceae and Sapotaceae as being among the five most important plant families.

My vegetation data should not be used as or cited as a comprehensive survey of the LMNHFR vegetation. In no way do my results represent all the floral diversity of the reserve. My methods represent trees I define as sun-exposed trees between the altitudes of 800 and 1600 meters.

Appendix 2

ANIMAL ACTIVITY PATTERNS OBTAINED WITH CAMERA TRAPS

INTRODUCTION

Animals observed during survey walks can be alerted by olfactory, auditory, and visual cues. Each cue can cause an otherwise inactive animal to become active. During survey walks, it is not possible to determine the state (active or inactive) of an animal before it is recorded. As a result, assessing animal activity patterns using active methods of detection may not give a good representation of the animals' activity.

The unobtrusiveness of camera traps makes their use an ideal method of determining when animals are active in a given habitat. Because a camera trap will only take a photograph when it is triggered by motion, only active animals are photographed. Thus, the animal's normal behavior causes the trap to be triggered rather than an external factor causing an otherwise inactive animal to become active.

METHODS

Four camera traps (CamTrakker Atlanta, Georgia) triggered by infrared motion sensors were deployed at eighteen different locations within the LMNHFR from March to October 2007. Nine of these camera trap locations were in gallery forest and nine were in non-gallery forest (Figure A2.1).

Camera traps were set along well-worn game trails with the intent of assessing which mammals were present in the reserve. Therefore, camera traps were set at locations where they were most likely to take photographs of animals, in contrast to survey trails, that were cut without regard to where animals would be encountered. Data obtained from camera traps were used only to assess activity patterns, and no comparisons were made between camera trap data and dung or sight data.

RESULTS

In gallery forest, 55 photos were taken over 62 camera days. In non-gallery forest, 31 photos were taken over 61 camera days (Table A2.1).

Activity patterns assessed solely from these photographs show that buffalo and bay duikers are exclusively nocturnal, Maxwell's and black duikers are primarily diurnal and red river hogs are primarily nocturnal. Yellow-backed duikers and bushbuck are equally active during the day and night (Table A2.1).

Opportunistic observations during both day and night reveal the same activity patterns with one exception. Buffalo were regularly observed in grasslands between 0630hrs and 1000hrs and again between 1600hrs and 1830hrs. Fresh dung and feeding evidence observed during early morning hours also indicated buffalo were active at night. Given these additional observations, buffalo are more accurately categorized as active both diurnally and nocturnally as previously reported (Korte 2008).

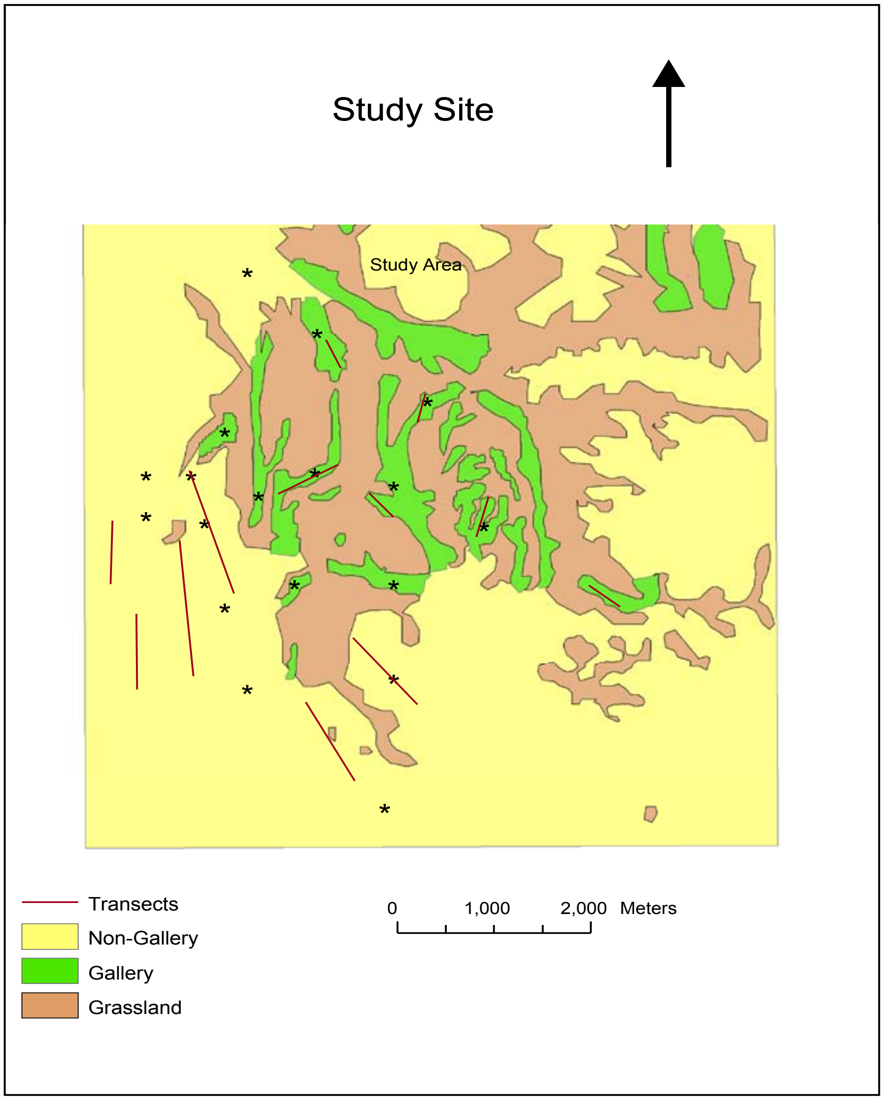

Figure A2.1. Locations of where camera traps were set in the study area.

Table A2.1. Activity patterns of study species based on camera trap data from the LMNHFR.

			Activity patterns	
Species		Photos	% Nocturnal	%Diurnal
Bay duiker	*Cephalophus dorsalis*	10	100	0
Black duiker	*C. niger*	16	12	88
Yellow-backed duiker	*C. silvicultor*	11	55	45
Maxwell's duiker	*Philantomba maxwelli*	33	18	82
Bushbuck	*Tragelaphus scriptus*	7	86	14
Forest buffalo	*Syncerus caffer nanus*	5	100	0
Red river hog	*Potamochoerus porcus*	4	75	25
Total		86		

DISCUSSION

To fully assess an animal's activity pattern with camera traps, they should be placed in all areas accessible to the particular species. During this study, only four camera traps were utilized and therefore we could not place camera traps in all accessible areas. The results are a good indication of when animals are active in those areas in which camera traps were placed, but do not represent animal activity in those areas where traps were not placed. These data are particularly limited with respect to assessing activity patterns in grassland areas where no traps were set. Yet, in spite of these limitations, observations of study species in grassland during the day and night give a good indication that, even if camera traps were placed in grassland, the results would not materially differ from those reported here.

APPENDIX 3

LONG TERM MAMMAL RECORDS FROM THE LOMA MOUNTAINS NON-HUNTING FOREST RESERVE (LMNHFR)

INTRODUCTION

Information on large mammals in the LMNHFR is scanty. I have found only five publications giving reference to large mammals in the LMNHFR (East 1990; Atkinson *et al.* 1992; Grubb *et al.* 1998; Kortenhoven 2002; Kormos 2003). Three of these publications used information from interviews and did not have a field component, and only two conducted *in situ* research in the LMNHFR (Atkinson *et al.* 1996; Kortenhoven 2002). If the LMNHFR is to gain the international attention necessary for its conservation, it is essential to have current information on the large mammal species that occur within the reserve's boundaries. I have included my own personal observations of large mammals within the reserve spanning a 19-year period.

METHODS

From 1989 to 2008, I observed, heard, or photographed 47 species of large mammals within the boundaries of LMNHFR. The presence of three species was based on interviews. Data on the presence of large mammal species were collected primarily through *ad lib* observations while working within the LMNHFR. During fieldwork, species were identified from dung, tracks, feeding evidence, sightings, and calls.

In addition to field observations, I frequently asked local hunters to list those species they knew to occur in the reserve. Pictures were not used for species identification. My experience indicates that hunters will fit animals to pictures and as a result, errors occur such as a picture of a giraffe easily becoming a waterbuck or a picture of a cheetah being interpreted as a leopard (pers. obs.).

RESULTS

From 1989 to 2008, 13 primate species, four large rodents species, one Lagomorph species, 12 Carnivore species, three scaly ant-eater species, one hyrax species and 16 ungulate species were recorded in the LMNHFR (Table A3.1).

Table A3.1. Mammal records for the LMNHFR collected from 1989-2008.

Common Name	*Scientific name*	Kuranko name*	O	H	F	T	D	I	IUCN Status
Primates									
Chimpanzee	*Pan troglodytes verus*	Woroŋ	X	X	X	X	X	X	EN
Western pied colobus	*Colobus polykomos*	Bando	X	X	X			X	LR/nt
Western red colobus	*Piliocolobus badius*	Kewulaŋ	X	X				X	EN
Olive baboon	*Papio anubis*	gBoŋ	X	X	X		X	X	
Sooty mangaby	*Cercocebus atys*	gBekwi/gBoŋkorɛ	X	X	X			X	LR/nt
Patas monkey	*Cercopithecus patas*	gBaŋfeŋ wulaŋ						X	
Vervet monkey	*C. aethiops sabaeus*	gBaŋfeŋ gbɛ	X					X	
Diana monkey	*C. diana diana*	Serelɛ kulɛ	X	X				X	EN
Cambell's guenon	*C. campbelli*	Kaŋfeŋyɛ	X	X				X	LR/lc
Lesser spot-nosed guenon	*C. petaurista*	Suŋgbɛi	X	X				X	LR/lc
Potto	*Perodicticus potto*	Kontɛ		X				X	
Senegal galago	*Galago senegalensis*	Pensɛ						X	
Demidoff's galago	*Galagoides demidovii*	Pensɛmɛnsɛ	X	X				X	
Lagomorpha									
Hare	*Lepus saxatilis*	Fasaŋnikoroh	X						
Rodentia									
Beecroft's anomalure	*Anomalurus beecrofti*	Sogonikona						X	
Crested porcupine	*Hystrix cristata*	Balɛ	X		X		X	X	
Brushtailed porcupine	*Atherurus africanus*	Tɛrɛ/Kɛsɛkɛsaŋ	X		X		X	X	
Cane rat	*Thryonomys swinderianus*	Sogonɛ	X		X		X	X	
Carnivora									
Ratel	*Mellivora capensis*	Firɛ wuli						X	
African clawless otter	*Aonyx capensis*	Menɛ					X	X	LC
Slender mongoose	*Herpestes sanguinea*	Kurɛkurɛnɛ	X	X					
Cusimanse	*Crossarchus obscurus*	Kolokɛrɛbambaŋ	X	X					
Marsh mongoose	*Atilax paludinosus*	Sunya	X					X	
Common genet	*Genetta genetta*	Sɛlaŋ	X					X	

Blotched genet	*G. tigrina*	Firɛ Sɛlaŋ	X					X	
African civet	*Civettictis civetta*	Kuyaŋ	X				X	X	
African palm civet	*Nandinia binotata*	Firɛ yenkumɛ	X	X				X	
Serval cat	*Leptailurus serval*	Soŋkoŋ dɛlaŋ					X	X	
Golden cat	*Felis aurata*	Dɛlaŋ/Bambaŋ	X				X	X	VU
Leopard	*Panthera pardus*	Kuli/Waraŋ	X	X	X	X	X	X	
Philodota									
Giant ground pangolin	*Smutsia gigantea*	Konsoŋ kansaŋ			X	X		X	LR/lc
Tree pangolin	*Phataginus tricuspis*	gBosorɛ	X					X	LR/lc
Long-tailed pangolin	*Uromanis tetradactyla*	gBosorɛ wulaŋ	X					X	LR/lc
Uranotheria									
Rock hyrax	*Procavia capensis*	Konkobara	X	X	X	X	X	X	
Ungulata									
Aardvark	*Orycteropus afer*	Keŋfɛ			X	X		X	
Pygmy hippopotamus	*Hexaprotodon liberiensis*	Yimalaŋ			X	X	X	X	EN
Red river hog	*Potamochoerus porcus*	Kosɛ	X	X	X	X	X	X	LR/lc
Common warthog	*Phacochoerus africanus*	gBɛsɛ/Laɛ	X	X	X	X	X	X	
Water chevrotain	*Hyemoschus aquaticus*	gBeremɛ	X					X	DD
Forest buffalo	*Syncerus caffer nanus*	Sigiŋ†	X	X	X	X	X	X	LR/cd
Bongo	*Tragelaphus euryceros*	Yinkiyaŋkɛ				X	X	X	LR/nt
Bushbuck	*T. scriptus*	Mina	X	X	X	X	X	X	LR/lc
Waterbuck	*Kobus ellipsiprymnus*	Sensɛ				X	X	X	LR/cd
Maxwell's duiker	*Philantomba maxwelli*	Woyaŋ/Fori	X		X	X	X	X	LR/nt
Bay duiker	*Cephalophus dorsalis*	gBondaŋ	X		X	X	X	X	LR/nt
Black duiker	*C. niger*	Taɛ/Firɛlabah	X		X	X	X	X	LR/nt
Yellow-backed duiker	*C. silvicultor*	Firɛnensiŋ	X		X	X	X	X	LR/nt
Zebra duiker	*C. zebra*	N/A	X						VU
Red flanked duiker	*C. rufilatus*	Funɛma gBondaŋ	X					X	LR/nt
Royal antelope	*Neotragus pygmaeus*	Fasaŋ	X				X	X	LR/nt
Total species	50								

*Kuranko names were obtained by Kortenhoven from a multitude of hunters between 1983 and 2008. O = observed, H = heard, F = feeding evidence, T = tracks, D = dung, I = interview with local hunters, EN = endangered, LR/nt = lower risk/near threatened, LR/lc = lower risk/ least concern, VUL = vulnerable, DD = data deficient, LC = least concern, Ŋ = ng sound, ɛ = eh sound; ɔ = oh; † The Kuranko recognize two sub-species of Buffalo collectively referred to as Sigiŋ, subspecies specific names are *Syncerus caffer nanus* = Konkyebeŋ-sigiŋ and *Syncerus caffer brachycerus* = Meŋ-sigiŋ

Only three species, Beecroft's flying squirrel (*Anomalurus beecrofti)*, Senegal galago *(Galago senegalensis*), and ratel (*Mellivora capensis*) were recorded solely based on interviews and were not seen or heard during surveys.

Three species that I have recorded in the LMNHFR, pygmy hippopotamus (*Hexaprotodon liberiensis),* bongo *(Tragelaphus euryceros),* and zebra duiker *(Cephalophus zebra*)), are at risk of extinction in Sierra Leone and elsewhere (Kingdon 1997).

My research team confirmed the presence of pygmy hippopotamus in 2007 and 2008. In 2007, a pygmy hippopotamus was killed by a trapper from the town of Konobaia on the southwestern side of the LMNHFR. Responses to my inquiries indicated that the animal was killed near the Seyi River at the southern base of the Loma Mountains (9° 9.831'N, 11° 11.084'W). The killing of a pygmy hippopotamus was confirmed by a photograph of the recently killed hippo's canine tooth, obtained by one of my field assistants. Interviews with the hunter revealed that pygmy hippopotamus were present and seen by him on two occasions in 2008. Pygmy hippopotamus dung and footprints were recorded by my research team at 23 different locations along the Seyi River, substantiating the hunter's claims.

I observed bongo dung and hoof-prints on four different occasions on the Loma Plateau between 2006 and 2008. Between 2006 and 2008, hunters also confirmed bongo presence at the western side of the LMNHFR. The evidence of bongo during this study was low in comparison to1989 and 1992 when I saw bongo dung and hoof-prints frequently.

In 1992, I recorded zebra duikers in the LMNHFR. During the current research period (2006-2008), I did not record zebra duiker. A more extensive survey is needed to determine whether zebra duikers still occur in the LMNHFR.

There are no recent records of elephants within the reserve boundaries, but in 2006, 2007 and 2008, evidence of elephants was recorded 6 km west of the LMNHFR along the Bagbeh River (9°15.140'N, 11° 16.362'W). Local residents indicated that elephants had been seen within the reserve in recent history, but without a definitive timeframe. Many of the hunters, who ranged in age from 40 to 60 years, agreed that elephants had occurred in the reserve after they began hunting. These reports indicate that elephants were possibly present as late as the early 1980s. All hunters concurred that elephants had not been seen on the Loma Plateau and were seen only in the surrounding lowlands.

DISCUSSION

Grubb *et al.* (1998) reported 71 large mammal species for Sierra Leone. Three of these species, Buffon's kob (*Kobus kob*), oribi (*Ourebia ourebi*) and bush duiker (*Sylvicapra grimmia*), are probably extinct within the country, so the 50 species found on Loma represent more than 70% of Sierra Leone's large mammal fauna. Of the species recorded in LMNHFR, 31 percent do not occur outside West Africa and 14 of these species are endemic to the Upper Guinea forest, making the LMNFHR of great global conservation value.

The decrease in bongo evidence is likely a result of a post-war (2001-2006) increase in hunting made possible by easy access to military style firearms (i.e. AK-47s, Heckler & Koch G3s and Type 56-1 rifles). The hunting that has occurred in the reserve is not limited to large mammals.

There has been a noticeable decrease in all mammals in the reserve since 1989, when I first began going to the LMNHFR. Yet, in spite of poaching, the area remains one of few places in Sierra Leone where large mammals can be observed with regularity.

Appendix 4.

Table A4.1. Coordinates and elevations for the start and end of each survey trail.

Forest type	Survey Trail	Start	End	Elevation (m)
Non-gallery forest	MT	9°12'26.00"N	9°12'1.60"N	1130
		11° 9'3.30"W	11° 9'3.80"W	1089
	SFT	9°11'19.20"N	9°10'49.80"N	1217
		11° 7'57.00"W	11° 7'40.30"W	1165
	PLT	9°12'19.20"N	9°11'28.40"N	1286
		11° 8'40.70"W	11° 8'35.40"W	1212
	CT	9°12'45.10"N	9°11'59.60"N	1288
		11° 8'37.40"W	11° 8'21.70"W	1281
	NNT	9°11'43.00"N	9°11'18.30"N	1349
		11° 7'41.20"W	11° 7'19.30"W	1156
	LPT	9°11'51.80"N	9°11'23.10"N	1163
		11° 8'54.70"W	11° 8'54.30"W	1130
Gallery forest	GFT	9°12'36.20"N	9°12'20.80"N	1541
		11° 6'55.30"W	11° 6'59.80"W	1508
	BKFK	9°13'14.60"N	9°13'3.80"N	1608
		11° 7'16.80"W	11° 7'19.90"W	1455
	SLT	9°13'34.10"N	9°13'23.50"N	1519
		11° 7'51.00"W	11° 7'45.70"W	1608
	LFT	9°12'03.14"N	9°11'55.18"N	1487
		11° 6'21.65"W	11° 6'11.50"W	1479
	LST	9°12'37.20"N	9°12'28.10"N	1507
		11° 7'36.10"W	11° 7'27.60"W	1483
	NKT	9°12'47.60"N	9°12'36.30"N	1508
		11° 7'46.90"W	11° 8'6.90"W	1455

BIBLIOGRAPHY

African Flowering Plants Database. Conservatoire et Jardin botaniques de la Villle de Genève and South African National Biodiversity Institute, Pretoria,"Retrieved [9 March 2008]", from<http://www.ville-ge.ch/musinfo/bd/cjb/africa/>.

Atkinson, P., P. A. Turner, S. Pocknell, G. Broad, A.P. Koroma, D. Annaly and S. Rowe (Eds) 1996. Land use and conservation in the Mount Loma Reserve, Sierra Leone. Norwich: School of Biological Sciences, University of East Anglia

Beard, J. S. 1955. A note on gallery forests. Ecology. 36:339-340.

Blake, S. 2002. Forest buffalo prefer clearings to closed-canopy forest in the primary forest of northern Congo. Oryx. 36:81-86.

Bodmer, R. E. 1991. Strategies of seed dispersal and seed predation in Amazonian ungulates. Biotropica. 23:255-261.

Buckland S.T., D. R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers and L. Thomas. 2001. *Introduction to distance sampling. Estimating abundance of biological populations.* Oxford: Oxford University Press. 432 pp.

Chiarello, A. G. 2000. Density and population size of mammals in remnants of Brazilian Atlantic forest. Conservation Biology. 14:1649-1657.

Cole, N. H. A. 1974. Climate, life forms and species distribution on Loma montane grassland, Sierra-Leone. Botanical Journal of the Linnean Society. 69:197-210.

Cottam, G., J. T. Curtis, and B. W. Hale. 1953. Some sampling characteristics of a population of randomly dispersed individuals. Ecology. 34:741-757.

Cottam, G. and J. T. Curtis. 1956. The use of distance measures in phytosociological sampling. Ecology. 37:451-460.

Dahdouh-Guebas, F., and N. Koedam. 2006. Empirical estimate of the reliability of the use of the Point-Centred Quarter Method (PCQM): Solutions to ambiguous field situations and description of the PCQM+ protocol. Forest Ecology and Management. 228:1-18.

Dankwa-Wiredu, B., and D. L. Euler. 2002. Bushbuck (*Tragelaphus scriptus Pallas*) habitat in Mole National Park, northern Ghana. African Journal of Ecology. 40:35-41.

Davies, G. A., N. Leader-Williams, J.R. MacKinnon, and H.S. Newing. 2001. The effects of logging on tropical forest ungulates. Pages 93-124 In: Fimbel, R. A. A., A. Grajal and J.G. Robinson (Eds). *The Cutting Edge: conserving wildlife in logged tropical forests.* Columbia University Press. pp. 808

Dubost, G. 1984. Comparison of the diets of frugivorous forest ruminants of Gabon. Journal of Mammalogy. 65:298-316.

Dubost, G. and F. Feer. 1988. Behavioral-differences in the genus Cephalophus (Ruminantia, Bovidae), as illustrated by Cephalophus rufilatus gray, 1846. Zeitschrift Fur Saugetierkunde-International Journal of Mammalian Biology. 53:31-47.

East, R. (Eds). 1990. Antelopes Global Survey and Regional Action Plans. Part 3: West and Central Africa. IUCN/SSC Antelope Specialist Group. Gland, Switzerland. pp. 171

Estes, R. D. 1991. *The Behavior Guide to African Mammals.* University of California Press. pp. 660

Ewel, J. 1980. Tropical succession: manifold routes to maturity. Biotropica. 12:2-7.

Fay, J. M. 1988. Forest monkey populations in the Central African Republic: The northern limits. A census in Manovo-Gounda-St. Floris National Park. Mammalia. 52:57-74.

Feer, F. 1989a. The use of space by 2 sympatric duikers (*Cephalophus callipygus* and *Cephalophus dorsalis*) in an African rain-forest - the role of activity rhythms. Revue D Ecologie-La Terre Et La Vie. 44:225-248.

Feer, F. 1989b. Comparative diet of *Cephalophus callipygus* and *C. dorsalis*, sympatric bovids of the African sempervirent forest. Mammalia. 53:563-620.

Feer, F. 1995. Seed dispersal in African forest ruminants. Journal of Tropical Ecology. 11:683-689.

Fimbel, C. 1994. The relative use of abandoned farm clearings and old forest habitats by primates and a forest antelope at Tiwai, Sierra-Leone, West-Africa. Biological Conservation. 70:277-286.

Gautier-Hion, A., L. H. Emmons, and G. Dubost. 1980. A comparison of the diets of 3 major groups of primary consumers of Gabon (primates, squirrels and ruminants). Oecologia. 45:182-189.

Ghiglieri, M. P., T. M. Butynskii, T. T. Struhsaker and L. Leland. 1982. Bush pig *(Potamochoerus porcus)* polychromatism and ecology in Kibale Forest, Uganda. African Journal of Ecology. 20:231-236

Grubb, P., T.S. Jones, A.G. Davies, E. Edberg, E.D. Starin and J.E Hill. 1998. *Mammals of Ghana, Sierra Leone and The Gambia.* Trendrine Press, St Eves, Cornwall, Great Britain. pp.320

Hart, J.A. 1986. Comparative dietary ecology of a community of frugivorous forest ungulates in Zaire. Doctoral dissertation. East Lansing: Michigan State University.

Hart, J. A., M. Katembo, and M. Punga. 1996. Diet, prey selection and ecological relations of leopard and golden cat in the Ituri Forest, Zaire. African Journal of Ecology. 34:364-379.

Hawthorne, W. and C. Jongkind. 2006. *Woody plants of Western African forests: A guide to the forest trees, ferns, shrubs and lianes from Senegal to Ghana.* Kew Publishing. Royal Botanic Gardens, Kew, UK. pp. 1023

Henschel, P., K. A. Abernethy, and L. J. T. White. 2005. Leopard food habits in the Lopé National Park, Gabon, Central Africa. African Journal of Ecology. 43:21-28.

Heydon, M. J. and P. Bulloh. 1997. Mousedeer densities in a tropical rainforest: the impact of selective logging. Journal of Applied Ecology. 34:484-496.

Hofmann, T. and H. Roth. 2003. Feeding preferences of duiker (*Cephalophus maxwelli, C. rufilatus,* and *C. niger*) in Ivory Coast and Ghana. Mammalian Biology. 68:65-77.

Jaeger, P. and M. Lamottee. 1966. Les richesses floristiques et faunistiques des monts Loma (Sierra Leone). Bulletin de l'IFAN. 28A:1149-1190.

Jaeger, P. 1983. Le recesement des plantes vasculaires et les originalites du peuplement vegetal des monts Loma en Sierra Leone (Afrique Occidentale). Bothalia. 14:539-542.

Jenny, D. and K. Zuberbühler. 2005. Hunting behaviour in West African forest leopards. African Journal of Ecology. 43:197-200.

Kingdon, J. 1997. *The Kingdon field guide to African mammals*. Academic Press, London and New York: Natural World. pp. 450

Kormos, R., C. Boesch, M.I. Bakarr, and T. Butynski. (eds.). 2003. West African chimpanzees. Status survey and conservation action plan. IUCN/SSC Primate Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK.ix + 219 pp.

Korte, L. M. 2008. Habitat selection at two spatial scales and diurnal activity patterns of adult female forest buffalo. Journal of Mammalogy. 89:115-125.

Kortenhoven, A.P., 2002. Antelopes of the Loma Mountain region. Gnusletter. 21:8-9

Kouamé, N. F., K.E. Kouassi and A. Lebbie. 2009. Botanical survey and forest structure of the Loma Mountains Non-Hunting Forest Reserve. Unpublished report submitted to the World Bank.

Koster, S. H. and J.A., Hart. 1988. Methods of estimating ungulate populations in tropical forests. African Journal of Ecology. 26:117-126.

Lumpkin, S. and K.R. Kranz. 1984. *Cephalophus silvicultor*. Mammalian Species. 225:1-7.

Lwanga, J.S. 2006. The influence of forest variation and possible effects of poaching on duiker abundance at Ngogo, Kibale National Park, Uganda. African Journal of Ecology. 44:209-218.

McCoy, J. 1995. Responses of blue and red duikers to logging in the Kibale Forest of Western Uganda. M.Sc thesis. University of Florida, Gainesville

Mitani, J.C., Sanders W.J., Lwanga J.S. & T.L. Windfelder. 2001. Predatory behavior of crowned hawk-eagles (*Stephanoaetus coronatus*) in Kibale National Park, Uganda. Behavioral Ecology and Sociobiology. 49:187-195

Mitchell, K. 2007. Quantitative analysis by the point-centered quarter method. Hobart and William Smith Colleges. 25 June, 2007 <http://people.hws.edu/mitchell/PCQM.pdf>

Morton, J. K. 1986. Montane Vegetation. Pages 247-271 In: *Plant ecology in West Africa*. G. W. Lawson (editor). John Wiley and Sons Ltd., United Kingdom.

Muchaal, P. K. and G. Noss. 1999. Impact of village hunting on wildlife populations in the Western Dja Reserve, Cameroon. Conservation Biology. 13: 385-396.

Mühlenberg, M., A. Galatluong, P. Poilecot, B. Steinhauerburkart, and I. Kuhn. 1990. The importance of forest islands within wet savannas for the conservation of rain-forest animals: the Ivory-Coast case. Revue D Ecologie-La Terre Et La Vie. 45: 197-214.

Newing, H.S. 1994. Behavioural ecology of duikers (*Cephalophus* spp.) in forest and secondary growth, Taï, Côte d'Ivoire. PhD thesis, Stirling University, Scotland

Newing, H. 2001. Bushmeat hunting and management: implications of duiker ecology and interspecific competition. Biodiversity and Conservation. 10:99-118.

Nummelin, M. 1990. Relative habitat use of duikers, bush pigs, and duikers in virgin and selectively logged areas of the Kibale Forest, Uganda. Tropical Zoology. 3:111–120.

Payne, J.C. 1992. A field study of techniques for estimating densities of duikers in KorupNational Park, Cameroon. M.Sc. Thesis, University of Florida, Gainesville.

Plumptre, A. J. 2000. Monitoring mammal populations with line transect techniques in African forests. Journal of Applied Ecology. 37:356-368.

Plumptre, A. J. and S. Harris. 1995. Estimating the biomass of large mammalian herbivores in a tropical montane forest - a method of fecal counting that avoids assuming a steady-state system. Journal of Applied Ecology. 32: 111-120.

Poorter, L., F. Bongers, F. N'Kouamé and W. D. Hawthorne. 2004. *Biodiversity of West African forests: an ecological atlas of woody plant species*. CABI Publishing, Wageningen. pp. 528

Ralls, K. 1973. *Cephalophus maxwelli*. Mammalian Species. 31:1-4.

Rovero, F. and A.R. Marshall. 2004. Estimating the abundance of forest antelopes by line transect techniques: a case from the Udzungwa Mountains, Tanzania. Tropical Zoology. 17:267-277.

Savill, P. S. and J. E. D. Fox. 1967. *Trees of Sierra Leone*. Sierra Leone Government Press, Freetown. pp.316.

Shultz, S. 2008. Population density, breeding chronology and diet of Crowned Eagles (*Stephanoaetus coronatus*) in Taï National Park, Ivory Coast. Ibis. 144:135-138.

Siegel, S. 1956. *Nonparametric statistics for the behavioral sciences.* New York: McGraw Hill. pp.312

Struhsaker, T. T. 1997. *Ecology of an African rain forest*. University Press of Florida, Gainesville. pp. 434

Tutin, C.E.G. and M. Fernandez. 1984. Nationwide Census of Gorilla (*Gorilla g. gorilla*) and Chimpanzee (*Pan t. troglodytes*) Populations in Gabon. American Journal of Primatology. 6:313-336

Tutin, C. E. G., L. J. T. White, and A. Mackanga Missandzou. 1997a. The use by rain forest mammals of natural forest fragments in an equatorial African savanna. Conservation Biology. 11:1190-1203.

Tutin, C. E. G., R.M. Ham, L. J. T. White and M.J.S. Harrison. 1997b. The primate community of the Lopé reserve, Gabon: Diets, responses to fruit scarcity, and effects on biomass. American Journal of Primatology. 42:1-24.

Walsh, P. D., K. A. Abernethy, M. Bermejo, R. Beyersk, P. De Wachter, M. E. Akou, B. Huljbregis, D. I. Mambounga, A. K. Toham, A. M. Kilbourn, S. A. Lahm, S. Latour, F. Maisels, C. Mbina, Y. Mihindou, S. N. Obiang, E. N. Effa, M. P. Starkey, P. Telfer, M. Thibault, C. E. G. Tutin, L. J. T. White, and D. S. Wilkie. 2003. Catastrophic ape decline in western equatorial Africa. Nature. 422:611-614.

Walsh, P. D. and L. J. T. White. 1999. What it will take to monitor forest elephant populations. Conservation Biology. 13:1194-1202.

Waltert, M., S. Heber, S. Riedelbauch, J. L. Lien and M. Muhlenberg. 2006. Estimates of blue duiker (*Cephalophus monticola*) densities from diurnal and nocturnal line transects in the Korup region, south-western Cameroon. African Journal of Ecology. 44:290-292.

Waterman, P.G., and K.M. Kool. 1994. Colobine food selection and food chemistry. Pages 251–284 In: A. G. Davies and J. F. Oates, (Eds.) *Colobine Monkeys. Their Ecology, Behaviour and Evolution.* Cambridge University Press, Cambridge. pp.429

White, L. J. T. 1994. Biomass of rain-forest mammals in the lope reserve, Gabon. Journal of Animal Ecology. 63:499-512.

Whitesides, G. H., J. F. Oates, S. M. Green, and R. P. Kluberdanz. 1988. Estimating primate densities from transects in a West African rain forest: a comparison of techniques. The Journal of Animal Ecology. 57:345-367.

Wilkie, D. S., and J. T. Finn. 1990. Slash-burn cultivation and mammal abundance in the Ituri Forest, Zaire. Biotropica. 22:90-99.

Wilson, V.J. 2001. *Duikers of Africa: masters of the African forest floor. A study of duikers, people, hunting and bushmeat*. Zimbabwe: Chipangali Wildlife Trust. pp. 798