

**VEGETATION HISTORY AND LOGGING DISTURBANCE:  
EFFECTS ON RAIN FOREST MAMMALS IN THE LOPE RERERVE,  
GABON (WITH SPECIAL EMPHASIS ON ELEPHANT5 AND  
APES).**

**Lee J- T. White**

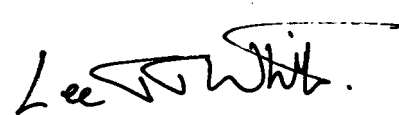
**Thesis submitted for the degree of Ph.D  
University of Edinburgh  
1992**



I hereby declare that:

a) This thesis was composed by myself;

b) The work described is my own **work**, except for data on group composition of elephants, which I analysed, but which was collected **by** researchers named in the acknowledgements section, as well as by myself.

A handwritten signature in black ink, appearing to read "Lee J. T. White". The signature is stylized with a large, sweeping flourish over the "White" part.

Lee J. T. White

10 August 1992.

## **Abstract.**

An investigation of the effects of commercial mechanised selective logging on rain forest vegetation and mammals, was undertaken in the Lope Reserve, central Gabon, between January **1989** to July **1991**. Vegetation in Lope is mostly semi-evergreen lowland tropical rain forest, but there are some localised patches of savanna, which are thought to be natural in origin, but which are maintained today by regular fires started by humans. Study sites were established in areas of forest logged **20-25**, **10-15**, and **3-5** years previously.. a fourth was logged during the study, and a fifth remained unexploited. None of the study sites had been subject to hunting in the recent past.

A line-transect five kilometres in length was cut across the drainage in each site. Forest composition and structure was assessed along each transect, by identifying and measuring trees and lianes in botanical plots, counting stem density of herbaceous vegetation in the families Marantaceae and Zingiberaceae, and by measuring canopy cover at three heights. At total of **4885** trees and lianes of **327** species occurred in five **2.5** ha samples of plants greater than 10 cm dbh, whilst **1832** individuals of **137** species were found in five 25ha samples of trees greater than 70cm dbh. There were marked differences in structure and species composition both between and within sites. A model was developed to attempt to explain this variation, based upon the theory that much of **Lope** had been covered by savanna vegetation during a previous cool, dry climatic phase, and that forest structure and composition reflected recolonisation of the savanna by forest. Physical features such as swamps, rocky outcrops and altitude were also considered. Two types of multivariate analysis were applied to botanical data and supported the model. The effects of logging on forest vegetation were assessed by returning after logging to botanical plots established before exploitation. Damage levels were low, compared to other parts of the World, resulting in about a 10% reduction in canopy cover.

Patterns of fruit production were studied by counting fallen ripe and unripe fruit on transects. Fruits encountered were classified on the basis of their morphology and dispersal mechanism. There was a period of low fruit production during the major dry season, when frugivores are likely to suffer dietary stress. A number of plant species which did produce fruit at this time were identified as

species which might represent 'keystone' resources. Over 70% of fruit species were animal-dispersed, demonstrating the important role animals play in the ecology of tropical rain forests.

Forest elephant (***Loxodonta africana cyclotis***) diet, ecological role and group structure were analysed. The bulk of the diet consisted of the bark and leaves of trees, and some monocotyledons in the families Marantaceae and Zingiberaceae, but fruit was also important. Large-scale seasonal movements in response to fruit availability were detected. Elephants were important seed dispersers for many plant species, and were responsible for less than 1% of natural tree mortality. The social structure of these forest elephants differed from that of populations that have been studied in east and southern Africa. Average group **size** was 2.8, and no groups of more than **10** individuals were encountered.

Densities of primates, ungulates and squirrels were assessed using standard line-transect censuses. Resolution was poor, but statistical differences were detected between sites for some species. Chimpanzee, (***Pan t. troglodytes***) densities declined in logged forest, but no other species could be shown to decline after logging. Some other differences between sites were related to vegetation composition. Biomass was high, estimated at **up to 4692.6** kg km<sup>-2</sup>, but was dominated by elephants, which made up 25-82%.

Conservation implications of this study are discussed, and recommendations made.

## Acknowledgements.

I gratefully acknowledge the Leverhulme Trust, Wildlife Conservation International (the conservation branch of the **New** York Zoological Society), The Royal Society (London?), the Conder Conservation Trust, the Richard Brown Scholarship (University of Edinburgh?), the Conrad Zweig Trust, **CONACO** (Gabon) Ltd., Mr Sebastian Clairmonte and the Centre International de Recherches Médicales de Franceville, for financial support.

Four l'autorisation de travailler dans la Reserve de Faune de la Lope, je suis tres reconnaissant a la Direction de la Faune de la Ministère des Eaux et Forêts, et surtout Alphonse Mackanga et Joseph Maroga-Mbina, les deux commandants de la brigade de la Lope pendant mon séjour.

Liz Rogers, my supervisor at Edinburgh, provided constant support and enthusiasm from our first meeting, in the Summer of 1987. For all her time, energy, patience and friendship I am very grateful.

Caroline Tutin, my field supervisor, encouraged me to undertake this study, and shared with me her knowledge of the forest. She gave constructive advice and help throughout my time in Gabon. Michel Fernandez a toujours été prêt a m'aider et me conseiller et, avec son travaille a la Station d'Etudes des Gorilles et Chimpanzés, il m'a gagne au moins six mois à un an de temps. Miff et Michel ont partager leur maison et leur vie avec moi, et je tiens beaucoup a leur amitié. Sans eux, cette etude n'aurait jamais été commencée

Liz Williamson patiently taught me my first 30-40 tree species, which helped me to overcome the daunting task of starting the botanical study. My enthusiasm for trees **was** further fired by Chris Wilks and Gordon McPherson, and without the help of these three people that section of this thesis would never have got off the ground. Gordon has spent many hours identifying my botanical specimens, and I also thank Frank White, David Harris and Mike Harrison for identifications. Missouri Botanic Garden and the Herbarium at Libreville provided material support, and I thank Peter Goldblat and Art Louis of these two institutions for their help. **Jan** Reitsma provided information about the trees in his Lope botanical plot. In Edinburgh, Colin Legg made time in a busy schedule to help analyse the vegetation data, and was enthusiastic even though the names meant nothing to him - thank you.

I thank Sebastian Clairmonte, Karen McDonald, Richard Parnell, Toyo, Ben Voysey, Glenys White, Chris Wilks, Liz Williamson, Dorothea Wrogeman, and particularly Caroline Tutin and Michel Fernandez for help in the field. I am grateful to the following colleagues, who contributed to the data on elephant group sizes and foods: Catherine Bouchain, Jean-Yves Collet, Jean-Paul and Chantal Coupin, Alick Cruickshank, Anna Feistner, Michel Fernandez, Stephanie Hall, Rebecca Ham, Boo Maisels, Richard Parnell, Ann Pierce, Caroline Tutin, Ben Voysey and Dorothea Wrogemann.

Les nombreux employés de la Société Forestier du Gabon (SOFORGA) m'a fait bienvenu a leur chantier - merci beaucoup pour l'hospitalité cordiale, et aussi à Ralph Fischer, qui m'a attendu a l'aéroport quand je suis arrive pour le premier fois, et qui est devenu un bon coupin, qui m'a beaucoup aidé a Libreville. Nigel and Isabelle Orbell provided similar in Franceville. Lizo, Rich, Rebecca and Miff and Michel made my time in Gabon special.

Many people gave advice and/or commented on drafts of papers and chapters, and this **work** has benefitted from their input. Thanks to: Kate Abernethy, Anthony Collins, Georgina Dasilva, Mike Harrison, John and Terry Hart, Dave Hill, Colin Legg, Jean Maley, Tom and Erica McShane, John Newbery, Madan and Monica Oli, Richard Parnell, Liz Rogers, Caroline Tutin, Ben Voysey, Liz Williamson.

## Table of Contents.

	Page
Declaration	I
Abstract	II
Acknowledgements	IV
Table of Contents	VI
List of Tables	IX
List of Figures	XI
List of Plates	XII
CHAPTER 1: INTRODUCTION	1
CHAPTER 2: VEGETATION	
Introduction	10
Study Area	11
Methods	17
Results	
Species Composition	
Trees >10 cm dbh	22
Trees >70 cm dbh	30
Forest Structure	37
Herbaceous Vegetation	42
Effects of Disturbance	43
Vegetation Categories	43
Multivariate Analyses	50
Discussion	
Comparison with other areas	57
Forest History in Lopé	60
Appendix 2.1: Plant Species on Transects	71
Appendix 2.2: Supplementary List of Plant Species	83

	Page
<b>CHAPTER 3: PATTERNS OF FRUIT PRODUCTION</b>	
Introduction	<b>88</b>
Methods	<b>89</b>
Results	90
Discussion	<b>107</b>
<b>CHAPTER 4: THE EFFECTS OF LOGGING ON FOREST VEGETATION</b>	
Introduction	<b>114</b>
Methods	114
Results	
Sample of Trees >70cm dbh	<b>115</b>
Sample of Plants > <b>10cm</b> dbh	<b>122</b>
Discussion	<b>135</b>
<b>CHAPTER 5: ECOLOGY OF FOREST ELEPHANTS</b>	
Introduction	<b>139</b>
Methods	<b>143</b>
Results	
Group Composition	<b>145</b>
Diet and Ecological Role in the Forest	<b>147</b>
Seasonal Movements	<b>171</b>
Discussion	
Group Size and Composition	<b>175</b>
Diet, <b>Seed</b> Dispersal and Ecological Role in the Forest	<b>177</b>
Seasonal Movements	<b>184</b>
<b>CHAPTER 6: BIOMASS OF RAIN FOREST MAMMALS AND EFFECTS OF LOGGING</b>	
Introduction	<b>188</b>
Methods	
Census Methods	<b>188</b>
Animal Sighting Censuses	<b>189</b>
Dung and Nest Counts	190
Dung and Nest Decay Rates	<b>192</b>
Statistical Tests	192

	Page
Estimates of Density and Biomass from Census Data	
Animal Sighting Censuses	193
Dung and Nest Count Censuses	<b>195</b>
Biomass Calculation	196
Statistical Tests of Differences in Animal Densities	
Between Sites	<b>198</b>
Results	
Pooling of Data	<b>199</b>
Density Estimates	200
Discussion	
Reliability of Biomass Estimates	<b>212</b>
Logging and Mammals	<b>215</b>
Camparison Between Sites	<b>218</b>
Comparisons with other Areas	<b>220</b>
 CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS	 224
 REFERENCES	 230

## List of Tables.

Table	Page	
2.1	Species in top 10 for basal area or number of stems	23
2.2	Dominant families > 10cm dbh	26
2.3	% species overlap between sites for species >10cm dbh	30
2.4	Czekanowski coefficient for trees > 10 cm dbh	30
2.5	Species >70cm dbh in top 10for basal area	32
2.6	Dominant families >70cm dbh	33
2.7	% species overlap between sites for species >70cm dbh	37
2.8	Czekanowski coefficient for trees >70cm dbh	37
2.9	% canopy cover at different heights	38
2.10	Stem density for Marantaceae and Zingiberaceae	42
3.1	Number of species in each fruit category / site	92
3.2	Overlap of fruit species between sites	93
3.3	Species which were detected with ripe fruit each month	99
3.4	Plant species producing fruit during at least four months	106
3.5	Species producing fruit in the major dry saeson	107
4.1	Top 15 species >70cm dbh	117
4.2	Top 10 families >70cm dbh	117
4.3	Botanical data for plants >70cm dbh	118
4.4	Summary of logging damage to trees >70 cm dbh	121
4.5	Top 15 species for plants >10 cm dbh	122
4.6	Top 10 families for plants >10 cm dbh	123
<b>4.7</b>	Botanical data for plants > 10 cm dbh	124
4.8	Summary of logging damage to trees > 10cm dbh	130
5.1	Group size in forest, savanna and at salines	146
5.2	Group composition at salines	147
5.3	Elephant foods	148
<b>5.4</b>	Life forms of elephant foods at <b>Lope</b>	156
5.5	Characteristics of fruits consumed by elephants	162
5.6	Frequency of barked trees on transects	170
5.7	Observed and expected frequencies of barking	171
6.1	The number of censuses conducted in each site	192

<b>Table</b>		<b>Page</b>
<b>6.2</b>	Estimates of average group spread and detection distance	201
<b>6.3</b>	Defecation rates of species censused on dung counts	203
<b>6.4</b>	Average group sizes and individual weights	204
<b>6.5</b>	Densities using hazard-rate, Fourier and Whitesides' methods	205
<b>6.6</b>	Dung densities using hazard-rate, Fourier and Whitesides'	206
<b>6.7</b>	Average sighting frequencies / census	207
<b>6.8</b>	Density of individuals calculated by different methods	210
<b>6.9</b>	Estimated species biomass for the sites	211

## List of Figures

Figure	Page
1.1 Location of Gabon in Africa	2
1.2 Gabon, showing the location of Lope Reserve	5
2.1 Lope Reserve, with locations of transects and savanna	12
2.2 Rainfall recorded at SEGC 1984-1990	13
2.3 Profile diagrams of the five transects	19
2.4 Species-area plots for species >10cm dbh	29
2.5 Species-area plots for trees >70 cm dbh	36
2.6 Diameter classes for plants > 10 cm dbh	39
2.7 Estimated heights for plants > 10cm dbh	40
2.8 Estimated heights for trees >70cm dbh	41
2.9 Distribution of 50m segments into vegetation categories	49
2.10 TWINSPAN vegetation categories for plants >10cm dbh	51
2.11 TWINSPAN vegetation categories for plants >70cm dbh	52
2.12 <b>CANOCO</b> plot for plants >10 cm dbh	54
2.13 <b>CANOCO</b> plot for plants >10 cm dbh	55
2.14 <b>CANOCO</b> plot for 100msamples of trees >10cm dbh	56
2.15 Model for succession from savanna to mature forest	63
2.16 <b>CANOCO</b> plot for plants > 10cm dbh	64
2.17 <b>CANOCO</b> plot for plants >10 cm dbh	65
3.1 Pie chart showing relative frequencies of fruit categories	93
3.2 Number of species detected with ripe fruit each month	95
3.3 Number of species detected with unripe fruit each month	95
3.4 Number of ripe fruit counted / month	97
3.5 Number of unripe fruit counted / month	97
3.6 Number of months during which species produced ripe fruit	98
4.1 Girth class for plants > 10cm dbh	132
5.1 Average fruit score for dung piles	157
5.2 Number of species of ripe fruit on transects	158
5.3 Elephant dung densities for sites 1-4 (March'89-Feb'90)	172
5.4 Elephant dung densities for Sites 1-5 (Jul'90-June'91)	174
5.5 Elephant dung and <i>S gabonensis</i> fruit counts in Site 2	174
6.1 Cumulative average chimp nest group encounter rates	209

## List of Plates.

Plate		Page
2.1	Views of savanna and forest-savanna mosaic	15
2.2	Savanna patches, and savanna colonisation	16
2.3	Marantaceae forest	48
2.4	Forest types [8] and [16]	48a
2.5	Savanna fire, and forest-savanna boundary	59
4.1	Cut trees	116
4.2	Logging road and latterite pit	134
5.1	Forest elephants, family unit in a saline	144
5.2	Elephant <b>foods</b>	160
6.1	Gorilla and nest	191

## Chapter 1 —

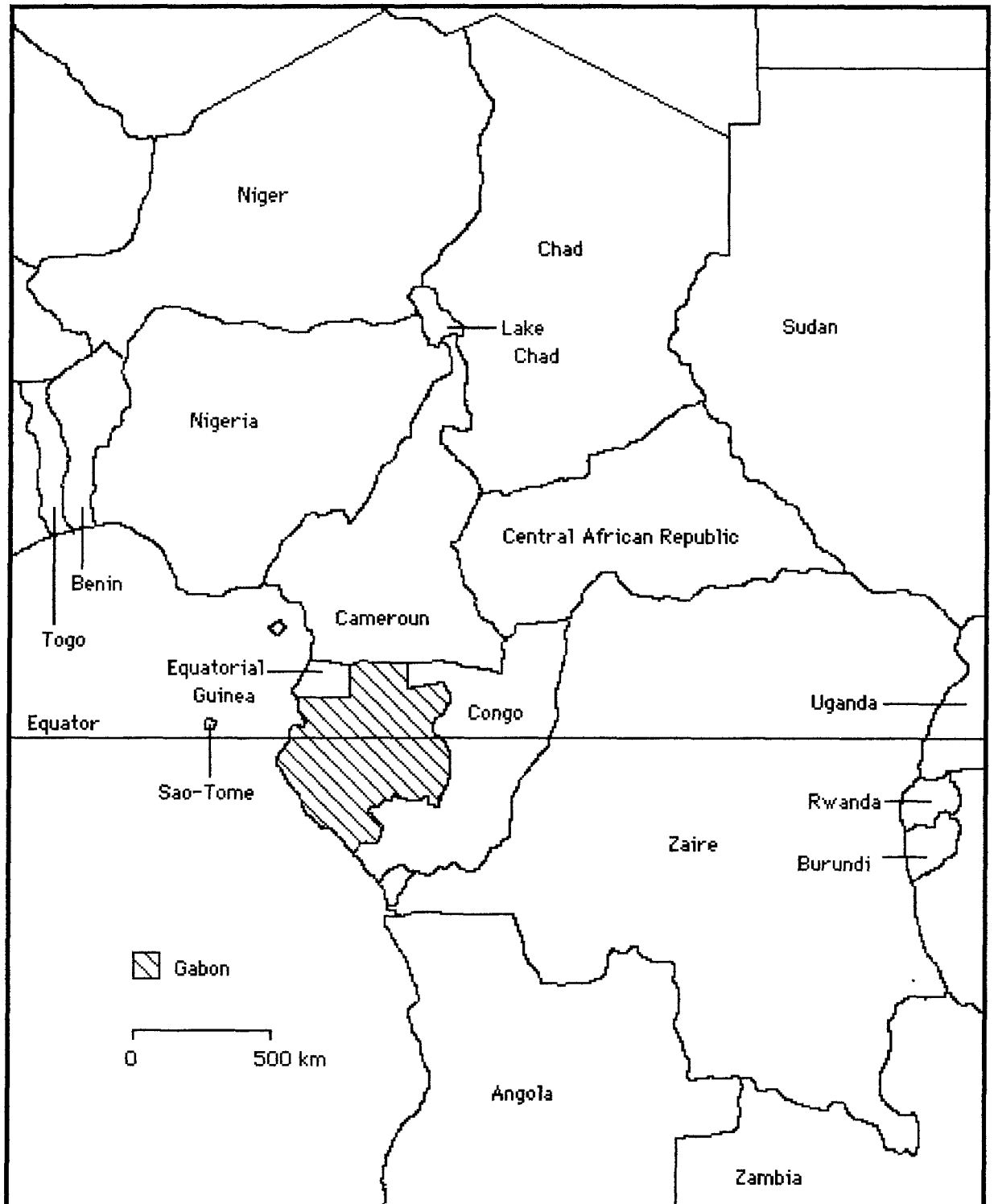
### Introduction.

Gabon is on the equator on the West Coast of Africa (3°N-3°S, 8°E-15°E), and covers 267,667 km<sup>2</sup> (Figure 1.1). The human population of Gabon is low: an official census in 1980 recorded 1,232,000 inhabitants (EDICEF, 1983), but outside organisations estimate the population to be below one million (Pourtier, 1989; World Bank, 1986). About 50% of the population is urban, and as a result of a resettlement programme in the 1950's all villages are sited on roads or navigable rivers (see EDICEF 1983, p. 49). Rural population density is below 2 inhabitants km<sup>-2</sup>, and vast areas of the interior are unpopulated. Limited numbers of indigenous hunter-gatherers, the pygmies, maintain their traditional life-style in parts of the north-east and south-west. Pourtier (1989) gives an excellent review of Gabon's cultural and economic history.

The "red wood", *Pterocarpus soyauxii*, used to colour paint, was probably Gabon's first export, and wood dominated the economy until the mid-1960's (EDICEF, 1983; Pourtier, 1989; Wilks, 1990). Annual production peaked at about 1.85 million m<sup>3</sup> year<sup>-1</sup> in 1972, but crashed in 1974 to about 1 million m<sup>3</sup> year<sup>-1</sup>, due to reduced demand from Europe, and has remained stable at this level ever since. Wood exports were traditionally dominated by one tree species, Okoumé, *Aucoumea klaineana*, which made up 90% or more of production, but in recent years the industry has diversified somewhat, and in 1987, of 830,000 m<sup>3</sup> of wood exported from Libreville, the major port, Okoumé made up 72%. A further 53 commercial species were exported, but only 14 accounted for 5,000 m<sup>3</sup> or more (Wilks, 1990). Wilks (1990) estimated that in 1988, 46% of Gabon's forest had been selectively logged at least once, and each year about 2,500 km<sup>2</sup> is logged, 60% of which has not previously been exploited. Less than 30% of production is processed in the country.

Oil exports began in 1958 and rose throughout the 1960's to the mid-1970's, replacing wood as the major part of the economy (EDICEF, 1983; Pourtier, 1989), and in 1987 wood made up 11.9% of exports, compared to oil, manganese and uranium (production of the latter two began in the early 1960's), which accounted for 84% (Wilks, 1990). In the early 1980's, this mineral wealth gave Gabon the highest per capita income in Africa south of the Sahara (Pourtier,

Figure 1.1: Location of Gabon in Africa.



1989), and reduced the economic pressure on the forest.

Local demand for timber, which is limited, is satisfied by logging operations close to major population centres, and most logging activities are geared towards the export market. Gabon contrasts sharply with nearby Nigeria, which has banned timber exports, and has become a net importer, because of high local demand due to its large human population (e.g., Kio, 1983). The number of tree species exploited in Gabon is determined by the fickle demands of the international market for tropical timber. Due to the high per capita income and dependence upon imports, cost of living (and hence both labour and transport costs) is high, and this reduces the number of species that are commercially viable, especially in the interior of the country. These factors limit the intensity of commercial forestry. Extraction rates are about 1.5 trees ha<sup>-1</sup> (CTFT, 1974; cited in Wilks, 1990) and result in about 10% canopy loss, but damage levels vary with location, being higher in the coastal sedimentary basin (closer to the ports of Libreville and Port-Gentil, where lower transport costs permit intensification of logging), and lower in the interior (Wilks, 1990). Low human population has resulted in low levels of deforestation (Myers, 1989; Wilks, 1990) and Gabon is unlikely to lose a significant proportion of its forests in the next 50 years (Barnes, 1990).

Gabon's forests are floristically diverse, with estimates of the total number of plant species varying between 6,000-10,000 (Breteler, 1988; Floret, 1976; Hallé & Le Thomas, 1968; Lebrun, 1976). Over 22% of species recorded in the 'Flore du Gabon' were endemic (Brenan, 1978) and there is a greater recorded diversity of rain forest plant species and genera in Gabon, than the whole of West Africa, even though collection has been less complete (Breteler, 1988). Reitsma (1988) recorded the second most species diverse plot of rain forest found to date in the World, in the Monts de Cristales, northwestern Gabon. The diversity of plant life in Gabon has been attributed to the fact that it was the centre of a forest refuge, during arid periods in the Pleistocene when savanna vegetation replaced forest over much of its present range (see Hamilton, 1982; Kingdon, 1990; Malèy, 1987; Reitsma, 1988).

The diverse fauna includes over 150 mammals, with at least 20 primates, and 600 birds (Nicoll & Langrand, 1986; Wilks, 1990). Recent faunal surveys illustrate the importance of Gabon for the conservation of African rain forest wildlife: There are an estimated 35,000 western lowland gorillas, *Gorilla gorilla* and 64,000 chimpanzees, *Pan t. troglodytes* - there are more apes in

Gabon than any other- African country (Tutin & Fernandez, 1983<sup>1</sup>); Barnes et al. (unpublished manuscript-) estimated the elephant population to number 87,000 – one of the largest populations in Africa, and one of the few considered stable; and a new primate species, **the** sun-tailed guenon, *Cercopithecus solatus*, was discovered as recently as 1984 in the “Foret des Abeilles” in the centre of the country (Harrison, 1988a). Gabon is considered a high conservation priority (e.g., McShane, 1990; Oates, 1986) and McShane (1990) suggested that it represented a rare opportunity to initiate a conservation programme ‘before the crisis’.

In the ‘oil boom years’ of the early 1980’s many development projects were undertaken within Gabon, the largest being the construction of the “transgabonais” railway, completed in 1987, linking the capital Libreville, on the coast, to Franceville, 650km inland. This opened up large parts of the country that had previously been inaccessible, and the government planned to grant logging concessions over an area of 30,000 km<sup>2</sup> of previously unexploited forest, which would be made commercially viable by the railway (Figure 1.2). Reduction of commodity prices (principally oil) in the late 1980’s reduced Gabon’s revenues by almost 50%, resulting in a budget deficit and pressure to boost other sectors of the economy (Arnaud, 1987; cited in McShane, 1990; Pourtier, 1989). These factors seemed likely to result in a large increase in commercial logging and hunting pressure on the forest. There are currently no protected areas in Gabon within which logging is forbidden, nor have there been any detailed investigations of the effects of logging on forest vegetation and wildlife, upon which management decisions could be based.

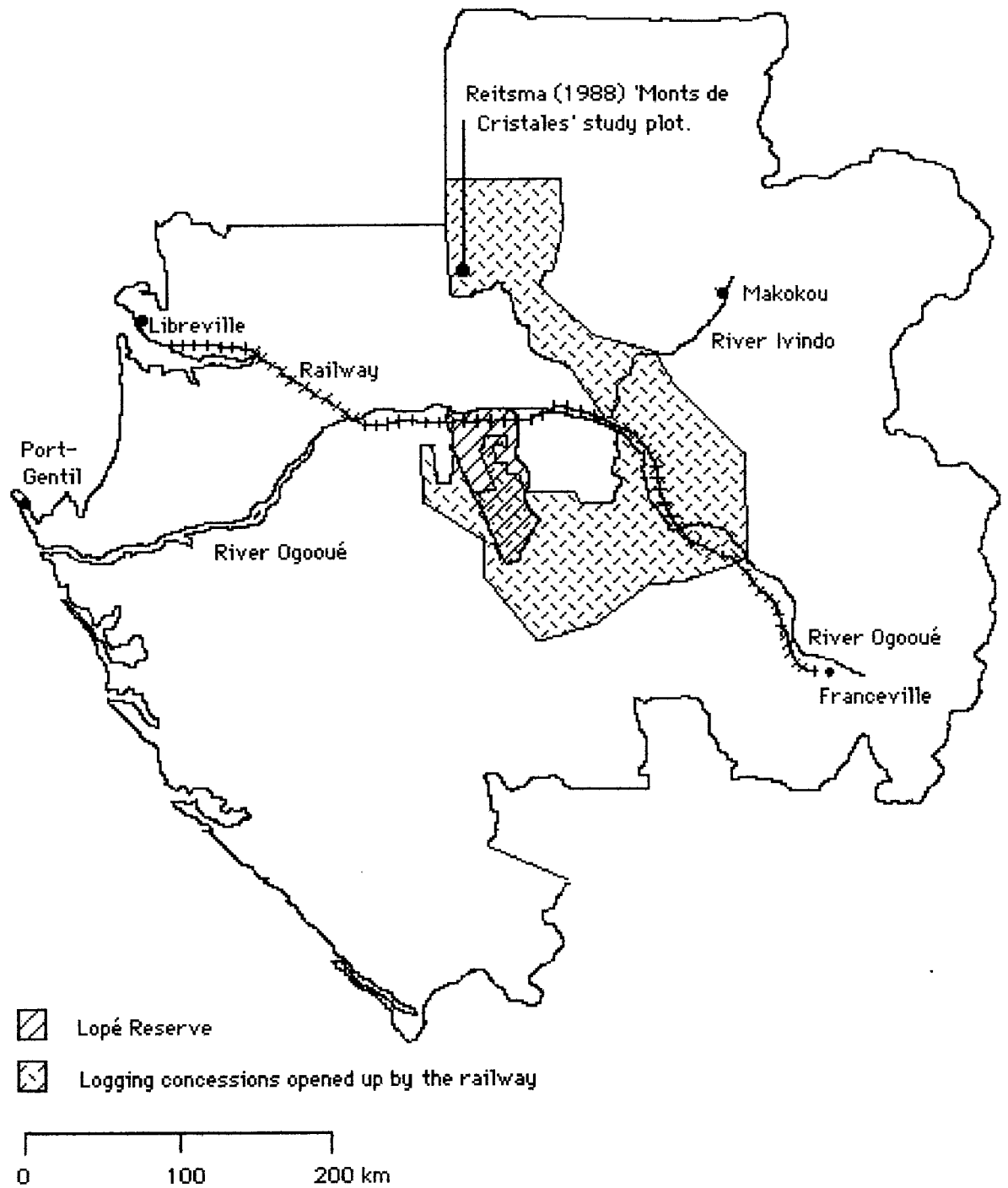
Logging has been shown to cause changes in densities (generally decreases) of African forest primates (many examples in Johns & Skorupa, 1987). Commercially valuable tree species in Africa are often important food plants for forest animals (e.g., Martin & Asibey, 1979; Skorupa, 1988; Struhsaker, 1975), so logging may have a serious effect on wildlife at intensities lower than can be supported in regions such as Malaysia, where animal communities appear to be able to withstand particularly high damage levels (Johns, 1989). Leighton & Leighton (1983) demonstrated the keystone role played by a limited number of plant species, which produced fruit during an annual period of overall scarcity, and suggested that were logging to focus on these species, the effects on frugivorous

---

<sup>1</sup> - a shorter version was published in 1984

<sup>2</sup> - a short summary was published in 1986

Figure 1.2: Gabon, showing the location Lope Reserve.



animals might be out of proportion with the actual damage levels. Fruit production in Lopé is seasonal and the major dry season (June–August) is a period of fruit scarcity (Tutin *et al.*, 1991a; Williamson, 1988), so if logging were to selectively effect species that provide food at this time of the year, it might have adverse effects on wildlife despite low damage levels.

Johns & Skorupa (1987) highlighted the lack of information available on the effects of logging on primates (and other wildlife) in the central African forest block, which covers about 1.7 million km<sup>2</sup> (FAO, 1981), and strongly recommended that at least one community-level investigation be undertaken in the region. Biomass of mammals of the same, or closely related species, often varies markedly in different areas. There are few data on biomass of rain forest mammal communities, and determinants of biomass are poorly understood (e.g., Oates *et al.*, 1990; Terborgh, 1983). Factors that determine biomass in undisturbed areas, and mechanisms for changes caused by logging will be closely related, and any investigation of the effects of logging must take both into account.

This study was started in January 1989, to investigate the effects of commercial mechanised logging in the Lopé Reserve, Gabon, on rain forest vegetation and mammalian wildlife, particularly apes and elephants.

The emphasis on gorillas, chimpanzees and elephants was because:

1) Gabon is a major sanctuary for these three species.

2) Ecological information on apes was available for Lopé. Little is known about the biology of forest elephants, *Loxodonta africanacyclotis* (e.g., Dudley *et al.*, 1992), but Lopé was an ideal location to investigate their ecology, and preliminary data had been collected at SEGC.

3) The three species were thought to respond differently to logging; densities of chimpanzees were consistently lower in logged forest (Struhsaker, 1975; Tutin & Fernandez, 1983; Skorupa, 1988); gorilla densities tended to be higher in disturbed areas (Harcourt, 1981; Murnyak, 1981; Tutin & Fernandez, 1983); and Olivier (1978) found increased densities of Asian elephants in logged rain forest in Malaysia, although no data are available for African forest elephants.

4) Elephants and gorillas (to some extent) are large-bodied animals and play an important ecological role in the African rain forest (e.g., Jones, 1954; Kortlandt, 1983; Western, 1989). In Kibale forest, Uganda, elephants interfere with regeneration in gaps created by logging (Kasenene, 1992).

Lopé was chosen as the study area for several reasons:

1) There was a research programme underway in the reserve at the 'Station d'Etudes des Gorilles et Chimpanzés' (SEGC), established in 1983. The SEGC main study area had been exploited for *Aucoumea klaineana* in the 1960's, and was the ideal location for a study site to investigate the longer-term effects of logging. There was a growing data base on the ecology of apes (e.g., Tutin *et al*, 1991a), which might enable informed ecological interpretations of any observed changes in the populations of chimpanzees and gorillas in response to logging (cf., Skorupa, 1988). In addition, densities of apes calculated during this study could be compared to those from long-term residence records of known social groups within the SEGC study area.

2) Lopé was a reserve within which hunting was illegal, and poaching was not a significant problem (C.E.G. Tutin & M. Fernandez, personal communication), so it would be possible to investigate the effects of logging without the complicating factor of hunting (cf. Johns & Skorupa, 1987). An independent investigation of the effects of hunting on rain forest mammals was underway in northeast Gabon, where there was no logging (Lahm, 1992).

3) Logging was underway close to SEGC, and it was possible to establish five study sites within 25 km of one-another, in forest that had been logged 20-25, 10-15 and 3-5 years previously, as well as in a site that would be logged during the course of the study, and an unlogged control.

4) Rainfall in the Lopé area was about 1500mm year<sup>-1</sup>, lower than the rest of Gabon, and the presence of isolated patches of savanna suggested that forest vegetation in Lopé might be particularly sensitive to logging damage.

Johns (1989) showed that inter-site differences in primate densities in several sites in Tekam Forest Reserve, peninsular Malaysia, were greater than changes due to logging. He warned that only by monitoring an area through a complete logging cycle, would it be possible to reliably assess changes caused by logging. Such studies must be considered priorities if logged rain forests are to be managed for wildlife conservation, but until they have been undertaken, the effects of logging over time will have to be assessed indirectly. It was hoped that, by selecting sites that had been logged at different stages in the past, responses over time of rain forest mammals to logging could be assessed, whilst work in an area logged during this study would provide the basis for long-term monitoring. Within five study sites selected, the aims of this investigation were to:

1) analyse the structure and composition of rain forest vegetation and attempt to explain any differences between sites, and in particular, to test whether proximity to the savanna edge influenced vegetation (Chapter 21;

2) monitor fruiting patterns in order to investigate which plant species might fulfil a 'keystone' role in Lopé, and whether they were targeted by loggers. (Chapter 31;

3) undertake a vegetation study before, and return after logging, to directly assess extraction rate and levels of incidental damage due to felling, and road and skidder trail construction for extraction of logs (Chapter 4);

4) study the diet and investigate the ecological roles played by forest elephants (Chapter 5);

5) undertake censuses to estimate the densities of large mammals along line-transects located in each of the study sites, in order to investigate any differences caused by logging (Chapter 6);

6) estimate biomass of all mammals censused, and attempt to explain any differences by reference to botanical data (Chapter 61;

7) set up sites where long-term monitoring of the effects of logging on

vegetation and wildlife could be monitored;

8) make management recommendations to the Ministère des Eaux et Forêts in Gabon (Ministry of Water and Forests), which might also be applicable to other central African countries (Chapter 7).

Field work was undertaken between January 1989 and July 1991.