LONG TERM SYSTEM FOR MONITORING THE ILLEGAL KILLING OF ELEPHANTS (MIKE)

CENTRAL AFRICAN FORESTS: FINAL REPORT ON POPULATION SURVEYS (2003 – 2004)

March 2005

A report by the
Wildlife Conservation Society
USA

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Table of Contents

Figures

Tables

Acknowledgements

This report describes an enormous amount of work and effort carried out across central Africa by teams of dedicated researchers, their field assistants, guides and porters. It is difficult to describe the hardship imposed by weeks and months of nomadic living in central African forests, and the dedication and endurance that researchers and their staff must maintain in order to collect rigorous field data over extended periods.

The MIKE inventories were given strong political and administrative supported by the Wildlife Departments of Cameroon, Gabon, Republic of Congo, Democratic Republic of Congo, the Central African Republic, and Equatorial Guinea where unfortunately no field work was implemented. Site-based management authorities at each MIKE site provided much needed logistical, administrative, political, and technical support to MIKE, and in most cases provided their best field personnel to MIKE activities for extended periods. The Wildlife Conservation Society in Republic of Congo and DRC, World Wildlife Fund in Cameroon, CAR, and Gabon, Lukuru Wildlife Research Institute and Max Plank Institute in DRC, and the Canadian Centre for International Cooperation and Research in CAR were totally instrumental in any success this program has enjoyed. Among staff of the MIKE Central Coordinating Unit, Mr. Sebastién Luhunu guided the inventory programme to completion with an open collaborative spirit, with patience, understanding, and dedication. The MIKE administrative assistant, Erice Nyambe, provided much needed local administrative help and support. The MIKE Director, Nigel Hunter, is thanked for his appreciation and his public acknowledgement of the effort required to make these surveys happen. Despite some hiccups along the way which are almost inevitable in a program of this complexity and scale but with limited resources, it has been a great pleasure to work with MIKE. The Administrative staff of WCS Africa Program provided much needed support.

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Hopefully this report and its annexes, though late in coming, will be useful to the Wildlife Departments and Governments of central African elephant range States, and help them to plan effectively for long-term success in the conservation and management of forest elephants in their wonderfully rich and diverse nations.

Chapter 1: Introduction

Historical Perspective

African elephants (*Loxodonta africana*) once have roamed across Africa from Cairo to the Cape of Good Hope (Cumming et al. 1990). Unlike on other continents humans and elephants share a long evolutionary history in Africa, which may be why elephants have persisted in the Old World and not in the New, where immigrating human populations found elephants naive to humans and human aggression (Owen-Smith 1988). Ivory has been a symbol of luxury and wealth for at least the last seven thousand years, and elephants have probably been killed to supply ivory over much of this time (Meredith 2001). The empires of Egypt, Greece, Rome, Arabia, and Europe all collected ivory and hunted African elephants voraciously, and by the 16th century elephants had been exterminated from north Africa, and their distribution was already shrinking in sub-Saharan Africa (Cumming et al. 1990), as Arab traders bought ivory on the Kenyan and Tanzanian coast and sent hunting missions deep into the continent. The first sailors to anchor in the harbour at Good Hope saw elephants along the coast and wallowing in the sea (Meredith 2001). Inevitably, the new European settlers quickly moved north and left a land bereft of elephants in their wake. By the turn of the 20th century, the elephant population of Africa was perhaps 1 million animals, a fraction of former numbers, scattered across sub-Saharan Africa.

As elephants were being hunted in the savannas of east, west, and south Africa and open woodland, the forest elephants of west and central Africa fared rather better since penetration of the forest zone was difficult and slow (Barnes 1999). However as roads railways and trading networks developed in west Africa during the 17th century and beyond, and the price of ivory climbed steeply, the intensity of elephant poaching in west African forests increased dramatically and elephant numbers and range dwindled until the population collapsed just before World War 1, a collapse from which it never really recovered (Roth and Douglas-Hamilton 1991, Barnes 1999).

The vast equatorial forests of the Congo Basin remained largely unexplored and un-developed for most of the history of the ivory trade, and it was not until European explorers, led by Stanley, opened up the region to trade and development (Meredith 2001) Ivory, along with slaves and later rubber, quickly became one of the Congo Basin's most important commodities. The number of forest elephants that may have existed in central Africa before intense commercial exploitation began can only be speculated upon, but could have been very large – given most of the available habitat was suitable to elephants across much of the ca. 2 million km^2, there could easily have been an average density of 0.5 elephants km^{-2}, or 1 million elephants in the forest zone. Based on an estimation of carrying capacity and surface area, (Milner-Gulland and Beddington 1993) speculated that there were 1.4 million forest elephants in 1814.

The ivory trade declined following the first world war, and elephant numbers across the continent experienced some respite from hunting for ivory, and by the 1960's elephants were probably as numerous as at any time over the past century (Spinage 1994). However, by the 1950's, ivory was again becoming more popular in consumer markets, and by the mid-1970's concern was growing over the future of Africa's elephants. The price of ivory rose dramatically, and a well-documented explosion of elephant poaching occurred, which during the 1980's, reduced the African elephant population by perhaps as much as 50% (Douglas-Hamilton and Douglas-Hamilton 1982, Cobb 1989, Luxmoore et al. 1989, Milliken 1989, Barbier 1990, Milner-Gulland and Beddington 1993).

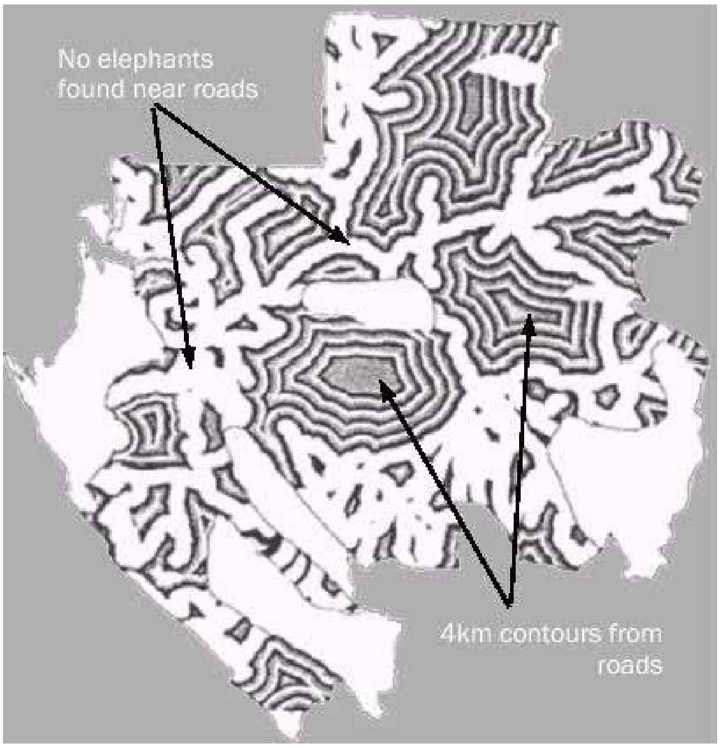
During this time, considerable interest turned to central Africa since the impact of poaching on this portion of the population was unknown and the forest was thought to harbour potentially large numbers of elephants (Barnes 1989b). Systematic surveys were initiated across the forest block with the goal of determining the size of the forest elephant population, and the impact of the ivory trade (Michelmore et al. 1994, Barnes et al. 1995). The main conclusions from this study, which took place in 6 central African nations (DRC [then Zaire], Congo, Gabon, Central African Republic, and Equatorial Guinea, and Cameroon) were that 1) poaching was rife in the forest zone, as a result of which humans determined the distribution of elephants, even in the most remote forest areas, 2) the total estimated forest elephant population was some 172,000 individuals in the six countries surveyed (Table 1) or about one-third of the continental total at that time (Barnes et al. 1995). A model of the impact caused by poaching based in the relationship between elephant abundance and distance from human access estimated that some 44% of the original forest elephant population of central Africa had been lost (Michelmore et al. 1994). The importance of roads and navigable rivers (since they provide humans with access) on the distribution of elephants was graphically illustrated (Figure 1). Barnes et al. (1997) stated: '*The dung-pile gradient shows how elephants avoid roads and villages, resulting in a partitioning of the forest, with man living in a narrow ribbon along the roads and elephants in the depths of the forest*'.

Table 1. Estimates of forest elephant numbers in Central Africa in 1989 (From Barnes *et al*. 1995)

Country	Estimated number of forest elephants
Cameroon	12000
Central African Republic	2000
Congo	31000
Equatorial Guinea	400
Gabon	55000
Democratic Republic of Congo (former Zaire)	72000
Total	172,400

The strong evidence from both the savannah and forest zones that elephant poaching was out of control and was threatening the future of the African Elephant itself, helped lead to the African Elephant Conservation Act of the United States Fish and Wildlife Service in 1988 which prohibited the import of ivory into the United States, and spawned the African Elephant Conservation Fund. At the COP of 1989, the Parties of CITES voted to put the African elephant on Appendix 1, thus banning the international trade in elephant products, including ivory.

Figure 1. Distribution of forest elephants in Gabon (from Barnes et al. 1997).



Despite low sampling intensity and limited geographical range, a number of important conclusions and recommendations came from the central Africa wide survey. Four major constraints to successful elephant management were highlighted: 1) ignorance of basic forest elephant biology, 2) ineffectiveness of wildlife departments in central Africa, 3) corruption, and 4) the difficulty of working in remote forests (Barnes et al. 1995). It was also concluded that while elephants represent a potential economic resource for local communities and national economies through sustainable harvesting mechanisms, no active management of elephants could succeed if corruption was widespread within wildlife departments. It was recommended that detailed inventories of elephant numbers be carried out regularly to determine trends in population size and the impact of poaching, while building capacity within range states to effectively manage elephant populations.

Despite these conclusions and recommendations, and concerted efforts of some individuals and international conservation organisations no monitoring system of forest elephant populations or law enforcement capacity and effort was developed or implemented in central African nations for a decade following the ivory ban. Several one-off and uncoordinated baseline population surveys and research projects (mostly as part of studies focussing on other goals) provided some quantitative information on the status of forest elephants (Stromayer and Ekobo 1991, White 1994, Hall et al. 1997, Powell 1997 Blake 2002). Eventually plans for a comprehensive elephant monitoring program gathered momentum, and in 1997 at the 10th COP, the Parties resolved to establish a monitoring system across the entire range of the African and Asian elephants [Resolution Conf. 10.10]. It was intended that this system would facilitate decision-making by the Parties regarding the protected status of elephants. It was also the first attempt to provide a systematic and detailed assessment of the impact of the Parties' decisions to allow, restrict, or suspend trade in a particular species (and/or its parts and derivatives). The monitoring system, now known by its acronym MIKE (Monitoring the Illegal Killing of Elephants), was endorsed at the 41st meeting of the CITES Standing Committee in February 1999, with the overarching goal:

'To provide information needed for elephant range States to make appropriate management and enforcement decisions, and to build institutional capacity within the range States for the long-term management of their elephant populations.'

This endorsement was then confirmed by CoP 11, which gave the go ahead for MIKE implementation, but not before modifying the original objectives to include support for making decisions on appropriate management, protection and enforcement needs, as well as building capacity.

As part of the implementation process, the Wildlife Conservation Society was asked by the MIKE Directorate to collaborate with MIKE and coordinate the technical and administrative development and execution of forest elephant inventories in seven central African MIKE sites; Salonga, Bangassou, Dzanga-Sangha, Nouabalé-Ndoki, Boumba Bek, Minkebe, and Monte Alen. WCS accepted this task, and the relationship was formalized in a Memorandum of Understanding (MOU) signed in 2002. The remainder of this report summarises activities and achievements made by the MIKE program toward achieving forest elephant inventories in central Africa between 2003-2004.

Summary of knowledge of MIKE sites in 2002 as reflected in the African Elephant database

Despite calls for inventory and monitoring following the first region wide survey in 1989 (Barnes et al. 1995), the state of knowledge of forest elephant populations and conservation status in central Africa remains poor, even in key protected areas and national parks (Blake and Hedges 2004). Since 1995, the African Elephant Database (AED) has tracked estimates of elephant abundance in key elephant range, including many of the current suite of MIKE sites. Since then, only three surveys in the range of forest elephants, one of which occurred in a current MIKE site, were reported that included a sufficiently rigorous survey methodology (Class B[1] or better) to provide a robust estimate of elephant numbers (Table 2). Where they do exist, elephant abundance estimates are largely based on best guesses often in the absence of any supporting data (Blake and Hedges 2004). While there has been considerable effort in some sites to better understand the conservation status of elephants (Fay and Agnagna 1991c, Fay 1993, Turkalo and Fay 1995, Ekobo 1998, Van Krunkelsven et al. 2000, Blake 2002, Blom et al. 2004a), the present MIKE inventory would be the first systematic full/near full coverage inventory across these important conservation sites ever undertaken.

[1] Class B surveys are dung counts in which 95% confidence intervals are quoted around the mean density estimate and where an on-site dung decay study was completed (AED, 2002).

Table 2. Forest elephant population "estimates" referenced in the AED

					African elephant database			
Site	Country	Km^2	Created	Status	1995	1998	2002a	N Class B surveys
Bangassou	CAR	12000		Community Forest	2640	1120	1600 (1200)	0
Boumba Bek	Cameroon	2485		Reserve pending ratification as NP	1404	1250	1250	1
Dzanga Sangha	CAR	4347	1990	NP and Reserve complex	1750	3000	2977 (290)	0
Minkebe	Gabon	7560	2002	NP	-	-	-	0
Nouabalé-Ndoki	Congo	4200	1993	NP	3479	-	431 (2300)	0
Salonga	DRC	36560	1970	NP	6330	-	12500 (2500)	0

Introduction to MIKE in central Africa

In 1997, at the 10th meeting of the Conference of the Parties (COP) to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Parties resolved to establish a monitoring system across the entire range of the African and Asian elephants [Resolution Conf. 10.10]. It was intended that this system would facilitate decision-making by the Parties regarding the protected status of elephants. This was also the first attempt to provide a systematic and detailed assessment of the impact of the Parties' decisions to allow, restrict, or suspend trade in a particular species (and/or its parts and derivatives). The monitoring system, now known by its acronym MIKE (Monitoring the Illegal Killing of Elephants), was endorsed at the 41st meeting of the CITES Standing Committee in February 1999, and between 1999 and 2001 a Pilot Program, funded by the United States Fish and Wildlife Service and the Wildlife Conservation Society was implemented in central Africa to assess the feasibility of full scale implementation of the program in forest ecosystems (Beyers et al. 2001).

During implementation of the pilot program and in the light of some lessons already being learned, the goals and structure of the MIKE program was discussed again at the 11th meeting of the Conference of the Parties in 2000, which led to a revision of Resolution Conf. 10.10, and the objectives previously agreed were broadened to include 'establishing an information base to support the making of decisions on appropriate management, protection and enforcement needs' and 'building capacity in range States'. The MIKE program currently has the following aim: 'To provide information needed for elephant range States to make appropriate management and enforcement decisions, and to build institutional capacity within the range States for the long-term management of their elephant populations.' More specific objectives within this aim are: (1) 'To measure levels and trends in the illegal hunting of elephants', (2) 'To determine changes in these trends over time', and (3) 'To determine the factors causing such changes and to assess to what extent observed trends are related to CITES changes in listings or ivory trade resumptions' (www.cites.org/eng/prog/MIKE).

The MIKE program plans to achieve these objective through a site-based system of collecting data on elephant population trends, the incidence and patterns of illegal killing, and the effort and resources employed in detecting and preventing illegal hunting and trade. The MIKE program is also charged with developing and using a standardized methodology for data collection and analysis.

The pilot project, which focussed on three sites, the Lope Ituri, and Odzala protected areas in Gabon, Congo Brazzaville, and the Democratic Republic of Congo (DRC) demonstrated that implementation of MIKE in forests was indeed feasible, and a full-scale program involving 55 sites across Africa was initiated thereafter. The plan is to repeat surveys in each site every 2–3 years. Within the range of forest elephants in central Africa 11 sites were chosen, each based around a protected area. This document reports on progress made toward achieving forest elephant population surveys during 2003-2004 at six MIKE sites in five nations within the range of forest elephants in central Africa (Figure 2). Sites included were Salonga, Bangassou, Dzanga-Sangha, Nouabalé-Ndoki, Boumba Bek, and Minkebe. An elephant inventory was also planned for Mont Alen in Equatorial Guinea, though for funding reasons this site was eventually excluded. Technical and administrative coordination for the surveys was provided by the Wildlife Conservation Society (WCS) working in collaboration with national Wildlife Departments, the MIKE Central Co-ordinating Unit and Sub-regional Support Unit and site-based NGO's including the World Wildlife Fund (WWF), the Wildlife Conservation Society (WCS), the Lukuru Wildlife Research Project (LWRP), the

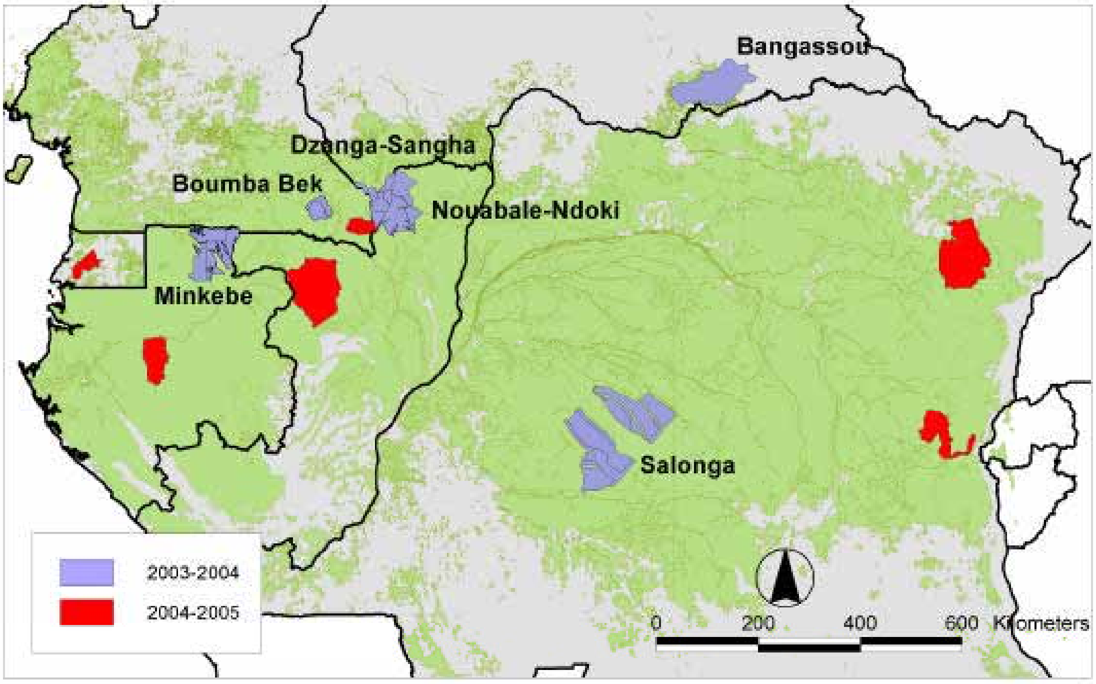
Max Plank Institute (MPI) and the Canadian Centre for International Studies and Cooperation (CECI). The surveys were made possible by funds provided by the European Community, USFWS, WWF International, CARPE and WCS.

At its inception, a 5-stage implementation plan (Table 3) was adopted in order to accomplish the surveys and complete preliminary data analysis and reporting in time for the 13th COP to CITES in Bangkok, in October 2004.

Table 3. MIKE forest elephant survey implementation plan

	Proposed timeframe MONTHS					
ACTIVITY	1-3	3-6	6-9	9-12	12-15	15-18
1) Initial site contact and planning, site MOU, team recruitment	X					
2) Field survey training	X	X				
3) Site reconnaissance, follow-up training, and design develop t.		X				
4) Field surveys and data management			X	X	X	
5) Analytical training and analysis						X

Figure 2. MIKE forest elephant inventory sites



Chapter 2: Phase 1 – Initial site contact and planning, site MOU, team recruitment

2.1 Initial planning

The purpose of Phase 1 was to set the technical, logistic, and administrative framework on which forest elephant surveys would be developed and implemented. MIKE was a new programme and there was a need at field level to develop an understanding of what MIKE was, what it hoped to achieve, and how best the program could be managed. In addition, the role of WCS as technical coordinator for this round of MIKE forest surveys in Central Africa was not well-established, and nor were the roles and responsibilities of each organization involved in the implementation of MIKE. The field managers of MIKE sites had not always been adequately briefed on the MIKE project, its mandate, objectives, or to what extend they could or should be involved in the design, implementation, and management of the program. For their part, MIKE personnel did not have a good understanding of constraints and opportunities present at each site, in relation to infrastructure, personnel and technical capacity, potential co-funding opportunities, and other similar issues. Phase 1 then, involved discussions at each site with the objectives of developing greater understanding of the context for implementation from both sides, defining roles and responsibilities of WCS staff, MIKE site officers, and site-based management authorities, and the drafting of MOU's which would serve as the basis for collaboration among parties.

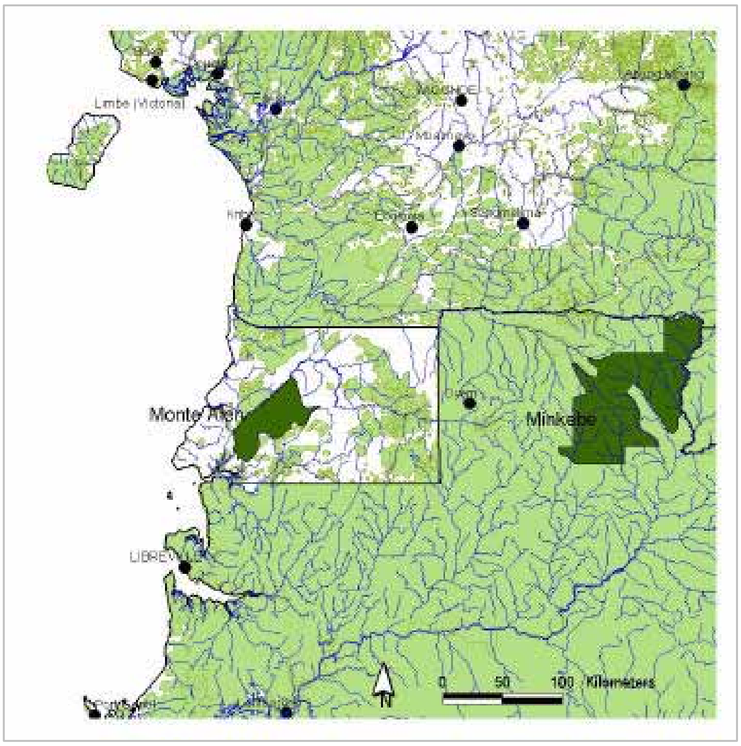
Before site visits took place, site managers and MIKE officers were contacted with an outline of the goals and objectives of MIKE, and the request to open the discussion of how best to maximize the outputs under the mandate of MIKE with site-based goals, needs, and constraints (e.g. management or technical capacity), and also to begin the process of field team leader identification and selection. A basic TOR (Terms of Reference) was included in the communication with a profile of the capacity required to fulfil the role as MIKE inventory "Team Leader". Team Leaders would be responsible for implementation of fieldwork, data management, some analysis and reporting. These technical staff were identified and nominated by the site-based staff in collaboration with the MIKE Inventory coordinator and MIKE Sub-Regional Support Officer (SSO) (for an explanation of MIKE staffing structures refer to the MIKE web site (http://www.cites.org/eng/prog/MIKE/index.shtml). Suitable team leader candidates would be critical to the success of the whole program, as was their availability for MIKE through the time-span of the surveys.

During site visits, the possibility of synergies between the goals of the MIKE program and site-based goals of monitoring and inventory were explored. Discussions of the current state of knowledge of elephant abundance and distribution, existing monitoring programs, results already available, and what made most sense from biological and conservation management perspectives in terms of survey zone definitions. Information on the biological and human land-use characteristics of each site were collated and spatial data that site managers were willing to share were used to prepare a suite of draft survey designs that were again discussed with site managers, site and national MIKE officers before being offered to the MIKE Technical Advisory Group (TAG) for comment. At all sites, MIKE was welcomed as a valuable contribution to on-going monitoring efforts and to capacity building locally and nationally. Memoranda of Understanding were drawn up between MIKE and each site management authority, which are included in annexes here.

A summary of the result of site-level discussions follows including a table of major opportunities, constraints, and other planning information for each site gleaned from site visits and other background research.

Monte Alen

Mont Allen National Park, Equatorial Guinea's MIKE site, covers 2007km^2 of mostly lowland forest rising to an altitude of 783m. Government management of the National Park has been assisted by the Programme for Conservation and Rational Utilization of Forest Ecosystems in Central Africa (ECOFAC) of the European Union (EU), and funded by the European Commission (EC) for more than a decade. The region is notable for its high rainfall, rugged terrain and high biodiversity. Mont Allen has considerable tourist appeal, and receives a steady number of tourists, catered for in an impressive lodge.



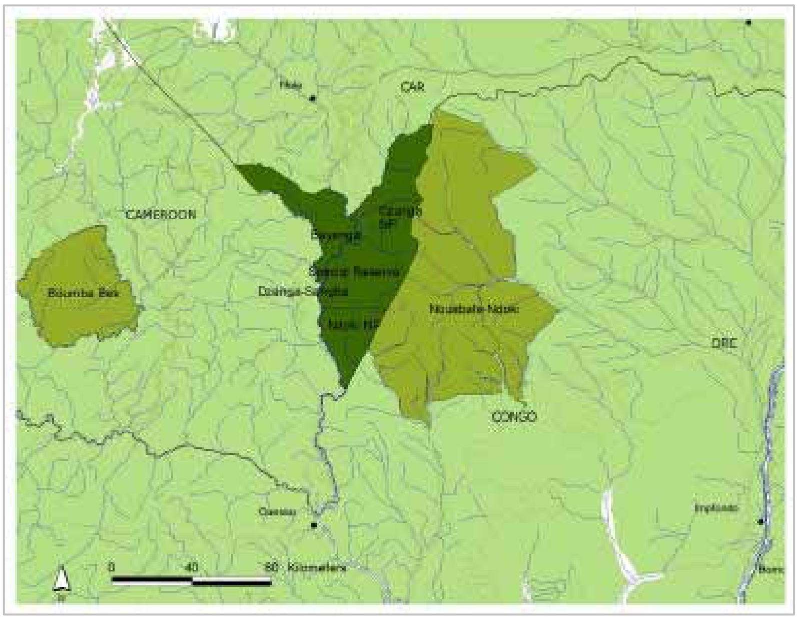
Information on the large mammals of the region, particularly elephants, was limited at site level, though an intensive taxonomic inventory had been conducted under the auspices of ECOFAC. No systematic elephant surveys had ever been completed, though in 1995 it was estimated there were ca. 400 elephants left in the entire country (Barnes et al. 1995). The African Elephant Database quoted three different population estimates for Mont Allen of 405, 80, and 300 individuals in 1995, 1998, and 2002 respectively (Said et al. 1995, Barnes et al. 1998, Blanc et al. 2003). There is little doubt that a MIKE survey in Mont Allen was necessary since, 1) it probably contains most of the nation's remaining elephants, and 2) could form the precursor of a nationwide survey, 3) estimates of the true number of elephants in the national Park were based on speculative guesses.

In October 2002, the MIKE SSO for Central Africa and WCS Inventory Coordinator met with the MIKE National Officer in Equatorial Guinea, and the Mont Allen Site Officer (SO) in Malabo. Brief meetings were held with the *Secretaire Generale du Ministere des Forets, Peches, et Environment*, who expressed strong support for the MIKE programme, and with representatives of a local conservation NGO – *l'Association Amis de la Nature*. Meetings were also held in Bata with the *Delege Regional*, and the *Secretaire Delege du Ministre des Eaux et Forets*, and with the Director of CUREF

(Programme for the Conservation and Rational Use of Forest Ecosystems). All offered their firm support for the MIKE programme, as did the ECOFAC National Director and Technical Advisor. However, as site-based managers, ECOFAC were keen to point out that the future of the EU program at Mont Allen was unclear, including funding, and that the program had limited management capacity to offer an incoming MIKE survey, suggesting that MIKE must operate in Mont Allen largely autonomously from ECOFAC. Given this limited local technical and management capacity a strategy was proposed in which the MIKE survey in Mont Allen would be developed implemented after surveys in other sites had been established when the coordinators would have more time to devote to the specific training and management needs in Mont Alen. This would give the Equatorial Guineans time to select staff, and for the ECOFAC management team to plan for some minimal logistical support for teams.

Unfortunately, funding from MIKE to implement an inventory in Mont Alen was not forthcoming before the COP of 2004, and to date no MIKE survey has been completed. There is no further reference to Mont Alen in this report, though a survey is planned for the 2005-2006 phase of MIKE.

Dzanga-Sangha

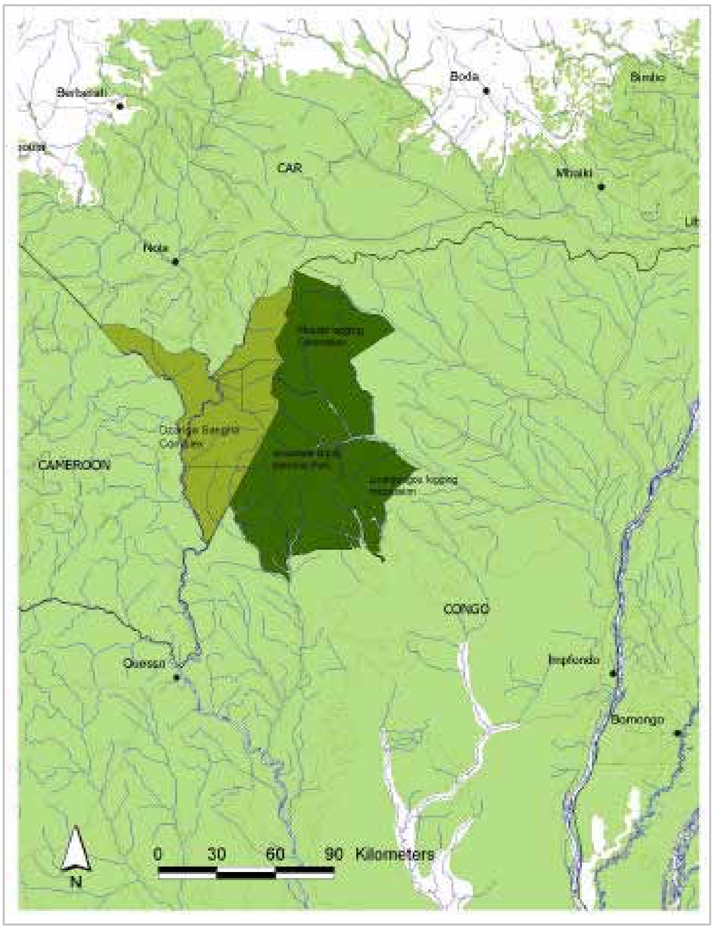


The Dzanga-Sangha Dense Forest Reserve was established in 1988, followed by the designation of two National Parks within the reserve in 1990. The surface area of the complex is some 4350km^2 of lowland forest, of which

1150km^2 is National Park. The area is outstanding for its spectacular forest clearings (bais) which attract large numbers of forest elephants and other wildlife (Turkalo 1999, Turkalo and Fay 2001). The complex is managed by the Dzanga Sangha Project, a partnership between the national government of CAR, WWF, and GTZ. A considerable amount of scientific research has been carried out in the area, beginning with extensive elephant and ape surveys in the 1980's (Carroll 1986, 1988, Fay 1989b, a), and the site is home to the longest continuous study of forest elephant social organization and behaviour (Turkalo and Fay 2001). Nearly 3000 elephants are known to visit a single bai, the Dzanga Bai, in the Dzanga National Park.

A site visit was not made to Dzanga-Sangha until March/April 2003, due to budgetary restrictions. However, previous communications with the site had been excellent, and both the MOU and survey design had been extensively discussed with the National Director and with the Project Principle Technical Advisor. The project was very willing to support the MIKE Inventory Programme, and discussed co-funding of activities, and using MIKE survey designs and methods as the basis of the park's monitoring programme. During the site visit, a Team Leader was commissioned, co-funding for the survey from the WWF-project confirmed, and an MOU was signed.

Nouabalé-Ndoki

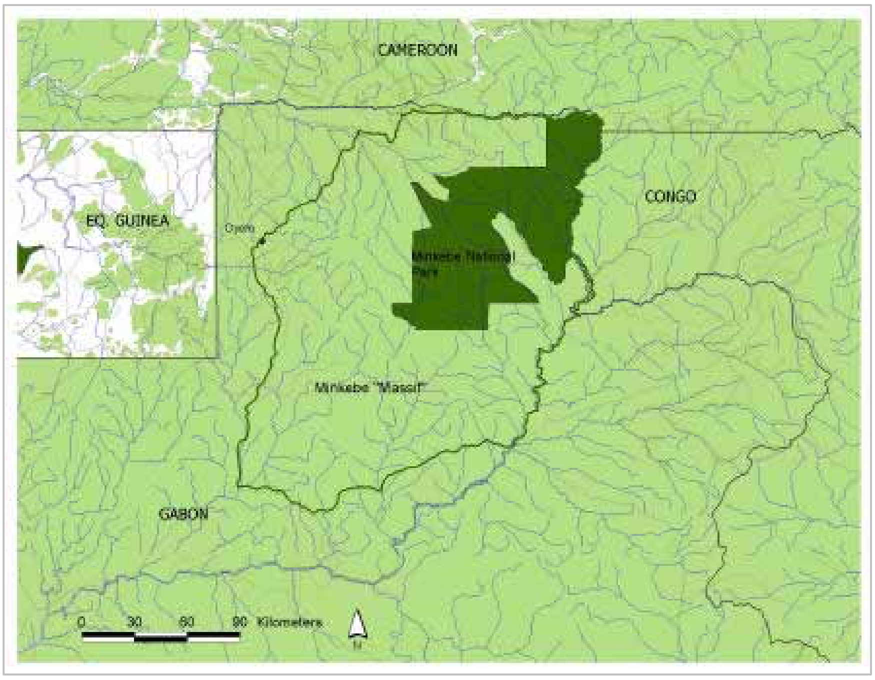


Nouabalé-Ndoki National Park covers 4220km^2 of moist lowland forest and is one of the most important elephant conservation areas in central Africa (Blake 2002). This is primarily due to low human population density and its inaccessibility, however in recent years logging interventions have expanded enormously throughout the northern Republic of Congo. Significant progress has been made in wildlife management in forestry concessions surrounding the park to the south, while to the north wildlife management interventions have not been solidified. The site provides a wide human activity gradient from high impact to a tranquil core area, which makes it particularly interesting as a MIKE site. There is a considerable body of ecological and socio-economic data on forest elephants dating from 1989, much of which the project were ready to make available to the MIKE programme. The Nouabalé-Ndoki National Park is managed collaborativ ely between the Government of Congo and the Wildlife Conservation Society. A buffer zone management project, PROGEPP, is similarly managed with a major logging company, *Congolaise Industrielle du Bois*.

The Nouabalé-Ndoki site managers were very positive toward MIKE, offered logistical support, immediately nominated two experienced technicians as Team Leaders, and additional staff were identified to complete two separate field teams. There was a strong desire from within the project to extend the MIKE survey zone as deep into the neighbouring logging concessions as MIKE funding would allow.

Minkébé

The Minkebe forest block, which covers 33,000km^2 of mostly primary lowland tropical forest in the northeast of Gabon, is bounded to the north by Cameroon, to the east by Congo border, and by national roads to the east and south. The Minkebe Forest is as an area of outstanding elephant density and conservation value (Barnes *et al.* 1991). At its heart lies the 7600km^2 Minkebe National Park, created in late 2002. The National Park and the Minkebe forest management block (Minkebe Massif) are managed jointly by the Government of Gabon and WWF.



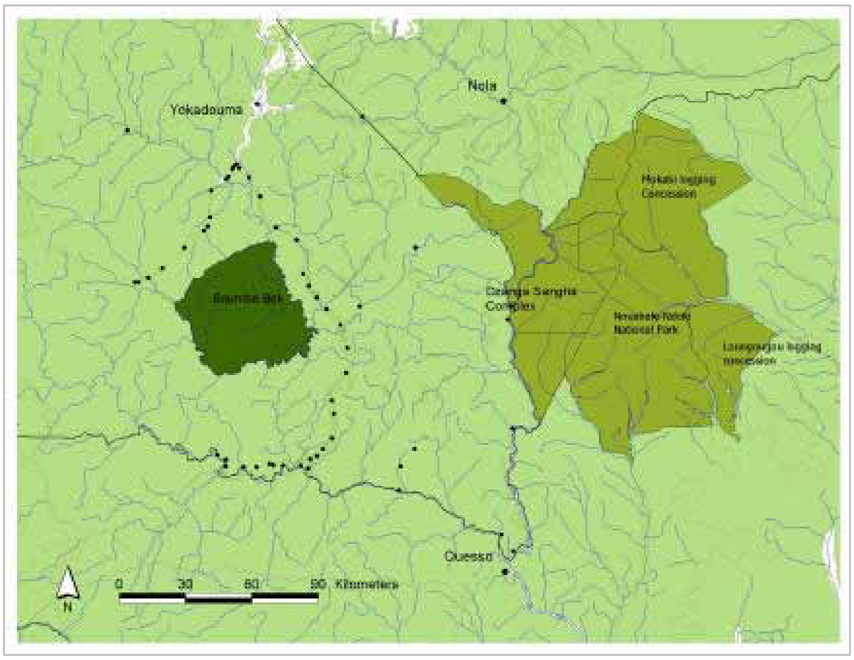
Forest elephants of the region were known to be under considerable pressure around the peripheries of the massif, particularly to the north. The large human population across the border in Cameroon, and the Gabonese from the east had an extensive network of camps along the border, which provides easy access for elephant poachers (Huijbregts 1999). Huijbregts (1999) estimated that ca. 250 elephants were killed every year, mostly by pygmies from Cameroon. Artisanal diamond mining occurs within the Minkebe Forest close to the National Park, which has a considerable impact on wildlife to supply meat to the camps, though apparently only a limited role in elephant poaching (Lahm 2002). Much of the forest block outside the national park is included in logging concessions which is further increasing pressure to the east and south. The project has initiated a programme in collaboration with several forestry companies aimed at reducing the ecological impact of timber exploitation. In the 1990's, the Minkebe forest witnessed a catastrophic decline in its gorilla population, most likely due to the Ebola virus (Huijbregts et al. 2003). Surveys of apes as well as elephants were critically needed to determine whether fragments of a once considerable and contiguous ape population remain. Like Nouabalé-Ndoki, Minkebe experiences a wide range of human influences, including a core area that was said to be devoid of human presence.

The project was eager to collaborate with the MIKE Inventory Programme and wished to use MIKE as the basis of their inventory and monitoring program. During the site visit the project management asked for technical assistance from MIKE to develop an extensive survey in the Mekambo Forest block to the southeast of Minkebe. A team leader was identified, Marc Ella Akou, who had extensive experience in ecological monitoring methods, and led the MIKE pilot surveys in Minkebe, in 2000.

Boumba Bek

The Boumba Bek Forest is part of a network of protected areas and forest management units in Southeast Cameroon, which together comprise a surface area of over 2,000,000ha. Boumba Bek is currently managed by the Cameroon Ministry of Water and Forests (MINEF) with technical support from WWF Cameroon and GTZ. In the late 1980's and early 1990's, south east Cameroon contained outstanding concentrations of forest elephants and other wildlife (Stromayer and Ekobo 1991, Barnes et al. 1995). The growing human population, market hunting, and the impact of industrial logging have had a severe negative impact on the region's fauna, though some areas, including Boumba Bek, were, before this MIKE survey, said to still contain high densities of elephants.

Selective logging is the major land use and economic activity in the region, though safari hunting of elephants and other large game species contributes significantly to the local and national economy. Unfortunately, there are no viable data on population structure and abundance on which to base annual harvest quotas, and limited management capacity to effectively enforce them. Stromayer and Ekobo (1992) and Ekobo (1998) studied forest elephant movements and ecology in Boumba Bek and found significant seasonal change in distribution and abundance. Estimates abundance of elephants in Boumba Bek however varied so vastly (between 250 and 7000) that a confident approximation of the true number was unavailable at the initiation of MIKE. More recently, the WWF Project has initiated a satellite tracking study of elephants in the region aimed at better understanding seasonal distribution and ranging of the elephant population (http://www.fieldtripearth.org).



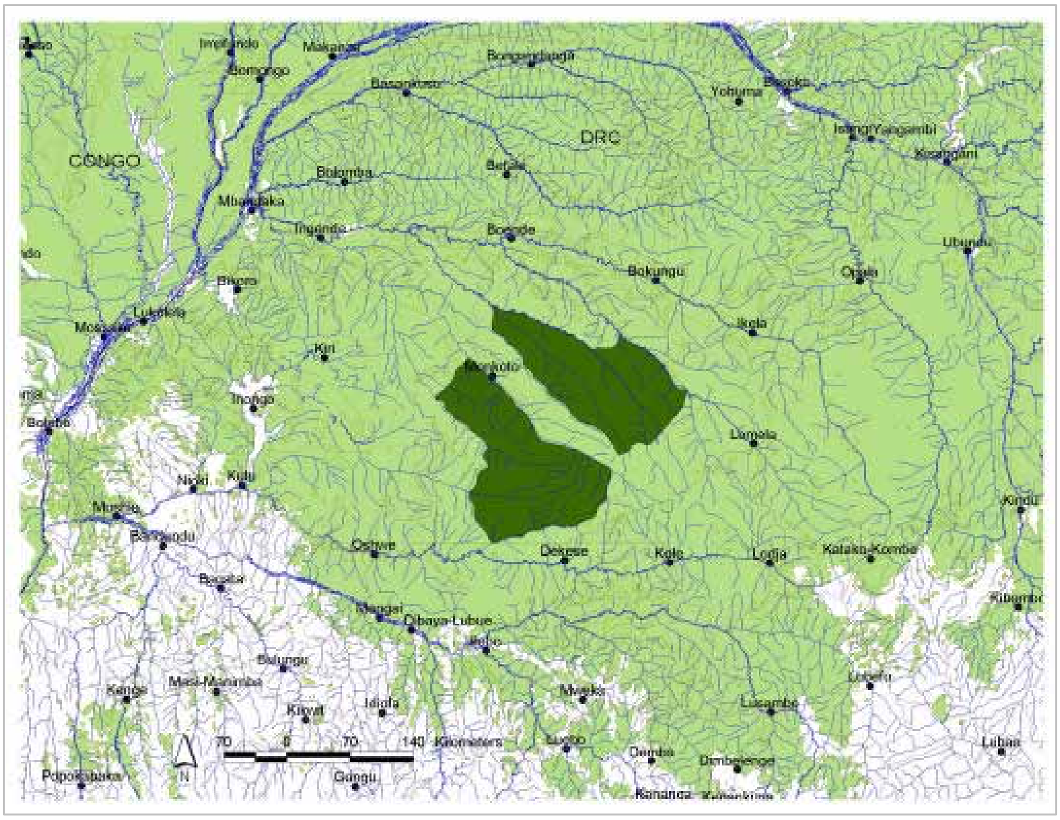
Prior to a site visit, meetings were held at national level with the Wildlife Director and the MIKE National Officer of Cameroon, and with representatives of WWF. The Wildlife Director was concerned with how WCS would take on a coordinating role for MIKE in Cameroon when WWF was the most active NGO in the MIKE sites. There was a general conception that WCS was setting up a programme with their own in-house personnel to conduct WCS elephant surveys in the WWF site. It was explained that the role of WCS in MIKE was to providing technical coordination and supervision rather than active management on the ground in sites that already had appropriate management capacity. It was stressed that the MIKE inventory would be integrated into the WWF-MINEF programme in SE Cameroon. Following this, a constructive dialogue continued, and the outcome of the meeting was positive. Following further discussions between WWF, WCS, and MINEF, a Memorandum of Understanding was drawn up and signed between the three parties and MIKE. A site visit took place in March 2003 to finalise practical details of implementation and management.

Salonga

The Salonga National Park, created in 1970, covers some 36,000km^2 and is the largest forested National Park in Africa. Lowland tropical forest, extensive swamps, and transitional vegetation from forest to savannah/gallery forest to the south dominate the vegetation of the park. Salonga is the only National Park in the range of the bonobo (*Pan paniscus*). In the past, Salonga certainly contained large numbers of forest elephants, however a wave of poaching reduced the population dramatically (Alers et al. 1992). The park is divided into two blocks by a corridor of relatively high human population density. The Park is currently managed by the *Institute Congolaise de la Conservation de la Nature* (ICCN), and is divided into 6 management blocks, each with its own administrative headquarters. The Park was incorporated into the ECOFAC programme in the early 1990's until the EC stopped direct technical and financial support due to the widespread political unrest in DRC in the early 1990's. Several international research organisations have research/conservation operations in and close to Salonga including the Max Plank Institute (MPI), the Zoological Society of Milwaukee (ZSM), and The Lukuru Wildlife Research Project (LWRP).

The logistical difficulties facing operations in the Salonga NP were ~~are~~ impressive. The main park HQ and logistical base, Monkoto at the extreme west of the park is a 3-4 day trip by dugout canoe from the Congo River town of Mbandaka. The park is larger than Belgium, and with limited existing infrastructure, access into the interior of the park would be challenging. The limited capacity and infrastructure seem during this visit meant that MIKE needed to be semi-autonomous in Salonga. The absence of a strong management and research program in Salonga, with the exception of the NGO programs, meant that recruiting of team leaders was carried out in Kinshasa.

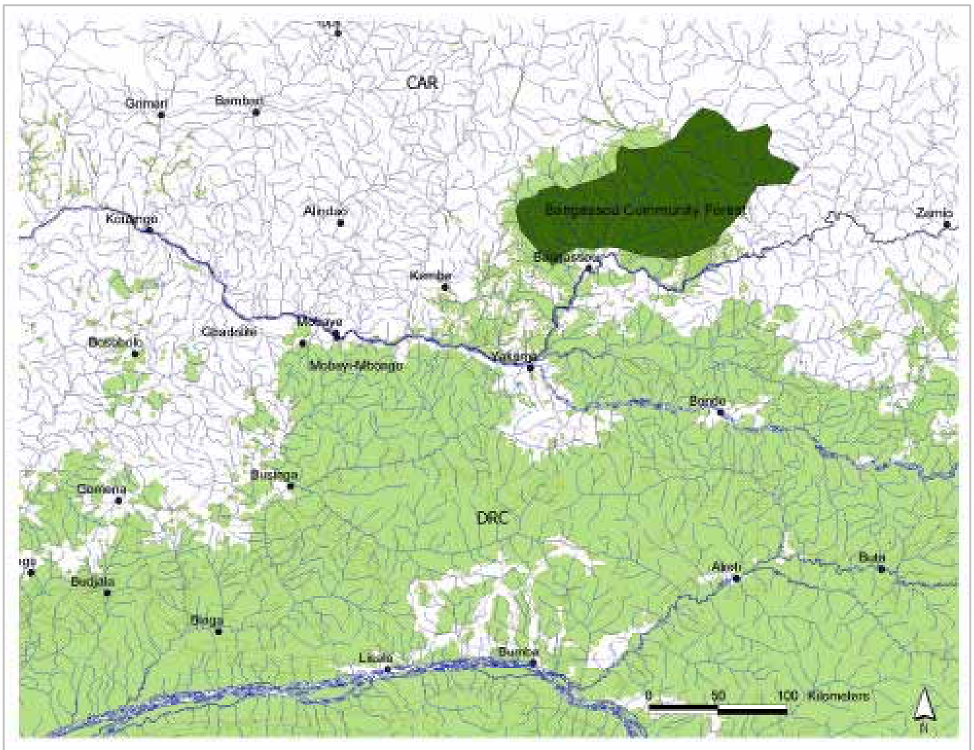
In early 2003, members of the MIKE team in DRC visited Salonga for the first site-level meetings. They found that Park administrative systems were largely dysfunctional due



to years of under-funding, infrastructure was close to nil, with no functioning outboard motors or vehicles, no radios, generators and very little basic field equipment. Despite this, the principle of MIKE was well received by local authorities, local people, and the ICCN. Politically, initiating a program such as MIKE was complex, since there has been considerable friction between ICCN and local people at various times in the past. Local people use and rely on the park for hunting, fishing, and collecting other forest products, and interventions by ICCN and other groups perceived to be in support of law enforcement are seen with some hostility. There are even some substantial villages within the limits of the park, and local people are obliged to hunt and fish for subsistence purposes. The team were quick to point out that the role of MIKE is not law enforcement, nor management interventions beyond basic field inventory work, but that MIKE was a government-mandated program, and therefore must be executed in any event. After considerable negotiations the program was accepted locally.

Bangassou

Bangassou was the least known of the central African sites in terms of the management context and local conditions. Elephant surveys had been conducted there in the late 1980's (Fay 1991, Fay and Agnagna 1991a) in which a substantial number of elephants was found to exist, but which were under heavy and increasing threat from ivory poachers from CAR and Sudan. WWF conducted follow up surveys in 1995 and found that elephant populations had probably been further reduced. There is no formal protected area in Bangassou. Instead a community conservation project was in



progress managed by the Government of CAR, and the Canadian Centre for International Studies and Cooperation (CECI).

Due to a shortfall in funding for MIKE and the remoteness of the site, it was decided that activities in Bangassou would be postponed until the other sites were operational. As the MIKE programme got underway in other sites, it became evident that the Bangassou Forest Project of CECI was gearing down their activities due to the ending of a funding phase. Following this, it was decided that a survey was not feasible in Bangassou without considerable technical support from an experienced field researcher, and in October 2003 a consultant, Dr. Elizabeth Williamson, was hired by WCS to take charge of MIKE survey development and implementation. Dr. Williamson and the MIKE SSO made a reconnaissance visit to Bangui and Bangassou in October 2003 to assess the feasibility of implementing elephant surveys. CECI staff, including the project Director, were very positive about the prospect of conducting MIKE inventories in Bangassou, though it was stressed that with funding running out, the project could provide little in terms of support. Despite this, the terms of a workable collaboration were developed, in which a limited burden was put onto CECI, an MOU was drafted and plans were made to recruit staff, train them and complete a pilot study before the end of 2003. Plans were made to completing a full-scale survey in early to mid 2004 just before the cessation of CECI operations in Bangassou.

Table 3. Management context summary of MIKE sites following site visits

Monte Alen

Potential for collaboration with site managers	Good. National and Ex-pat Directors were open to the objectives of MIKE and saw it as a positive initiative. However management support options were very low. Teams would need to be self sufficient in terms of logistics, finances, and personnel.
Recruitment of team leaders	Suitable Team Leaders not available within project. The project said they would work with the national MIKE Officer to find potential can didates.
Availability of local staff	Said to be readily available, and the many local villages support this. However limited experience of long stints in the field.
Infrastructure	Two ECOFAC pick-ups are based in Bata, for the national director and the ECOFAC technical advisor, who travel to the site frequently but irregularly. Generator runs at the site during working hours but does not supply electricity to the ECOFAC offices. Well built office space at site, electrical installations are available but have never been connected. Well-built forestry concession style camp at site. However this was said to be full with no space available for the MIKE team leader. The project could oversee the construction of a house for the MIKE team Leader at a cost of 4,500,000CFA, well beyond MIKE budgetary limits. Storage space is limited. Food for forest surveys will mostly need to be bought in Bata and transported to the site by local taxi. The project may be able to provide vehicles depending on demand.
Estimated Poaching Intensity	Not well known, but some cases reported. Human activity reported throughout the park. The country was said to still maintain strict regulation of firearms, particularly large calibre rifles and automatic weapons. This may result in lower poaching rates than in other central African nations, where such guns are easier to obtain.
Knowledge of elephants	Limited at the site level. Systematic data have not been collected on elephant and large mammal distributions. Project guides highlight the main point of high elephant concentration as the Lana River swamps, which bisects the park.
Human Elephant conflict	Crop damage reported at villages to the north and west of the park, but the level has not been quantified. Five elephants killed some time ago by the army as an *Abattage Administratif*.
GIS	Baseline data layers (park borders, roads, rivers, villages, mountains) provided by CUREF. Extends to entire country. Little GIS expertise at project level, either site or Bata.
Research reports available	Numerous reports completed but unavailable at the site or in Bata. Few on large mammals or socio-economics.
Constraints to realizing the MIKE inventory objectives.	Landscape. The Mont Allen National Park has exceptional relief – steep mountains, sometimes close to vertical. This will constrain the placement of transects since it will be 1) close to physically impossible to complete in such areas, 2) dung density data will be meaningless on heavy slopes due to decay rate differences with flatter terrain. A relief map is not available and statistical help is required if we are to properly take these inaccessible areas into account during survey design. The general difficulty of travelling and working in such terrain should not be underestimated. Personnel. Few people trained in fieldwork, and a small pool from which to select and recruit. Also limited technical assistance will mean that the MIKE team leaders must be autonomous and self-motivated, an therefore their capacity needs to be higher than in those sites where there is technical supervision and logistics help available. Housing will be difficult, however tents or the hotel may be available when team leaders are not in the forest.

Dzanga-Sangha

Potential for collaboration with site managers	Excellent. Managers wish to use MIKE as the basis of their large mammal monitoring programme and have already agreed to co-finance the MIKE survey.
Recruitment of team leaders	Team leader found and recruited, and two candidates for assistant team leader from within the existing project. The team leader was enthusiastic at the recent training programme (below), though his experience is limited.
Availability of local staff	Readily available.
Infrastructure	The project has several vehicles but they are often fully occupied with project activities. Nevertheless good planning and some flexibility should ensure that vehicles are available for MIKE staff. Generator runs at the site during working hours and evenings. Well built electrified office space at site. Office space should be available for the MIKE team leader. All supplies for forest work can be readily bought in Bayanga town, which is also the project HQ. Housing is also available for the MIKE team Leader in Bayanga.
Estimated Poaching Intensity	High. It seems that despite the presence of the project eco-guards elephant poaching is high in both the park and reserve. The large logging town adjacent to Bayanga, extensive diamond mining to the north of the reserve, strong pressure from Cameroon just across the Sangha River all contribute to the current levels of poaching.
Knowledge of elephants	Inventory and monitoring data have been collected on elephant and large mammal distribution in selected areas of the park and reserve, however there has never been an extensive and systematic survey of both park and reserve. While there are clearly extremely high densities in Dzanga NP, current distribution and abundance in the rest of the region is limited, and conditions in the reserve west of the Sangha River are largely unknown.
Human Elephant conflict	Crop damage has occurred in Bayanga and still does occasionally. The project has tried electric fencing and wire alarms with some success.
GIS Research reports available	Little GIS data and expertise at site level. However a more extensive GIS is housed in Bomassa the HQ if the Nouabalé-Ndoki Project, and it is intended that data will be shared between the two projects. Several PhD theses and numerous research articles and reports are available at the project site and in scientific journals.
Constraints to realizing the MIKE inventory objectives.	Capacity. There is a limited pool of people trained in ecological research methods in CAR, and a small pool from which to select and recruit. However it is hoped that therewill be considerable technical support available from project staff within the tri-national area of Dzanga Sangha, Nouabalé-Ndoki and Boumba Bek to ensure high quality data collection.

Nouabalé-Ndoki

Potential for collaboration with site managers	Excellent. Managers will incorporate MIKE into their existing large mammal monitoring programme.
Recruitment of team leaders Availability of local staff	Two team leaders provided and both already work for the project. Performance of the team leader at the MIKE training was generally good, however while they were familiar line-transect survey methods, neither has extensive experience, since recce surveys have formed the basis of the monitoring programme in Ndoki. Like all other recruits, both need practice to develop their survey skills and adopt the MIKE methodology. Readily available.
Infrastructure	Excellent. The project has several vehicles available for MIKE staff. Generator runs at the site during working hours and in the evenings until 10.00pm. Well built electrified office space at site. Air-conditioned office space readily available for the MIKE team leaders. Supplies for MIKE teams readily available, and housing is not a problem
Estimated Poaching Intensity Knowledge of elephants	Highly variable. Low to non-existent inside the park, and increasingly intense with distance from the park boundary. Strong anti-poaching efforts to the south have ensured low poaching levels to a distance of ca. 30km or more from the park. To the east and north poaching is increasing in intensity with the arrival of the logging companies (Inkamba-Nkulu, pers comm. Boudjan, Pers. comm). Good. Ecological studies are on-going through funding from the USFWS, studying elephant distribution, ecology, social organisation, ranging behaviour and management issues. However no systematic survey throughout the park and its peripheral zones has yet been completed.
Human Elephant conflict	Crop damage considerable in Bomassa village, the HQ is the NNNP. Elephants are coming closer to other villages around the park following anti-poaching success.
GIS	Extensive, including land use cover, roads, rivers, human populations, and a vegetation map produced by the University of Maryland. Landsat imagery available on site.
Research reports available	Extensive library of research conducted at the site since 1989.
Constraints to realizing the MIKE inventory objectives.	Capacity. A small pool of experienced people means that competent assistant team leaders will be difficult to find in the time available. However the projects have on-going training programmes and a number of potential candidates who may be able to meet expectations.

Minkebe

Potential for collaboration with site managers	Excellent. Managers will incorporate MIKE into their existing large mammal monitoring programme. The project also wishes to export the MIKE method to other forest areas of conservation interest in northeastern Gabon.
Recruitment of team leaders	One experienced team leader already recruited and a second being considered.
Availability of local staff	Readily available.
Infrastructure	Good. The project has several vehicles available for MIKE staff occasional use. Twp project bases in the towns of Oyem and Makokou have functional offices, electricity, and office space for the MIKE teams. Supplies for MIKE teams readily available, and housing is not a problem. Project pirogues are available however operational costs are high.
Estimated Poaching Intensity	Highly variable. Low to non-existent in a core area, and increasingly intense with distance toward the Cameroon border, which is under huge pressure. It would seem that pressure from the roads around the park to the east and south is low despite the high human population and easy access to trade routes.
Knowledge of elephants Human Elephant conflict	Moderate. Extensive reconnaissance surveys were conducted in the late 1990's, which established the consistent relationship between elephant abundance and distance from human settlement and roads. However no systematic survey throughout the entirety of the park and its peripheral zones has yet been completed. Intensity not known to the MIKE team at present, though crop damage is known to occur.
GIS	Extensive, and made freely available to the MIKE inventory team. The MIKE site Officer is a proficient GIS-user. WWF and WCS Libreville can also provide data and technical support.
Research reports available	Project technical documents are available in Libreville.
Constraints to realizing the MIKE inventory objectives.	Capacity. One strong team leader available, and several project individuals have survey experience. A training course will be held in June for the WWF inventory team and it is hoped candidates will be available for MIKE thereafter. Surface area and logistics. The Minkebe forest block is a huge 32000km^2, and the park is in the most isolated, difficult and therefore expensive region to access within the block. The proposed Minkebe survey block along with the Salonga NP in DRC, is an order of magnitude larger than the other MIKE sites.

Boumba Bek

Potential for collaboration with site managers	Good. There has been some suspicion toward the involvement of WCS in the MIKE programme in SE Cameroon. However, there now seems to be a good understanding of roles and responsibilities between WWF, WCS, MINEF, and MIKE.
Recruitment of team leaders	One experienced team leader with extensive experience in the region has been nominated already recruited and good possibilities exist for finding assistants. The WWF project has a large team of field-workers with experience in transect methodology.
Availability of local staff	Readily available.
Infrastructure	Good. The project has at least two vehicles will be available for MIKE teams with some planning. A project base in Yokadouma has functional offices and electricity for the MIKE teams. Supplies for MIKE team are readily available, and housing is good.
Estimated Poaching Intensity	Highly variable. Thought to be low in core areas of protected areas, but intense around large logging towns and villages. Levels not well known in the immediate MIKE site area.
Knowledge of elephants	Extensive reconnaissance surveys were conducted in the 1990's, which established the consistent relationship between elephant abundance and distance from human settlement and roads. However few reliable data from the more recent past on elephants, apes, or human distributions.
Human Elephant conflict	Intensity not known to the MIKE team at present, though crop damage is known to occur.
GIS	Extensive, and made freely available to the MIKE inventory team. WWF has considerable technical expertise both at the site level and in Yaoundé.
Research reports available	Project technical documents are available for the purposes of planning the MIKE surveys and data analysis.
Constraints to realizing the MIKE inventory objectives.	A legacy of institutional concerns during the MIKE pilot programme continues to lead to some suspicion. However good progress made and a spirit of collaboration is developing.

Salonga

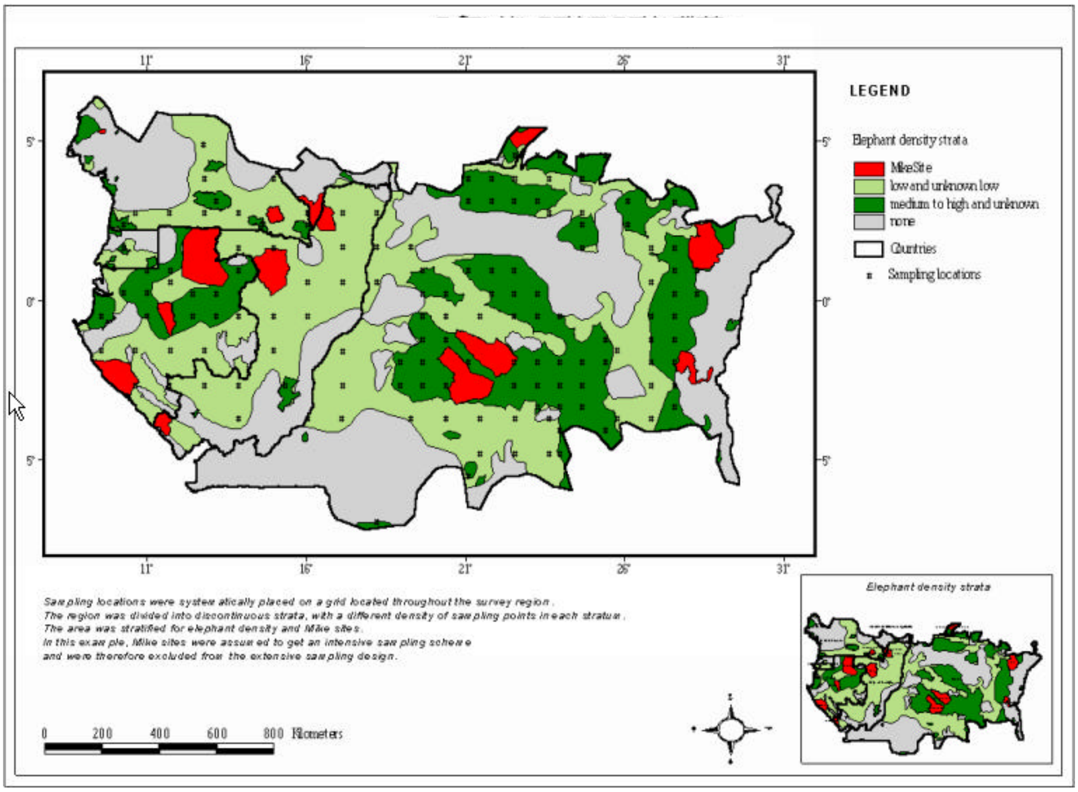
Potential for collaboration with site managers	MIKE is an integral part of the ICCN plan for Salonga National Park.
Recruitment of team leaders	Team leaders have yet to be identified.
Availability of local staff	Readily available as guides and porters.
Infrastructure	Poor. The MIKE teams will need to be logistically independent and self-sufficient throughout the surveys. A logistics base will be required in Monkoto with shortwave radio access to Kinshasa.
Estimated Poaching Intensity	Current poaching intensity is poorly known. In the past, poaching was high in many areas of Salonga (Alers *et al.* 1992) and large areas may be devoid of elephants. The decline in infrastructure and transport routes to the Congo River, and stagnation of the local economy may have reduced poaching levels in recent years.
Knowledge of elephants Human Elephant conflict	Poor. No extensive ecological survey of Salonga has been completed to date. Unknown.
GIS	Basic vegetation map available, and vector coverages of roads, rivers, and villages. However these are incomplete, and there is almost no ground validation.
Research reports available	Unknown on site.
Constraints to realizing the MIKE inventory objectives.	Qualified personnel, the enormity of the region, and limited financial resources. Simply travelling to Monkoto, one of the least isolated areas of Salonga takes close to one week from Kinshasa, and costs ca. $3000. All supplies except the most basic foodstuffs comes from Mbandaka, and once in Monkoto teams then have to disperse to the forest across an area the size of Belgium by river and on foot only. Even for seasonal fieldworkers familiar with local conditions the conditions in Salonga are daunting. The geographical distances involved and the lack of technical supervision on the ground means that team leaders will have little technical and management support. Currently to cover the entire area of Salonga, the MIKE coordinators have devised a survey plan that will cost in the order of $93,000 for the entirety of the park. The MIKE budget will allow a maximum of ca. 60000, which will only ensure adequate coverage in the southern sector.

2.2 Survey design

MIKE survey design issues across Africa, and perhaps especially in central Africa, has been one of the most contentious issues in the MIKE program. Originally, a site-based approach was proposed which included 13 sites in central Africa, of which 9 were in dense forest (Thomas et al. 2001), all were protected areas or conservation areas of some kind with little or no provision to sample outside them. While this approach to monitoring elephants may be suitable in regions and countries in which elephants are confined to protected areas (e.g. South Africa), in central Africa a significant proportion of the population occurs outside of protected areas (Blanc et al. 2003). A monitoring program located in only these sites would be unlikely to be representative of the larger central African elephant population (Thomas et al. 2001). Indeed, basing the program solely in and around protected areas would potentially bias the results toward the "best case" conservation scenario, and thereby hinder efforts to assess population trends, levels of illegal killing, and the impact of the ivory trade (Blake and Hedges 2004). In order to make valid inferences on population trends across the range of the species, sampling either systematically or purposively across the full range of factors influencing elephant abundance and rates of illegal killing. Recommendations from the MIKE Pilot Project were for multi-scale, design un-biased, stratified surveys across the Congo Basin forest using dung counts on line transects (Thomas et al. 2001) (Figure 3). It is widely acknowledged that dung counts on line-transects (Buckland et al. 1993) are the most efficient way to count forest elephants in forests (Barnes 2001, Barnes and Dunn 2002), though sampling details are debatable (Walsh and White 1999, Walsh et al. 2000, Beyers et al. 2001, Walsh et al. 2001). Transects would be systematically placed with effort allocated according to known or suspected elephant abundance to improve precision and efficiency. Within this framework, it was proposed that the suite of designated MIKE sites should, since they are of particular management importance, constitute a separate survey stratum, and be more intensively surveyed using consistent design and methods. MIKE sites it was proposed would also serve as bases of operations for field teams. The proposed design principles also took a range of constraints into account (e.g. war or other access issues, and staff or financial limitations), by dividing the region into sub-sets or "study areas" which could be surveyed according to local and other conditions.

Unfortunately logistical, technical, funding, and political constraints could not support the survey design recommended across the entire Congo basin, and the focus remained on working largely within MIKE sites. Given this, several important criteria guided MIKE survey designs at site level which are discussed in turn below.

Figure 3. Recommended survey design for MIKE elephant inventories in Central Africa (from Thomas et al. 2001)



Design un-biased versus model-based surveys

For animal populations in which complete counts are impossible, inferences about a population must be made from a sample from within the population. There are two main approaches to sampling – design-based and model-based, and the selection of the appropriate approach in the context of sampling forest elephant populations in forests has been discussed in terms of the MIKE programme (Thomas et al. 2001) and elsewhere (Walsh et al. 2000, Walsh et al. 2001). Briefly, in a design-based approach, sampling ensures that every individual within the population has an equal chance of being sampled. Random or systematic placement of sample units means there is no inherent bias in the design, for example increased sampling intensity near to easy access points, or away from mountainous areas, and if the design is correctly implemented, the resulting estimate of population size is un-biased. Sample units, in this case line-transects, are laid out randomly or systematically (with a random start point) across the survey zone, and elephant dung is counted following standard methods (Buckland et al. 1993, White and Edwards 2000b). The survey design and analysis software package Distance 4.1, which has the advantage of being accessible to non-specialists after appropriate training, can be used to both generate design un-biased surveys *and* analyse the survey data once collected. A disadvantage of design un-biased surveys is that to produce a valid abundance estimate, the survey must be completed as planned in its entirety or estimates will be biased. This presents real feasibility problems in areas such as central Africa, where insecurity, illness, logistical difficulties, and inconsistencies in funding may render a survey impossible to complete.

In a model-based survey design, line-transects are still be used as sample units, but there is no need for random or systematic coverage of the survey area, but it is important to cover the full range of all of the factors which might influence the distribution of, in this case, elephants. For example if human impact varied between 1-20 people per square kilometre in the survey zone, sample units must be placed in areas covering the full range of human densities if a valid population estimate is to be made. A statistical model is fitted to the survey data, which predicts elephant dung density from line-transect data. Model-based designs have some considerable advantages – sample units may be distributed to increase efficiency since logistically convenient locations may be chosen as long as the full range of covariates thought to influence distribution is covered. However there are risks in that if not all of the relevant covariates are included in the model, results will be biased by some unknown amount. Model-based surveys also have the advantage of providing information on the factors responsible for observed distribution and abundance. For example, the model may strongly suggest that distance from logging towns is a good predictor of elephant abundance, and the model may provide an estimate of the magnitude of the relationship. Finally, model-based designs have the ability to increase the precision of an abundance estimate over a design-based survey because they explain more of the variance in the sample data. The biggest disadvantage is that inferences about the population come from the model alone, and if the model is wrong (and it will be to some degree since models are always abstractions of reality), the inferences will be wrong. Unfortunately there is no way, using the same data, to test the model by reanalysing the data as if it were un-biased. Finally, the analysis of model-based designs requires highly advanced statistical expertise, which is expensive, and in the context of MIKE in central Africa, in short supply.

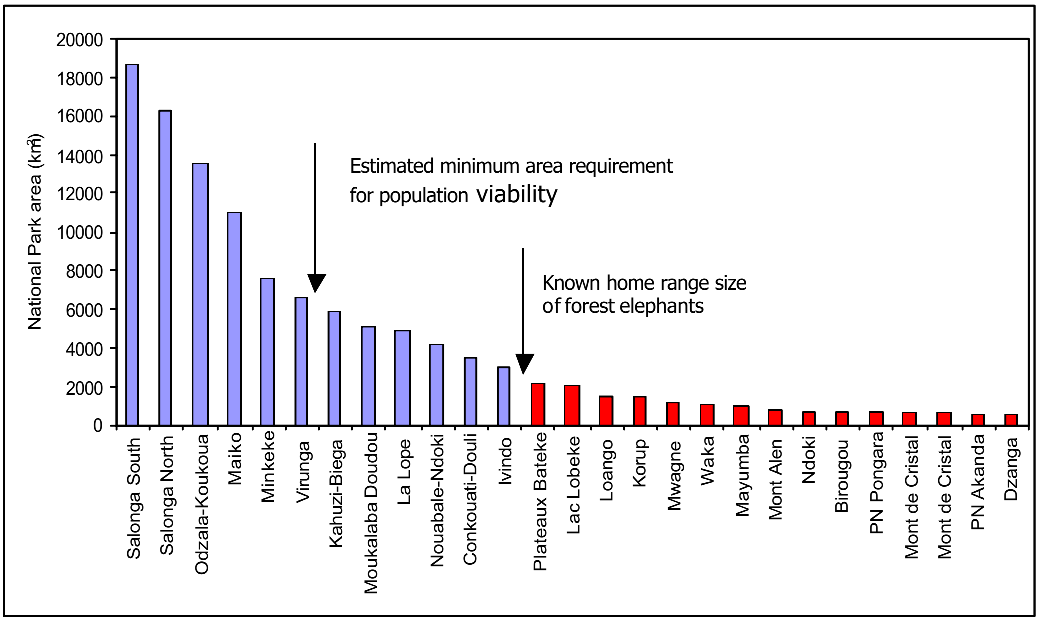
A design-un-biased approach to sampling elephants in the central African MIKE sites was implemented with the goal of estimating elephant abundance within a strictly defined geographical area at each site. It is possible to conduct both design-based and model-based analyses of the data. Furthermore, because of its contentious political underpinnings, the MIKE program must provide the most robust, most unambiguous technical products possible, and the design-based approach to sampling provides this possibility. The big drawback of this sampling design was that it restricted abundance estimates to the geographic boundaries of the survey zone, and would not easily allow extrapolations to the rest of central Africa.

Sampling intensity versus geographic coverage

Protected areas provide a biased sample of the Congo basin forest because their elephants would be expected to be under better protection and less intense threat than elephants in non-protected areas or in close proximity to large human populations. It was decided therefore to: 1) make explicit that the site-level surveys would probably be unable to make statistically valid statements about the status of forest elephants across their range in central Africa, 2) to treat MIKE sites as the "study areas" of (Thomas et al. 2001) and attempt to complete design un-biased surveys within sites, 3) make a strong attempt to expand survey zones outside of protected areas and include as wide a range of covariates in the survey zone as possible, particularly human influences in order to capture at least some of the impact of these factors on elephant abundance in the analysis.

Forest elephants are large-bodied animals that exist at low population density and which roam over large areas (at least 2300km^2) and which can exhibit considerable seasonal variation in individual ranging patterns and population distribution (Blake 2002). It is likely that to maintain viable populations, forest elephants require in the order of 6000km^2 based on figures from a population viability study by (Armbruster and Lande 1993), an area considerably bigger than most of central Africa's national parks (Figure 4).

Figure 4. Area of central Africa's national parks, possible minimum area requirements for viable elephant populations*, and forest elephant home range size.

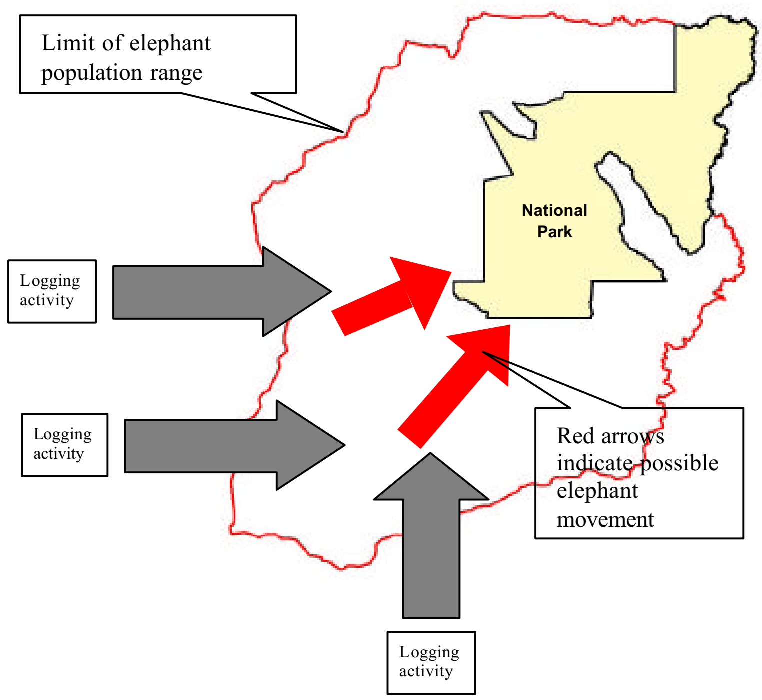


* (Armbruster and Lande 1993) suggested an area of 1000 miles^2 (2593km^2) was necessary to maintain an elephant population at a mean population density of 3.1 individuals mile^{-2} (in a semi-arid environment with a survival probability of 99% over 1000 years. Using the same parameters, and assuming a more realistic population density of 0.5 forest elephant km^{-2}, the minimum area requirement would be ca. 6000km^2.

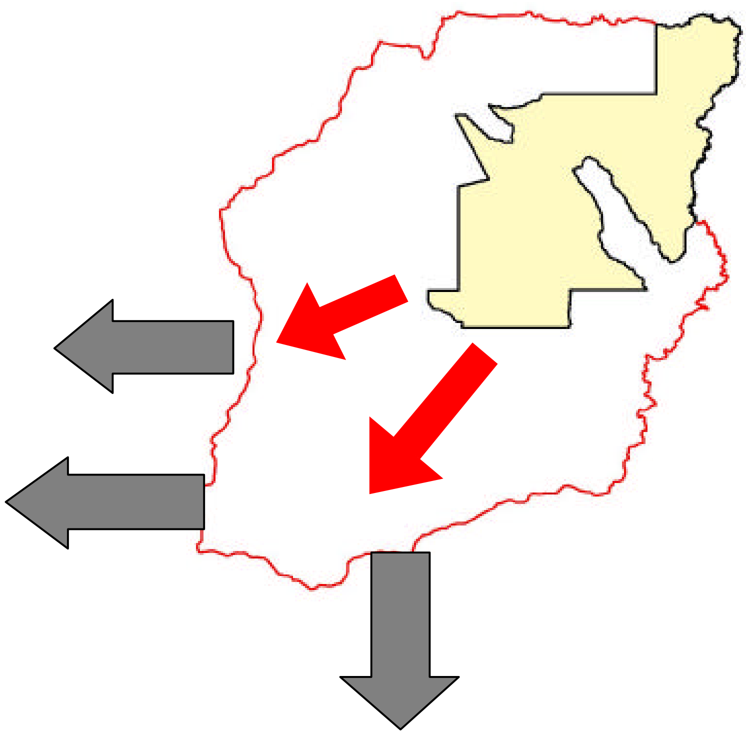
Elephant populations within central Africa are not confined to national parks as in many other areas of Africa, and it is more realistic on biological and management grounds to consider forest blocks in terms of "elephant landscapes" – areas in which a discrete, or near discrete elephant population is confined, which may span 1 or more national parks and their peripheral areas. Human impacts are largely responsible for the distribution and abundance of forest elephants, which operate over large spatial scales (Michelmore et al. 1994), and which usually define the boundaries of elephant populations. It is of limited value then to sample elephants within a landscape over a small area relative to the landscape itself (Figure 5). However, most elephant landscapes in central Africa have assumed, rather than proven, boundaries, and those assumed landscapes are huge. A trade-off exists between the precision of an abundance estimate and the area sampled – necessarily it costs more to move across a large area, and therefore for a given budget, sampling intensity must decrease as area surveyed increases. A balance must be struck between precision and the bigger management context including gathering information on elephant distribution, human activities, and sign of illegal killing. With limited data available from the majority of MIKE sites on elephant abundance and the limits of their distribution the trade-off between scale and intensity was largely a judgemental decision. As survey areas and sampling plans were developed, it was important to recognise that the current round of MIKE inventories constituted the first systematic surveys across most of the sites, and were rather reconnaissance in nature. A stronger emphasis was placed on gaining an overview of the population status of elephants and the management context within the landscape than on obtaining highly precise information from a small area of the landscape. Data from these surveys would allow more refined design planning in future. The decision was made to sample as large an area at each site as possible across a wide range of land use, protection status, human population and activity levels, while maintaining a target precision (in this case represented by the Coefficient of Variation [CV]) of the abundance estimate of 25%.

Figure 5. Problems of small area coverage when surveying forest elephant populations.

a) Shifting human impact

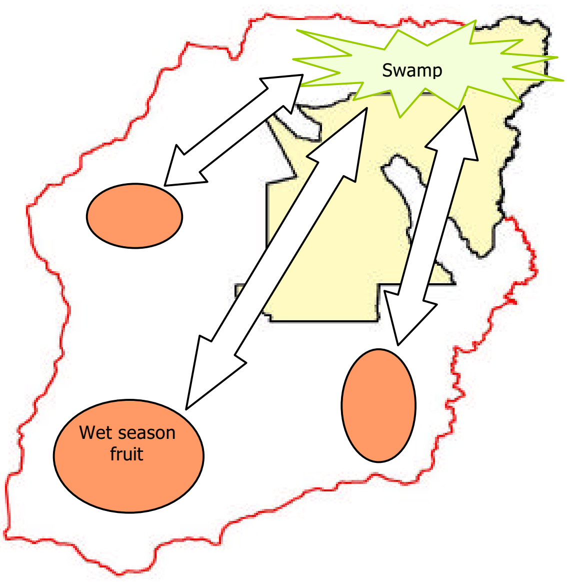


In this example from the Minkebe forest of northeastern Gabon, a contiguous elephant population occupies the region bounded in red. As logging activity moves into the southwest of this region, elephants may be expected to move northwards towards and into the national park to escape from disturbance and potentially increased poaching. If repeated population surveys are restricted to the national park, they will show an increasing elephant population, while the overall population of the landscape may be declining!



If on the other hand, sampling begins when logging is in retreat and illegal killing is diminishing, elephants may expand their range out of the protected area, with the result that even though the population may be increasing, survey data may show a decrease in elephant density.

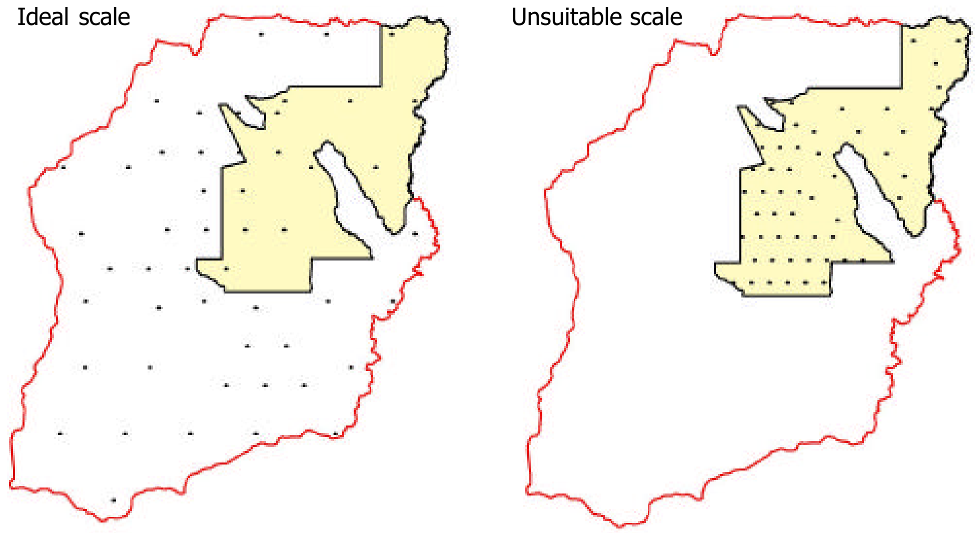
Figure 5 (cont'd)
b) Seasonal change in distribution due to forage availability



This example illustrates possible seasonal change in elephant distribution caused by habitat. Elephants are concentrated in and near the swamps to the north of their range during the dry season, while in the wet season they disperse out toward the south to feed on an abundance of fruit. Failure to account for these movements could lead to considerable changes in abundance estimates under different ecological conditions

c). Ideal sampling scale

In Figure 5c, sampling is across the range of the elephant population (i.e. the elephant landscape), and therefore changes in the distribution of elephants do not affect the abundance estimate of the site, since they all take place within the survey zone. They may however influence precision. To the right, only a small proportion of the elephant's range of sampled, which is subject to large fluctuations in elephant abundance due to seasonal movements and or human activity.



2.3 Impact of swamps

Swamps are an important year round habitats for forest elephants, but particularly during dry periods (Blake 2002). Swamps provide water, an abundant food source of browse, and may be safe havens in which elephants can hide in heavily poached areas. Swamps should therefore be taken into account in any reliable estimate of elephant abundance within a given site. This offers numerous problems for survey design and field methods, since no method for reliably counting elephants exists in swamp habitats. Dung decay rate conversion becomes all but meaningless when swamp habitats may dry out completely in the dry season, yet be inundated to a depth of a metre or more during the wet season. In the current MIKE inventories swamps were excluded from the survey zone where information on their distribution were sufficiently good to include their limits in GIS layers. Elephant density estimates were therefore confined to *terra firma* areas of each site, which introduced several potential sources of bias, considered below.

First, in some areas, elephants are frequently found in very high concentrations in *terra firma* forest immediately adjacent to swamps, over distances to the order of tens of metres (Blake 2002). If swamp boundaries are poorly located and poorly geo-referenced on site base maps, and *terra firma* close to swamps is excluded from the final survey zone, transects have no possibility of being located within these sections of *terra firma*, resulting in an underestimate of true *terra firma* elephant abundance. Second, since elephant use of swamps varies seasonally, a single abundance estimate in *terra firma* has no way of taking into account the proportion of elephants that may be residing in the swamp portions of the region which introduces an unknown error into the abundance estimate and makes trend detection very difficult over time. Finally, reducing this bias cannot be reliably accomplished by conducting repeat surveys at the same time of year, since rainfall, and leaf and fruit phenology, which drive elephant habitat selection are notoriously temporally and spatially inconsistent (Chapman et al. 1999, Blake 2002).

One can imagine a forest composed of 20% swamp and 80% *terra firma* containing 100 elephants, in which surveys were conducted in the same month over three successive years. In this forest, the availability of fruit varied over the three surveys from maximum possible production (100%) in survey 1, to 60% in survey 2, to 30% in survey 3 because of natural variation in rainfall, insolation, and other factors. Imagine too that a 10% reduction in fruit availability results, on average, in an individual elephant spending 5% more of its time foraging in swamps. During the first survey then all the elephants would be available to be counted because they would be permanently in *terra firma*. However, in the second survey each elephant would spend 20% of its total time in the swamps, which would result in a 20% decrease in dung available for counting on a line-transect survey, and therefore a 20% reduction in the dung density/abundance estimate. During the third survey, the elephants would spend 35% of their time in swamps, and therefore only 65% of total dung production would be available for counting. The elephant population in *terra firma* would have apparently have been reduced by 35% from the first survey and 15% since the second. Unless this variable swamp use is understood and taken into account there would be no way to explain the apparently dramatic loss in elephant abundance over the three-year monitoring period.

The inability to estimate elephant abundance in swamps also compromises inter-site comparisons of elephant abundance. For example in the Lopé National Park, probably less than 5% of the surface area is swamp, while in Salonga NP, perhaps 20% is swamp or seasonally flooded forest. The proportion of the total elephant dung produced being unavailable for counting would be unequal in these two sites simply as a consequence of the amount of swamp available, compounded by the influences discussed above, and the habitat quality of the swamps at each site. This the number of elephants in Salonga would be underestimated, while in Lope a more accurate assessment would be made, underestimated by only 5% assuming equal use of swamp and *terra firma* habitats.

2.4 Transects and recces

Methods are fully described in the methods section. The classic method for estimating elephant abundance in central African forests has been to use dung counts along line-transects (Barnes and Jensen 1987, Barnes 2001). However transects are labour intensive and costly to cut, slow to survey, and difficult to access in large landscapes, they are potentially harmful to vegetation, and if cut badly may 1) allow poachers easy access to the forest, and 2) bias future surveys if they become elephant paths. For these reasons, Barnes (1989a) suggested a "short-cut method" for estimating elephant abundance called "*The Poor Man's Guide to Counting Elephants*", which dispenses with transects and uses "path of least resistance" survey routes (recces) as either a surrogate for, or complement to, data from line-transects. Dung piles, and other sign, are simply recorded with distance along the path, but no attempt is made to measure perpendicular distances or walk in a completely straight line. This original notion was refined over time (e.g. Hall et al. 1997). Using field data from the Gamba Complex, Gabon, (Walsh and White 1999) demonstrated convincingly that appropriately designed combinations of transects and recces (recce-transects) could significantly improve the efficiency of field surveys by increasing precision across a range of effort levels, but could also still suffer from the disadvantages of transect surveys.

The MIKE pilot study investigated the improvement in precision when recce data was included in the analysis, and found that it increased precision in two of three sites surveyed (Buckland and Thomas 2001), as a result of which the use of recce-transect combinations was recommended. However at subsequent discussions with the TAG on this issue, they were unconvinced that recces would be useful and suggested, though not strongly, that they be dropped from field methods. During discussions with site managers, they felt that given the effort involved in getting to a sample location, more data should be collected than that obtained from transects alone, since they were starved of information on a range of species not easily detected on transects alone. For example, when transects are cut at the same time as sign counts take place (as would be the case in MIKE), they provide poor information on primate abundance since primates flee when they hear the noise associated with transect cutting. There is substantially less noise generated when walking a path of least resistance survey and a systematic record of primate encounter rate can be obtained. While the goal of MIKE was not to count primates, it should maximize its relevance to site-based managers to gain their full support and encouragement, and compromises such as this were felt justified, particularly if the recces could improve the final estimate of elephant abundance.

The MIKE pilot study investigated a second recce method which became known as Travel-recces. Travel-recces are not intended for direct comparison with transects to improve precision of abundance estimates, but rather are more in the spirit of Barnes' original "*Poor Man's Guide*", and are conducted as walks between sample unit locations. On travel-recces the emphasis is placed on covering ground efficiently while systematically collecting a small dataset on signs of particular interest such as human activity elephant dung. It was this combination of Line transects and Recce travels that became the methodology recommended for MIKE by the TAG.

Travel-recces play a critical unique role in assessing human activity, including illegal killing of elephants during field surveys. Carcasses and hunting camps are so rare that they are almost never detected from transects, and seldom on walks between transect locations following compass bearings and with few deviations. However if walks are made more flexible to allow for deviations toward interesting features, such as following machete cuts made by hunters or fishermen or following a particularly large elephant trail, they can lead field teams to important discoveries such as carcasses, poaching camps, gold mining camps, etc. which are important pieces of information for MIKE, but which would never be found from less flexible survey methods. Travel-recces are highly biased by, for example, the characters of guides and researchers, their level of field experience, by the way in which hunters lay down spoor, and many other such aspects. The data produced must be treated with these biases fully acknowledged.

Target precision of dung density estimate

It is essential to the MIKE program that trends in elephant populations are monitored over time. The accuracy and precision of population size estimated is therefore critically important. Accuracy depends mostly on bias reduction already discussed in the context of survey design – while precision depends on the variation in the distribution of the population within the study area and the allocation of sampling effort. The greater the precision, the greater is the power of successive surveys to detect a change in population size, discussed in detail in (Buckland et al. 1993) and in the context of elephant surveys by (Walsh et al. 2001, Barnes 2002). Buckland et al (1993) defined the relationship between variability in the target population, effort, and precision of density estimates by a variant of the following equation simplified by S. Strindberg, which was used to generate the curves in Figure 6:

$L = (b / \{cv_t(\hat{D})\}^2)(L_0 / n_0)$,

where:

L = total transect length required
b = Dispersion Parameter (estimated at 3 [Buckland et al, 1993, page 242])
$cv_t(\hat{D})$ = Target Coefficient of Variation
L_0/n_0 = Estimated dung encounter rate on line transects
CV = Target precision required

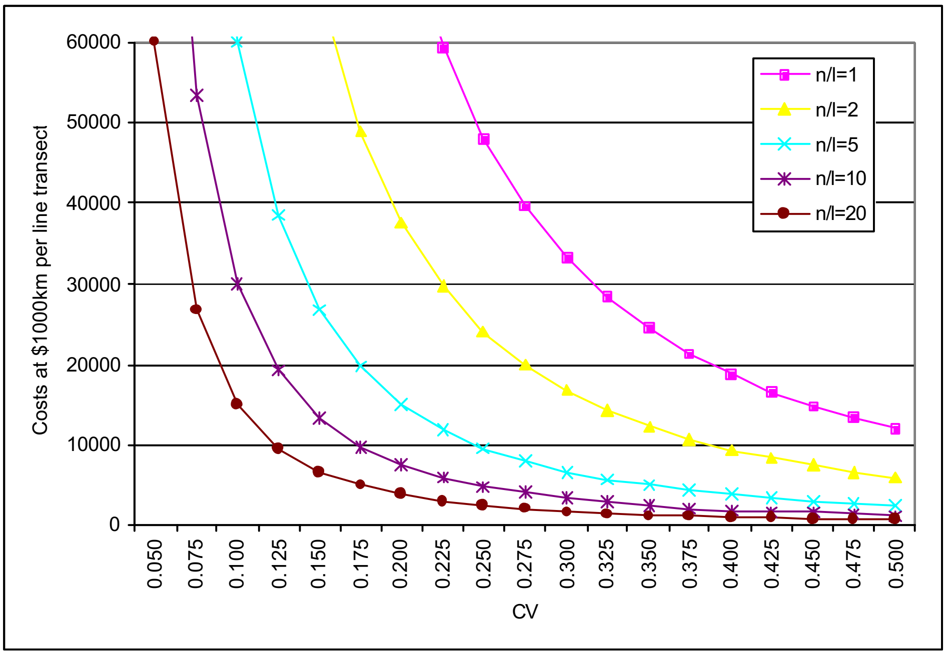
This means that line length increases with the square of the CV, thus, unfortunately, small increases in precision require, beyond a certain threshold, large increases in survey effort and therefore cost (figure 6). For example, in a forest in which dung piles are randomly distributed and where on average 2 dung piles are observed per km of transect, it would require something like 24 km of transects to achieve a density estimate with a CV of 25%. If a precision of 10% (CV) were the target, at least 150 km of transects would be required, or more than 6 times the effort (money and staff time!) for a 15% improvement in precision. Since precision is also inversely proportional to abundance (Barnes 2002) it is cheaper to survey in areas of high elephant density (Figure 6). Walsh et al. (2001), who investigated the relationship between the mean and variance of abundance estimates, showed that in fact, that sample variance increases non-linearly with abundance, and their conclusions would modify the relationships described in Figure 6 and potentially improve sample efficiency. Detailed discussion is beyond the scope of this report, and Figure 6 is intended to illustrate the approximate, and rather alarming, implications of abundance and target CV on effort and budgets. Returning to the ability to detect trends in elephant population size while keeping within budget and surveying as large an area as was feasible, a compromise was agreed among the MIKE TAG to fix the target CV on dung density estimates to 25% at each site. In the absence of field data on which to base effort levels required, prolonged discussion of design efficiency was rather hypothetical beyond generalities.

Implications of a 25% target CV for trend detection

If MIKE wants to be able to detect a 10% decrease in elephant numbers in a given site with a probability of p = 0.05 and with 90% certainty [p=0.05 is not the same as 90% certainty in a two-tailed test], how many surveys are required over varying levels of precision per survey? Using the software program TRENDS for effort calculations, for a CV of 25%, 11 surveys would be needed, while if the precision (CV) were set at 10%, only 6 surveys would be needed. For a single site this implies more than a 10-fold cost increase for the ability to detect the 10% change after six compared to nine surveys. A further trade off to consider here is that with an annual decrease in the population of 10%, only 53% of the population will be left after 6 surveys, and after 9 surveys just 39% (assuming one survey is completed per year), therefore the price of timely information may be justified. The reality at the start up of this phase of MIKE, was that while these calculations were helpful in setting some approximations on budget versus precision, the dearth of quantitative data from most of the central African MIKE sites, meant that accurate estimates of effort requirements were impossible. Practical considerations were that 1) the distribution and abundance in the majority of the MIKE sites was poorly known, 2) the MIKE budget was limited, 3) the mandate was to attempt to complete population surveys in 7 sites in 6 countries and report on them at COP 13, less than 2 years after the initiation of the program, 4) the technical capacity to carry out the surveys was extremely low. The approach was therefore to set a low, but hopefully achievable target CV that was sufficient to provide an approximate elephant abundance from which future survey designs could be refined while moving toward a real ability to detect trends. It was hoped that basic abundance estimates derived from standard Distance analysis would be improved by using spatial modelling (Thomas et al. 2001, Walsh et al. 2001) techniques to 1) increase precision, and 2) provide valuable information on the factors responsible for elephant distribution. Furthermore, elephant abundance estimation was only one in a suite of MIKE datasets aimed at understanding change in elephant conservation status (LEM, recce data, etc), and the ability to monitor change both at site level and beyond would come from analysing these in combination (Burn et al. 2003).

Final survey designs generated for MIKE, and actual field trajectories are provided in site-level reports which accompany this report, while transect placement and basic statistics for each design is provided below under "field inventories and data management".

Figure 6. Cost implications of line-transect surveys at different dung-pile abundance and desired Coefficient of Variation



Dung decay and defecation

If dung density estimates are to be reliably transformed into elephant density estimates, it is necessary to know both the defecation rate of elephants (number of dung piles produced per elephant per day) and the disappearance rate of elephant dung piles (Wing and Buss 1970, Barnes and Jensen 1987, Barnes 2001). Some studies have shown considerable promise in developing models which take variability in dung decay rate due to rainfall (White 1995, Barnes and Dunn 2002) and diet into account (White 1995) both of which may considerably bias estimates of elephant abundance if not correctly incorporated into data analysis. Most studies of defecation have concentrated on savannah elephants, and tend to concur that defecation rates do not very markedly either between sites or seasons, hovering around 17 dung piles produced per elephant per day (Wing and Buss 1970, Tchamba 1992), though (Ruggiero 1992) found nearly a two fold change in defecation rate depending on diet. Studies of forest elephant defecation rates mostly involve small datasets and conclusions are equivocal, though Merz (1986), Tchamba (1992), Ekobo (1995), and Theuerkauf and Ellenberg (2000) estimated 20, 18, 17, and 17.5 piles per day respectively with no statistical difference between seasons.

Following the MIKE Pilot study it was recommended that decay and defecation rate studies be implemented in at least a selection of MIKE sites (Beyers et al. 2001), but that in lieu of data successive surveys should be repeated in the same months to minimise variability. Unfortunately two main schools of thought exist on how exactly to do decay rate studies and at the time of the initiation of the present survey cycle there was no preferred methodology in place. It was proposed that decay studies following methods described by Barnes and Dunn (2002) in which decay is calculated across a range of rainfall values would be implemented in 2-3 MIKE sites, however as survey implementation got underway, funding restrictions prevented these from taking place. Following consultation with the TAG, the most urgent priority was to obtain systematic estimates of dung density from as many sites as possible from the current survey cycle, use existing models where possible (e.g. Barnes' rainfall model from Ghana), and plan to implement appropriate research at the beginning of the next cycle. Studies of decay and defecation were not therefore implemented in this phase.

Chapter 3: Phase 2 – Field Survey Training

In their paper entitled "What will it take to monitor forest elephant populations" Walsh and White (1999) summarise the capacity building challenge required to develop appropriate monitoring of elephants in central Africa:

"Because of the paucity of wildlife conservation and management infrastructure, getting good information on elephants is likely to require a massive training program and huge monitoring effort in each central African nation with a major elephant population…..In addition, commitment will have to extend beyond simply training and outfitting survey teams. Monitoring programs will have to be designed, organised, and administered, field teams will require supervision, and data will require compilation and analysis…..Mounting an elephant monitoring program in central Africa will require an exercise in institution building".

This is the scale of the task facing the MIKE program in the central African sub-region. Following the experiences gained from the MIKE Pilot Program, a number of specific recommendations toward training were made, which included the following of particular importance:

- Selection of MIKE researchers should be done carefully, and candidates should meet agreed profiles.
- National Elephant Officers, and if possible, Site Officers and Field Leaders responsible for field data collection should also be trained in at least the preliminary stages of data analysis. This is important to ensure motivation and data quality.
- With line transect survey methods an understanding of the basic elements of survey design and analysis is essential.
- Field Leaders and National Elephant Officers should be trained such that they can select and train field teams in future. The requirement to train others ensures that national staff fully understands methods and protocols and are able leaders. The MIKE program should emphasize training of trainers, and leadership.

- Extensive practice in the field is essential. Accuracy and efficiency in data collection improved markedly during the course of the pilot project. It is estimated that at least two to three months of field work are required before confidence, efficiency and accuracy is achieved for line transect data collection.
- Quality control of fieldwork, data collection and reporting is essential and must be planned from the start.
- Field Leaders must be trained to weigh options and make decisions concerning surveys in relation to constraints in the field. The actual implementation of a survey plan may depend on factors such as the availability of potable water for camping, weather, sickness, impassable areas etc. It is not possible to include all these factors in the sampling plan. Field Leaders will be challenged to make decisions on the spot.

The task of capacity building to the extend ultimately required to run an effective programme from within the sub-region was well above the funding levels that were available to MIKE for these surveys and also for the time frame of this two-year reporting phase. The goals of this training programme were therefore restricted to the possible and the necessary – not an ideal approach but a pragmatic one. Building on WCS' collective extensive training experience exemplified in the text of (White and Edwards 2000a), a three stage training programme was developed for field team leaders with the following goals:

1. Prepare field team leaders with the knowledge and practical experience necessary to implement a pilot study involving line-transect sampling in their respective MIKE sites and following retraining after the pilot study, to go onto successfully complete the full scale MIKE survey.
2. Develop sufficient competence in data management such that MIKE data can be collected in the field, transcribed into electronic format (Access and/or Excel) organized into a standardized framework, backed up and archived, retrieved for analysis, and moved into the MIKE data management hierarchy.

3. Conduct basic data analysis (summary tables and graphs of encounter rate), understand and complete an analysis of elephant data and produce a valid elephant dung abundance estimate using Distance 4.1, and write a final report of a standard acceptable to donors and range states.

The three phase training was organized as follows; Research principles and basic field methods training, site reconnaissance and quality control, and a final course in data analysis and reporting. In this section, Phase 1 is summarised. The time frame and intensity of training was constrained by uncertainties of funding, MIKE coverage, staff competence levels and motivation, and the requirement of completing surveys in as many of the seven designated MIKE sites as possible. An overview of the training phase is provided in Table 4 below. The small group of MIKE staff below were largely responsible for executing surveys on foot over more than 50,000km^2 of remote central African forests.

Figure 7. Personnel responsible for training and executing MIKE forest elephant inventories in central Africa at the Somalomo Training centre, Dja Reserve Cameroon.

From Left to right: Calixte Mokombo (Nouabalé-Ndoki), Bruno Bokoto de Somboli (Dzanga-Sangha), Omari Ilambu (Salonga), Dr. Fiona Maisels (Trainer), Inogwabini Bia-isia (Trainer), Dr. Stephen Blake, Inventory Coordinator, Marc Ella Akou (Minkebe). Dja (Guest), Patrick Boudjan (Nouabalé-Ndoki), Lambert Bene Bene (Boumba Bek).

The field training course was held at the Somalomo Training Facility in the Dja Reserve, Cameroon, managed by ECOFAC.

The objectives of training course were as follows:

- To familiarise all participants with the goals and objectives of MIKE and its place within the CITES process.
- To finalise data collection protocols, data collection forms, and produce a technical handbook on the methodology and various protocols developed.
- To ensure that all participants understood and could practically execute the technical aspects of elephant and ape inventories using recce-line transect methods and distance sampling.
- To ensure that team leaders were able to train their assistants in the MIKE methodology
- To clarify the site level data management system, and the flow of information and raw data through the MIKE hierarchy.
- To walk team leaders through the process of survey design using Distance 4.0, and develop pilot study itineraries and preliminary survey designs for each site.
- To provide guidelines on the management of MIKE funds, and establish financial and technical reporting systems, and protocols for communication between MIKE team members and the WCS coordinators.

Four main activities were completed:

- An overview of the MIKE programme with presentations by the SSO for Central Africa and the inventory coordinator.

- Presentations by trainees on the characteristics of the respective sites, with a focus on the opportunities and potential problems and constraints posed at each site
- A course on the theory and practice of design, methods, and implementation of wildlife surveys with a focus on forest elephants and apes
- Practical exercises in the forest in field methods, data collection, and management, followed by data management and an outline of data analysis procedures using Distance 4.0

Due to financial constraints, not all of the team leaders from Salonga could be present in Somalomo, therefore a second training course was held in the Salonga National Park, led by Inogwabini Bila Isia, Omari Ilambu, and Dr. John Hart (for full report of this training see Annexes). In addition, the Minkebe team leader was unable to begin the MIKE survey until July 03, and therefore a follow up training session was held with the MIKE Minkebe team in Minkebe in June 2003.

Table 4. Training programme calendar

semaine 1			
Date	**Sujet**	**But**	**Formateur (s)**
12 Fev	Arrivee des participants. Bien Venu		Mortier Luhunu
12 Fev	Logistiques de stage te du site (lodgement, norriture, equipement disponibles). Sommaire du Programme et Objectifs. Introductions des participants.	Orientation	Philippe, Blake, hart, Luhunu
13 Fev	Introduction du CITES et MIKE 1. Historic. Objectifs globaux et regionaux. Sommaire du Programme Pilote Afrique Centrale.	Comprehension de 'Pourquoi MIKE'	Luhunu. Hart
13 Fev	Introduction de MIKE 2. But, Objectifs, approches - sites, definitions. Inventaires et LEM.	Comprehension de MIKE aujhord'hui, global et sous-regionale	Luhunu. Blake
13 Fev	Cartes des sites; Elements de base, covariables necessaires pour stratification et modeles spatiales	Compred l'importance des cartes pour les inventaires	Hart
13 Fev	Presentations des sites; Geographie, ecologie, elephants, occupation du sol, problematique de la gestion.	Comprehension des sites et contreints de travail	Participitants
13 Fev	Ramasse les donnees spatiales existant des sites; discussion de qualite des donnees. Liste des donnees a trouve.	Base de donnees prelinilaire.	Tout le Monde
14 Fev	L'approache scientifique. REVUE: Identification des buts, objectifs. Definition des sites et methodes. Echantionnage, biais, replication, stratification, certitude et precision.	Revision	Maisels, blake database
14 Fev	Dessin de sondage pour les sites MIKE avec Distance.	Comprehension l'importance des cartes et comment developper un plan d'echiontionnage en DISTANCE	blake
14 Fev	Examples de Salonga...pratique le soir	comprehension de dessins	tout le monde
15 Fev	Carte Boussole, et GPS 1: Navigation par carte et boussole, mettre les waypoints sur GPS; fonction de GPS, et navigation, tracklogs, waypoints	Revision.	Inogwabini, Maisels
15 Fev	Carte Boussole, et GPS 2	Savoir comment saisir les Tracklogs et Waypoints sur 'Handspring Visor', saisir en Ordinateur er importer en excel	Blake
16 Fev	Transects de Ligne, Recces, DISTANCE et Modeles spatiales	Comprehension des advantages et disadvantage de chaque methode et analysis.	Maisels, Hart, Blake
16 Fev	Transects de ligne 1; Discussion des donnees a collecter. Exercises - trouve l'origine, coupe, collecte des donnees, measure, checksheets.	Standardisation des methodes. Savoir comment forme les debutants	Maisels
semaine 2			
Date	**Sujet**	**But**	**Formateur**
17 Fev	Transects de ligne practique	Comprehension de dist perp.	
18 Fev	Law Enforcement Monitoring; collete de donnees integration avec les bas de donnees biologique et MIKE LEM	Definir le systeme de LEM	Hart
19 Fev	Mission recce transects en Foret - voyage au centre du Parc	voyage. Discute workplans et planning budgetaire.	Tout le Monde
20 Fev	Mission recce transects en Foret	Pratique. Tomber d'accord sur la terminologie, methodologie, et donnees finales.	Tout le Monde
21 Fev	Mission recce transects en Foret	Pratique. Tomber d'accord sur la terminologie, methodologie, et donnees finales.	Tout le Monde
22 Fev	Mission recce transects en Foret	Pratique. Tomber d'accord sur la terminologie, methodologie, et donnees finales.	Tout le Monde

23 Fev	Mission recce transects en Foret	Pratique. Tomber d'accord sur la terminologie, methodologie, et donnees finales.	Tout le Monde
Semaine 3			
Date	**Sujet**	**But**	**Location**
24 Fev	Mission recce transects en Foret	Pratique. Tomber d'accord sur la terminologie, methodologie, et donnees finales. TOUT LE MONDE DEMONTRE UN NIVEAU DE COMPETENCE NECESSAIRE DE REALISER LES INVENTAIRES	Tout le Monde
25 Fev	Mission recce transects en Foret-retour a Somalomo	Voyage	Tout le monde
26 Fev	Debriefing de mission en foret. Saisi des donnees recce et transect; Corrige le bas de donnees Access	Savoir l'integration des donnees collectees avec les donnees GPS en access. Finaliser le fiches de bases de donnees	Tout le Monde. Blake montre comment utiliser access.
27 Fev	Saisi des donnees recce et transect; Corrige le bas de donnees access	Savoir l'integration des donnees collectees avec les donnees GPS en access. Finaliser le fiches de bases de donnees	Tout le Monde.
28 Fev	Introduction Distance, control de qualite des donnees, estimationd de densite.	Savoir comment juger la qualite des donnees (largeur efficace et distance de visibilite). Estimation de la densite des elephants et des chimpanzes	Maisels, Inogwabini, Blake
1 Mars	Revision protocoles transects, saisie des donnees, bases de donnees, et controle de qualite	Chaque participant demontre le competence necessaire.	
2 Mars	Developper les dessins de sondage finales	Faire comprendre aux gens comment balancer la recherche scientifique ideale avec les realites financieres et logistique. Generer un plan de travail pour chaque site, avec missions definies, waypoints clarifies.	Blake, Hart, Inogwabini, Maisels. Participation de tout le monde.
semaine 4			
Date	**Sujet**	**But**	**Formateurs**
3 Mars	Developper les dessins de sondage finales	Faire comprendre aux gens comment balancer la recherche scientifique ideale avec les realites financieres et logistique. Generer un plan de travail pour chaque site, avec missions definies, waypoints clarifies.	Blake, Hart, Inogwabini, Maisels. Participation de tout le monde.
4 Mars	Gestion de projet; Inventaire, finances, personnel.	Mettre un systeme de communication et finances en marche. Rapportage trimestrielle.	Blake Inogwabini, Hart
5 mars	Cloture		

Main results of initial training

Choice of site

There had been some debate in the planning phase of MIKE regarding a suitable site to stage the initial MIKE methods training. One possibility, the Lopé centre contained high densities of elephants in the immediate vicinity of the centre, many variable habitats, steep hills and other real world hazards which would have allowed extensive "real" practice of methods. The high elephant density was favourable since it would have allowed all team leaders to have practice in the standardization of dung age classification – important in dung decay studies. The other possibility, Somalomo Training Centre in the Dja Reserve, offered good infrastructure, but elephant densities were very low around the training centre, and only a small patch of forest in the middle of the reserve contained sufficient densities to guarantee finding any elephant dung on transects. Contrary to the advice of the survey coordinator, the Somalomo site was selected, which unfortunately had strong negative consequences for the success of the training course, and compromised the future compatibility of data collected during the MIKE program. Only 13 elephant dung piles (none fresh), 14 gorilla nest sites, and no chimp nest sites were found during practical work from 35km of transects and recces, which provided inadequate real experience and no chance for trainers and team members to reach consensus on dung pile age classification, nest identification, and other issues which were to prove important during execution of the surveys and analysis. A similar distance of surveys in the Lopé NP would have probably resulted in some 350-400 elephant dung piles.

Standards attained by team leaders

Early in the training course it became clear that significantly more instruction and practice was required in basic field skills such as navigating with map, compass, and GPS than had been anticipated. This reduced the time devoted to more advanced skills such as transect methodology, and the principles of Distance Sampling. However, by the end of the program, Team Leader standards were judged to be sufficient to enable them all to conduct pilot studies at their respective sites, as a basis for follow-up training. All team leaders were highly motivated, and all worked hard to achieve the maximum in the time available. In future iterations of the MIKE program, initial training of researchers with limited forest experience should be very significantly increased. A period of 6-8 weeks of relatively intense training theory and practical methods implementation and basic data analysis based in region of high elephant density is recommended as a minimum requirement before students begin pilot studies.

Training resources

A MIKE Resource CD was produced for all participants at the end of the training course. The CD was intended to provide a tool kit for MIKE implementation, within a file structure and database management system in which all administration data (accounting, contracts, etc), reporting templates, and other MIKE products could be kept in a systematic way, common across all sites. All methods and protocols were included, an extensive digital library of pdf files including hundreds of scientific papers, books on methods (for example the African Elephant Specialist Group's "Studying Elephants" handbook and White and Edwards "Research methods"), the series of the African Elephant Specialist Group's publication "Pachyderm" in French and English that is available on the internet. Software backups available on the CD included Distance, Gardown and Ozi-explorer GPS download software, GpilotS for transferring data from GPS to handheld computer. Templates for data entry in MS Access and agreed upon field codes and field form structure for recording field observations were provided. Each team was given 2 hard copies of the book "Conservation Research in the African Rain Forests: a Technical Handbook" (White and Edwards 2000a) as a field reference.

Chapter 4: Phase 3 – Site reconnaissance, follow-up training and final survey design development

4.1 Site reconnaissance

Site reconnaissance surveys (pilot studies) were conducted in Nouabalé-Ndoki, Boumba Bek, Dzanga-Sangha, and Bangassou (Figure 8). The goal of the MIKE pilot studies was 2-fold: 1) to enable team leaders to put skills learned on their training courses into practice, learn from mistakes, and refine their field procedures accordingly, and 2) to provide data on elephant dung encounter rates from which to design the final MIKE surveys. In Minkebe and Salonga pilot studies were not completed because both sites were so large that pilot studies were prohibitively expensive, and in Minkebe, some data on elephant abundance existed already from the MIKE Pilot Program of 2001. Furthermore, the MIKE team leader in Minkebe was an experienced field researcher, having been through an intensive field training for MIKE personnel in 1999, and had just completed a Diploma at the Garoua Forestry School, Cameroon.

In Salonga, a short transect survey had been conducted by (Van Krunkelsven et al. 2000) primarily to determine bonobo distribution, but which had provided an impression of elephant dung pile abundance. Their data and the experience of the MIKE Technical Assistant, Inogwabini Bila-Isia, who had spent more than 5 years in Salonga, was used to guess encounter rate of elephant dung piles. In the Nouabalé-Ndoki, a pilot study of the park was completed, but in the buffer zone (Mokabi logging concession) an intensive reconnaissance study 1 year previously had provided an indication of the dung encounter rate to expect. Encounter rates generated from the pilot studies are shown in Table 5 below.

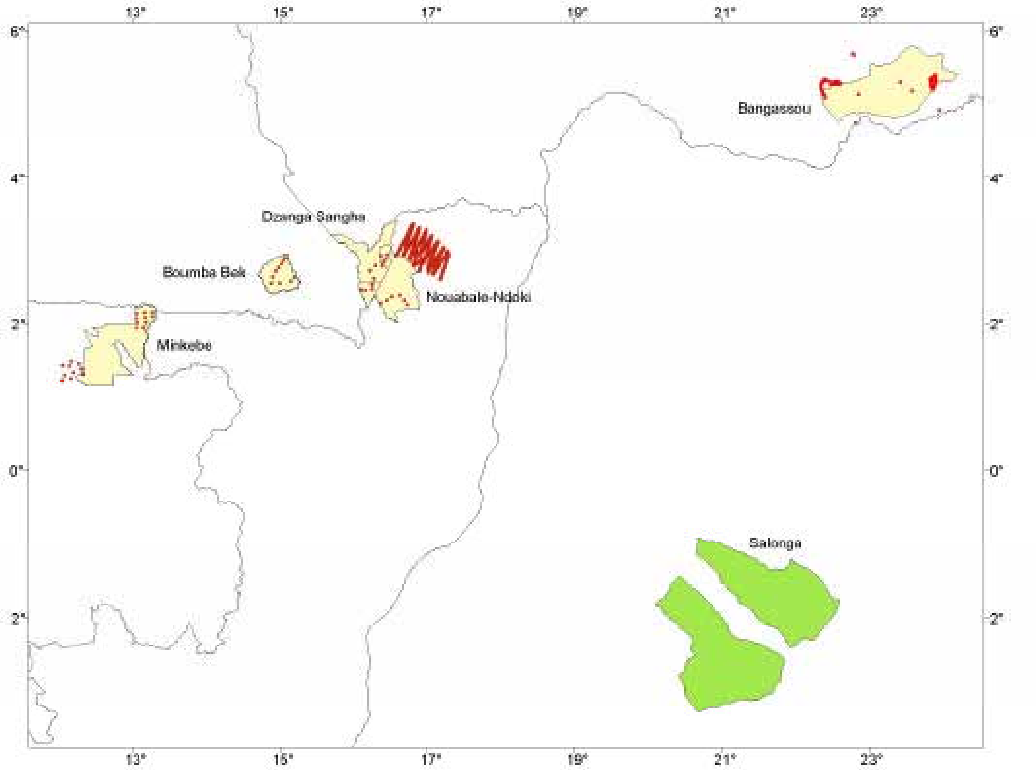
Table 5. Elephant dung encounter rates generated from pilot studies, stratification, and effort allocation

Zone/stratum	Mean dung n/L (piles/km)	Variance (n/L)	Estimated dispersion parameter (b)	Km of transects required for 25% CV	Km of transects in final design
NNNP buffer zone	1.8	6.51	3	27	46
Boumba Bek	3.1	42.54	3	16	47*
Dzanga-Ndoki	10.3	20.92	3	5	7.5
Dzanga-Sangha	4.8	14.92	3	10	26
Minkebe North	12.4	83.38	3	4	20
Minkebe south	15.5	82.94	3	3	16
Minkebe buffer zone	*3*	-	*3*	*16*	*25*
NNNP	6.8	18.97	3	7	25
Dzanga-Sangha Reserve	1.8	1.58	3	27	24
Salonga high impact	*0.5*	*?*	*3*	*96*	*95*
Salonga Low Impact	*1*	*?*	*3*	*48*	*54*

Italics indicates that pilot studies were not carried out in these strata. * In Boumba Bek, the sample size was increased beyond that necessary to achieve a target precision of 25% for the elephant abundance estimate, because the site managers were particularly interested in surveying ape populations in addition as elephants, and were keen to have a 25% CV on the gorilla abundance estimate.

At the Bangassou site, a pilot reconnaissance survey was carried out in which 65km of recces and 3km of transects were completed, the transects at a distance of at least 25km form the nearest village site (Williamson and Maisels 2004). The majority of sign recorded was of human activity and elephant sign was low with only one dung pile recorded from the entire survey. Based on these results an un-biased survey to estimate elephant abundance could not be recommended, and a more intense follow-up survey was designed from which it was hoped a better understanding of the abundance and distribution of Bangassou elephants could be obtained from which to design a future MIKE inventory of abundance.

Figure 8. Pilot studies and data source surveys used to define final survey designs



4.2 Follow-up training

Unfortunately, due to a lack of funding, a follow-up training workshop after the pilot studies did not take place as had been planned, which due to the limited experience of field teams, was a considerable blow to the programme. A period of consolidated exploration of data, discussion of constraints and difficulties encountered during surveys from technical to logistical issues, followed by retraining and revision of goals would have been highly productive. In place of the workshop, a series of site visits were made to each of Salonga, Boumba Bek, Nouabalé-Ndoki, and Dzanga-Sangha by the assistant coordinator, which included a meeting of team leaders from the latter three of these sites. While not a satisfactory solution, this was all that was possible within the limitations of a fluctuating and unstable budget at that time. Pilot study data appeared to have been well collected and managed, and the decision was made to proceed to the full-scale surveys after designs had been finalized and approved by the TAG.

4.3 Final survey design

Surveys in all sites with the exception of Bangassou were designed using the "systematic segmented trackline sampling" option of Distance 4.1 (Thomas et al. 2003). This design typically provides the most even sampling coverage probability of any of the built-in Distance survey designs (S. Strindberg, pers. comm.). In this program, GIS shapefiles of the study area and strata for each site were generated in ESRI Arcview and imported into Distance 4.1. The number of transects in each stratum is set by the user as is transect length and orientation. Transect length was set to a length of 1km which assured high replication across all sites, with the exception of Dzanga-Sangha, where in the high elephant density stratum, transect length was 0.3km. This was because the predicted encounter rate indicated that only 6km of transects was required, and top ensure adequate spatial coverage, more but shorter transects were required. The program was constrained to generate only complete transects (rather than splitting a transect that falls on a boundary into two dispersed segments) which reduces the logistical burden but does slightly bias coverage probability. On the advice of the TAG (Dr. Ken Burnham), this bias was considered negligible and ignored.

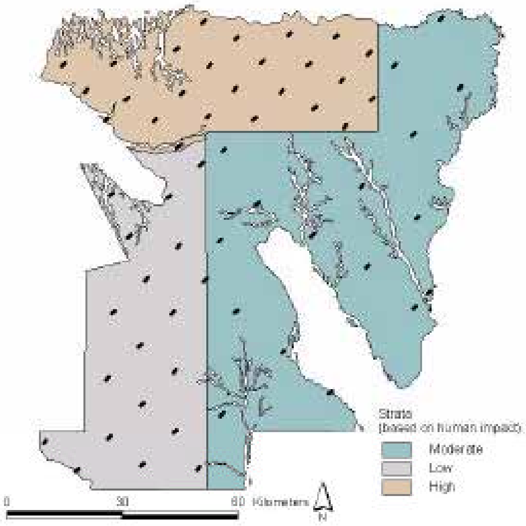
Survey designs were discussed with site-based managers for their relevance to their impressions of the extent and distribution of the elephant population, and with regard to the feasibility of implementation. Before start-up all survey designs were proofed by Dr. Sam Strindberg, the WCS statistician and then passed onto Dr. Ken Burnham, MIKE TAG member with distance sampling skills, for final comment, revision, and approval.

The geographic display of final designs and summary statistics are shown in Figure 9 and Table 6.

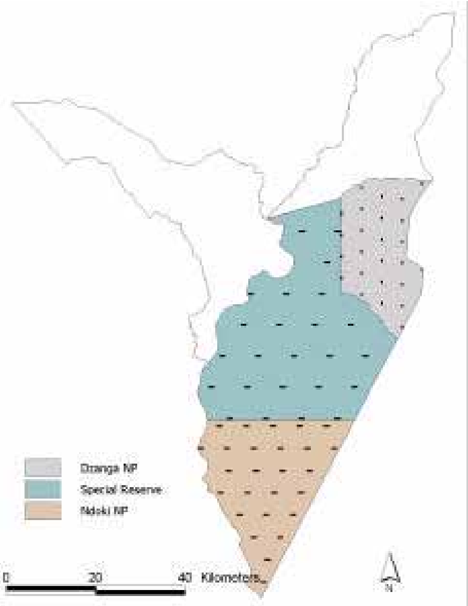
Table 6. Summary of survey effort in each MIKE site

	Surface area (km^2)						
MIKE site	Protected areas	Survey zone	Stratum (based on human impact)	Stratum area (km^2)	N transects	Transect length	Total transect length
Boumba Bek	2383	2383	Reserve	2383	47	1	47
Minkebe	7338	9320	Low impact (within NP)	2514	16	1	16
			Medium impact (within NP)	4505	20	1	20
			High impact (outside NP)	2301	25	1	25
Salonga	34898	25140	Low impact (within NP)	14704	54	1	54
			High Impact (within NP)	10437	95	1	95
Nouabalé-Ndoki	4220	7821	Low impact (NNNP)	3991	25	1	25
			High impact (Mokabi UFA)	2669	45	1	45
Dzanga-Sangha	2293	2554	Low impact (DNP)	499	25	0.3	7.5
			Medium impact (NNP)	746	26	1	26
			High impact (SR)	1309	24	1	24
Bangassou	12011	N/A	N/A		-	-	-
	63143			46058	402		384.5

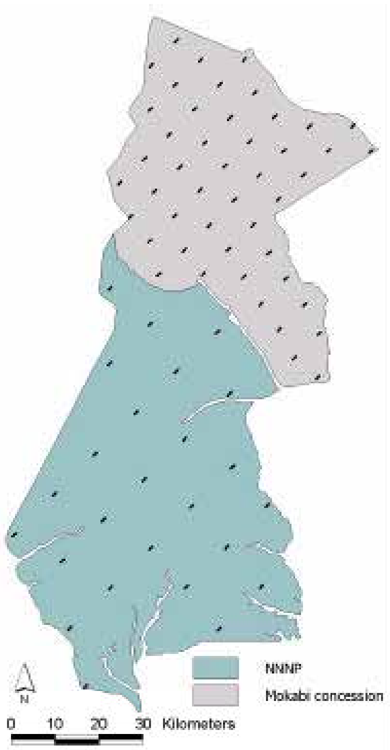
Figure 9. Final survey designs for MIKE forest elephant inventories



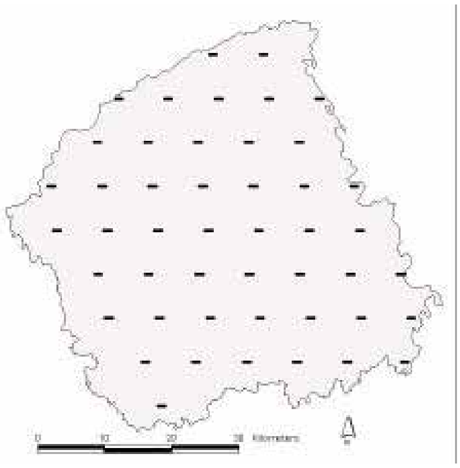
a) Minkebe



b) Dzanga-Sangha

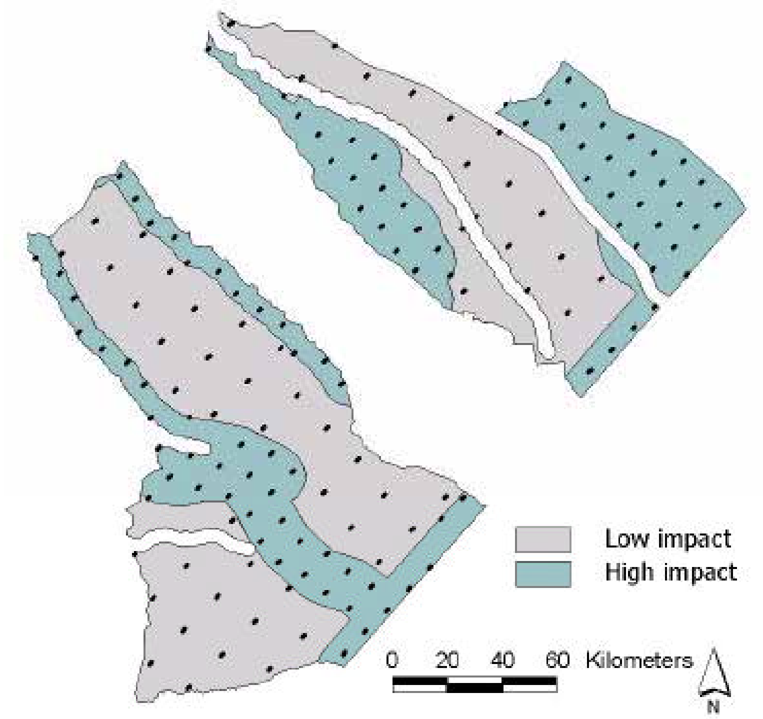


c) Nouabalé-Ndoki

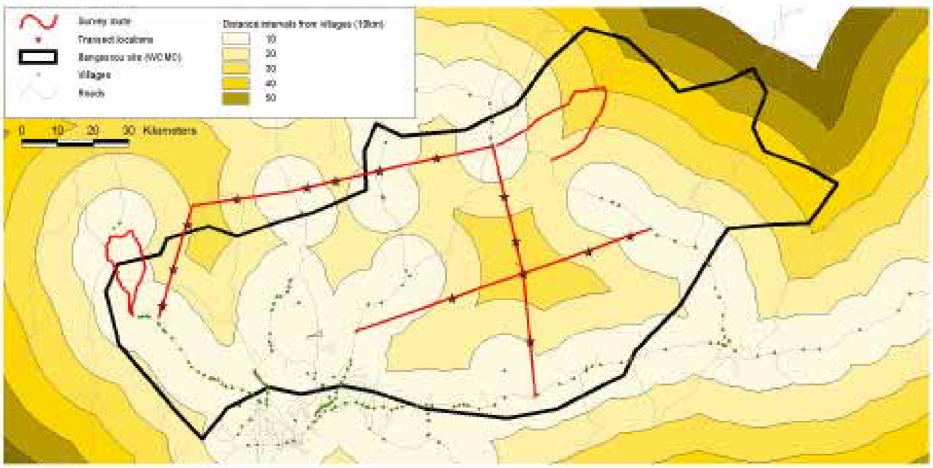


d) Boumba Bek

Figure 9 contd.



e) Salonga



f) Bangassou

Chapter 5: Phase 4 – Field surveys and data management

5.1 Survey implementation

Full reports from each site are provided as annexes to this report, and here only a summary of major results is presented. Final field methods are provided in the Annex.

Mechanics of implementation

Field surveys in all sites with the exception of Nouabalé -Ndoki took considerably longer than had been planned, with the cause varying between sites. By far the greatest investment in effort went into Salonga, which was both the most remote site, and the site with the least logistical and administrative support. In Salonga, the MIKE team had to be self-sufficient and autonomous from the park authorities, which presented some considerable logistical challenges. The Salonga base camp was set up in the village of Monkoto, a large village in the western sector of the Salonga area, between the two national park segments. The village is some 3-4 days up river by dugout canoe from the Congo River. Boats, outboard engines, fuel drums, fuel, and spares all had to be purchased and manned. No storage facilities existed in Monkoto, and field teams negotiated with local authorities and villagers for rented storage space. There was no generator for powering computers, nor a functional office in which to keep electronic apparatus, and no radio with which to communicate with bases in Kinshasa and Mbandaka. Thus radios, generators, solar panels, and a host of other essential equipment was purchased and transported to the park. Survey teams organized this, hired boat drivers, storekeepers, and camp guards. In the absence of housing, field teams constructed a small, tented field camp under tarpaulins near the ICCN HQ in Monkoto which served as their base for the following year. Finally and despite the initial period of discussion and negotiations at village level, and with local authorities, there were numerous problems from these groups in allowing MIKE teams to operate in the forest. In some cases village chiefs prohibited teams to enter "their" forest, at other times, local authorities did the same. On several occasions, known elephant poachers, who were obviously against MIKE presence in the region, seriously threatened MIKE teams with violence if they went into the forest. It is a tribute to the

Salonga Team Leaders persistence (and bravery) that they were able to find ways round these obstacles.

Bangassou offered some similar challenges, with limited support available from CECI due to their funding crisis. Two issues however were responsible for delays in Bangassou. First, an extensive survey of the area was not possible during the dry season, when many of the smaller rivers dry up and water is unavailable across much of the zone. Second, The threat of danger posed by armed Sudanese and Chadian poachers was very real, and when they were in the area, the risk to unarmed field teams was too high to take. By contrast, in all other sites, there were functional protected areas management infrastructure, staff, and administrations, which rendered MIKE implementation considerably easier than Salonga and Bangassou. At these sites boats and vehicles could be hired by MIKE, office space was provided, local staff were known and made available, and all of the administrative functions of the conservation projects were mobilised to help complete the surveys.

With the exception of Bangassou, the time taken to complete the surveys was disappointing (see Table 7) which was mostly due to extended periods of down time between surveys. Rapid survey implementation was important for several reasons. First, elephants may undergo strong seasonal movements, which shift their local areas of concentration, and therefore surveying over a short time frame would reduce bias due to distribution shifts. Second, the factors that control dung decay (White 1995, Barnes and Dunn 2002)and possibly defection (Ruggiero 1992), are seasonal, thus completing a survey under similar climatic conditions would reduce bias. Third, the target date for completion of all analysis and reporting of MIKE results was COP 13 scheduled for October 2004. Fourth, and not least, funding was extremely tight for these surveys, and more time spent conducting surveys the more costly the program became due to salaries and other operations costs. In most cases, field projects helped cover the costs of field teams when they over-extended time to survey completion.

Table 7. Survey implementation details

Site	Start date	End date	Total Days	Field days	Field days as % of total days	N teams	Length of recce surveys (km)	N transects completed
Boumba Bek	8-Oct-03	10-May-04	215	71	33	1	473	47
Dzanga-Sangha	16-Aug-03	30-Apr-04	258	87	34	2	383	75
Minkebe	30-Jul-03	25-Jun-04	331	113	34	1	659	60
Nouabalé-Ndoki	24-May-03	14-Dec-03	204	93	46	2	732	71
Salonga	23-May-03	5-Jul-04	409	160	39	2/4	1727	130
Bangassou	10-May-04	18-Jun-04	39	39	100	2	505	14
Total			1456	563			4479	397

Chapter 6: Phase 5 – Data analysis and reporting

6.1 Analysis and reporting workshop

A data analysis and reporting workshop for team leaders from all MIKE forest elephant survey sites (see list of participants in Table 8) was held at the WCS training centre near the Lopé National Park, Gabon, between 1 July and 15th August 2004. The workshop was divided into 3 themes; data management, data analysis, and reporting (Table 9).

Table 8. Workshop participants

Name	MIKE site	Country	Affiliation	Status
Omari Ilambu	Salonga	DRC	WCS/ICCN	Team Leader
Mbenzo Pupa	Salonga	DRC	WCS/ICCN	Team Leader
Falk Grossmann	Salonga	DRC	WCS	Team Leader
Bruno de Semboli	Dzanga-Sangha	CAR	WWF/MEFCEPT	Team Leader
Rosine Bayogo	Bangassou	CAR	CICI/MEFCEPT	Team Leader
Patrick Boudjan	Nouabalé-Ndoki	Congo	WCS	Team Leader
Calixte Mokoumbou	Nouabalé-Ndoki	Congo	WCS	Team Leader
Lambert Bene Bene	Boumba Bek	Cameroon	WWF	Team Leader
Marc Ella Akou	Minkebe	Gabon	WWF	Team Leader
Cedric Mouya	Minkebe	Gabon	WWF	Technical Assistant
Stephen Blake	Regional		WCS	Regional Inventory Coordinator
Didier Divas	None		UMD	GIS specialist
Fiona Maisels	Regional		WCS	Training and monitoring specialist

This workshop was the first time that the MIKE survey team had been together since the initial field methods training course in March 2003, therefore the first day was therefore spent discussing each teams progress and achievements of the past year, and finalising the goals and calendar of the workshop. A framework for the final report had previously been developed and sent to all participants, which was refined into a working draft early in the workshop. The definition of report sections, including specific tables, graphs, maps, and analysis products helped orientate the workshop from the start into a series of logical activities aimed at producing the required outputs, which focused the workshop and reduced the time spent on non-essential activities.

Table 9. MIKE analysis and reporting workshop program, July-Aug 2004.

	Goal	Activity	Benchmarks	Led by:
1	Field data cleaned, formatted, backed up, and ready for analysis	Remaining data entry - transects, recces, rainfall.	GPS data integrated with attribute data, including photos, in access and/or excel	Blake, Maisels
		Random verification with field-books	Shape files created including attribute datasets	
		Clean data and format		
		Backup		
2	Spatial datasets from every site available in Arcview	Assemble all available GIS layers into an Arcview Project	Arcview projects created	Blake, Maisels, Divas
		- roads		
		- rivers		
		- villages and human populations		
		- camps		
		- land-use		
		- logging activity		
		- vegetation		
		- conservation activity (anti-poaching patrols, conservation villages, etc)		
3	Exploratory data analysis complete	Encounter rates of selected variables on transects and recces from excel data	Encounter rate tables and graphs for recces and transects.	Blake, Maisels
			Elephant dung	
			Elephant encounters (sightings and vocalisations)	
			Ape nests	
			Ape encounters	
			Humans - all sign and broken down into category	
			Elephant carcasses	
			Other large mammals	
4	Site level abundance estimates for elephants and apes	Basic Distance analysis	Abundance estimates with confidence intervals	Blake
5	Covariate values for spatial data attributed to transects at all sites	Spatial analyst used to generate covariate surfaces across landscapes	Dependent/independent variables tables generated compatible with requirements for spatial modelling	Blake
6	Site level reports drafts	Report writing	Draft reports English and French	Blake, Maisels
		Drafts sent to site managers and Luhunu		
		Comments back		
7	Final reports completed	Report writing	Final reports	
8	Reports available to wildlife directors			

The first major exercise for every field team was entering remaining field data in either excel or access, archiving in Access, backing up data to CD and to an external hard drive. Field teams varied considerably in their level of preparation for the workshop. The Nouabalé-Ndoki team, the most experienced field researchers in the group, finished their survey several months previously and their data was cleaned and archived coming into the workshop. Teams from Minkébé and Salonga had just finished the survey, and had only entered about 1/3 of their data into the custom-built MIKE Access data entry form. In the case of the Salonga team, the first 3 weeks at least was spent entering and organising data, while the Minkebe team only completed data entry at the end of the workshop, leaving no time for data analysis and reporting from that site. At the Boumba Bek site, cyber-trackers (field computers with data logging software) were used throughout the survey, which considerably reduced the time needed for data entry, cleaning, and verification.

Insufficient training time was given to data entry and basic management however some team leaders had not applied sufficient effort toward data entry and learning basic computer skills. During fieldwork, MIKE team leaders were encouraged to take time while physically recuperating between field missions to enter data from the previous mission, and provide copied data on CD to the MIKE site officer, local management authority, and the MIKE coordinator, and not go back to the field until this had been completed. This has the duel benefit of backing up and archiving data, and also providing timely input to the MIKE hierarchy. Furthermore mistakes in methodology and data collection could have been found promptly and rectified had the coordinator had punctual access to the datasets as they were being collected. Unfortunately, in most cases this important step was not implemented.

Site-level reports were produced by teams from Nouabalé-Ndoki, Boumba Bek, Salonga, Bangassou, and Dzanga-Sangha, which are presented in the Annex section following this report. The following Chapter provides a regional summary of the major results of the surveys, and ends with a set of conclusions on the current status of elephants in the MIKE sites and overall progress made during these surveys to the MIKE goal and objectives.

Chapter 7: Summary of results

7.1 Elephant dung abundance

Field data conformed well to the assumptions of Distance sampling in three sites (Minkebe, Nouabalé-Ndoki, and Dzanga-Sangha), and valid dung density estimates using Distance 4.1 were possible. In the case of Salonga, field data were well collected and detection curves fitted the data extremely well (see site-based report), however the sample of observations (dung piles) after truncation was only 35, which is lower than the recommended minimum of 60-80 data-points for valid analysis (Buckland et al. 1993). Distance analysis was precluded for the Boumba Bek dataset due to data collection errors, with a severe rounding problem rendering fitting a detection function to the data invalid. However an attempt was made to correct for this problem and produce an order of magnitude density estimate as explained below. In Bangassou, dung density estimates were impossible due to a very small sample size of dung.

Elephant dung density varied over three orders of magnitude across the suite of MIKE sites (Table 10). By site, Salonga contained the lowest estimated dung density, with an average across the site of just 91.6 piles km^{-2}, more than 6 times lower than that recorded in any other site with the probable exception of Bangassou, with an 0.5 piles km^{-1}. Dung density was highest in Minkebe– indeed the density within the Minkebe National Park, was 60 times greater than that in Salonga NP, and 5.7 times greater than that in the Nouabalé-Ndoki National Park. Among national park sectors of MIKE sites, Nouabalé-Ndoki and Dzanga-Ndoki contained comparable dung densities with estimates of 1136.1 piles km^{-2} (NNNP), 1114.2 piles km^{-2} (Dzanga NP), and 960.4 piles km^{-2} (Ndoki NP). Within the Salonga site, there was little difference in dung density by stratum with 92.4 and 90.2 piles km^{-1} in the low and high human impact strata respectively. In Boumba Bek, a valid dung density estimate for the site was not possible due to methodological problems discussed later in this report. However dung encounter rate, at 2.4 piles km^{-1} suggested that density was relatively low compared to the other protected areas surveyed with the exception of Salonga.

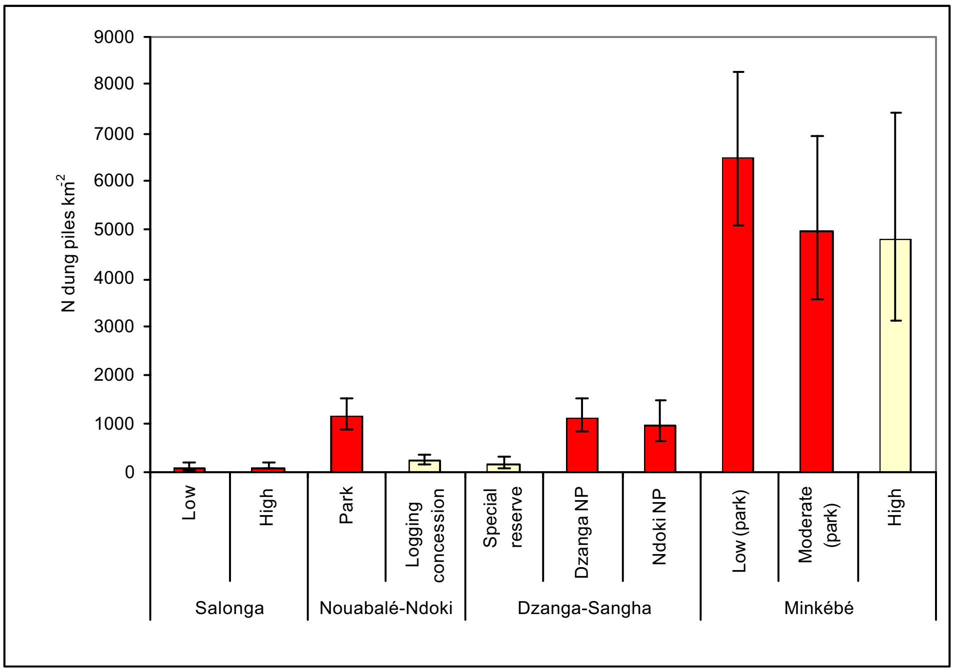
In MIKE sites in which sampling occurred both inside and outside of national parks, elephant dung density was consistently higher inside parks compared to peripheral strata outside the parks (Figure 10 and Table 10). In Nouabalé-Ndoki, dung density in the national park was 4.7 times higher that that in the Mokabi logging concession, while in Dzanga-Sangha, dung density within the Special Reserve was 6.4 times lower than the mean value within the 2 national park sectors. Within the Minkebe site, the dung density across the two park strata was 5461.8 plies km $^{-2}$, and 4807.8 piles km $^{-2}$ in the unprotected stratum to the northwest of the park. The survey zones in Salonga and Boumba Bek did not extend beyond reserve borders so protected area versus the exterior are unavailable.

Table 10. Summary results of elephant dung density by stratum and site from line-transect surveys

Site	Stratum	n dung piles observed	f(0)[1]	P[2]	ESW[3]	n/L (piles km^{-1})[4]	Dung density (km^{-2})	% CV	95% Confidence Interval Lower	Upper
Salonga	Low human impact	16	0.6362	0.6164	1.572	0.29	92.4	38.7	43.9	194.4
	High human impact	20				0.28	90.2	33.3	47.4	171.6
	Combined	**36**					**91.6**	**29.8**	**51.4**	**163.3**
Nouabalé-Ndoki	NNNP	208	0.0273	0.4882	366.2	8.32	1136.1	13.9	856.5	1506.9
	Logging concession	82				1.8	243.4	23.3	153.4	386.2
	Combined	**290**					**778.3**	**12.7**	**602.2**	**1006**
Dzanga-Sangha	Special reserve	36	0.0225	0.3052	442.5	1.4	162.7	30.8	87.5	302.6
	Dzanga NP	71				9.9	1114.2	14.6	827.2	1500.7
	Ndoki NP	221				8.5	960.4	21.5	620.3	1486.9
	Combined	**328**					**581.7**	**12.9**	**449.5**	**752.8**
Minkebe	Low human impact (park)	306	0.0679	0.2609	147.2	19.1	6498.3	11.6	5106.8	8269
	Moderate human impact (park)	243	0.0808	0.2192	123.6	12.3	4980.9	16.3	3557.6	6973.5
	High human impact	398	0.0604	0.2935	165.56	15.9	4807.8	21.5	3112.9	7425.6
	Combined	**947**					**5347.6**	**9.5**	**4417**	**6474**
Boumba Bek		115				2.4	-	-		
Bangassou		7				0.5	-	-		

[1] Value of probability density function at a perpendicular distance of zero for line transects
[2] Probability of observing an object in defined area
[3] Effective strip width of line transects
[4] n/L Encounter rate of elephant dung piles

Figure 10. Elephant dung density by MIKE site and survey stratum (National Park sectors in red)



Elephant abundance

Estimates of elephant abundance from dung density were crude because no on-site data were available for either elephant defecation rate or dung pile decay rates, necessary for valid conversion of dung pile density to elephant density (Barnes and Dunn 2002). In the absence of site-based data, for the purposes of this analysis, defecation rate and mean dung decay time at all sites was set at 19 dung piles per day, and 90 days respectively. No variance or confidence intervals were associated with these values since they were based on informed guesses rather than field data. Elephant density estimates from Distance analyses are shown in Table 11. This output suggests that of the four national parks inventoried, only two (Minkebe and Nouabalé-Ndoki) contains over 1000 elephants. Minkebe NP itself may contain on the order of 20,000 elephants, while the Nouabalé-Ndoki was estimated to hold 2652 elephants! However, given that they are contiguous in space, the Nouabalé-Ndoki-Dzanga-Ndoki Complex of national parks may contain ca. 3400 elephants in a single population. In Boumba Bek, the dung encounter rate from transects suggests an elephant density of ca. 0.133 km $^{-2}$, and a crude estimate of 318 elephants in the reserve (Table 11 and explanation below).

Table 11. Elephant dung pile density and crude elephant abundance estimate

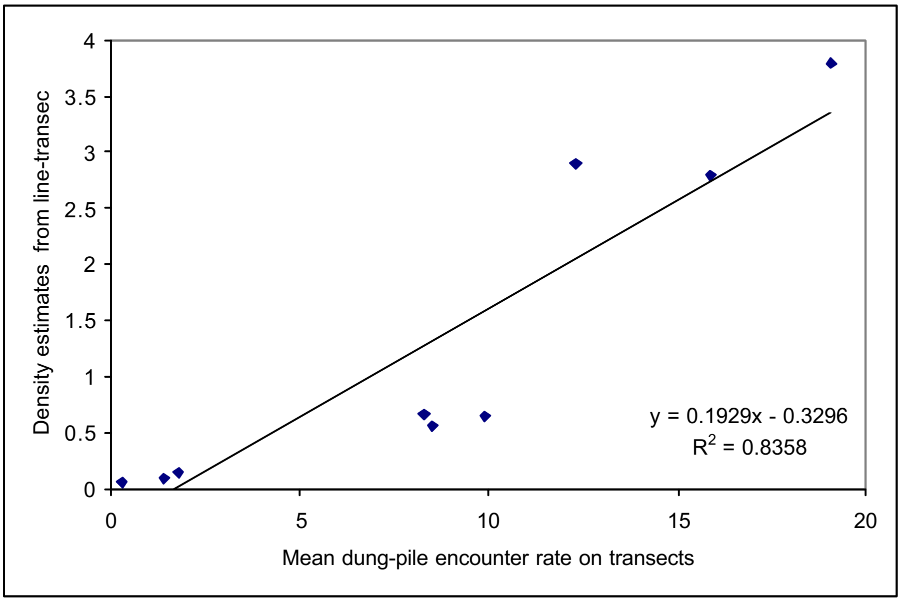
Site	Stratum	n/L (piles km^{-1})	Dung (km^{-2})	% CV	Elephant density	N elephants	95% CI min.	95% CI max.
Salonga	Low	0.3	92	38.7	0.054	794	377	1672
	High	0.3	90	33.2	0.053	392	206	746
Nouabalé-Ndoki	Park	8.3	1071	13.3	0.66	2652	1999	3517
	Logging concession	1.8	229	22.9	0.14	380	239	603
Dzanga-Sangha	Special reserve	1.4	163	30.8	0.095	125	67	232
	Dzanga NP	9.9	1114	14.6	0.651	325	241	438
	Ndoki NP	8.5	960	21.5	0.561	419	271	649
Minkebe	Low (park)	19.1	6498	11.6	3.8	9556	7510	12160
	Moderate (park)	12.3	4981	16.3	2.9	13122	9372	18371
	High	15.9	4808	21.5	2.8	6469	4188	9991
Boumba Bek		2.4	-	-	0.133*	318*	-	-
Bangassou		0.5	-	-	-	-	-	-

* This crude estimate was calculated by estimating dung density from encounter rate encounter rate and dung density estimate from all strata in Minkebe, Nouabalé-Ndoki, Dzanga-Sangha, and Salonga, and applying the relationship to the encounter rate for Boumba Bek. The relationship between encounter rate and dung density estimate was given by the formula y = 0.193x −0.330 (R = 0.836). This assumes that the characteristics of the detection curve for Boumba Bek was notwildly different from other sites (see explanation below).

Dung density estimate for Boumba Bek

When mean dung pile encounter rate on line-transects was plotted against the mean encounter rate on travel recces on a stratum-by-stratum basis, a significant positive correlation was found (Figure 11. Spearman’s rho: 0.914, n = 10, P = <0.001). Under the assumption that there were not significant differences between observer ability in Boumba Bek and other sites, this relationship was used to convert the dung pile encounter rate into dung density. This is clearly an extremely crude estimation, but does provide an order of magnitude appreciation of dung pile density and elephant abundance.

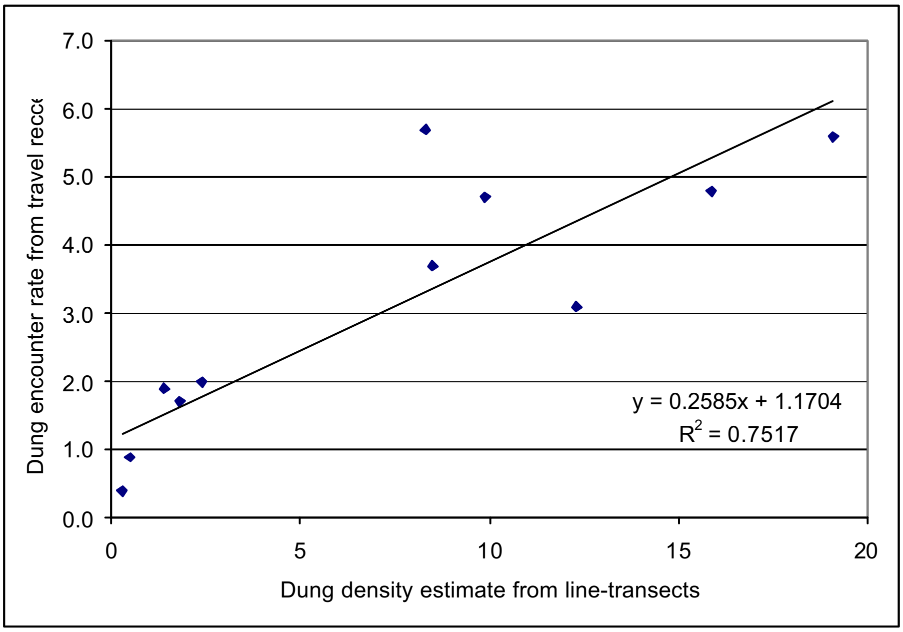
Figure 11. Relationship between mean dung pile encounter rate and estimated mean dung pile density in transects across MIKE survey strata



Elephant dung encounter rate on travel-recces

The results and interpretation of travel-recce data in relation to elephant abundance and distribution is discussed in considerable detail in site level report. For the purposes of this regional summary report, it is important to note that a strong positive correlation existed between elephant abundance as estimated from line-transects and travel recces on a stratum-by-stratum basis (Figure 12. Spearman's rho: 0.865, n =12, P < 0.001). Particularly low encounter rates were recorded in the Salonga NP, to a maximum of 5.7 piles km^{-1} in the Nouabalé-Ndoki NP. The strong correlation across sites and observers suggests that travel- recces may have some value in estimating the status of elephant populations in central African forests when budgets and time are limited as was originally argued in the "Poor Man's Guide to Counting Elephants" (Barnes 1989a).

Figure 12. Relationship between dung encounter rate recorded on transects and travel-recces.



7.2 Human sign abundance

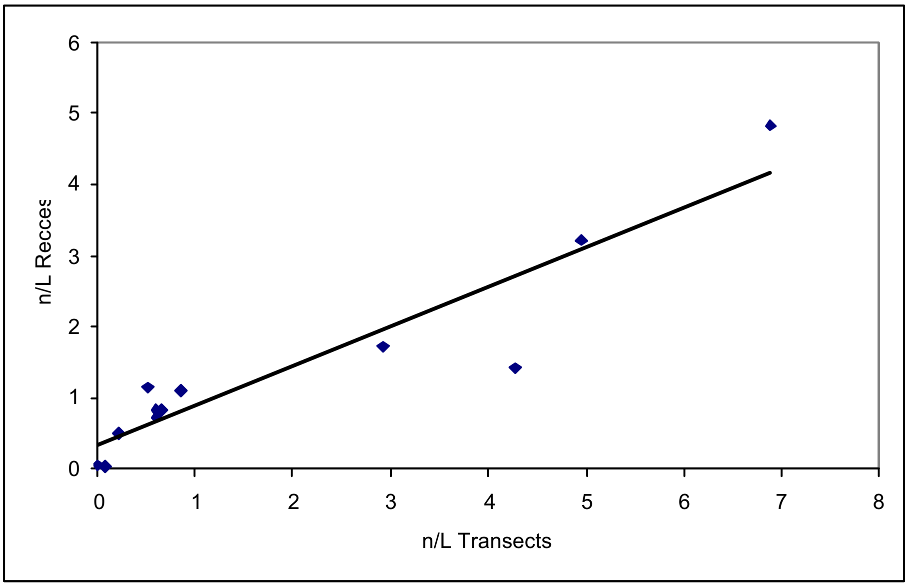
Across the suite of MIKE sites, four survey strata were outstanding for their high abundance of human sign recorded on line transects; the Dzanga-Sangha Special Reserve, the DNP and NNP, and the Mokabi logging concession (Table 12), with sign encounter rates of 6.89, 4.28, 2.92, and 4.96 signs km^{-1} respectively. These four strata in two MIKE sites form, along with the Nouabalé-Ndoki National Park, a single contiguous forest block. In all other strata throughout the suite of MIKE sites, human sign encounter rates were below 1.0 km^{-1}. In the DNP an unknown but probably significant proportion of the human sign was made by researchers and park guards, thus overestimated the index of human impact when using human sign as an index of threat. In contrast, 2 strata had exceedingly low human sign abundance, the Nouabalé-Ndoki and Minkebe National Park low human impact stratum (Table 12), In the Minkebe low impact stratum not a single human sign was recorded on 16km of transects. A similar pattern was seen in the encounter rates recorded on recce-voyages – with just 1 human sign recorded every 25km of travel recce. In all other strata human sign was relatively common, even in the heart of established national parks.

There was a significant positive correlation between human sign encounter rate on transects and travel-recces (Figure 13. Spearman's rho: 0.940, n = 12, P <0.001) indicating that travel-recces may provide a valid estimate of the level and distribution of human activities in forests.

Table 12. Summary data on human sign abundance by site and stratum on transects and on recce-voyages.

Site	Stratum	Encounter rates					
		All human sign TRANSECTS	All human sign RECCE-VOYAGES	Hunting camps	Elephant hunting camps	Snares	Shotgun shells
Boumba Bek		0.60	0.82	0.03	0.00	0.14	0.00
Nouabalé-Ndoki		3.24	1.36	0.07	0.02	0.30	0.29
	NNNP	0.08	0.03	0.00	0.00	0.00	0.00
	Mokabi	4.96	3.22	0.17	0.04	0.72	0.69
Dzanga-Sangha		5.10	2.62	0.34	0.00	0.47	0.38
	SP	6.89	4.84	0.59	0.00	0.47	0.32
	NNP	2.92	1.72	0.39	0.00	0.63	0.61
	DNP	4.28	1.42	0.15	0.00	0.41	0.35
Minkebe		0.32	0.51	0.05	?	0.02	0.08
	High impact	0.60	0.72	0.10	?	0.03	0.04
	Moderate impact	0.21	0.51	0.04	?	0.00	0.00
	Low impact	0.00	0.04	0.01	?	0.00	0.00
Salonga		0.76	1.00	0.14	0.02	0.20	0.00
	Low impact	0.65	0.83	0.10	0.03	0.12	0.00
	High impact	0.85	1.10	0.27	0.03	0.26	0.00
Bangassou		0.50	1.14	0.11	0.00	0.06	0.33

Figure 13. Relationship between human sign encounter rates recorded on transects and recces by stratum across all MIKE sites



Evidence of illegal killing of elephants was recorded in every MIKE site, including within the limits of national parks (Table 13). Carcasses of elephants confirmed as having been poached were found in every site, with the highest number of carcasses, 19, recorded in Minkebe. Paradoxically, Minkebe also contained the highest absolute number and highest density of elephants of any MIKE site surveyed. However, the highest encounter rate of carcasses on reconnaissance surveys was recorded in Dzanga-Sangha, with 6 poached carcasses found during 383 km of recces (Table 13), for an encounter rat of 1.57 poached carcasses per 100km of travel-recce walked. The Minkebe site was ranked second with a poached carcass encounter rate of 13.7 per 100km. One carcass was found on a line-transect in Boumba Bek, however none were found in Boumba Bek during recces. There are two possible reasons for this; 1) elephant poaching rates are low and carcasses are rare, 2) Methodological differences in reconnaissance survey style at Boumba Bek reduced the probability of finding carcasses at this site compared to the other sites, which is discussed below.

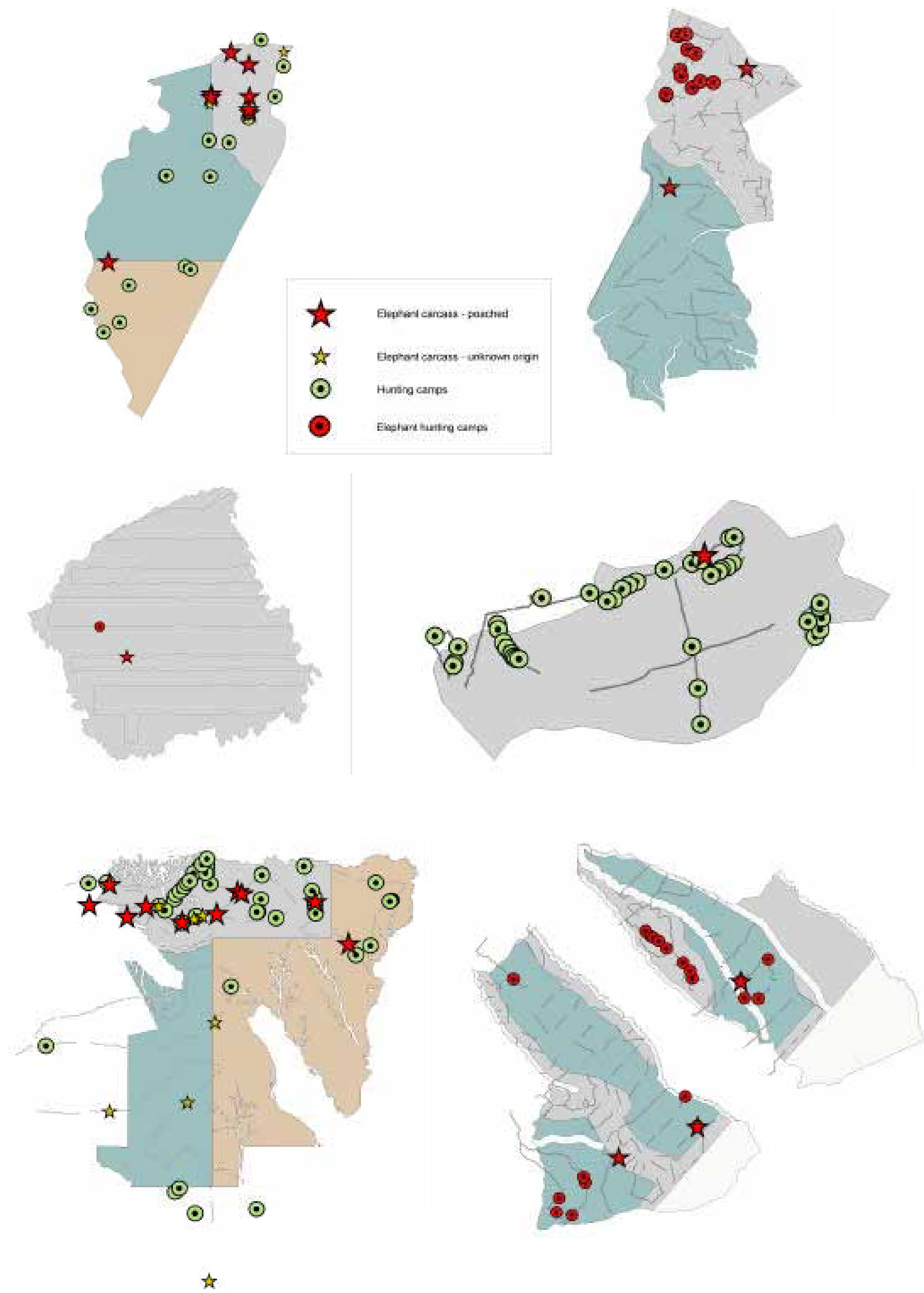
The distribution of positive signs of elephant poaching varied between sites (Figure 14). In Minkebe and Nouabalé-Ndoki confirmed poached carcasses were extremely rare, with just one carcass in each national park, and both parks appear to be relatively secure from heavy poaching, while data suggests that their peripheral areas are experiencing a relatively high intensity of poaching. The opposite trend was recorded in Dzanga-Sangha, where all but 1 of the 9 poached elephant carcasses were inside or within 2km of the Dzanga National Park, the stratum which contained the highest density of elephants at the site. This carcass distribution suggests that elephant hunters are targeting the area containing the highest elephant abundance, despite the fact that it is a protected area. Just three poached elephants were found in Salonga and one in Bangassou.

Hunting camps were recorded in every site and in every national park, though elephant camps were positively identified in just three of the six sites (Nouabalé-Ndoki, Salonga, and Boumba Bek). It is often difficult to positively identify elephant poaching camps from other kinds of camp (presence of elephant guns and ammunition), and it is likely that elephant hunters also occupied some of the 'other' camps. Across all sites, 53 confirmed elephant poaching camps and 235 "other" camps were recorded on travel-recces. No elephant poaching camps were recorded in the Nouabalé-Ndoki National Park, while 13 were recorded in the contiguous Mokabi logging concession. Similarly in Minkebe, just 6 out of 45 hunting camps were inside the national park.

Table 13. Summary data of signs of illegal killing of elephants recorded on reconnaissance surveys

Site	Recce effort (km)	N poached carcasses (recces)	Carcass enc. rate (per 1000km)	All carcasses found during inventories	Confirmed poached	Poached as % of all	N confirmed elephant hunting camps	N other hunting camps	Camp encounter rate (per 1000km effort)
Boumba Bek	473	0	0.0	1	1	100	1	15	34
Bangassou	504	1	2.0	3	2	100	0	47	93
Nouabalé-Ndoki	732	2	2.7	3	2	67	13	53	90
Salonga	1727	3	1.7	4	3	75	39	58	56
Dzanga Sangha	383	6	15.7	11	8	73	0	17	44
Minkebe	658.5	9	13.7	19	11	58	0	45	68
Total/mean	4477.5	21	4.7	41	27	67	53	235	64

Figure 14. Elephant carcasses, elephant hunting camps, and other hunting camps

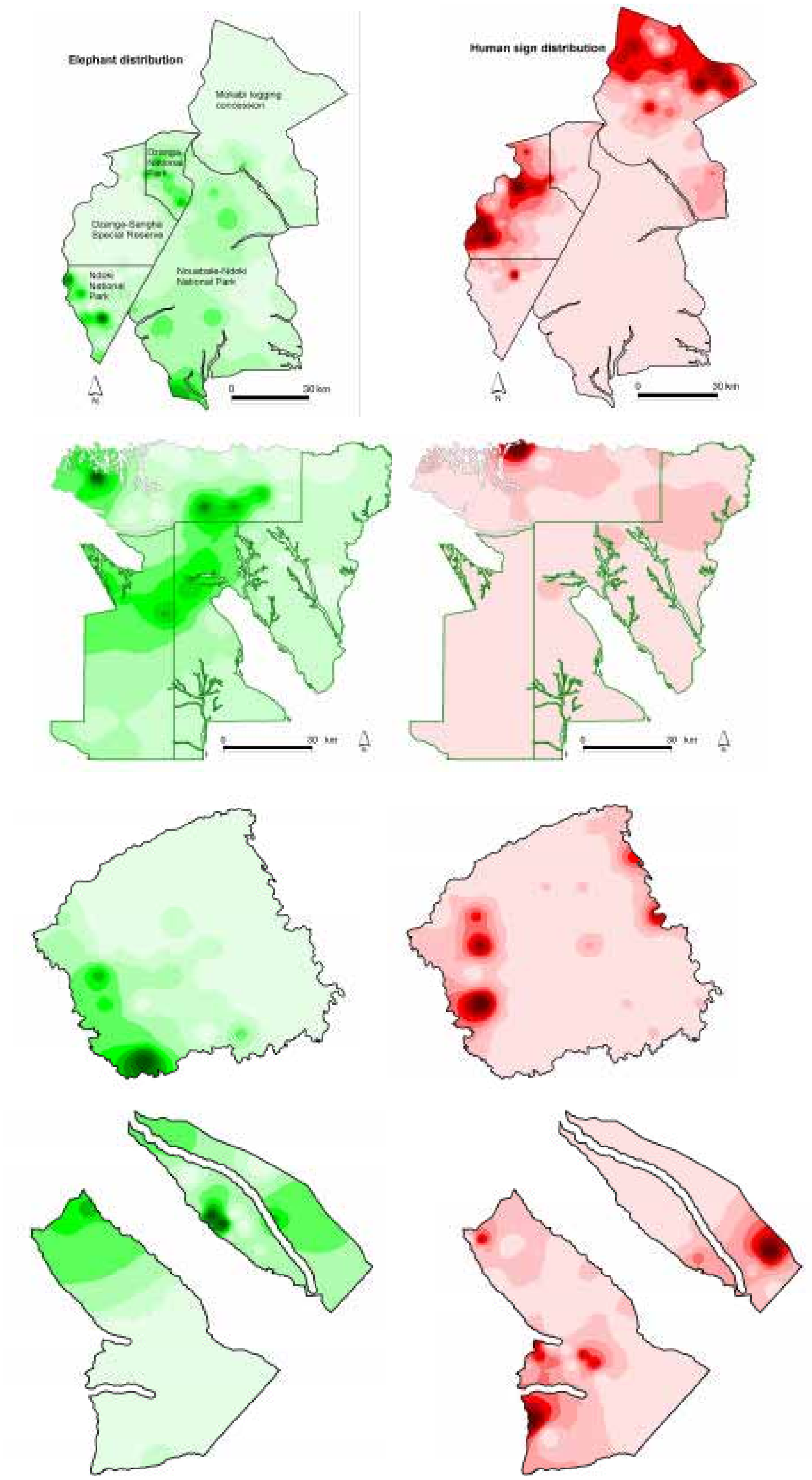


7.3 Distribution of elephants and human activity

Simple interpolation maps based on line-transect data are highly informative of the distribution of elephant dung piles, and therefore of elephants themselves (Figure 15). Figure 15 shows maps generated in ESRI ArcView GIS by interpolating encounter rates on line-transects across MIKE survey areas. In sites where there were sufficient data to construct reliable interpolation maps (Dzanga-Sangha, Nouabalé-Ndoki, Boumba Bek, and Minkebe) two main trends were clear; 1) elephant dung abundance and human sign abundance were highly negatively correlated, 2) as a consequence of 1, elephant density was highest in the most remote areas of each site including national parks (Figure 15 below). In the Nouabalé-Ndoki/Dzanga Sangha complex, elephants were largely confined to the national parks, with elephants largely absent from the Dzanga-Sangha Special Reserve, and from the northern sector of the Mokabi logging concession (Figure 15). Elephant distribution was the mirror image of human sign distribution in this extended landscape, and the interpolation map shows clearly the edge of elephant range in this site in the upper Mokabi logging concession. Similarly in Boumba Bek Reserve, elephants were found in low density across much of the reserve, with the point of highest concentration to the extreme south, the most remote point from human settlements. In Minkebe, the band of highest elephant density was found in a corridor in the remote centre of the park with the exception of a small area to the northwest in which exceptional dung density was recorded on one transect. Though close to human settlement it is likely that this zone provides a sanctuary for elephants for two main reasons. First, the inter-digitated vegetation types of swamp and terra firma provide excellent feeding habitat for elephants, and second, the deep and complex swamp system makes it difficult to penetrate the area from the north, which discourages poaching.

In Salonga NP the mirror image pattern of human and elephant distribution was less evident from transect data, probably due to the very small dataset of elephant dung. A broad pattern of elephant activity concentrated to the northwest and human activity to the south and east was evident, while the most obvious result from Salonga was the dearth of elephants across the entire survey area. Out of a total of 130 transects completed, the highest dung piles encounter rate recorded on any transect was 6 km^{-1}, well below even the mean encounter rates for the Nouabalé -Ndoki, Dzanga Sangha and Minkebe NPs.

Figure 15. Interpolation maps of elephant and human sign recorded on line-transects



Chapter 8: Summary of results – Great Apes

8.1 Gorillas

Evidence of western lowland gorillas was found in all sites within the range of the species (i.e. absent from Bangassou and Salonga). Gorilla nest group encounter rate was highest in the Ndoki NP sector of the DNNP at 1.04 groups km^{-1}, followed by Boumba Bek, with 0.74 nest groups km^{-1}, the Dzanga sector of DNNP (0.66 groups km^{-1}), and the Mokabi logging concession in the Nouabalé-Ndoki site (0.5 groups km^{-1}). Exceptionally low encounter rates were recorded across the entire Minkebe site, including the national park (Table 14) with only three gorilla nests seen from 60km of line-transects. Group size estimates were unreliable at this site due to the limited number of fresh and recent nest sites, and are included in Table 14 for illustrative purposes.

Table 14. Gorilla nest group encounter rates on transects

Site		Nest group encounter rate (km^{-1})	95% CI lower	95% CI upper	Mean group size	95% CI	Median group size
Boumba Bek		0.74	0.476	1.166			
Nouabalé-Ndoki site		0.48	0.34	0.67	3.5	2.32	2
	NNNP	0.48	0.26	0.88			
	Mokabi	0.5	0.32	0.72			
Dzanga Sangha site		0.8	0.56	1.14	2.7	1.02	2
	Special Reserve	0.58	0.3	1.12			
	NNP	1.04	0.62	1.74			
	DNP	0.66	0.25	1.77			
Minkebe site		0.05					
	Low human	0					
	Moderate human	0					
	High Human	0.12	N/A		2.66	N/A	

1. Confidence intervals are not applied to data from Minkebe since only three gorilla nest groups were found during the entire survey

The limited number of nest groups recorded from line-transects meant that gorilla density was estimated in only two sites: Nouabalé-Ndoki, Dzanga Sangha, in which 34 and 46 nests respectively were recorded. It is recommended that a minimum of 60-80 observations are necessary before a reliable detection curve can be fitted to line transect data (Buckland et al. 1993), therefore these estimates are presented to illustrate the order of scale of the density estimates and abundance of gorillas and should not be interpreted as definitive estimates. In order to covert nest group density to weaned gorilla density, a nest disappearance rate of 50 days was taken from a published study from the Dzanga-Sangha site (Blom et al. 2001), while nest group size was calculated from the MIKE field data using only sites aged in the field as fresh or recent (Table 14 above). Estimated gorilla abundance was 2691 (1794-4063) and 4990 (3046-8175) in the MIKE survey zones of Dzanga-Sangha and Nouabalé-Ndoki respectively (Table 15). The contiguous forest of the Dzanga-Sangha/Nouabalé-Ndoki complex may contain in the order of 7600 gorillas. It should be noted that line-transects were discontinued in swamps, a habitat which may contain very high gorilla abundance (Blake et al. 1995) , and it is likely that the true abundance of gorillas is higher within the MIKE survey zones than these figures suggest.

Table 15. Gorilla density recorded in MIKE sites

					95% CI			95% CI	
Site	Stratum	Total Transect effort (km)	Gorilla density (weaned ind. Km^{-2})	CV (%)	lower	upper	N weaned gorillas	Lower	upper
Dzanga-Sangha									
	Special Reserve	24	0.84	33.39	0.43	1.64	1098	562	2143
	NNP	26	1.49	26.47	0.87	2.5	1115	179	1279
	DNP	7.5	0.96	50.6	0.36	2.56	479	655	1897
Dzanga-Sangha	site	57.5	1.05	20.59	0.7	1.58	2691	1794	4063
Nouabalé-Ndoki	NNNP	25	0.71	35.6	0.35	1.43	2835	1405	5721
	Mokabi	46	0.81	24.44	0.5	1.3	2155	1334	3481
Nouabalé-Ndoki	site	71	0.75	25.07	0.46	1.22	4990	3046	8175

8.2 Chimpanzees and unidentified apes

All nest groups in which a) no ground nests could be found and b) no positive identification as to the species by other means (e.g. dung, hair, prints) could be made, were classified as unidentified ape nests (see methods). Given that very few fresh chimpanzee nests were found which could be positively identified, the majority nest groups were classified as unidentified apes, most of which were probably chimpanzees. Nest group encounter rate was highest at the Nouabalé-Ndoki site, with a mean of 2.14 groups km^{-1} across the site, followed by Boumba Bek (1.75 nest groups km^{-1}) (Table 16). In Dzanga-Sangha, encounter rates were moderate in the NNP, but were extremely low in the Special Reserve and the DNP, an order of magnitude lower than in Boumba Bek, Nouabalé-Ndoki, and the NNP. Unidentified ape encounter rate was still lower at the Minkebe site, with only 0.08 nest groups km^{-1}. Unidentified ape sign was almost absent from Minkebe, with not a single nest seen in the moderate human impact stratum and only 10 nest groups of any great ape species were recorded throughout the entire survey.

Table 16. Summary data on ape nest encounter rates recorded on line-transects by site.

Site			95% CI			
		n/L (nest groups km^{-1})	Lower	Upper	Mean group size	95%ci
Boumba Bek		1.75	1.25	2.44	1.9	0.12
Nouabalé-Ndoki		2.14	1.72	2.65	2.3	0.31
	NNNP	2.16	1.53	3.05	3.0	0.23
	Mokabi	2.13	1.61	2.83	1.9	0.28
Dzanga Sangha		0.87	0.64	1.18	1.8	0.45
	Special Reserve	0.29	0.15	0.56	1.7	0.82
	NNP	1.57	1.13	2.2	1.0	
	DNP	0.27	0.07	0.97	1.9	0.53
Minkebe		0.08			3.2	
	Low human	0.19				
	Moderate human	0				
	High Human	0.13				

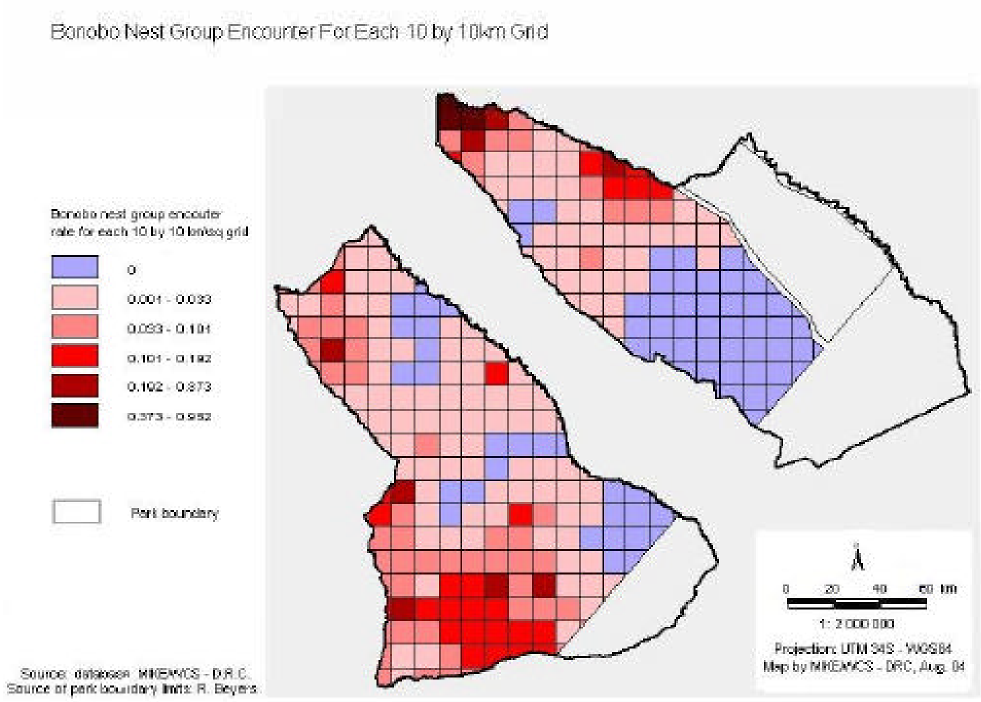
8.3 Bonobos in Salonga NP.

Methodological issues and an extremely low nest encounter rate precluded the ability to calculate bonobo densities from nest data, however the encounter rate of nest groups on line transects was just 0.26 groupskm^{-1} (95% CI = 0.14), one-quarter that recorded by Van Krunkelsven et al. (2000). Mean group size was estimated at 2.8 individuals, considerably lower than the mean group size of 5.1 recorded by Van Krunkelsven et al (2000). Bonobo sign was highly concentrated in open canopy forest with an understory dominated by species of Marantaceae, which is consistent with previous observations form other sites(Malenky and Stiles 1991, Malenky et al. 1994, Van Krunkelsven et al. 2000).

Observations of bonobo nest group encounter rate on recces were too variable to be of use in anything but an overall appreciation of the relative distribution of bonobos across the zone because researchers were walking fast between transect locations and not concentrating on nests or feeding signs. A nest group encounter rate distribution map was produced from travel-recce data (Figure 16) by dividing the survey area into 10x10km blocks and assigning the sign encounter rate of bonobos on all travel recce segments within the block to that block. While the frequency of observations was consistently low across the region (never reaching a mean of over 0.95 signs km^{-1}, areas of relatively high sign were found in the extreme northwest of the northern block and a more extensive area in the southern sector of the southern block. No sign of bonobos was seen in a large expanse of forest covering over 4200km^2 to the southeast of the northern block.

An order of magnitude estimate from these observations puts the bonobo population of Salonga between 1000 and 10,000 individuals, a highly unsatisfactory level of precision and confidence. One park wide survey can reveal nothing about recent population trends, but the MIKE dataset can now be used as the basis for refining bonobo, elephant, and other large mammal surveys as part of a long term monitoring program.

Figure 16. Bonobo nest group encounter rate on travel recces within 10x10km blocks



Chapter 9: Discussion of results and implications for conservation

The suite of sites selected for this phase of MIKE was thought to be arguably the most important priority conservation areas for elephants in central Africa. Among other notable priority areas not included were Odzala National Park, The Okapi Faunal Reserve, and the Lope National Park, as they had been covered in the MIKE Pilot phase. These surveys have shown that while Minkebe, Dzanga-Sangha, and Nouabalé-Ndoki may indeed contain large and important populations (Table 17), the remainder of the MIKE sites surveyed had low numbers of elephants, and in the case of Salonga, an extremely low elephant density across the largest and most isolated forested national park in Africa. Among the MIKE sites surveyed, Minkebe contains an elephant population of exceptional size of probably between 20-40,000 elephants - perhaps the single largest contiguous population in central Africa. The Nouabalé-Ndoki-Dzanga-Sangha Complex, comprising 2 MIKE sites in a single contiguous forest block rated second among current MIKE sites, both in terms of local densities of elephants, and in the total size of the elephant population with a combined population of approximately 3900 elephants. While a dung density estimate was not possible in Boumba Bek, the encounter rate recorded at that site suggests a moderate elephant density, and probably several hundred elephants resident in the reserve at the time of this survey. Bangassou has long been known as an important forest elephants site in the context of the Central African Republic, a country in which this species is limited to a small band of habitat to the extreme south of the country however, even here elephants are found only in small pockets of forest and in low numbers. The vast Salonga National Park, which had never previously been systematically surveyed, and which was thought to contain a large elephant population due to its size and remoteness, contains few elephants. The total number of elephants in the entire park may be as low as 2000 individuals.

Table 17. Estimated forest elephant density in MIKE sites compared to other sites across central Africa.

Country	Site	Density (N° km-2)	Year	Source
Gabon	Minkebe NP Low impact stratum	3.8	2004	MIKE 2004
Gabon	North Lopé Reserve: Marantaceae	3.0	1991	White1994
Gabon	Minkebe NP moderate impact stratum	2.9	2004	MIKE 2004
Gabon	Minkebe NP high impact stratum	2.8	2004	MIKE 2004
Cameroon	Southeast	2.6	1991	Stromayer & Ekobo 1991
Congo	Piste Sembe Secteur Ekutu-Mambili	2.2	1989	Fay & Agnagna 1991
Cameroun	Extreme southeast	1.8	1989	WCI 1989
Gabon	North Lopé Reserve: marantaceae	1.7	1989-1991	White1994
DRC	kahuzi Biega lowlands >20km from village?	1.6	1997	Hall et al 1997
Congo	Odzala (Questionable result, Hunter, pers. com)	1.4	2000	Beyers et al, 2001
Congo	Piste Sembe (Mbandza-Sembe),	0.9	1989	Fay & Agnagna 1991
Congo	Nouabalé-Ndoki	0.9	1989	Fay & Agnagna 1991
Gabon	North Lopé Reserve: closed forest	0.9	1989-1991	White 1994
DRC	Iruri	0.7	2000	Beyers et al, 2001
Congo	Nouabalé-Ndoki NP	0.7	2004	MIKE 2004
CAR	Dzanga NP	0.7	2004	MIKE 2004
Congo	Motaba River region	0.6	1989	Fay & Agnagna 1991
CAR	Dzangha-Sangha	0.6	1991	Fay 1991
DRC	Ituri	0.6	1989	Alers et al 1992
CAR	Ndoki NP	0.6	2004	MIKE 2004
Cameroun	Dja Reserve	0.6	1994	Williamson et al. 1995
DRC	kahuzi Biega lowlands 11.5-20km from village?	0.6	1997	Hall et al 1997
Gabon	Mountains	0.5	1989	Barnes et al. 1995
CAR	Forest near Bangassou	0.5	1991	Fay 1991
Gabon	West	0.5	1989	Barnes et al. 1995
Gabon	Northeast	0.4	1989	Barnes et al 1991
Gabon	Lope	0.4	2000	Beyers et al, 2001
Gabon	Northeast	0.4	1989	Barnes et al. 1995
DRC	Maiko >10km from road/river	0.4	1989	Alers et al 1992
Ghana	Bia National Park	0.3	1983	Short 1983
Congo	Mboukou	0.3	1989	Fay & Agnagna 1991
DRC	Salonga >10km from road/river	0.2	1989	Alers et al 1992
Cote d'Ivoire	Tai	0.2	1986	Merz 1986b
DRC	Lomami <10km from road/river	0.2	1989	Alers et al 1992
Cameroun	Southeast	0.2	1989	WCI 1989
Cote d'Ivoire	Tai	0.2	1983	Short 1983
Sierra Leone	Gola Forest	0.2	1986	Merz 1986a
Congo	Nouabalé-Ndoki Mokabi logging concession	0.1	2004	MIKE 2004
Equatorial Guinea	South	0.1	1988	Alers & Blom 1988
DRC	Salonga <10km from road/river	0.1	1989	Alers et al 1992
Uganda	Impenetrable Forest	0.1	1986	Butynski 1986
Gabon	High Human density	0.1	1989	Barnes et al. 1995
CAR	Dzanga Sangha Special Reserve	0.1	2004	MIKE 2004
DRC	Maiko <10km from road/river	0.1	1989	Alers et al 1992
DRC	Maiko >10km from road/river	0.1	1989	Alers et al 1992
DRC	Salonga Low human impact	0.1	2004	MIKE 2004
DRC	Salonga High human impact	0.1	2004	MIKE 2004
DRC	Kahuzi Biega lowlands <11.5km from village?	0.0	1997	Hall et al 1997
CAR	Ngotto	0.0	1991	Fay 1991

Current survey results highlighted in red.

Just as Michelmore et al. (1994) showed on a national scale, and almost every study reveals on a smaller scale (Hall et al. 1997, Powell 1997, Theurekauf et al. 2001, Blake 2002, Blom et al. 2004a) human activity is overwhelming the range and distribution of forest elephants. What is striking about the present study is the almost perfect mirror image between human sign distribution and elephant distribution in Dzanga-Sangha and Nouabalé-Ndoki, Minkebe, and the impact of distance from human infrastructure in Boumba Bek and Minkebe. Pockets of relatively high elephant abundance were found only in the heart of protected areas and protected area complexes. In Dzanga-Sangha it is likely that the elephants are split into two distinct zones in the national park sectors, with the adjacent Nouabalé-Ndoki National Park offering access between the parks. In the Bangassou forest, forest elephants occurred in small pockets in the most remote areas of forest, surrounded by human activity. In Salonga NP, no trend in relation to human sign distribution could be determined however this may have been due to low elephant dung encounter rates on transects and travel-recces.

The encroachment of human activity into wilderness has been the hallmark of the decline of the African forest elephant (Barnes 1989b, 1999), and the loss of biodiversity generally (Sanderson et al. 2002). This study has shown that adverse human impacts are penetrating some of the conservation areas most critical for the survival of this species. Not only was illegal human activity found consistently throughout the MIKE sites with very few exceptions (Nouabalé-Ndoki National Park, the heart of the Minkebe National Park), but elephant populations in all MIKE sites were found to be threatened from active elephant poaching, even in remote and well-established national parks. Every reserve and national park surveyed had some sign of active elephant poaching, and in some cases, elephants would appear to have been depleted to very low numbers. Particularly concerning is that poaching was particularly high in sites of highest recorded elephant density (Minkebe and Dzanga National Parks), indicating that the heaviest poaching is occurring where the chances of success re greatest, irrespective of protected status. When possible, poachers are targeting areas where elephants are most abundant.

Site summaries

Bangassou

There is little doubt that the elephant population of Bangassou has diminished over the last decade both in number and range. Elephants are now restricted to most remote parts of the site surveyed and only at distances greater than 20km from villages and roads does elephant dung encounter rate on travel-recces approach a mean of 2 piles km^{-1}. No survey work was carried out to the north of the site, on the forest savannah boundary and into the savannahs, but local people were confident that elephant numbers diminished even further on moving north. The continuing loss of Bangassou's elephants due to poaching is no surprise. In 1991 based on a study conducted in 1989, the year the ivory ban came into effect, Fay (1989) wrote the following:

"As in many elephant habitats, poaching in the CAR is common. If the present rate of poaching continues, there will be very few elephants left in the country in another five years.

Specifically concerning Bangassou, he continued:

"Certainly the remaining elephant population in the Bangassou region is heavily poached. During this study many elephant hunters were encountered. The infrastructure is in place to traffic the products from this illicit activity which is not overly covert in the region".

Since that time the country has fallen into repeated periods of civil unrest, AK47's and other firearms have become commonplace (an AK47~~6~~ can be locally purchased for ca. $50, and bullets for $0.5 each,), and poverty levels have considerably increased in the last 20 years. Penetration of the Bangassou area by heavily armed and well-organized Sudanese and Chadian poaching parties has also increased according to local people. These military style elephant poaching parties who make annual excursions to the area are locally feared and basically above the law (see site level report). Elephant meat is commonly on sale in the Bangassou market, less than 500m from the regional office of the wildlife department, thereby demonstrating that government management of the situation is out of control (see Annexes). In Bangassou local people said the primary motivation for hunting elephants may be meat, and elephants are shot indiscriminately of body size or ivory. Elephant meat has always been widely consumed in Bangassou (Fay and Agnagna 1991b), but in the 1980's ivory was the main driving force behind poaching. The loss of elephants carrying large tusks from the population may be at least part of the reason for this shift, allied to a reduction in populations of smaller game.

The elephant population of CAR has collapsed over the last 30 years from perhaps 70,000 in the early 1970's to no more than ca. 7000 individuals (Blanc et al. 2003), and more likely 2000-3000 individuals in the light of this study, of which only a small fraction may be forest elephants. The number of elephants remaining in Bangassou cannot be established from this survey, but an educated guess would put the population between 500-1000. In a nation all but devoid of elephants, the simple fact that Bangassou contains ANY elephants must render it a priority conservation area for this species. The challenge of how to adequately protect the few remaining elephants unfortunately remains as difficult as ever given the prevailing political, economic, and social conditions in CAR and neighbouring countries (Blom et al. 2004b).

Salonga

This study suggests that Salonga may contain as few as 2000 elephants down from an estimated 8300 in 1989 (Alers et al. 1992). It is however difficult to compare these surveys given the considerable potential sources of error in both. First, the survey of Salonga in 1989 was extremely limited in its geographical coverage and sampling effort, with just 70 km of line transects completed in localised areas. Secondly neither survey estimated dung decay and defecation rate parameters. Third, neither survey took the possible effect of swamps into account. An important fraction of the Salonga National Park is swamp vegetation which offers elephants not only good feeding opportunities, but may provide relatively safe cover from humans. Under poaching pressure it is not unlikely that significant numbers of elephants seek refuge deep in thick swamp, thus rendering themselves unavailable for counting on line-transect surveys. There is no currently feasible way to census elephants in swamps, though camera traps and infrasound offer intriguing possibilities for further research.

This survey showed that small pockets of moderate elephant density existed in areas of favourable vegetation. The two high concentration points illustrated in Figure 15 above were in the immediate vicinity of a large forest clearing (*bai* or *Botokanjoko*) to the northwest of the southern block, and the second, in the south centre of the northern block. There was no clear relationship between elephant abundance and human activity, which may have been due simply to the small number of observations, but may also be because human penetration of the park has been so complete and poaching so intense that elephants have no refuge left open to them. At this point, when nowhere is safe, elephants may once again make ranging decisions based on ecological criteria rather than on safety. Swamps, which were not systematically surveyed during this MIKE inventory, are extensive throughout the park, and may offer some refuge for elephants. It is difficult to say how many elephants were alive in Salonga in the 1960's, before modern commercial poaching begin in earnest, but if one assumes that Salonga provides adequate ecological conditions for elephants to exist at moderate densities (0.5 individuals km^{-2}), there were probably at least 16,000 in the two park sectors and there may have been many more. The future of elephants in Salonga is indeed precarious.

The situation for bonobos and other wildlife of the Salonga National Park appears to be similar to that of elephants, though with no historic data on density and distribution of large mammals trends cannot be determined.

The decline of elephants in Salonga is not surprising given the historic and actual conditions that exist at the site and throughout the DRC. In 1992 Alers et al. wrote:

"*There are still many elephants in Salonga NP, but they are suffering from organized poaching. The park guards are out-numbered and out-gunned, and the poachers are armed with automatic weapons………Elephants have been depleted along the large* *rivers. They have either been eliminated or survive at low density from the northwest corner of the northern block……".*

They go on to say of DRC:

"The heavy poaching has not only reduced the numbers of forest elephants but fragmented the population, which once ranged throughout the forests of Zaire, into about half a dozen sub-populations separated by large expanses of empty forest…. The future of Zaire's elephants must lie in a few well-protected national parks".

Unfortunately since that time there has been little or no improvement in park management and conservation success. During this survey evidence of elephant poaching was commonly seen even in remote areas of the park. Poachers remain heavily armed in many cases, while park guards do not. The extensive river system offers easy access throughout the park is not policed, and facilitates the evacuation of bushmeat and ivory to the Congo River. An important factor in the failure of conservation in Salonga has been the destabilization of the DRC following the overthrow of the Mobutu government in 1997. A bloody civil war, which spawned an enormous proliferation of automatic weapons and the collapse of civil society, has left the country in turmoil, and it is not surprising that national park management has been neglected. At the time of the present survey, ICCN park management authority had no budget, no basic management infrastructure such as vehicles, radios, generators, nor even camping equipment and functional firearms for park guards, except for a small donation provided by a bonobo conservation NGO (the Lukuru Wildlife Research Project) (Blake and Hedges 2004). The ICCN national park staff were, at the time of this survey, paid the equivalent or $2 per month -considerably less than the price of 1kg of ivory. Salonga was designated a World Heritage Site by UNESCO in 1984, yet this seems to have had little or no tangible impact on management capacity and even promised bonuses for park guards of $30 per month, were months in arrears (Blake and Hedges 2004). In 2001, Hart and Mwinyihali (2001) called Salonga a "poachers paradise" while Van Krunkelsven et al. (2000) quoted local poachers, saying that "elephants were becoming very difficult to find". The development of the Congo Basin Forest Partnership (Anon. 2005) offers some hope that management conditions may improve in Salonga, but sustained financial, political, and institutional commitment as described by Inogwabini et al. (2005) is required if the trends of the last several decades are to be reversed.

Dzanga-Sangha

The elephant population of Dzanga-Sangha is was highly concentrated into the two national park segments with few elephants in the special reserve. This difference may in part be explained by habitat factors –the Dzanga NP for example has an exceptional mineral lick complex which attracts large numbers of elephants (Turkalo and Fay 2001), while the Ndoki sector is rich in herbaceous clearings favoured by elephants and other browsers (Blake. Peers. obs.). Yet the juxtaposition of signs of human activity with elephant abundance shows convincingly that human impact overwhelms other factors. In the Special Reserve, human activity is high and increases toward the Sangha River, while elephant density is low but increasing with distance from the Sangha. In the national park sectors, human activity is relatively low compared to the special reserve, and elephant density correspondingly high.

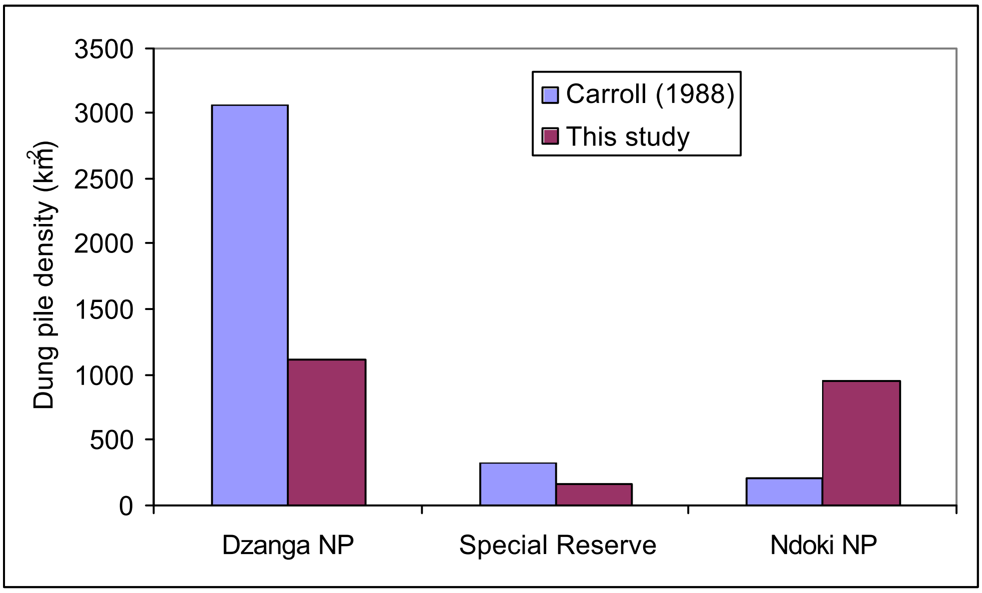
In the first comprehensive survey of elephants and apes in Dzanga-Sangha, (Carroll 1988) estimated elephant abundance in 10x10km forest blocks distributed across the site and extrapolated the results to the entire reserve. It is informative to compare these data with the present survey (Figure 17). The figure shows that estimated elephant density in the DNP has decreased by almost three fold over the last 16 years (from 3064 to1114 piles km^{-2}), while that in the special Reserve has all but halved (323-163 piles km^{-2}). In contrast, elephant density in the Ndoki sector has risen by a factor of four!

Some knowledge of the local situation helps explain these apparently contradictory trends. Poaching in the Dzanga NP and the Special Reserve has increased over recent years (Blom, Greer and Turkalo peers. comm.), as evidenced by the carcass data from this study. The effect on the population abundance and distribution may be two-fold.

First the elephant population will be reduced if poaching rates exceed natural mortality and birth. Second, elephants move out of the dangerous areas. Elephants are highly mobile in the Ndoki ecosystem, and may travel up to 100km in a straight line (Blake 2002). They also have the entire Nouabalé-Ndoki National Park as a safe refuge, and are likely to favour this area increasingly as Dzanga becomes more dangerous. This is also true for the special reserve. Dzanga-Sangha elephants probably do not cross the Sangha River in CAR because poaching on the western side is at least equally as intense as in the Special Reserve. So what is responsible for the observed increase in elephant density in the Ndoki National Park?

As Carroll (1988) and Fay (1989b) and Fay and Agnagna (1991c) both point out, the area immediately across the Congo-CAR border on the Congo side was a site of intense elephant hunting in the 1980's centred on the village of Bomassa. However in 1991, a conservation programme was initiated and by 1993, the Nouabalé-Ndoki National Park was created with its headquarters in Bomassa. Reducing elephant poaching was and is a key goal of the programme, and by the mid 1990's poaching based out of Bomassa had been eradicated (Blake, peers. obs.). At the same time, protection activities along the Sangha River came into being which resulted in reduced access to the Ndoki NP by Cameroonian elephant poachers. Therefore, while poaching increased in other sectors of Dzanga-Sangha complex, local conditions in the Ndoki NP were ameliorated, and therefore elephants have returned to the area. This is a speculative scenario, however research teams and park management staff has noticed a sharp increase in elephant density in Ndoki NP over recent years, with a concomitant reduction in abundance in the Dzanga NP thereby lending support to this scenario.

Figure 17. Estimated elephant dung density in the Dzanga Sangha Complex in 1988 and 2004 this study.



Nouabalé-Ndoki

The most dramatic result from the MIKE survey in Nouabalé-Ndoki was the remarkable difference in elephant abundance and human activity between the national park and adjacent logging concession. Among national parks surveyed, the Nouabalé-Ndoki had the lowest encounter rates for all human sign, with only a single hunting camp found on recce surveys, no snares nor shotgun cartridges. By contrast the Mokabi logging concession, immediately to the north had the highest recorded encounter rates of elephant hunting camps, shares, and shotgun shells of any MIKE site in the survey. Elephant poaching has been high in the Mokabi for at least the last 10 years (Blake et al. 1997, Eves 1998), but with the arrival of industrial logging in the late 1990's, the forest became accessible, the human population has increased dramatically with the installation of several permanent logging camps and an influx of people from Congo and CAR, and a concomitant increase in human activity and impact, including that from commercial bushmeat hunting and elephant poaching (Blake 2002, Stokes 2004). Elephants have been all but eradicated from a large part of the northern sector of the MIKE survey area, and there is little chance that anything more than a handful of elephants remain north of the population limit as identified in this study to the edge of the tropical forest block in CAR.

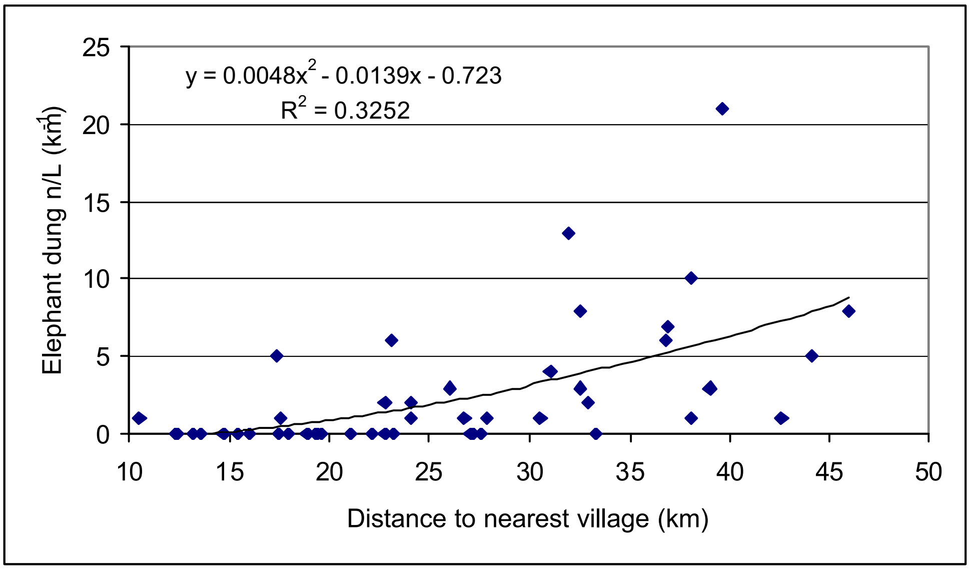
The stark difference between the two strata is due primarily to the vastly different management practices. Since the early 1990's the Nouabalé -Ndoki National Park has been the focus of an intense commitment toward conservation on behalf of Government, international conservation NGO's, and international donors, with a budget running into between $500,000-1,000,000 per annum. The mandate for strong law enforcement has been assured by national park status, and the political will to support law enforcement and other conservation programmes, such as education, outreach, community conservation. By contrast, the Mokabi concession has no protected status, commercial logging is active, government has not approved international NGO support for conservation, the capacity to enforce wildlife laws is close to zero, the logging company has not engaged in wildlife management and numbers of elephants and other wildlife has been severely reduced. Illegal killing of elephants goes largely unchecked.

However even the national park is not completely secure. In 2003 and 2004, eco-guards reported finding increased sign of elephant poaching and general human activity along the western border of the park near the CAR (Djoni-Bourgess, pers. comm.). Because of external pressure, elephants are now increasingly confined to the national park, the long-term impact of which, unless the trend is reversed, must be an overall population reduction and a smaller range. As human pressure increases with logging taking place to the limits of the park, it is likely that this "effective area" (the area "available" to elephants) of the park will be further reduced with serious negative consequences for population viability (Woodroffe and Ginsberg 1998). As elephant populations around Ndoki lose ground, poachers will increasingly be drawn to operate inside the national park. The costs of protection will increase, and the risks of failure will climb without proactive measures to provide adequate protection to elephants outside, as well as inside, park borders.

Boumba Bek

Despite at least three surveys in Boumba Bek (including the present inventory under MIKE), the abundance of elephants has never been clearly determined. A survey in the early 1990's indicated that there may have been as many as 3300 elephants in the area at a mean density of 1.42 km^{-2} (Stromayer and Ekobo 1992). Following this initial inventory, Ekobo (1996) quoted two wildly different populations estimates, of 7000 and later 250 individuals, and suggested that the differences might be due to a seasonal migration taking elephants out of the reserve. The AED of 2002 quotes Ekobo, stating that there were ca. 1250 elephants in Boumba Bek. Such inconsistencies make it difficult to put the present the current survey results in a local context, particularly given the methodological problems. What is somewhat consistent between this survey and that of Stromayer and Ekobo (1992) is the distribution of elephants. In both surveys elephant density increased markedly with distance from humans; in this study there was a positive correlation between distance from the nearest village and elephant dung encounter rate on transects (Figure 18. Spearmans rho = 0.658, n = 47, P < 0.01). However, the impression of Stromayer and Ekobo (1992) was that human influence extends "only a short distance" into the reserve from the east, whereas in this study human sign density was, according to transect data (Figure 18) higher to the west of the reserve than the east. Based on travel-recce data, human activity was high toward both the eastern and western borders, with lower human sign abundance in the middle of the reserve (see Annex). In the present study, there was no evidence of elephant encounter rate stabilising even at 45 km from the nearest village. Elephant abundance was apparently still tending to rise at this distance –which supports the notion that the adverse effects of humans on elephants now extend deeper into the Boumba Bek Reserve.

Figure 18. Relationship between elephant dung pile encounter rate and distance from the nearest village



The highest concentration of elephants recorded in Boumba Bek was to the southeast, immediately adjacent to the Nki Reserve. The proposal for a single contiguous national park in Boumba Bek and Nki covering some 7000km^2 will create the second largest national park in the range of forest elephants west of the Congo River, and is an extremely positive decision for elephant and biodiversity conservation for which the Government of Cameroon and the WWF must be congratulated. The absence of villages and human encroachment around much of the Nki extension could, with effective management, support a viable elephant population.

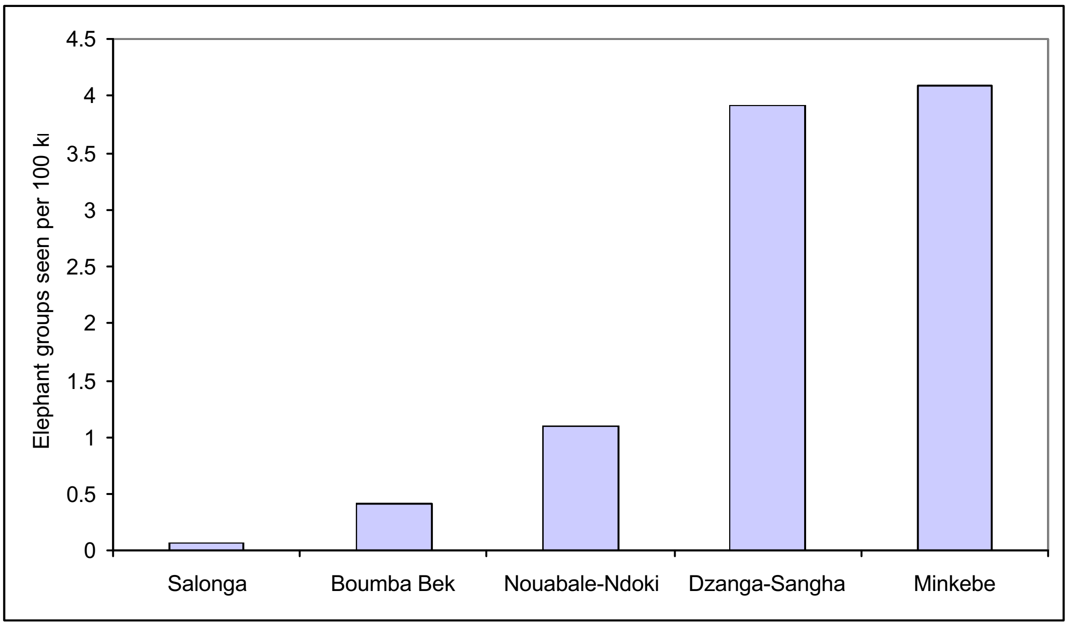
Minkebe

This survey has demonstrated that the Minkebe region of northeast Gabon holds an exceptionally high density of elephants, and may contain the single largest contiguous population of forest elephants in Africa. However, the rate of illegal killing of elephants is having a strong negative impact certainly on the distribution, and abundance of the population. While elephants remain abundant across most of the area survey, the highest concentration is in a narrow block in the most remote sector of the forest. Elephants are now most concentrated in a narrow band in the heart of the Minkebe forest massif.

Evidence of illegal killing was seen only in the north and west of the survey zone. The heart of the park was all but devoid of any human sign confirming earlier reports by (Huijbregts et al. 2003). Elephant poaching teams operating out of southern Cameroon and the Minvoul area of Gabon are responsible for most of the elephant killing, previously described by De Wachter and Huijbregts (pers. com.) who suggested that as many as 250 elephants were being killed annually in the north of the Minkebe forest. If effective measures are not taken immediately, poachers will continue to move further into what is now untouched forest in the heart of the park as elephant numbers decline in the north. It is probable that poaching pressure is being exerted to the southwest and south, areas which were not surveyed in this phase, though anti-poaching patrols from the Minkebe National Park management team suggest they are improving security there, and the highest pressure remains in the north (de Wachter, pers com.).

These survey results suggest an elephant population size that is difficult to believe. Elephant surveys in other areas have estimated elephant population densities of 3.8, 2.6, and 2.2 elephants km^{-2} (Table 17) but these have been of small pockets of exceptional density. The MIKE Minkebe survey indicated a high and exceptionally high density over a vast area. While there will always be doubt over *elephant population* estimates until reliable decay and defecation studies are done on-site, several sources of evidence point to the reliability of the transect data on which at least the *dung density* estimate here is based. First, the principle researcher at this site, Marc Ella Akou is a trained and reliable field researcher with years of similar experience. Second the data required little fitting to obtain a reliable detection function in Distance 4.1 suggesting that the perpendicular distance measurements were accurately recorded. Third, the number of direct encounters with elephants at this site was, extremely high (Figure 19). On average just over four groups were observed every 100km of travel-recce compared to one and 0.4 groups per 100km in Nouabalé-Ndoki and Boumba Bek respectively (Figure 19). Only Dzanga Sangha had a comparable encounter rate of live elephants.

Figure 19 . Direct encounters of elephants during travel recces



The Dzanga site is exceptional given that 1) the large number of forest clearings permits easy observations, and 2) in some sectors of the park elephants are habituated to researchers being present, and they are slow to flee. Fourth, with the exception of the high density of elephants in the swamp mosaic to the northeast already commented on, the majority of the highest density elephant band lies over 50km from the nearest village which according to (Barnes et al. 1997) was expected to contain upwards of 1500 dung piles km^{-2} in 1989.

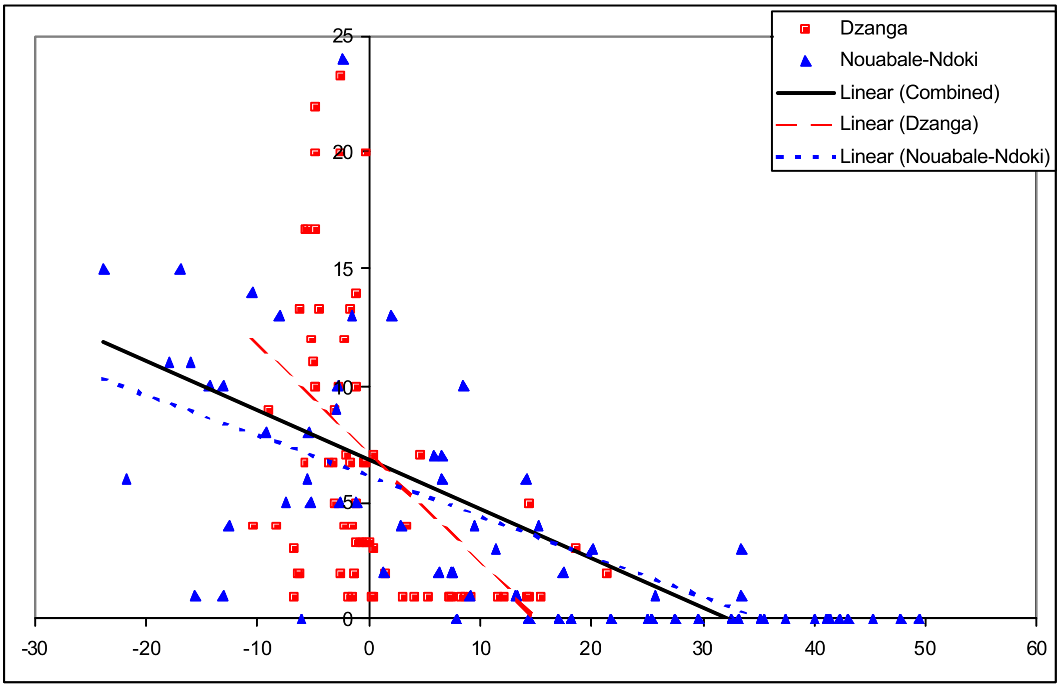
Even with these caveats, it is likely that something else may be responsible for the exceptional density of elephants reported in Minkebe – compression! Whether or not compression is a real phenomenon in the African elephants is still debated, but good supporting evidence has been presented (Lewis 1986). The large brain size and intelligence of elephants, their ability to move over large distances, and their consistent response to move away from sources of danger from humans, would all suggest that it is possible. The Minkebe elephants, like elephants throughout the MIKE sites, are under considerable threat from human encroachment and illegal killing as witnesses in the north. However logging, diamond mining, elephant and bushmeat hunting are pushing further into the 32,000 km^2 Minkebe forest block. Pressure from all sides would consequently cause elephants to move further into the interior of the forest, the result of which would be increased elephant density in the remote and as yet peaceful forest core. Further research in the Minkebe Forest, as in the other MIKE sites, should extend the geographic range of inventories to investigate this possibility. This phenomenon has important implications for the design of MIKE surveys (Blake and Hedges 2004) which is discussed in the recommendations section below.

Distribution of elephants in relation to national park borders

Only in two sites, Nouabalé-Ndoki and Dzanga-Sangha, was the survey coverage sufficiently large outside of national parks to allow an analysis of the effect of distance from park borders on elephant abundance. At these contiguous sites, elephant density was strongly negatively correlated with distance from national park borders, i.e., elephant abundance decreased with distance outside national parks, and increased significantly with distance INSIDE parks (Figure 20). This relationship was highly significant for an analysis at the MIKE site level (Dzanga-Sangha and Nouabalé-Ndoki analysed independently) and for the combined landscape (Dzanga; $R^2 = 0.188$, $F_{(1,73)} = 16.842$, $P = 0.0001$: Nouabalé-Ndoki; $R^2 = 0.449$, $F_{(1, 69)} = 56.12$, $P < 0.0001$: Combined; $R^2 = 0.259$, $F_{(1, 145)} = 50.806$, $P < 0.0001$). These relationships predicts that that to the north of Nouabalé-Ndoki NP, elephant abundance drops to zero at a distance of 35.5 km from the northern border of the park, while in Dzanga-Sangha the limit of elephant range is predicted at 15.1 km from the western border of the parks.

Regression equations such as these are a source of important additional monitoring information. Rather than rely on just an abundance estimate as the monitoring metric, a lot of additional information on conservation success can be quantitatively obtained from studying the form, slope, intercept of the relationships in Figure 20. The biggest problem with the use of these curves in a quantitative way is the scatter of points about the regression line which leads to low precision and therefore limited capacity to detect trends, and a more complex but more powerful spatial modelling approach has greater ability to assess change in distribution.

Figure 20. Elephant dung encounter rate on transects with distance from park boundaries (negative values on x-axis indicates within park limits)



In the case of the Nouabalé-Ndoki/Dzanga Sangha complex, if a subsequent MIKE survey revealed no detectable difference in abundance across the same site, yet the slope of the regression becomes significantly steeper, and the intercept on the X-axis is pushed significantly to the left, this would be strong evidence that elephants are moving into the national park, and losing range. If on the other hand, the intercept is pushed to the right – i.e. the distance from the park border to the point where elephant abundance equals zero has increased since the last survey, it would indicate that the elephant population is gaining ground, perhaps in the light of some conservation intervention. Similarly, if the curve flattens but the X-axis intercept remains constant, it would suggest that there are fewer elephants in the study area overall, but their range has remained the same. It is hoped that the TAG can advise on options using spatial modelling techniques to link abundance estimation and spatial distribution to improve the detection of change in both abundance and distribution.

Table 18. Simplified indicators of population trends from change in the relationship between elephant abundance and distance from park borders.

	X-axis Intercept to right	X-axis intercept constant	X axis intercept to left
Slope increases	Population increasing, Range increasing	Population increasing, Range stable	Population ? (calculate area under graph) Range decreasing
Slope constant	Population increasing Range increasing	Population stable Range stable	Population decreasing Range decreasing
Slope decreases	Population ? (calculate area under graph) Range increasing	Population decreasing Range stable	Population decreasing Range decreasing

It is important in future iterations of MIKE that attempts are made to map the limits of elephant distribution outside of national parks, and that the limit be included in survey zone definitions. This will facilitate not just abundance estimation, but distribution, and trends in surface area available to the elephant population.

Chapter 10: Concluding remarks

In this report, a five-phase implementation plan to develop, execute, analyse and disseminate the results of forest elephant inventories in Central Africa between 2003-2004 and under the auspices of the MIKE program was described. Surveys were based in a suite of six MIKE "sites" designated by CITES based in and around national parks and conservation areas, namely Salonga (DRC), Bangassou and Dzanga-Sangha (CAR), Nouabalé-Ndoki (Congo), Boumba Bek (Cameroon), and Minkebe (Gabon). A team of national researchers from Gabon, Cameroon, CAR, Congo and DRC was brought together in the Somalomo Training centre, Cameroon to be trained in field methods, data collection and data management, and to standardise final survey methods. Additional teams were also trained in Gabon and DRC. Based on pilot study results and existing data on elephant abundance, final un-biased stratified survey designs were developed based on systematic placement of line transects across defined survey zones. Survey areas were defined based on maximizing geographic coverage outside, as well as inside, of protected areas and sampling of elephant abundance across a wide range of ecological and human gradients, while maintaining sufficient sampling intensity to estimate elephant dung density within survey zones with a coefficient of variation of 25%. Ape density estimates were also made based on nest group counts on line-transects. An attempt was also made to maximize systematic data collection on transects and "travel recces" between transect locations on all forms of human sign to assess intensity of use, particularly signs of illegal killing, and its impact on elephant populations. Following completion of surveys a data analysis and reporting workshop was held at the Lope Training Centre, during which site based reports were elaborated, and in most cases completed. The results of surveys were summarized in a series of six 2-page fact sheets presented to the MIKE directorate and Central African Wildlife Directors in Bangkok before the Conference of the Parties to CITES. The following conclusions were drawn from this phase of MIKE implementation in central African forests.

1. Site managers saw the MIKE programme as a valuable contribution to elephant conservation at site-level as well as at international level and support for the

programme from site-based partners was generally excellent. Site management authorities provided both in-kind logistical and administrative support and in some cases financial contributions to MIKE inventory operations, without which this phase of MIKE could not have been executed.

2. The training of MIKE researchers were under under-funded and under-estimated, both in terms of initial training and subsequent follow-up supervision. Indeed, one of the three scheduled training programs was cancelled due to funding shortfalls. While inadequate training and follow-up resulted in some methodological shortfalls in data quality, the critical MIKE dataset – the estimation of elephant abundance from line transects - was well executed in all but one site. Unfortunately in Boumba Bek, rounding errors of perpendicular distances resulted in a poor fit of transect data to detection function curves, resulting in invalid estimation of elephant dung density at this site.
3. Studies of dung decay and defecation rates were not carried out at site level during this phase of MIKE which compromised accurate estimation of elephant density based on dung counts. Instead, a decay time of 90 days and defecation rate of 19 dung piles per day was used to convert dung density into elephant density.
4. Over 46,000km^2 of dense forest was systematically surveyed using Distance sampling techniques and an additional 12000km block (in Bangassou) surveyed less intensively. Data were collected on a total of 4478km of travel-recces, and 384.5km of line transects on which 9362 and 1723 elephant dung piles respectively were recorded. The combination of travel-recces and design un-biased line-transect surveys proved effective, when methods were implemented correctly, in estimating elephant dung density, ape abundance, and human sign abundance. The original target CV of 25% on elephant density estimates was achieved in 7 of 10 strata in which correct methodologies were used, and 3 of 4 sites. Particularly low elephant abundance in Salonga NP and Dzanga Sangha Special Reserve and meant that effort requirements were underestimated, and precision (CV) in these strata was 92.8% and 30.8% respectively.

5. Across sites, elephant density was highest in Minkebe, where dung density was estimated to be 5348 dung piles km^{-2}, or 3.1 elephants km^{-2} in the area surveyed. The density of elephants in Minkebe was nearly 7 times higher than the second placed site, Nouabalé-Ndoki, which had an estimates elephant density of 0.5 elephants km^{-2}. In Dzanga Sangha, the overall elephant density was 0.3 elephants km^{-2}, while in Salonga the density recorded was just 0.5 elephants km^{-2}. Estimated elephant population size in the survey zone at each site was estimated at 29147, 3032, 869, 1186, and 318 in Minkebe, Nouabalé-Ndoki, Dzanga-Sangha, Salonga, and Boumba Bek respectively. In Bangassou the dearth of elephant sign and the sampling design meant that a valid estimate of elephant abundance could not be calculated, however it is likely that there are less than 1000 elephants in the region. In survey zones that extended beyond park borders, elephant density was significantly lower outside of national park borders.
6. Signs of elephant poaching were found in every MIKE site, and within every national park. Twenty-one poached elephant carcasses were found on recces, giving a mean poached carcass encounter rate of 1 per 212km of travel recce walked. There was no consistent pattern in the distribution of carcasses inside versus outside of national parks. Nine poached carcasses were found in Minkebe, all outside the national park, while in Dzanga Sangha 9 out of 10 carcasses were found wither inside or within 2km of the Dzanga National Park. A total of 53 confirmed elephant poaching camps were found during the surveys, and 235 hunting camps in which no direct sign of elephant poaching was recorded. Elephant poaching camp detection rate was 1 camp for every 84.5 km of travel-recce surveyed.
7. The distribution of human activities and human settlement overwhelmingly determined the distribution of elephants, and this survey suggest very strongly that elephant numbers in MIKE sites are not only declining due to poaching but that they are becoming restricted to the heart of national parks. Parks in which management capacity was low, civil conditions unstable (e.g. Salonga), and where anti-poaching was not a major part of the management philosophy (e.g.

Bangassou community forest) contain few elephants and the population appears to have significantly declined. In sites which have invested in management infrastructure and personnel, and where there is a strong protection philosophy within a comprehensive conservation programme, elephants continue to be found in high densities within national parks. It is clear that in areas where there is no mandate for the international community to support conservation (e.g. the Mokabi logging concession in Congo), or where enforcement regulations are weak (e.g. Dzanga Sangha Special Reserve) elephants are under severe threat. Of great concern was that observed elephant poaching rates were highest in two of the most critical conservation areas in which still hold high numbers of elephants – Minkebe NP and Dzanga NP.

8. The encounter rate of gorilla nest groups was highest in Dzanga-Sangha, followed by Boumba Bek and Nouabalé-Ndoki. The range in abundance was relatively low across these sites between 0.48-0.74 nest groups km^{-1}, while gorilla abundance was strikingly low in Minkebe, with a mean encounter rate of 0.05 nest groups km^{-1}, consistent with previous research which demonstrates that the disappearance of apes from this site, probably due to Ebola. In Minkebe, gorilla nest encounter rate was highest in areas under high human impact, while they were completely absent from the heart of the park. Mean encounter rates of unidentified ape nest groups (comprised primarily of chimpanzees) were most frequently encountered in Nouabalé-Ndoki, followed by Boumba Bek, and Dzanga-Sangha at 2.14, 1.75, and 0.87 nest groups km^{-1} respectively. In Minkebe, mean encounter rate was just 0.08 nest groups km^{-1}.
9. In Salonga, poor nest searching and observing techniques over the first half of the survey meant that data on bonobo sign, including bonobo nests were unreliable. However evidence of the presence of bonobos indicate that they were widely distributed across the survey zone, but found at very low population density. Sign of bonobo as absent over an area of ca. 4200km^2 to the east of the Salonga survey zone.
10. Despite limited and fluctuating funds which led to inadequate training and follow-up supervision of field teams, the suite of MIKE forest elephant

inventories described in this report have contributed significantly and successfully to the overall goal of MIKE. Range State governments now have a quantitative understanding of the distribution and abundance of elephants in some of their most important national parks. Poaching of elephants for the clandestine ivory trade is alive and well in central Africa's national park system, elephant numbers are diminishing and the species is losing geographic range under human pressure. Human impacts are decreasing the available range of elephants even within national park borders as high density areas are confined the most remote core areas of national parks. Management systems must become more effective in reducing poaching both inside and outside of national parks of viable elephant populations are to remain or to be re-established.

11. These forest surveys have demonstrated the critical importance of MIKE as a tool to improve the management and conservation of forest elephants. MIKE and its partners must learn from the successes and failures of this of this phase to build a viable and cost effective programme in future iterations that will eliminate or reduce bias, increase precision and therefore the ability to detect trends in population size of elephants and apes. Clearly technical and management capacity remains weak at all levels in central Africa. Building appropriate capacity and executing surveys correctly still requires an "exercise in institution building". This can only happen with sufficient and reliable funding and MIKE inventories in central Africa. Elephants are a valuable ecological and economic resource in Africa, and the donor community and range states must significantly increase the funding available to MIKE if it is to achieve its stated objectives and report adequately on trends in elephant abundance, distribution, and illegal killing in the future.

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