Central African Megatransect Project

A Study of Forest and Humans

Proposal Submitted for Consideration
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Introduction

In the last 35 years the large, intact blocks of contiguous forest of central Africa have experienced a higher rate of human penetration and use than in any time in their history. Much of this penetration can be attributed to systematic, mechanized logging. This harvest is a systematic effort to extract a major portion of the standing biomass (flora and fauna) that impacts virtually every hectare of an exploited forest. Logging requires a massive road infrastructure and the importation of human labor for wood extraction. The construction of infrastructure and expanding human population and use has serious impacts on the forest ecosystem. However agriculture is known to be the primary cause of deforestation (Achard et al. 1998). To those who monitor these trends they seem to be "steamrolling over large areas and may be irreversible" (Achard et al. 1998). Because of the now recognized impacts by humans on forest ecosystems, there has been increasing interest in the last ten years to begin managing these lands in a more rational way. Land use managers in central African forests, in particular of protected areas, are now faced with the obligation to assess and monitor the natural resource base over very large areas with limited funds. More importantly managers are expected to identify positive and negative impacts on the resource base and modify management accordingly. Thus far the tools used for assessment, monitoring and evaluation are inadequate.

There has been a notable effort over the last 15 years to develop methods to assess the diversity and abundance of large mammals in central African forests (e.g. Aveling and Harcourt 1984, Tutin and Fernandez 1984, Barnes and Jensen 1987, Koster and Hart 1988, Whitesides et al. 1988 Barnes et al. 1989, Oates et al. 1990, Wilkie and Sidle 1990, Vickers, 1991, Alers et al. 1992, Payne 1992, White 1992, 1994, Wilkie et al. 1992, Auzel 1995, Bermejo 1995, Turkalo and Fay 1995, Eves and Ruggiero 1996, Tutin et al 1995, Oates 1996, Hall et al. 1997, 1998a, 1998b, Fay et al., in prep.). In general these methods have attempted to determine the density of various species over a geographical area using some form of line transect design.

In several cases these studies have revealed an inverse correlation between human proximity and use of the forest and the diversity and abundance of large mammals (Carroll 1986, Johns and Skorupa 1986, Alers and Blom 1988, Skorupa 1988, Barnes et al. 1989, Wilkie 1989, Wilkie and Sidle 1990, Agnagna et al. 1991, Barnes et al. 1991, Fay and Agnagna 1991a, 1991b, 1992, Barnes et al. 1991, Stromayer and Ekobo 1991, Alers et al. 1992, Wilkie et al. 1992, Lahm 1993, Blake 1994, Michelmore et al. 1994, Auzel 1995, Loudiyi 1995, Noss 1995, Williamson and Usongo 1995, Eves and Ruggiero 1996, Barnes et al. 1997, Barnes and Lahm 1997, Lahm et al. 1998, Fay et al., in prep.). This relationship is generally attributed to differential hunting pressure due to the logistical difficulties inherent in traveling long distances from a human settlement or a major transport route. One of the major human influences on large mammals in these studies is logging (White 1992, Wilkie et al. 1992, Plumptre and Reynolds 1994, Auzel 1995). However, large mammal diversity and abundance has also been shown to be affected by other industrial uses, history, habitat type, abundance of food, human tribal affinities and life ways, geographical location, political boundaries, substrate, and seasons (Tutin and Fernandez 1984, Johns and Skorupa 1986, White 1992, 1994, Fay and Agnagna 1992, Blake 1993, 1994, Blake et al. 1995, Noss 1995, Turkalo and Fay 1995,

Barnes and Lahm 1997, Fay 1997, Hall et al., In press). Finally, mammal diversity and abundance is influenced by management practices. If there is a presence on the ground that actively protects or manages wildlife, this is often correlated with higher diversity and abundance of large mammals (Robinson and Redford 1991, 1994, Vickers 1991, Wilkie and Sidle 1990, Wilkie et al. 1992)

The objective of this study is to develop a tool that uses large mammal diversity and abundance as the dependent multiple variable (i.e. multiple species) in a data matrix that would use objective data on human use, ecosystem and physical factors as the independent variables. This approach should provide the land use manager with a three-tiered tool for management.

It will provide:

- an objective view of large mammal diversity and abundance over the survey area;
- data on the threats, use, vegetation, soils and history of the forest;
- the means to understand the relationships between these resources, human use and ecological factors that will provide the necessary tool for reasoned management action.

The approach will be to use reconnaissance surveys that provide discreet data on important variables. The surveys are to be stratified over a pre-determined human influence gradient and use large, contiguous forest blocks as the basic unit of "study area". Empirical studies in northern Congo have shown that this can be a powerful and cost effective approach to collect and synthesize data necessary for management of large forest blocks (Eves and Ruggiero 1996, Blake1996, Fay et al. 1999).

Study Areas

The study area for this project is a number of contiguous forest blocks across Congo and Gabon that we will call "conservation polygon". The conservation polygon is defined as an area with no permanent human settlement. This polygon principle can apply to any management unit, not just protected areas. It is depicted as a point to point polygon with points centered on human settlements. In general the vertices of the polygon, both internally and externally, are made up only of obtuse angles while maximizing the area contained within it. This avoids the inclusion of areas that generally lie in another human influence zone. Subjective decisions are still necessary as to the limits of the conservation polygon when there are fingers of human populations which dead end or in the case of a single settlement within the polygon. Some knowledge of the access routes and human use zones are necessary to find a meaningful solution as to limit. The definition of polygons is also subjective in that camps often transition into permanent human settlements. In general, a permanent settlement has agriculture, wooden, stick and mud, or brick structures and more than one building. More detailed analysis of human influence decribed below eliminate the subjectivity from the analysis, but the polygon remains a very useful construct.

The definition of the conservation polygon is an important first step in conceptualizing how planning and management might occur in an area. Where a protected area is placed in the conservation polygon may suggest changing reserve limits in a planning excercise. The surface area and shape of the polygon is a telling statistic. Changes in the polygon limits provide a simple and graphic depiction of evolving human settlement patterns in the area of interest. This is a very simple but fundamental indicator of change and where conservation action is needed. Predicted changes in the polygon limits may lead to changes in land use rather than changes in the polygon limit.

As we proceed further the polygon concept gives way to an objective depiction of the level of human influence for any particular area in a polygon. This is accomplished by dividing the polygon into a very fine grid and using mathematical models to determine the influence humans giving by assigning a value to each grid cell based on the proximity to access routes and human populations.

Variables

The principal dependent variable, "**abundance of large mammal species** " will be a combination of values obtained from a number of techniques that assess abundance of species that make up the majority of biomass of large mammals in the forest.

The independent variables to be included in our study can be grouped into four categories: "**human influence** ", "**human impact** ", "**contextual** " and "**conservation** ".

The "**human influence** " multiple variable would be a number that includes:
- human populations,
- distance from human populations,
- importance of access routes, and
- distance from access routes.

A simple formulation for human influence can be determined for any grid cell and may include the closest 1, 5, or 10 settlements and access routes. It may be calculated for example as:

Human influence= Σ(human population/distance from settlement)+Σ((frequentation*age category of transport route)/distance from transport route).

The human influence value can be assessed in an *a priori* fashion for any cell in the polygon grid using existing data sets or socio-economic studies independent of forest surveys (Fay and Agnagna 1991, Mitchell and Slim 1991, Michelmore et al. 1994, Barnes and Lahm 1997, Lahm et al. 1998). The goal would be to make the human influence variable as simple as possible and still retain an acceptable level of significance with respect to dependent variables.

The "**human impact** " multiple variable would include
- logging and other industrial effects
- human encampments
- other evidence of human use of the forest in several categories

(White 1992, Wilkie et al. 1992, Michelmore et al. 1994, Plumptre and Reynolds 1994, Auzel 1995, Barnes and Lahm 1997, Lahm et al. 1998). Data for these variables are assessed simultaneously with large mammal surveys in the forest (Barnes et al. 1989, Blake 1996).

The "**contextual** " variables would include both quantitative and qualitative variables such as:
- geographical location,
- political boundaries,
- physical barriers to access,
- habitat,
- history,
- presence of non-human predators,
- substrate, and
- season.

(Tutin and Fernandez 1984, White 1992, Wilkie et al. 1992, Lahm 1993, Plumptre and Reynolds 1994, Barnes and Lahm 1997, Fay 1997)

The "**conservation** " variables are management influences on large mammal populations and include:

- concentration of conservation funds expended,
- density of conservation staff,
- logging company policy on hunting,
- level of government enforcement of wildlife laws,
- protection status of land and related variables.

(Robinson and Redford 1991).

In the following a research methodology is presented that uses these four categories of variables to develop the desired tool. The methodology will be used to collect a large empirical data set that will provide ample analytical possibilities for our research.

Research Questions

1. Over a large geographical area of central African forests, is it possible to detect significant correlations between the following sets of variables:

1) "human influence" and "abundance of large mammal species",

2) "human impact" and "abundance of large mammal species",

3) "human influence" and "human impact",

4) "contextual" and "abundance of large mammal species",

5) "conservation" and "abundance of large mammal species",

6) "conservation and "human impact"?

If the answer to these questions is yes, then:

2. Can one develop a methodology and modeling tools using regression analysis that yield valuable information for adequate land use management given the human and financial resources available?

Research and Analysis Design

Thirteen large blocks of contiguous forest polygons are to be included in the study. They are distributed across a very wide geographical range (spanning 800 by 400 kilometres) and vary greatly in both the independent and dependent variables (Map 1). In at least four of the 13 blocks, human impact is close to zero. For each of the forest blocks, a grid-based gradient of the "human influence" multiple variable will be displayed on a map. Using this map, a pair of reconnaissance surveys (Barnes et al. 1989) will be plotted that will start at a maximal human influence area and proceed to the center of minimal "human influence". Along the survey lines data will be collected on the "large mammal abundance and diversity", "human impact" and certain "contextual" variables in continuous strips and plots. Existing data sets and socio-

economic studies in each area will provide the data to evaluate “human influence” variables. Data on the “conservation” variables and the remaining "contextual" variables will be collected during surveys or from existing data sources. Survey lines will be broken into fixed “recce(s)” (reconnaissance walks) of 4-5km, that will take a single day to complete.

The first analysis phase will be to calculate simple statistics for every variable for each recce. A mean value and range for the multiple variable “human influence” will also be calculated for each recce.

In the second phase, the data from all the recces from the 26 surveys will be pooled, and a regression analysis will be carried out between the human influence and large mammal species abundance variables. The resulting regression line will be used as the standard against which each individual survey data set will be compared.

The third analysis phase will involve a step-wise multi-variate regression and principal components analysis approach to answer each of the research questions for the entire data set and for each of the 26 surveys independently.

The primary result will be an evaluation of whether or not human influence and human impact can be used as predictors of abundance of individual large mammal species. Based on the results of previous studies (Eves and Ruggiero 1996, Blake1996, Fay et al.1999), it is thought that human impact will be a better predictor of large mammal abundance and diversity than will human influence. Similarly, it is predicted that human impact will be negatively correlated with conservation variables (Blake and Fay 1999). Several contextual variables will probably be shown to have a significant relationship with large mammal diversity and abundance (Blake 1996, Blake and Fay 1999). These relationships can be used to further elucidate correlations between the human factors and the abundance of individual large mammal species and other independent variables.

The resulting data matrix should allow us to derive models of expected large mammal populations based on the vegetation, human use and management regime. This will not only allow us to compare between sites, vegetation types, and protected areas but also evaluate the effectiveness of conservation projects, relative impacts of logging practices, or other land uses, and past use. Differences in the slope and intercept of individual regression lines should be explained using the human impact, contextual and conservation variables. For example many surveys in the area around the Nouabale-Ndoki National Park in northern Congo have shown that there is a linear correlation between the distance from a village and elephant dung density. When one divides the data sets up by whether or not the nearest village is a “conservation village”, i.e. where a conservation project is active, changes in the intercept and slope become evident (see Fig. 1a-c, Blake and Fay 1999).

Figure 1a. Elephant abundance and distance from nearest village (all village types)

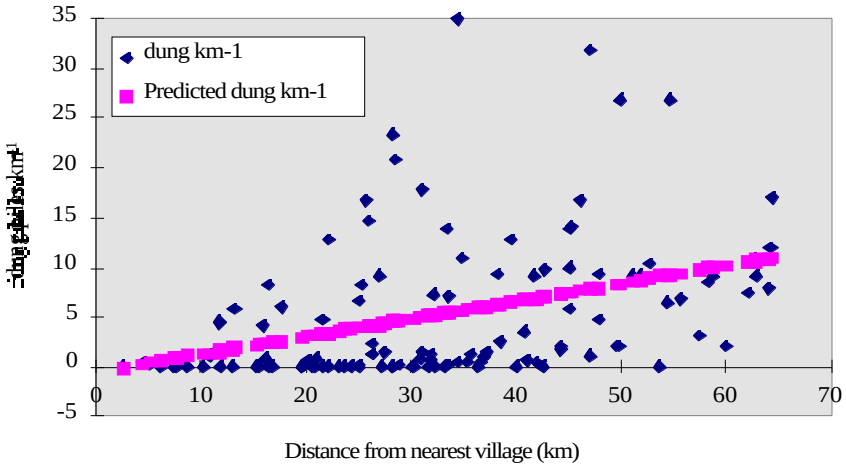


Figure 1b. Elephant abundance and distance from conservation villages

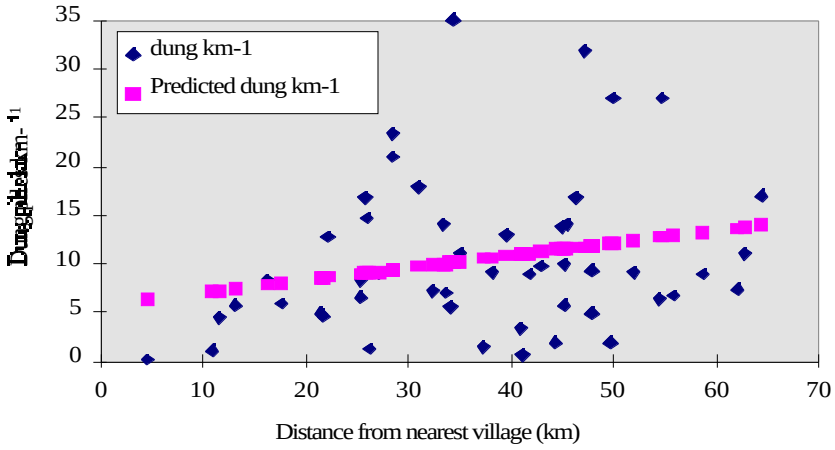
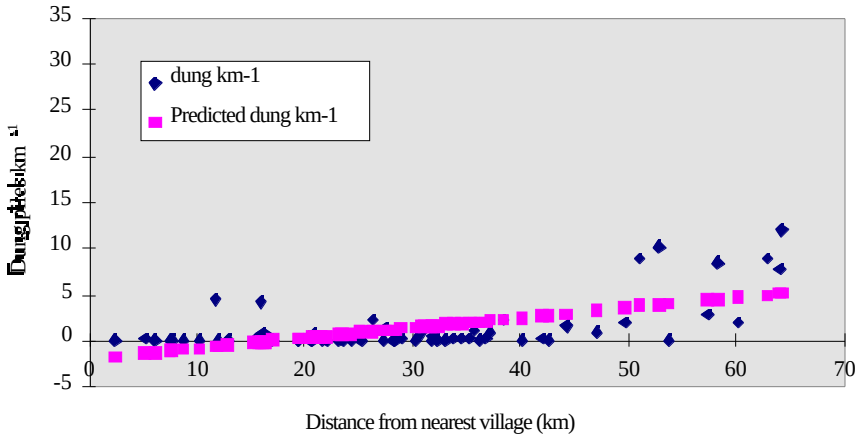


Figure 1c. Elephant abundance and distance from non conservation villages



The geographical element for each datum and background data sets and the human influence gradient will permit geographical depictions of all elements important for managers.

Methodology

Study Area

Our study area will be considered the 13 polygons that contain our contiguous forest blocks. These cover a band from southwestern Central African Republic, across northern Congo and Gabon to the Atlantic coast (see map I).

Site Choice

If one is seeking a meaningful tool to be used over a wide geographic area, then the base data set must be extensive. The 13 sites included in the study represent a broad range in all of the major categories of variables and individual variables of interest in the study. Four of the sites contain the largest intact forest blocks in central west Africa. In the center of these areas human impact drops to zero. The study survey line covers more than 1500 km.

Approximately 41% of the linear distance along the survey line will be in existing or proposed protected areas. For these areas some data are available on variables that are of interest in this study, in particular those in the human influence, contextual and conservation categories. These data will help in establishing the human influence gradient and conservation categorization for ten of the thirteen sites. Previously existing data on human impact and large mammal abundance will be useful as a general guide, but because they have been collected using disparate methods with teams of unequal experience, they are largely incomparable. These data will help to elucidate seasonal patterns in elephant distribution in a number of cases. Approximately 29% of the area is in currently logged forests. Certain data sets from these areas will be useful for the human influence and some contextual variables.

Potential Data Problems

One-off reconnaissance surveys are often criticized for certain statistical problems. In the research methodology we have sought to limit these problems.

Limited sample size -Typical line transect surveys in forest areas cover only a very small proportion of the study area. For example, of the polygons included in this study only 45% have ever been studied using transect or recce surveys. Where studies have been done the average sampling rate is less than 0.1% of the surface area. Therefore, standard techniques that estimate large mammal densities for a given surface area, in particular given the difficulties of extrapolating from secondary evidence, have confidence limits that are too wide to be meaningful. Using a modeling approach limits the problems associated with the small sample size because predicted values for dependent variables are derived from values of independent variables that can be determined for the entire study area.

Seasonality -Large mammal activity varies with season, rendering visibility and presence of spoor variable. Dung decay rates vary with season. We will limit this factor by traveling west and south on the survey, timing the study to follow the wet season throughout. Meteorological data will be available throughout the study area which will serve to quantify seasonal fluctuation during the survey. In any monitoring program, multiple samples per year would be included in the design and seasonal patterns would be discernible.

Forest elephants can cover wide areas during their annual movement patterns (Blake, pers. obs.). The difference between seasons in elephant presence can be dramatic (Fay, pers. obs.). For several areas this bias will be limited by existing data sets on presence and absence. One can also limit seasonal biases by including variables that persist throughout the year such as density and width of active elephant trails (Blake and Fay 1999). For any modeling tool it will be possible to include or exclude categories of elephant data depending on the objectives. For a one-off survey that seeks to determine overall elephant abundance data, "seasonal" categories may be excluded. For any elephant monitoring program detection of seasonal movement would be included in the study design (Blake and Fay 1999). In general modeling exercises it may be decided to exclude elephant data altogether for certain uses of the models.

Comparable Data -Two of the factors that usually bias data sets similar to the one being collected on this survey are observer experience and vigilance, and methods. Our survey will be an extensive one using the same highly experienced team and the same methods throughout. One of the results of this study will be to describe in a detailed way the exact methodology, training program and "team calibration" that should be employed in all such surveys.

Distance Measures -Distances along survey lines will be measured using a hipchain. The inaccuracies of GPS, in particular in the vertical dimension, render distance measures along a recce using these devices inaccurate. The combination of hipchain and GPS is a good one.

Geographic Location -The geographic location along the survey line will be recorded by storing a GPS fix every minute.

Distribution of Recces -A frequent criticism of continuous reconnaissance sampling is that it is biased toward trails. In empirical trials it has been shown that there is a strong correlation between reconnaissance and straight line transect data (Hall 1998b, Walsh and White, in prep.).

The continuous nature of the survey line, therefore non-independent sampling units, is also cited as a major problem. The method to be used will produce a one day recce that covers the

same length at more or less at the same time of day. The methodology also calls for the survey of five 400m2 circular plots each day, that will be censused for large mammal sign, vegetation, and many of the independent variables. The location of these plots is dictated by time of day. These data can be used in comparison with the continuous recce data. In analysis of continuous strips one can randomly include or exclude recce days or certain distances along recces to satisfy the assumption of independence of samples.

Data

There will be four principal sources of data covering the range of variable categories:

existing data,
aerial coverage,
socio-economic studies
ground surveys and point sampling.

Existing Data

The following existing data sets will be used in the preparation for subsequent data collection phases and in the analysis phase of the study:

- complete ERS radar mosaic of the entire study area,
- scanned 1:1,000,000 maps for entire study area,
- scanned 1:200,000 maps for the entire study area,
- TREES coverage of forest cover of the entire study area,
- quality Landsat TM images (from 1988-1992) that cover ca. 25% of the study area,
- quality SPOT images that cover ca. 25% of the study area,
- high resolution aerial radar coverage for ca. 20% of the study area,
- vector coverage of vegetation for ca. 30% of study area,
- vector coverage of protected areas and logging concessions for entire study area,
- vector coverage of principal transport roads and navigable rivers for entire study area,
- meteorological data from the entire study area,
- national census data for entire study area,
- detailed socio-economic data from ca. 55% of the study area,
- recce or transect data from ca. 45% of the study area covering <0.1% of surface,
- aerial videography of human settlements covering ca. 50% of study area,
- colonial documents and maps.

These initial data sets will be used as the basis for the project GIS. ESRI products and IMAGINE will be used as the two principal software packages for GIS. The ERS mosaic and 1:200,000 maps will serve as the base coverage for the entire study. Using a combination of all existing data sets, initial vector and spreadsheet components for the “human influence” variable grid will be catalogued and displayed. Features such as clearings, inselbergs, and swamps will be geographically displayed in coverages in order to permit exact location in the subsequent aerial phase.

Meteorological data will be used to schedule wet season travel for the entire survey line circuit.

Aerial Videography

Aerial Data

Over the last three years the Nouabale-Ndoki Project has developed a number of hardware and software innovations to produce quality, high-resolution, spatially referenced, digital video for land use management purposes. The resolution, versatility and accuracy of the system for remote sensing is unparalleled by any other technology (Fay et al. 1999).

The system is relatively simple and highly adapted to the conditions encountered in the region. The aircraft used is equipped with many modern communications, navigation and weather detection instruments that make it safe in a demanding environment for aviation. Data collection takes full advantage of the many innovations in geographical positioning, powerful computing, software, and video technology that have come on to the open market in the recent past.

Advantages of aerial videography

With the advent of digital camcorders the quality of inexpensive video imagery has improved to a level acceptable for most remote sensing needs. The mini-digital format is also fast becoming a worldwide popular standard.

Results can be viewed both in real time and immediately afterwards using the same hardware; quality control and data processing can be done in the field.

The equipment is simple, rarely breaks down in the field, and is cheap enough that back-up systems can always be carried on field missions.

The greatest advantage is that the plane can be used as an exploratory tool at any altitude. Resolution varies as needed and intense coverage can be made of features of interest.

Equipment

Cessna 182 – An aircraft specially equipped for aerial videography and photography. GPS-GPS positional data are received every second and recorded in an on board computer.

Radio altimeter-Radio altimeters record the above-ground altitude of the aircraft. The plane is equipped with a data link from the radio altimeter that is recorded with GPS data on the same computer.

Laptop computer – Data streams from the GPS, altimeter and time code data are recorded in the aircraft on a laptop computer. A moving map software package enables one to plan and execute flight plans accurately and also to locate images on screen during capture operations. The entire set of 1:200,000 maps for Congo and Gabon that have been scanned are geo-coded are available to the project. Satellite radar imagery is also available for the entire census line. Landsat TM images are available for a significant portion of the census line.

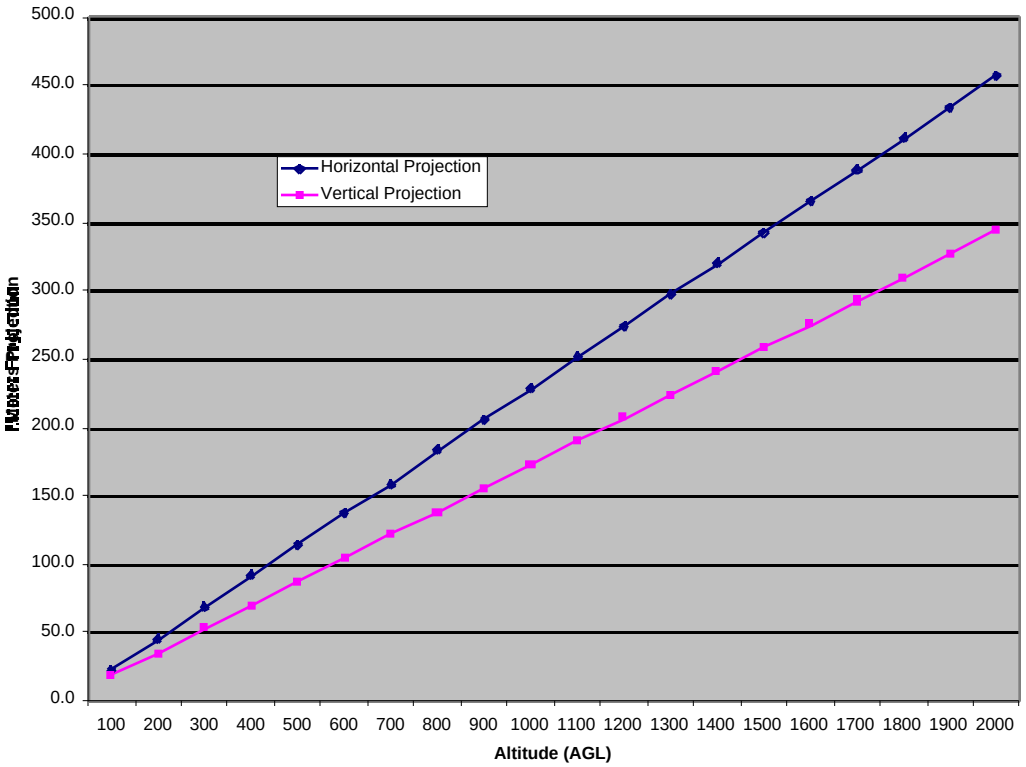
Digital video camera – A NTSC or PAL format Sony VX-1000 Digital Handicam is used depending on requirements.

A four way intercom with headsets provides four way radio annotation of the flight on the sound band of the video.

35 mm camera – This camera is equipped with a data back that permits exact location of photos using time and date data.

Data acquired

Video Image-The image quality that is obtained using digital handicams is truly spectacular. A maximum ground speed of 100 knots, using a shutter speed of 1:10,000 produces sharp images. Depending on the zoom and flight level, we can produce just about any resolution or ground frame width desired. The airplane moves a maximum of 5 mm during the frame acquisition. Thirty images are taken every second (108,000/hour) with NTSC and 25 (90,000) with a PAL format. Normally frame ground swath varies from 50 to 400 m depending on height above ground of aircraft (see graphs below which are the result of empirical calibration data). With a frame width of 200 m, 4000 ha of surface can be covered in an hour. Image overlap depends on aircraft height. At 400 ft the overlap per image is ca 95% which permits perfect framing of desired features, selection of superior images, and stereoscopic analysis. Using PAL and the wide format, using similar parameters, overlap is reduced to about 80% depending on ground speed and altitude. The Sony VX-1000 camera has proven to be a reliable workhorse for aerial work. Of course, because they are digital, the images are 100% reproducible and directly accessible on a computer. Each image is referenced through an RCTC time code.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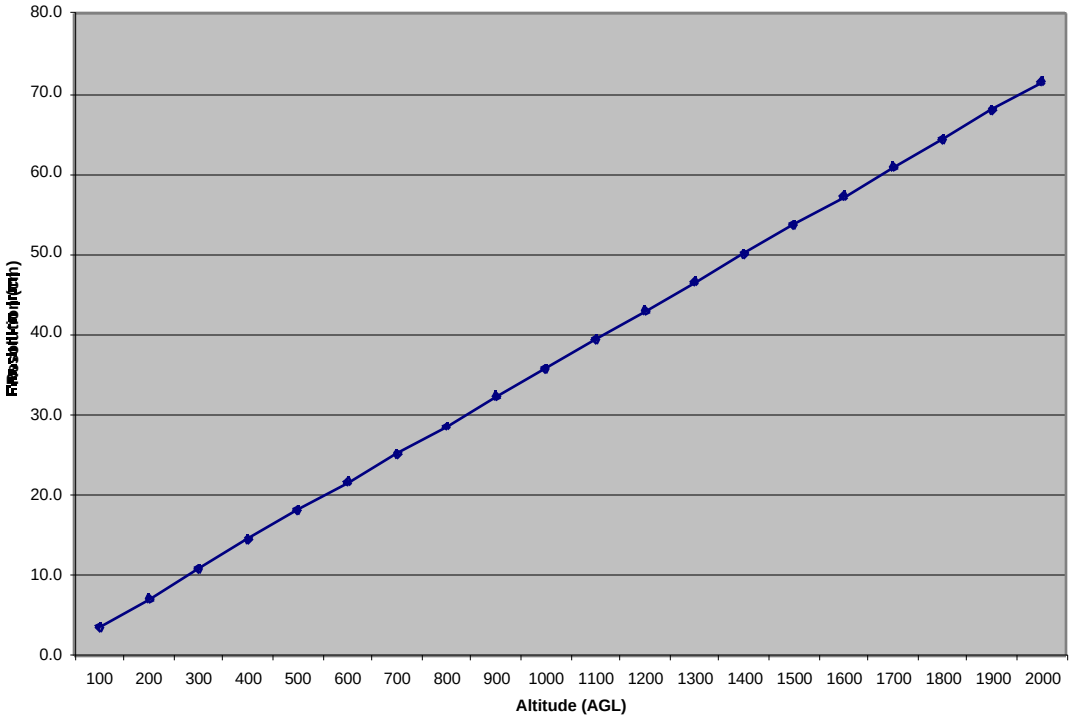
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Altitude (AGL)

35 mm film images – Photographs are taken simultaneously with video in order to obtain high-resolution images of point data such as clearings, villages, etc. A LCD monitor in the plane acts as a viewfinder for the camera.

Sound-Four observers can annotate imagery in real time. These vocal annotations are permanently associated with the videotape on the sound band. Post mission data interpretation is greatly simplified when observers richly annotate imagery according to systematic database categories such as vegetation type, polygon, feature type.

GPS-This permits accurate geographic location of data points. GPS data are permanently associated with the videotape. The aircraft flight line can be printed on screen over video mosaics, maps, satellite images which is a great aid in geographically accurate classification. Using our software it is possible to use GPS points on the moving map to control the tape. It is expected that soon it will be possible to put the tape on a DVD disc greatly facilitating access.

Radio altimeter-The radio altimeter data stream permits accurate image scaling and resolution calculations for the imagery.

Uses

Thus far we have used the videography principally in four domains.

Land Cover- It is quite simple to distinguish different types i.e. savanna, swamp, flooded forest, terra firma forest, Marantaceae forest. Low level, high-resolution videography permits detailed vegetation classification of satellite imagery. Many species of trees are identifiable from the air.

Land use-All land use features such as logging, roads, human habitations, burning, cultivation, plantations, forest regrowth, and even paleo-cultivation are readily classifiable from the imagery. We are able to use aerial videography to ground truth lower resolution imagery such as satellite images with great accuracy (Maisels et al.). Human populations and demographics are important to resource management and land use planning. Aerial videography is a very simple and quick way to census human populations. In most cases one can distinguish the relative wealth of a population, construction materials, house size, number of habitations, socio-economics (hunting, fishing, cultivation, subsistence), ethnic group, concession size, state infrastructure, commerce, cultivation area, and crops. Ground surveys must be done to fine tune data sets and aerial videography can be used to gain an excellent idea of the human situation over a very large area in a short amount of time. For instance all villages surrounding the Nouabale-Ndoki Polygon can be censused in a flight of four hours.

Large mammals-Traditionally large mammals have been censused using methodologies that depend to a great extent on an observer's experience. Aerial surveys have wide confidence limits and they are unverifiable. Data collected on the ground in forests are also subject to a large number of biases. We have developed a number of techniques for more accurate surveys of large mammals in savanna using complete counts, and for objective vegetation calibration. We have also developed techniques for forest areas using the evidence of large mammal activity in forest clearings and counts as indicators of population (Fay et al. 1999).

Data Processing

The first step in data processing is to verify that the various data sets have been properly recorded and that they are available and catalogued. A permanent, united database of all flight lines with each GPS fix, times, time code, radio altimeter data etc. is archived.

Each tape is reviewed on a large television screen. Images are labeled by variable and integrated into the database using a Greenwich Mean Time (GMT) reference. For example each time there is an occurrence of a village, the start-stop in GMT is recorded in the database, along with all the other associated data is recorded. This is done for land cover, use and a wide variety of features. In this way anyone can access the database and know exactly where to look for a particular vegetation type, clearings, rivers, cliffs, camps, etc.

When the initial processing is accomplished, the data can then be processed further depending on the specific needs of the project.

Aerial reconnaissance and GPS-linked vertical videography will be used initially for three purposes:

The first will be to record all human settlements and major access routes forming the perimeter of each of the 13 contiguous forest blocks. Settlements will be evaluated for population density by counting the number of buildings and estimating the number of inhabitants based on socio-economic data that exist for much of the areas to be studied. Using these data, existing maps and reports, and census data will permit a comprehensive depiction of the "human influence" gradient.

The second will be to do reconnaissance to plot survey lines over the 13 forest blocks. These will generally follow the gradient of the "human influence" variable and at the same time avoid obstacles and include features such clearings, inselbergs, or specialized vegetation types. GPS videography will permit localization of important features, obstacles (in particular swamps and Marantaceae forest), and the chosen survey line routes.

The third will be to do a survey of areas that were logged but for which detailed logging data are not available. This will apply to 10 of the polygons in Gabon covering a surface area of ca. 45,000 km^2. This will take approximately 40 hours of flight time to determine the general pattern of logging of all polygons. Based on these surveys and existing data sets the current logging situation for the entire survey will be mapped.

GPS track data will be imported into the GIS for display of survey line routes on base maps. From these, general way-points will be established for the ground survey.

In the final stages of the study, subsequent to the ground survey, further GPS linked aerial-videography will be used for two purposes.

The first will be to use ground-based data to locate and videograph human settlements and access routes that were not recorded in the first aerial phase of the study. These data will be used to adjust the "human influence" gradient analysis.

The second will be to cover as accurately as possible the exact survey line route covered during the ground surveys. The objective will be to produce be a high-resolution coverage of land cover, including canopy density and data on dominant trees for the entire survey line. This will be possible using GPS referenced vertical digital videography with audio annotation.

In all aerial surveys the plane will be flown 400 ft above the canopy. This will produce images of approximately 70x92 m in dimension with pixel coverage of 14.5 cm on a side. This will cover a swath that approximates the exact survey line for which we will have ground data. Secondarily all features of interest, such as forest clearings and inselbergs, will be over flown and captured in detail in a digital database.

Ground Data

General Data System

General data system

Both historical and scientific ground data will be collected using 35 mm film camera, digital camera, digital video, digital audio, GPS and written notes and quantitative data.

Equipment

35mm camera-A Canon EOS 3 will be used with three lenses: 17-28mm, 70-200mm and an image stabilized 300 mm. This camera will provide high quality, high resolution images for large mammals, people, camps and other situations where very high quality imagery is necessary.

Digital camera-A mega-pixel digital camera will be used for digital images of high resolution. This camera will be used primarily for vegetation studies.

Video camera-A standard 3CCD semi-professional video camera will be used for moving images and species image collections.

Digital Audio Recorder-A high quality Sony DAT recorder and stereo microphone will be used for quality sound recording. This will be for bird and ambient sound recordings.

GPS-Because all devices including written notes will have an accurate time record, GPS data can be correlated between geographic location and the data. A continual GPS track with 30 second updates will be recorded for the entire flight.

Historical Data

Historical data will concern two primary domains: natural and human history. For convenience we classify historical data as those that will not be collected in a systematic, numerical way. The methodologies employed will be standard except that digital video and 35 mm cameras will be used to the maximum extent possible to record images and sound.

Natural history will be approached in two ways. The first approach will be to make virtual collections of sound and images, via digital video and audio, of as many species as possible, vegetation types, geological features, soils, forest clearings, salines, animal behavior, and spoor. Over the year this virtual collection should include thousands of individual video, and sound clips and photographs, all with detailed verbal descriptions.

The second approach to natural history will be to ask the Aka (Pygmy) guides what they know of all that will be recorded throughout the trip. The Aka have a profound knowledge of natural history. This will include Aka names, taxonomy, uses by animals, and by humans, interrelationships, and their general knowledge of the natural history of each feature or species being observed. Over time, the data for each feature or species will accumulate. One local guide will accompany the group on each leg of the trip to add specific knowledge of the local flora and fauna. As we pass further to the west we will depend more heavily on the help of these local guides.

All human activities and sign observed on the recce will be recorded in a systematic way as discussed below. In addition details of human encounters on the trip will form an important part of data collection. This will include, hunting and gathering, poaching, mining, logging camps and several villages. Here several data sets will be collected (see socio-economic surveys below).

A regular log of our progress will be made, both from real time annotations and nightly summaries of the day's activities. We will capture the daily difficulties, health problems, encounters with large mammals and insects, river crossings, and hunting and gathering activities of our team as we cross the forest. This will serve as a popular chronicle of the voyage.

Socio-economic surveys

This section describes the methods that will be used in villages for socio-economic surveys. Because only a small number of villages will be traversed, more extensive qualitative data on human use of the polygon in general will be the focus of our surveys. This will include both people that are encountered in the forest and in villages that are on the periphery of each polygon. In most cases only one village will be visited whilst passing from one polygon to the next.

The data collection will follow a logical progression in each village. The data sought in each village will be as follows:

- maps of the village, fields, and traditional lands of that and neighboring villages;
- village census including livestock with associated questionnaire;
- material culture of each site will be documented including building types and materials, household goods, tools, weapons, toys, and religious objects,
- ethnic and linguistic affinities of the local populations using a standard list of words that will be recorded in the local language
- interviews on village history, ethnic groups, ethnic and social relations with neighboring villages;
- access into the forest;
- competition for forest resources;
- history of human settlement in the area and the oral tradition on their origins, the major occupations, limits of the traditional lands, communications, and changes of the recent past;
- information on transport routes past and present;
- resource exploitation past and present both locally and in the region;
- wildlife and fish populations past and present;
- forest types both past and present.

Video and audio recordings will be made in as much detail as possible in the time allotted for camp/village stays on the actual physical infrastructure, interviews and activities such as dances. Formal portraits of as many people as possible will be made, in particular those that are known.

Census.

Camp and village data collection begins with a participatory mapping exercise. This involves the whole community at once, and allowed the research team to get an idea of community dynamics. Participatory mapping is an especially effective way of enabling non-literate people

to understand the presentation of the information they have given (Lewis et al. 1997). It builds confidence and trust at the beginning of the research program.

Volunteers are asked to draw their village with a stick on the ground. This includes all buildings, their function, number of inhabitants, gardens, fruit trees, livestock, trails to water sources and forest areas. We will interfere as little as possible, and encourage other community members to comment, criticize or take a stick themselves. By visually sharing a map, all members of the community regardless of age or education can participate if they wish. Quantifying things using simple symbols and objects allows everyone to see, point to, discuss, manipulate and alter objects or representations. Triangulation occurs as people cross-check and correct each other.

Once the map is complete to everyone's satisfaction the buildings are numbered and details about each building is recorded. People are asked to use matches (whole match = one adult, half match = one child) to show how many people occupied each house. Using other familiar objects (beans, bottle-tops, etc.) participants are asked to indicate the number of people in each house who could read and write, or the households keeping livestock and which animals they had.

This map is then copied onto paper by two researchers and used as the basis for making a rough but standardized and accurate map of the village. We measure the village, record the cardinal points using a GPS.

The team then begins the census questionnaire (a structured interview). Calling people household by household, each member's name, sex, age, ethnic group, marital status, and principal activities and attendance are recorded. A typical adult could have between 4 and 9 principal activities.

Community administration, organization and land tenure and use

The framework for this part of the research is a semi-structured interview (Lewis et al. 1997). Anyone interested is invited to participate, but generally community leaders, experienced hunters and fishermen dominated the discussion. Key words and questions allow the interviewer to ensure that the main topics are covered without imposing a rigid structure on the discussion.

1:200,000 IGN maps are used to depict the extent of the village forest domain. This is extended to the domains of neighboring villages. They are asked about the extent of their range in relation to the polygon, which side of the polygon limit is more heavily used and for what purpose. Any local names that can be determined for rivers, mountains etc. are recorded.

Activity analysis

To investigate people's activities, we will use a combination of participatory techniques (drawing pie diagrams) and structured interview methods (using forms and questionnaires). The questionnaire begins with the seasons, followed by seasonal activity peaks. Then the focus switches to commercial activities in particular. Finally key informants are interviewed on specific procedures in order to create flow diagrams describing each commercial production process. In this part of the research focus groups determined by ethnic and gender identity are used.

Standard format for presenting baseline data

A standard pattern, is used such that data are presented consistently. The map presents the community as we found them at the time of our visit. Using symbols and numbers, the map presents geographic features, demography, buildings, economic activities, literacy and fruit trees. Census data are presented as current population, past population, ethnic make-up, and activity categories and comparing this graphically by season. This is important for assessing the possible relation to the human impact in the forest. A textual presentation of village history, village administration, traditional land claims (with resources, and communication networks) is extracted from the interviews. This is done in the context of information that was gathered not only for target villages but for neighboring villages (Lewis et al. 1997).

Reconnaissance Surveys

Over time it has been deduced that line surveys that use a “path of least resistance reconnaissance” method provide comparable results to strict line transects for one-off reconnaissance surveys (Hall et al. 1998b, Walsh and White, in prep.). This method calls for the observer to follow a general compass bearing where the use of human and animal trails is permitted. Along the survey line the observer notes data on a number of variables (large mammal spoor, human impact, and contextual), as they would on a straight-line transect. The path of least resistance has the advantages of leaving the forest intact after passage, a significantly increased sample size because of increased speed, and considerably reduced observer fatigue and deviation from a straight line.

Within each polygon a path of least resistance survey line will travel from maximum to minimum and back out to maximum human influence at the edge of the polygon. Samples will be a 4-5 km long section of the survey line which will be covered in a single day from about 7:00-16:00. The normal procedure will be to complete one sample each day.

A second method will be deployed in this study called "pulse of the forest" that provides discrete sample units along the survey line that are systematically spaced by time of day. Five "pulse of the forest" stations, including a $4m^2$, 200 m^2 and 400 m^2 vegetation quadrats, will be done each sample day. Data will be recorded on a number of variables important in assessing the physical and biological state of the forest at any one location.

Data will be collected continuously on the line and will form the backbone of the data set. The daily samples and "pulse of the forest" stations will provide statistically comparable multivariate sampling units in time and space. In addition extensive collections of soils, palm nuts and images and sounds of species will constitute discrete data sets that will be collected over the course of the study.

Path of Least Resistance Materials and Methods

Observers

The PI will collect all data on the survey line route. A second person will be responsible for identifying trees and clearing the path. In most cases this will be an Aka or Baka Pygmy with confirmed knowledge of natural history, in particular of trees. The PI will decide on the course. Porters will depart the previous night's camp one to three hours after the observers and will remain well clear of observers at all times.

All numerical data will be recorded on a digital dictaphone or pad. Images and sound will be collected using a digital video camera.

The following data will be collected along the trail:

- track
- physical features
- land use
- land cover
- mammal sign (including humans)

Track

Compass headings will be used to maintain the desired direction of travel, but we will be free to deviate if a particular feature is judged important, such as a large elephant trail. We will regain the determined route when deemed appropriate. Continuous data will be collected on at least four categories of "track type": human trail, no trail, large mammal trail and elephant highway. These will serve to evaluate the results for each type.

GPS readings will be continuous using a data logging unit that will record a fix every 30 seconds or minute along the recce length. Topofil will be used for distance measurements. Each datum that is recorded will be geo-referenced according to time in minutes, and distance using readout from topofil counter. Each evening the relevant GPS data will be transferred to ROM flash cards and hard disks such that there is no chance of data loss and all quantitative data will be entered into spreadsheets.

Physical Features

Physical, non-living features are important for the overall backdrop to the recce data set. We will collect the following data:

- Running log of general soil texture and color. Thus each time there is a noticeable change it will be recorded. Standard soil profile descriptions and small samples will be collected as opportunities present themselves along the recces. These will come from exposed soil profiles. A very small sample of soil will be collected at every "pulse of the forest" site along the trail along with a video image of the surface soil.

- Point recordings (GPS) and descriptions of features. Descriptions of all non-living physical features such as watercourses, waterfalls, clearings, cliffs, erosion, and human landscape modifications will be collected as encountered along trails.

Meteorology

Atmospheric pressure and temperature will be recorded at each "pulse of the forest" station and at hourly intervals using a computerized device. A rain gauge will be used to record all significant rainfall during the voyage. This is possible because the group will not move when it is raining. These will reflect under the canopy rainfall. Canopy characteristics will be described in each case.

Land Use

In the modern landscape evidence of humans abounds. This comes in three forms: archeological evidence, historical evidence and present day activity.

- Archeological evidence that we expect to find will consist of charcoal, palm nuts, pottery and possibly rock tools that are stored in the soil profile. In certain locations we will record rock carvings and shelters, smelting sites and alteration of soil topography.
- Historical evidence in the form of old village and agricultural sites can be recognized by their particular vegetation type and by artifacts such as pottery, and metal objects. We will also record soil topography alterations.
- Data for present day activity will come from encounters with people and from recent traces of human activity left by hunters and gatherers, villagers, prospectors and those engaged in industrial activities such as logging and oil exploitation.

Objective Data

For each encounter of human sign, the type of evidence (including a detailed description if necessary), the estimated age, and the location will be noted. For several such as charcoal, iron tailings, palm nuts and pottery, small samples will be collected for carbon dating.

Signs include:

- encounters with humans (number, origin, tribe, equipment, time in area, activity, reaction to survey team will be recorded);
- soil charcoal;
- evidence of smelting;
- ancient oil palm and *Antrocaryon micraster* nuts;
- rock engravings;
- rock tools;
- ancient village sites;
- pottery;
- old or current village sites;
- oil palm trees;
- rubber tapping scars on *Funtumia elastica* trees;
- current or past logging, mining, petrochemical or agricultural activity including tree fell sites, skitter tracks, roads, size, type and state of road, cut prospection lines, mining pits and other mining infrastructure, time since exploitation;
- camp sites, active or abandoned, with details of construction type, number of huts, beds, activity, details on trash pits, Bantu or Pygmy, smoking racks, animal carcasses, hunting paraphernalia;
- bark stripping for construction, mining sluices, beds, cords, medicines etc.;
- fire sites;
- sites where nuts such as *Panda oleosa*, or *Irvingia* spp. have been cracked open;

- machete cuts or broken stems;
- human trails, or where old cuts suggest that humans once passed frequently;
- snare lines, active or abandoned, counting number of snares or old snare holes
- shot gun shells;
- large mammal carcasses and kill sites;
- honey extraction;
- fishing activities.

A running tally of land use will be recorded. This will vary dramatically over the recce both on a macro and micro scale. To the trained eye the age and nature of the forest is evident from the tree species present and from their size. This often helps in determining past land use, in particular to about 50 years. A special effort will be made not only to describe present, obvious land use but, more subtle, past use.

Ancient Charcoal and Oil Palm Collections

When crossing watercourses systematic searches will be made for oil palm nuts. These provide evidence of past human habitation in the area (Fay 1997). Samples found will be stored in aluminum foil, noting the location and site characteristics. Sample size will be limited to ten nuts per site. Samples of any pottery or stone tools will be collected.

It has been discovered that over much of central Africa the soil profile occasionally contains ancient charcoal, iron extraction tailings, and pottery (Fay 1997). These can be used quite effectively for the determination of the ancient forest cover and composition and ancient land use in these areas. Whenever possible samples will be collected in exposed soil profiles. These will be cataloged and subsequently identified.

Land Cover

A running tally of vegetation type will be recorded using the following vegetation code (Blake 1996):

- Mixed Open Canopy Forest (mof)
- Mixed Closed Canopy Forest (mcf)
- *Aucoumea klaineana* forest (auf)
- *Saccoglottis* forest (scf)
- *Gilbertiodendron dewevrei* Forest (gdf)
- *Gilbertiodendron dewevrei* Forest with a *Haumania dankelmaniana* understorey (gdfh)
- Flooded *Gilbertiodendron dewevrei* Forest (gdf)
- Flooded Forest (ff)
- Swamp(swp)
- *Megaphrynium* Forest (megf)
- Vine Forest (vf)
- Clearings (cl)
- Savannas (sa)
- Young secondary Forest (ysf)
- Old secondary Forest (osf)
- Plantations (pl)

Vegetation designations will be added as new types are encountered.

At every "pulse of the forest" station a 360^{o} video recording will be made of the vegetation. This will be accompanied by audio data on locality, a general description of the vegetation at the site and identification and measurement of all trees 10 cm dbh and

above, as accurately as possible, within a 7.98 m radius of the center point. Trees 60 cm and above will be enumerated up to 11.2 m radius from the center point. In the center of the plot a 2x2m plot will be established where all stems will be recorded.

Mammals

It is estimated that over 80 large and medium sized mammal species will be observed during the survey (Kingdon 1997).

All Mammals

A record of all large mammals seen or heard will be kept throughout the survey. Observations will include number of individuals, location with respect to recce line, habitat and species associations. Notable medium-sized mammal sightings will be noted.

Spoor of a number of species will also be recorded as described below following the standardized methods (White and Edwards, in press).

Elephants

All signs of elephants (*Loxodonta africana*) will be recorded. All dung is recorded as to distance from the recce line and age. Dung is categorized into the following age classes to obtain a use curve: *Fresh* - fatty acid sheen present; *Recent* - still moist, odor present (break the boli if still intact), there may be flies, sheen no longer present; *Old* - overall form may still be present but equally it may be an amorphous mass, fungi or a patina of mold may be present, odor now musty; *Very Old* - flattened, dispersed, tending to disappear; *Very very old*- advanced state of decay. Other sign to be noted quantitatively and qualitatively include prints, feeding signs (including barking of trees), digging, saline use, and trail details including size (small, medium, large), use (abandoned, light, medium, heavy), and orientation. In areas of high and very high activity this will be noted.

Apes

The nest sites of both species, gorillas (*Gorilla gorilla gorilla*) and chimpanzees (*Pan troglodytes*), will be mapped. Fresh nests could be identified as either gorilla or chimpanzee nests by their odor and usually the presence of dung. Given the inherent problems in distinguishing between the two species for older nests, nest groups with at least one nest on the ground will be classified as gorilla nest groups, and those where the only visible nests are in trees classified as tree nest groups. It can be assumed that most of these are made by chimps, but a proportion will be gorilla's (Tutin et al. 1995).

The nature of the path of least resistance reconnaissance methodology has a bias against finding gorilla nests because favored sites for gorilla nest construction such as thickets and light gaps are avoided, but these data still useful in estimating gorilla abundance (Hall et al. 1999b). Nest count data will be complemented with data on feeding, dung, prints, encounters and vocalizations, with details of each. Chimpanzees also commonly respond to duiker distress calls in areas where they have not been hunted. The responses will be recorded in detail. The combination of data sets will produce a good idea of the relative density of both ape species.

Diurnal monkeys

Sixteen species of diurnal monkeys are expected to be encountered on the survey. All encounters and vocalizations heard will be noted with species identifications and numbers seen or heard. No set system (e.g. 2 species more than 50m apart) will be employed to determine the difference between single and multi-species groups, but if two or more species are in obvious close association they will be considered as a single group. In the case of vocalizations, if it cannot be positively determined that monkeys from more than one group are calling, it will be recorded as a single event. Where possible, activity will be recorded such as feeding, resting etc. Monkey vocal responses to duiker distress calls (see below) will also be recorded. In the case of mandrills an attempt will be made to determine approximate group size, surface area covered, direction of travel and activity.

Large Ungulates and Predators

Approximately 20 species of large ungulates and four predators will be encountered during the survey. Records of dung and distance from recce line will be made for all ungulate and predator species. In "pulse of the forest" duiker call sessions all observed ungulates and predators will be identified to species sexed and videographed, if possible. In the case of rare sightings such as bongo, sightings of tracks will be recorded.

"pulse of the forest" Stations

Quiet sits in the forest have been shown to be useful in sighting small mammals, birds and other animals.

It has also been shown that duiker distress calls emitted by Pygmy trackers elicit an immediate vocal response from a number of mammal species. The duiker distress calls are often followed by sightings of mammals that are attracted to these distress calls including not only duikers but chimpanzees, leopards, genets, and pythons. Previous research has shown that duiker response is well correlated with hunting pressure (Fay and Blake, in prep.).

Six times a day: at dawn, mid-morning, noon, mid-afternoon, dusk and two hours after sunset, observers will sit quietly for five minutes. At five minutes, a duiker distress call, emitted by one of the guides, will be made for ten seconds with a fifty second gap followed by a second session of duiker call that will be sporadic over four minutes. During this time all mammals heard or observed will be noted and videotaped when possible. These sessions will provide a wealth of quantitative, audio and image data.

Vegetation plots will coincide with day time "pulse of the forest" stations. Within each of the 400m2 plots all large mammal spoor will be recorded to use as point samples for relative abundance measurements.

Data on other taxa

Plants -It is estimated that over 1000 plant species will be observed during the project. A digital collection will be made of species of interest. This will consist of video of the plant, leaves, flowers, fruits, slash (where appropriate) and common name if known. Digital video cameras are able to capture minute detail in plants, including stamens, venation, pubescence and other characters necessary for identification. Small physical specimens will also be made of species such that they can be added to herbarium collections. Specimens will be collected only when fertile material is available.

Birds -It is estimated that over 400 birds will be observed during the survey. Opportunistic observations of birds will be made the entire length of the survey. Notes will include relative abundance, habitat, and video of individuals when possible. All unknown bird vocalizations will be made when possible. Bird recordings will also be made during "pulse of the forest" sessions.

Reptiles- Every reptile species observed along the survey will be videographed with standard narration on the habitat and its abundance.

Fish -Fish will be captured for consumption during the entire survey. Every fish that is caught will be videographed and described. When the team reaches the Atlantic Ocean we will work with local fishermen in Sete Cama in recording all species and their relative abundance for two weeks of fishing from small craft working the coast. The habitat of each will be recorded.

Insects -Notable insects, including caterpillars that are observed along the survey will be videographed. In the case of caterpillars abundance and host trees will be noted. Each evening a white sheet with a back light will be set up on a rack. After ten minutes of illumination the insects on the sheet will be videographed in detail. Habitat types of each site will be recorded.

Bats- A single mist net will be set every afternoon and evening. The net will be checked every 30 minutes and bats (and birds) that are captured will be videographed in detail. Hair samples will be collected from each individual captured. Small blood samples will be taken and preserved from each individual. Audio recordings of all bat vocalizations will be made as possible. All captured animals will be subsequently released.

Biting flies and ticks -Biting fly blood meals have been used in the past to determine the natural ecology of these species, the presence of host species, and the presence of blood borne diseases, both human and non-human. A single tse-tse fly trap will be carried on the voyage and set up opportunistically. Entire flies with their blood meals will be preserved for future analysis. Any other biting flies observed with a blood meal that is not from one of our guides will be collected and preserved.

Discreet samples and accessory data sets

Forest Clearings

There is an abundance of forest clearings along the entire proposed route. These clearings are concentration areas for large mammals and other animal life. Records will be made of the level of activity of all mammal species noted based on the presence of individuals, tracks and dung. A general map of each clearing will be made and notes taken vegetation, trails and use by animals and humans. An effort will be made to spend at least one full day from 6 am to 5 p.m. at each important forest clearing that is located during the trek.

Night Recce Surveys

Twice weekly a night recce will be run for at least two kilometers along the survey track followed during the day. This will be done with spotlights and will permit an evaluation of nocturnal mammal diversity along the survey route.

Brief Description of Polygons

In the following each of the seventeen polygons is described with a summary of expected results and preliminary data sets available.

Polygon 1 - Nouabale-Ndoki

Size: 20,530km^2 and its perimeter is 679.4 km.
Maximum distance from human settlement: 53 km
Land use boundaries: includes the Mokabi UFA, Dzanga-Sangha Reserve, Nouabale-Ndoki National Park, Loundougou UFA, and northern Kabo UFA.
Hydrographics: headwaters of the Ibenga, Yobe, Motaba, Likouala aux Herbes and Ndoki Rivers.
Topography: 350m - 650m. Generally flat with gentle rise to headwaters of rivers. There are no steep slopes, no exposed bedrock. In fact it is almost impossible to find a rock or a large pebble in the Ndoki forest. Toward the southern end of the polygon one enters the vast *Cuvette Congolaise.*
Vegetation: The northern UFA, Mokabi is a mixed dry forest. Much of the central plateau, at the headwaters of Motaba, has a dense cover of malapa (*Gilbertiodendron dewevrei).* Pure stands of this species also line riparian slopes with relatively dry soils. Most creeks are lined with swamps, sometimes more than 2km across.
Soils: The illuvial slopes have red ferric oxisols that grade to sands and white clays in the alluvial planes.
Features: The most interesting feature of this polygon is the abundance of clearings on the upper slopes as well as in the Ndoki Basin.
Principal mammals: The principal mammal species of interest are: the forest elephant (*Loxodonta africana cyclotis*), gorillas (*Gorilla g. gorilla*), chimpanzees (*Pan troglodytes*), bongo (*Tragelaphus euryceros*), sitatunga (*Tragelaphus spekei*), forest buffalo (*Syncerus caffer nanus*), giant forest hogs (*Hylochoerus meinertzhageni*), bush pigs (*Potamochoerus porcus*), leopards *(Panthera pardus*) ten species of anthropoid monkeys including the red colobus (*Colobus oustaleti*) and Allen's swamp monkey (*Allenopithecus nigroviridis*), and six species of duikers. In the northern included savannas there are spotted hyenas (*Crocuta crocuta*) and baboons (*Papio cynocephalus*).
Interesting mammals: The bongo antelope is an increasingly rare species. It is particularly common in this part of central Africa. It is very strange to be finding spotted hyenas along logging roads in this part of the world. We believe that these roads are providing access to savanna animals to the dense forest. This could have interesting and not always positive consequences for the forest fauna. Imagine chimpanzees all of the sudden faced with an unknown and very powerful predator.
Human Activity: There are three logging companies, three national parks and active logging in the north and south. A road was built in 1998 by the logging company Crystal that has opened the northern section of the polygon to new hunting, logging and diamond exploitation.This polygon has significant human activity on its periphery and the overall size has decreased by about 30% in the past year.. Human populations are most dense on the northwest border near Nola and Bayanga. Wildlife products from the northern sector of the polygon go directly to Nola, the principal town in the central African Republic 50 km to the west of polygon limit. About 1500 km^2 of the polygon has already been selectively logged for sapeli (*Entandrophragma cylindricum*), sipo (*E. utile*) and several other species, hunting for bush meat, safari hunting, and alluvial diamond exploitation occurs in the northwest. About 5,000 km^2 in the south was declared a National Park in 1990 in CAR and in 1993 in Congo. The two national parks and their peripheral zones have received significant conservation funding over the past 10 years. This has permitted a high level of protection of these forests and an increase in large mammal populations. A large amount of data exists for the national

parks and their immediate periphery on large mammal populations, flora, vegetation, and socio-economics. The areas outside the parks have received relatively little attention. The southern section of the polygon has been selectively logged for the past 30 years. This activity contributed to defaunation in what was an extremely rich wildlife area in the Ndoki Basin. Until 1991 this activity was limited to the western side of the Ndoki River when a dike was built. In 1997 a second dike was built and forest exploitation is proceeding north and south from these dikes. Since 1994 there has been an effort to install a conservation presence in the area. This has begun to have some positive effects on the overall quantities of bush meat being consumed, but has in no way affected the level of logging in the concessions.

Polygon 2 – Southern Pokola

Size: 8,973 km^2 and its perimeter is 524.3 km
Maximum distance from human settlement: 28 km
Land use boundaries: This polygon is contained entirely within a single logging concession, the Pokola UFA.
Hydrographics: The entire polygon is drained by the lower Ndoki River basin.
Topography: This polygon is in the Congo cuvette. It is completely flat. It doesn't even have that many termite mounds.
Vegetation: The vegetation to the west of the Ndoki River is dominated by *Gilbertiodendron dewevrei* in the drainages and a mixed forest dominated by *Entandrophragma* spp. The eastern section of the concession is an area called the Terre des Kabounga. The vegetation here is very open canopy Marantaceae forest. This is indicative of very old and extensive agricultural use of the forest (Fay 1997). Overflights show a large area with high numbers of oil palm trees (*Elaeis guineensis*).
Soils: The soils here are part of an enormous alluvial plane that stretches from eastern Zaire to the Atlantic coast. Part of the ancient Congo Sea.
Features:
Principal mammals:
Interesting mammals:
Industrial activity:
Hunting and gathering: This area is contained wholly within the *Congolaise Industrielle des Bois* (CIB) concession. It has been selectively logged for the last 35 years. About 60% of the concession has now been logged. A dike was build across the Ndoki River in 1991. This opened the area to the east of the Ndoki to exploitation for the first time in history. Previously there were human populations located in the east of the concession that were quite remote with trade routes out through the Likouala aux Herbes. Now the northern part of the polygon is covered in a dense road network. There are 7000 people living in Pokola on the western border and 900 people living in the Ndoki camp on the east side of the Ndoki. Wildlife populations have been reduced in this area which probably held large numbers of elephants and buffalo previously. The southern area remains relatively pristine except for penetration from the south by people from Ikelemba on the Sangha for elephant poaching. This part of the polygon has a large number of clearings and potentially still has considerable populations of elephant, buffalo and other wildlife. CIB will log the southern section of the polygon in the next ten years.

Polygon 3 - Lengoue

Maximum distance from human settlement:
Land use boundaries:
Hydrographics:
Topography:
Vegetation:
Soils:
Features:

Principal mammals:
Interesting mammals:
Industrial activity:
Hunting and gathering: The size of the polygon is 14,530 km^2 and its perimeter is 583.3 km. The maximum distance from human settlement attainable is approx. 50 km. This is the first polygon on the west side of the Sangha River. The terrain here is a bit more hilly and the density of *Entandrophragma* trees is considerably lower here. The area does have a relatively high density of ironwood (*Lophira alata*) and Aframosia (*Pericopsis elata*). The vegetation in the west of the polygon is very open canopy Marantaceae forest. This is due to what must have been a high human population density in the relatively recent past. The southern half of the polygon is flooded and swamp forest. The town of Ouesso on the northern border of the polygon has a population of 15,000 people. The Sangha River and the road to Liouesso, 75 km south of Ouesso, are principal arteries for the transport of wildlife out of the concession. The Lengoue River bisects the polygon. Overflights of the Lengoue showed 125 active fishing camps. The polygon is contained almost wholly in the East UFA concession of over 1,000,000 ha. A logging company was installed in the UFA in 1981. This was a large project funded by the World Bank. From the very start the company had financial problems and exploited only export round wood. However the concession has a very low density of high quality timber and thus much of the concession has already been exploited. In 1999 the concession was purchased by a South African-Dutch investment group. They have requested help in ecological management of the concession from the WWF-South Africa. The principal mammal species of interest are the same as those on the eastern side of the Sangha except the Bates' Dwarf Antelope (*Neotragus batesi*). The red colobus monkey drops out west of the Sangha.

Polygon 4 - Odzala and the Peripheral Areas

Maximum distance from human settlement:
Land use boundaries:
Hydrographics:
Topography:
Vegetation:
Soils:
Features:
Principal mammals:
Interesting mammals:
Industrial activity:
Hunting and gathering: The size of the polygon is 23,880 km^2 and its perimeter is 753.3 km. The maximum distance from human settlement attainable is approx. 67 km. Human populations over the past 1000 years probably heavily impacted the forest here. It is characterized by a very low density of trees and high density of Marantaceae, so much so that some people liken the vegetation to savanna. There are two logging concessions and a protected area in the central part of the area. There is no active logging within the polygon, it is confined to the north of the Ouesso-Sembe Road. There is a proposal to extend the Odzala National Park to over 800,000 ha which would exclude logging in the greater part of the polygon. There is a high concentration of forest clearings here frequented by large mammals along the Mambili River. These are inhabited by large number of elephants, gorillas and buffalo. The polygon holds the largest populations of elephants, gorillas and buffalo, possibly as many as 10,000, 20,000 and 3,000 individuals respectively, in Congo (Fay et al 1999). The southern fifth of the polygon is covered in anthropogenic savannas that are inhabited by about 2,000 buffalo, hundreds of elephants and a few, probably less than 10, lions (Froment, pers. comm.). This is probably the only remaining population of the Bateke lion whose range used to extend into the entire Bateke Plateau of several million hectares until relatively recently. This is the only savanna left north of the Congo River and south of the main forest block that

still contains significant wildlife populations. The western side of the polygon meets the Ogooué Basin where the limit is comprised of a 175 km long escarpment. This escarpment holds a large number of species not found to the east including the black colobus monkey (*Colobus satanas*). In the 1980s this area suffered a very high level of poaching for elephants via the Mambili River when the park was not protected (Hecketsweiller et al. 1991). As recently as 1996 this heavy exploitation continued outside the park to the north (Fay 1996). Most of this area currently has no legal status except the Odzala National Park, which accounts for about 15% of the area. It has been an integral component of the European Community ECOFAC project for the past 6 years and the fauna has enjoyed a relatively high level of protection from hunting during this time. For the last six years ECOFAC has done a number of studies on the flora, fauna and socio-economics of the area (Maisels 1996).

Polygon 5 - Djoua Valley

Maximum distance from human settlement:
Land use boundaries:
Hydrographics:
Topography:
Vegetation:
Soils:
Features:
Principal mammals:
Interesting mammals:
Industrial activity:
Hunting and gathering: The size of the polygon is 10,580 km^2 and its perimeter is 515 km. The maximum distance from human settlement attainable is approx. 26 km. This area is characterized by the very wide flood plain of the Djoua River that is dominated by seasonally flooded *Gilbertiodendron dewevrei* forest and a permanently flooded swamp 2-3 km wide along the river that is dominated by raphia palms. In the northern part of the sector there is a long band of *terra firma* forest between the Djoua and Karangoua rivers. The species of mammals here are largely the same as found in the Odzala complex except that the bongo is very rare here and it is where the mandrill (*Mandrillus sphinx*) attains its easternmost limit. In the past this area has been exploited in various areas for gold, both artisanal and industrial. This activity continues to be an important one in the region in particular in the area of Mount Nebemba where an small scale industrial operation began in 1995 but which is faltering. Because of transport difficulties the area does not export a lot of bush meat, but the gold activity has reduced wildlife in the NE part of the polygon. There is no commercial logging in the entire polygon. The area currently has no legal status as a protected area and is not in a logging concession. There is a movement afoot to include part of this polygon in the greater Odzala-Minkebe national park complex (WWF 1998). Surveys in the early 1980s on the south side of the Djoua River revealed high densities of elephants and gorillas but it may be that these have decreased significantly. The PI also did a survey to the north of this polygon in 1991 and found that the elephant population had been seriously reduced.

Polygon 6 - Minkebe Forest

Maximum distance from human settlement:
Land use boundaries:
Hydrographics:
Topography:
Vegetation:
Soils:
Features:
Principal mammals:

Interesting mammals:
Industrial activity:
Hunting and gathering: The size of the polygon is 37,410 km^2 and its perimeter is 882 km. The maximum distance from human settlement attainable is approx. 75 km. This is the largest contiguous forest block that will be surveyed during the study. The central area is dominated by a series of inselbergs that are covered with grass and as yet have not been explored scientifically. They no doubt have a very peculiar flora, which looks from the air quite similar to the inselbergs spread across the continent in the tropical areas. The Minkebé was depopulated earlier in the century and has been largely void of human settlements for 50 years. Previous to this time the area was dotted with a large number of villages. There are several old village sites indicated on maps and also visible from the air from the telltale oil palms present in dense patches here and there in the forest. Sparse habitation however has left this forest relatively intact. More recently humans have come to this forest to hunt and extract resources, but not to cultivate. Gold mining and elephants poaching are heavy especially on the eastern sides of this forest. There are some hundreds of people living in gold camps to the west of the Ivindo River. Fishing and hunting camps line the Ivindo. The areas to the south and west of the polygon are completely occupied with logging concessions that are currently inactive. Logging has begun on the SW side of the Polygon by a large Malaysian company, Delamur, that is very active in Equatorial Guinea. The road on the western side of the polygon is also populated by a high density of humans with the presence of three towns of over 10,000 people. There is a large road project that is being financed by the EEC which is going to open this area to Ebolowa in Cameroon which will considerably open access to markets. The fauna is typical of the area with populations of mandrills and black colobus. The Gabonese Government has drafted a decree to establish a reserve in this area of some 6,000 km2. The WWF have had an active conservation project in the area for the past year. A transect survey was done over much of the NE of the proposed reserve in 1992 and 1997 by the WWF. In general the results of these surveys show high human impact in the northern sectors studied and relatively little sign deeper in the polygon.

Polygon 7 - Mingouli Forest

Maximum distance from human settlement:
Land use boundaries:
Hydrographics:
Topography:
Vegetation:
Soils:
Features:
Principal mammals:
Interesting mammals:
Industrial activity:
Hunting and gathering: The size of the polygon is 12,790 km^2 and its perimeter is 493 km. The maximum distance from human settlement attainable is approx. 49 km. It is in this polygon that the vegetation changes to one dominated by okoumé (*Aucoumea klaineana*). This vegetation type is common in the western part of the polygon and largely continues to the coast of Gabon. The western part of the polygon is hilly and the east is a plateau. The Ivindo River divides the area in an area that is well known for a series of cascades, which has protected this area from river traffic in the past. The large mammals here are similar to those found farther to the north. The area has no legal status as a protected area except in the extreme NW where the Mpassa Forest Reserve of 6,000 ha is located. The rest of the area has been designated for logging. Intense logging has been ongoing on the eastern side of the Ivindo in the central part of the Polygon since 1991. A large logging camp with 100 houses was built by the Rougier logging company in the core area in 1996. The logging intensity is very high where cutting is ongoing. There is an effort to get area classified as protected. The Mpassa Forest Reserve was

the origin of much of the early work on African forest ecology carried out by the French (Anon. 1987). The research center, *Centre de Recherche Tropicale de la Mpassa* has fallen into disrepair since the late 1980s and much of the fauna that was once the object of study has been depleted. The town on Makoukou which has a population of about 12,000 is about 10 km to the east. This town has a significant impact both on the Mingouli Polygon and Minkebe Polygon.

Polygon 8 - Transgabonais Railroad and northern Forêt des Abeilles

Maximum distance from human settlement:
Land use boundaries:
Hydrographics:
Topography:
Vegetation:
Soils:
Features:
Principal mammals:
Interesting mammals:
Industrial activity:
Hunting and gathering: The size of the polygon is 3807 km^2 and its perimeter is 322 km. The maximum distance from human settlement attainable is approx. 17 km. This is an area between the main road and the Transgabonais railroad going to Franceville. The forest is dominated by okoumé and has been exploited in some areas over the past 15 years. The area is hilly and thus road construction has been extensive. The fauna is similar to that found in the Mingouli forest. The area has no protected status. The forest to the south of the road was studied rather intensively by Annie Gautier-Hion and her colleagues. These studies included primarily primate ecology but also forest regeneration, duikers, and soils. More recently the radeau des cimes (Canopy Raft) project has been active in the Foret des Abeilles area. This is a project to collect plants and animals in the forest canopy.

It is possible that we will encounter the sun-tailed monkey (*Cercopithecus solatus*) that was described by Mike Harrison only 12 years ago and is related to the montain species found in northwestern Cameroon and in the east African mountains from Itombwe to Ruwenzori.

Polygon 9 - Lopé Forest

Maximum distance from human settlement:
Land use boundaries:
Hydrographics:
Topography:
Vegetation:
Soils:
Features:
Principal mammals:
Interesting mammals:
Industrial activity:
Hunting and gathering: The size of the polygon is 18,270 km^2 and its perimeter is 649 km. The maximum distance from human settlement attainable is approx. 54 km. The Lopé Reserve lies to the west of the *Forêt des Abeilles.*. The countryside here is spectacular with mist covered hills, rocky rapids in the Ogooué River and savannas. This forest was home to ancient hominid civilizations that lived there for perhaps hundreds of thousands of years (Oslisly 1992). Stone-age people converted the forests and developed complex communities before they died off for unknown reasons some 1400 years ago. This has left the area with an interesting mix of savanna, okoumé forest and older, more complex forest. Past the main

savanna block we will pass into the southern reaches of Lopé. In general this is a closed canopy forest dominated by okoumé. Southern Lopé contains a large number of hills and included savannas that will be traversed.

In the past 15 years this entire area has been extensively logged for okoumé on all sides. The Forêt des Abeilles has been almost completely logged; the eastern and western parts of the Lope area have also been logged. The most intact block is in the central, western and southern reaches of the Lopé. Logged areas have become preferred hunting zones for poachers coming from Libreville to feed the markets there because access is easy and game is abundant. The fauna is also largely the same except here we will find the higher populations of forest elephants and buffalo due to consistent protection over the past ten years. It is possible that we will find the sun-tailed monkey at this location and determine its western range. Large groups of mandrills are known from this area. All other areas in this polygon are open and subject to repeated logging. Protection systems have improved here during that time. For the past 15 years teams from CIRMF and ECOFAC have been studying the ecology, human history and socio-economics of this area. The scientific literature is vast and varied and includes long term studies of gorillas, phenology, evolution of vegetation, effect of logging on flora and fauna.

Polygon 10 - Iboundji-Fougoumou

Maximum distance from human settlement:
Land use boundaries:
Hydrographics:
Topography:
Vegetation:
Soils:
Features:
Principal mammals:
Interesting mammals:
Industrial activity:
Hunting and gathering: The size of the polygon is 3460 km^2 and its perimeter is 253 km. The maximum distance from human settlement attainable is approx. 28 km. This is a block of forest that falls between two roads. It is dominated by okoumé forest. The principal mammal species of interest are the same as those found in the Lopé. Legally the area enjoys no protected status. The conservation status of this area is currently unknown and no scientific studies have been carried out thus far.

Polygon 11 - Moukalaba Forest

Maximum distance from human settlement:
Land use boundaries:
Hydrographics:
Topography:
Vegetation:
Soils:
Features:
Principal mammals:
Interesting mammals:
Industrial activity:
Hunting and gathering: The size of the polygon is 532 km^2 and its perimeter is 113 km. The maximum distance from human settlement attainable is approx. 8 km. The greater Nyanga River valley dominates this area. This river has its origins far to the south near the headwaters of the Kouilou River in the Republic of Congo. The vegetation on the upper Moukalaba is a

forest-savanna mosaic that lies between two mountainous zones. Though largely exterminated elsewhere, the Moukalaba valley still retains a fauna characteristic of this very large savanna covered valley. The remarkable species found here, some of which are found nowhere else in the central African forest zone, are the waterbuck (*Kobus ellipsiprymnus*), southern reedbuck (*Redunca arundinum*), common duiker (*Sylvicapra grimmia*), side-striped jackal (*Canis adustus*) and the African wild dog (*Lycaon pictus*). The current status of these species is unknown but some are thought to be extinct. The sub-species present are an unusual mix of southern and northern forms. How these species came to be in the Nyanga Valley remains largely unexplained. The elephant and buffalo populations are still relatively high, but the human population density, in particular to the south on the Nyanga River, is also high. A logging firm, CEB, had a sawmill on the upper Moukalaba for nearly 25 years exploiting the forest for tens of kilometers around the headwaters of the river. The town built by the loggers has gone from a population of nearly 5000 people in 1987 to one of perhaps 200 today. The impacts of this enterprise on wildlife were undoubtedly great, but the remnants observed on a recent aerial survey were encouraging. This included the confirmation of the continued presence of waterbuck.

Polygon 12 - Monts Doudou

Maximum distance from human settlement:
Land use boundaries:
Hydrographics:
Topography:
Vegetation:
Soils:
Features:
Principal mammals:
Interesting mammals:
Industrial activity:
Hunting and gathering: The size of the polygon is 892 km^2 and its perimeter is 131 km. The maximum distance from human settlement attainable is approx. 12 km. The west of the Moukalaba valley is formed by the Doudou mountain range. It is the largest mountain range in SW Gabon. The flora and fauna in this range is poorly known, having never been thoroughly inventoried. A montane species of Raphia palm is common on the slopes of the mountains. Recent surveys also reveal a high density of gorillas and other large mammals (White et al. 1998). The entire range was selectively logged in the 1980s. There are no humans living on the mountain and it certainly represents a refuge for large mammals given the rough terrain. This area has recently been designated as a reserve by the Gabonese government.

Polygon 13 - Western Gamba Complex

Maximum distance from human settlement:
Land use boundaries:
Hydrographics:
Topography:
Vegetation:
Soils:
Features:
Principal mammals:
Interesting mammals:
Industrial activity:
Hunting and gathering: The size of the polygon is 3000 km^2 and its perimeter is 331 km. The maximum distance from human settlement attainable is approx. 19 km. It is here on the coast of Gabon that we find a group of faunal and hunting reserves called the Gamba complex

in which the Moukalaba and Doudou areas are included. This complex has never been managed as an ensemble, but as a series of contiguous areas under government and private control. The Gamba complex contains great habitat diversity. On the eastern edge is the Rembo Ndogo that is lined with several lakes, papyrus swamps and forest clearings. A book written in 1898 by a female British explorer collecting beetles offers an interesting historical perspective of the crossing of the Rembo Ndogo (Kingsley 1898). It drains an area of approximately 200,000 ha of closed canopy *terra firma* forest. To the west is a low, swampy area that is the drainage basin of the Rembo Ngove with extensive expanses of raphia palm forest. Once across the Rembo Ngove we will enter the coastal plain area. The soils here are pure sand and the vegetation is made up of a series of bands of coastal savannas with very sparse grassy vegetation, terra firma and swamp forest, and coastal lagoons with mangrove. Finally we will hit the coast for the first time which holds very peculiar coastal scrub vegetation and a highly diverse fauna from the typical forest species to a wide array of coastal and marine species. The fauna is largely the same as found farther to the east except with the appearance of the collared mangabey (*Cercocebus torquatus*). The area has been managed for the past five years by the World Wildlife Fund. The current status of the protected areas is weak and there is considerable industrial activity in the area, principally oil and forestry. Little protection is afforded the reserve by the conservation project and bush meat is traded quite liberally in the area. The area has been studied extensively by oil companies over the past 20 years thus good vegetation and map data exist. They have also paid for various ecological studies in the region. Over the past three years the World Wildlife Fund have done a number of ecological and socioeconomic studies.

Data Analysis

Individual polygons are to be the basic management unit of interest in our study. Survey lines will be the designated groups of sample units. Individual daily sample walks and "pulse of the forest" stations will constitute the actual sample units. The goal is to produce a software tool that will allow users, in a standard way, to explore their recce data. This tool would provide the ability to display maps, to graphically depict relationships between variables or combinations of variables and finally to produce a one page depiction of the “state of the forest” of the unit. The one page would have four basic components:

- a map of the management unit showing the size and geographical location, the human influence gradient, transport routes, and recces included in the analysis;
- simple statistics on a number of key variables;
- four graphs, with two axes, equations, multiple R, and trend lines for each, showing human influence vs. mammal abundance, human impact vs. mammal abundance, human influence vs. human impact, and contextual variables vs. mammal abundance;
- statistics on conservation variables.

Each graph will contain two data clusters: that for the survey line of interest and second a survey line or combination of survey lines that is used for comparison. There will be one point representing the mean for each individual recces or "pulse of the forest" sample units. The comparative cluster could be all data from previous studies that are in the database, or all previous years from the same site.

This overall analysis package will be based on four software units: relational data base, statistical, image processing and GIS. These will be used in an integrated fashion for data exploration and output. Standard analysis capabilities will permit standard output and the ability to compare one study area, polygon, to others. It is hoped that this package will become a standard to be used in future survey and monitoring programs in the region.

Base Coverages

Base raster and vector coverage

A great deal of digital raster and vector data sets already exist for the areas that will be assembled to be used as base coverages for the GIS analysis. Many of these will have already been assembled in the preliminary phases of the work in establishing the 'human influence' polygons. Any additional data that are made available during the survey will be added to the GIS. These coverages will be used as need be for the various analyses that are to follow.

'Human Influence'

There are basically two elements that will constitute 'human influence':
1. location and size of human settlement,
2. type and location of transport infrastructure.

In both cases it is the distance from these variables that is important. Human settlements will be characterized as points and transport routes as lines in our analysis.

Human Settlements. Based on maps, census data, socio-economic data, national records, aerial videography and ground survey, a database of all human settlements within the polygon to a distance of 20 km from the polygon will be established. This database will contain the following columns: latitude of center, longitude of center, and estimated human population.

Transport Routes. Based on maps, logging and oil company data, national information services, satellite imagery, aerial videography and ground surveys, a data base of all major transport routes will be established. These will include rivers, roads, railroads, and major footpaths. Each will be given a classification based on its size and frequentation.

The entire polygon management unit will be set in a grid of $1km^2$ squares. For each square in the grid a value will be obtainable that reflects the distance and size of various numbers of the closest population centers, and the value for the type of transport route within various distances from each grid square. During the analysis phase various groupings of settlements and transport infrastructure combinations will be compared with the dependent variables.

Path of Least Resistance Data

For all path of least resistance data a relational database matrix will be established that will include all variables for which data were collected for each daily recce. The following columns will be established for each datum: recce, longitude, latitude, date, time and distance along recce. These will be included in each table in the relational database. Individual tables will be established for each of the following: soil, meteorology, features, vegetation, canopy cover, trails, human trail sign, camps and villages, oil palm, elephants, gorillas, chimpanzees, diurnal primates, large ungulates, predators, and medium-sized mammals. Some tables will have sub-tables if so deemed convenient. It is entirely possible that this list of tables will be expanded as work progresses.

In addition to location data for each table the columns will appear as follow:

- Soils: start of type, color, texture, description, and video image.
- Meteorology: temperature, pressure, and humidity, rainfall

- Features: type, description, video image
- Vegetation: start of type, description.
- Canopy cover: canopy cover1, cc2, cc3, cc4, cc5 (series of point samples taken from aerial videography, one every 500 m).
- Trails: species (including human), size, direction, use category.
- Human sign: type, est. age.
- Camps and villages: surface area occupied, humans (with sub-table), age, est. duration, activity, habitation size, construction materials, bed occupant, vector map, trash contents (with sub-table), objects (with sub-table), trees cut (with sub-table).
- Oil palm nuts: age nut 1-x.
- Elephants: Observation type, ind. 1-x, age 1-x, distance from recce line.
- Gorilla and chimpanzee observations and spoor: type of observation, number of individuals, food remain species.
- Gorilla and chimpanzee nest site: photograph of nest site, nest site number, ind. 1-x, age 1-x, height, construction type 1-x, vector map (fresh nests only).
- Diurnal primates, large ungulates, predators, and medium-sized mammals: species, observation type, ind. 1-x, age 1-x, height, and distance from recce line.

Pulse of the Forest Data

For all "pulse of the forest" site data a relational database matrix will be established that will include all variables for which data were collected during the survey. The following columns will be established for each datum: longitude, latitude, time and distance along recce. These will come from the same database for each table in the relational database. Individual tables will be established for each of the following: soil, meteorology, tree vegetation, herbaceous vegetation, hemispheric photo cover, 360^{o} panorama, duiker distress call, mammal spoor.

In addition to location data for each table the columns will appear as follows:

- Soils: color, texture, description, video image.
- Meteorology: temperature, pressure, and humidity.
- Tree vegetation: plot size, general vegetation type, species, diameter, collection reference.
- Herbaceous vegetation: general vegetation type, species, age of stem or leaf, diameter (for dicotyledons)
- Hemispheric cover: calculated cover.
- 360^{o} panorama: image mosaic.
- Duiker distress call: species, number of individuals, type of observation (visual etc.), approach distance, type of response.
- Mammal spoor: species, spoor type, age, size and direction for trails, species (food remains).

The possibilities for statistical analysis of the data set will be almost limitless. During the analysis and modeling stages data exploration may lead to analytical techniques other than those discussed here. However, in general, the following logic will be followed.

Our basic sampling units will be a pre-determined length of recce or a "pulse of the forest" station. Each recce day of 4-5 km will be analyzed separately as an independent sample. Independence assumptions will be fulfilled by analyzing various iterations of randomly selected, non-contiguous recce day samples.

Because "pulse of the forest" plots are physically separated, of a specific size, and located only by time of day, it is thought that they can be considered independent samples as their location is to be determined by time which is independent of the variables to be sampled.

The basic unit to be analyzed for quantitative variables will be abundance per km of survey line or per km^2. Data for each dependent variable, individual species, will have a particular analytical method applied to it to determine abundance per unit distance or area. These are generally described in the literature (cited in bibliography).

The categorical variables, vegetation, soils, logging concession, and political limits are interesting on their own. The analysis package will provide the ability to analyze each of these separately against any other variable in the data set. They will also be regarded as confounding variables such that their effects can be accounted for in attempts to assess the importance of human influence and impact on mammal abundance. MANOVA and PCA will be used to determine the relative importance of each of these variables in determining large mammal density and abundance.

Individual polygons are the basic management unit of interest in the overall study for multi-variate comparisons. Separate analysis of polygons will allow us to explore how the categories of dependent and independent variables are related. The polygon will also be used for data management in the long-term as more studies are added to the over all data set.

The first step in data analysis will be to use multivariate regression techniques to compare all combinations of *a priori* groups of variables and uni-variate combinations. These will be performed for recces using both linear and area abundance measures. Similar techniques will be used for "pulse of the forest" data. These techniques will serve to expose where there is significant correlation and answer some of the more basic research questions. It will also indicate useful combinations of variables to be included in the overall model.

The second step will be to partition the data by categorical variables to use the same techniques in order to compare the groups. This should permit a statistical evaluation of the importance of the categorical variables in explaining variability in the data set and the determination of weights for individual data.

The simple goal will be to determine a multivariate regression model that will explain the maximum variation in the data set using human influence as the principal determining factor. The same result will be sought using restricted sets of variables, for instance by species or type of human disturbance. In developing the model the fewest number of variables with an acceptable level of significance will be employed.

This model could then be used to compare data sets from different polygons and also in one polygon over time. Differences between the slope and intercept of the regression lines can be used to discuss why these may exist. In most cases this should be attributable to a particular management regime, either positive or negative *vis a vis* large mammals. Over time, as data from polygons accumulates, this could become a standard method used to evaluate areas that are surveyed for the first time against the overall data set that exists at the time, or for the same area on previous surveys, or for comparison with areas, say of similar polygon size in different countries. This type of analysis, while described in a very summary way here may give us the means to answer all of our research questions.

A similar process would be followed for the "pulse of the forest" data sets except with more specific vegetation analysis, i.e. *a postiori* determination of vegetation types and correlations between these and local animal and human abundance. These could be compared to the recces.

If these models are shown to be valid the applications for management are significant. For example a conservation project is to be established in an area. A monitoring program is desired because managers would like to have a reasonable idea of their success or failure over the years when management is applied. A polygon is established, data on socioeconomic variables are collected using overflights or ground surveys. The human influence grid is established. A standard polygon traverse survey line or lines are established and path of least resistance surveys are run four times a year. After one survey the data are compared with the existing database for all similar studies. It is found that the regression line for mammals vs. human influence is at a level that is about equal to a zone that was considered to contain moderate mammal populations. During the year it is noted that in the wet season there is a large surge in the elephant regression line and that the slope increases, meaning perhaps that a movement was being detected that passed through areas of the polygon with low human influence. Over three years of data collection it is noted that the intercept increases and the slope decreases for the overall regression. We may take this to mean that populations are increasing locally and that elephants may be using areas that they avoided previously because of poaching pressure. An analysis of the human impact vs. human influence regression shows an opposite pattern, i.e. that human use of the forest decreased over the period. It could work in the opposite direction; in particular if the human influence grid changes, for instance if a new logging camp or road is established closer to or within the polygon. This would show the overall size changing and new relationships between variables. This monitoring system could explore the data set on any number of variables in order to explore other relationships that may exist, their changes over time and in comparison with other areas.

It is believed that this type of method and analytical process could provide a very useful tool for management both on a local level and at the national and international level.

Scientific Collaborators

A wide range of scientific collaborators will be sought who will catalog and analyze different data sets. Many of these organizations and individuals have collaborated with the PI in the past. These collaborative ties will greatly facilitate the data analysis and final report production and provide the trained personnel, resources and technology to produce quality results.

The following are potential partners:

NCAR-atmosphere
ORSTOM-water and soils
CIRAD-Forets-trees and vegetation
NASA-imagery
JPL-imagery
ISPRA-TREES-imagery, data basing, GIS, statistical analysis
Tervuren-plant and animal taxonomy
Brussels Herbarium-plant taxonomy
Kew-plant taxonomy
Missouri Botanical Garden-plant taxonomy
American Museum of Natural History-plant and animal taxonomy
National Museum London-plant and animal taxonomy
Museum d'Histoire Naturel, Paris-plant and animal taxonomy
University of Maryland-imagery, GIS

Site Partners

A number of organizations are present on the ground in the various sites that will be traversed. Each will be contacted and partnerships with each will be sought. The needs and requirements of each will be taken into consideration while traversing each zone. These organizations are as follow:

ECOFAC-Ngoto
WWF CAR-Dzanga-Sangha
WCS Congo-Nouabale-Ndoki
CIB-Kabo
ECOFAC-Odzala
ECOFAC-WWF Gabon-Djoua
WWF Gabon-Minkebe
Ministere de Recherche Scientifique-Gabon-Mpassa
Rougier Gabon-Mingouli
Leroy Gabon -Foret des Abeilles
ECOFAC-WCS-Lopé
WWF Gabon- Gamba Complex

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