EVALUATION OF THE CARPO/GHOA BIOLOGICAL MONITORING PROGRAMME

FINAL DRAFT OF REPORT TO WWF CARPO

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SUMMARY

1. WWF CARPO has tasked itself with the Biodiversity goal of maintaining stable or increasing priority populations of target large mammal species within priority conservation landscapes. The scale and context over which this goal must be achieved is colossal – WWF CARPO includes priority landscapes in its portfolio which together cover well over half a million square kilometres of high biodiversity value tropical forest which is being threatened at an increasing and unprecedented rate.
2. It is critical that WWF CARPO monitor the effectiveness of their management interventions toward achieving this goal. WWF CARPO wish to know which conservation strategies are working where and why, and which are not. Therefore they wish to set up a coherent monitoring strategy that will help them achieve this, and which will strengthen their ability to manage adaptively and achieve higher standards of conservation effectiveness.
3. We were tasked with evaluating WWF current and historical bio-monitoring efforts in central Africa based on an analysis of biological monitoring data – specifically line transect and reconnaissance surveys (recce) of great ape and forest elephant populations - and to make recommendations for the implementation of bio-monitoring in the future. We were also charged with assessing current data management capacity and systems and providing recommendations on data management integration form site level needs, scaling up to a coherent data management system at the regional level.

4. We found dramatic variation in the quantity and quality of data received from the various landscapes. Several landscapes provided little or no bio-monitoring data – notably those in DR Congo and the landscapes in western Cameroon. Despite a long history of some form of bio-monitoring in the established WWF core sites (Dzanga-Sangha and Lobéké), the most recent data we received from these sites date from 2004 and 2002, respectively. A vast dataset from reconnaissance surveys carried out in the Minkébé forest of NE Gabon which began in 1998 was the earliest data we received.
5. We had requested that recce and line transect data be provided in a standardised format to facilitate the evaluation and render if feasible within the time frame of the project. Much of the data we received had not been formatted, making them very difficult to understand, prepare, analyse, and interpret. Other datasets only contained data summaries rather than raw data, with no meta-data or spatial/temporal reference. Some sites, for example, from the Gamba Complex and SE Cameroon, provided raw data that were clear, cleaned and well managed. However, even across sites with well managed data, the level of inconsistency between file structure, data nomenclature, and units was very high, and it was clear that the WWF CARPO data we received had never been systematically validated, managed, or analysed in a regional context. A huge amount of time was spent cleaning and preparing data for a regional assessment. Harmonised data are central to any effort to conduct analyses beyond the site level.
6. Data management systems for conservation are evolving rapidly across the Congo Basin, as MIST and SMART come online. Therefore concrete recommendations beyond some basic measures to improve current data management would be unproductive. However software development and the implementation of new methods always takes longer than anticipated, and while WWF work with SMART partners toward rolling out the new system, they should immediately introduce several data management improvements. We recommend that WWF CARPO immediately develop and implement a set of data standards for all sites that clarify data strictures and nomenclature. A regional data archive must also be established immediately, using we recommend Google Docs or Google Driver which are free, intuitive, and systems that WWF already uses in their intranet site. We further recommend that Cybertracker be adopted by all sites as their standard data collection tool. Strong in house expertise in the use and development of Cybertracker should ensure a smooth roll out. It sounds simple but it will be a quantum leap in monitoring capacity if every monitoring file produced has the same structure and the same names for the same observations that can be output as a text file with metadata and standardized file names, and is emailed or uploaded to a server in Yaounde.
7. Despite extraordinary efforts in some sites (e.g. Lobéké), line transect and recce survey coverage in time and space across the priority protected areas and parks was very low. In those landscapes where spatial coverage was higher, temporal replication was poor, thus precluding any valid test of change in conservation status of target species over time. One site, Lobéké National Park, was exceptional in terms of temporal coverage – having been systematically surveyed in 2002, 2006 and 2009. 2011 saw a considerable improvement in spatial survey coverage compared to previous years, which with the exception of 2004 as a result of the MIKE surveys, survey coverage was usually well below 5000km^2 across the entire landscape suite.

8. Line transects data, which have been the crux of most WWF bio-monitoring activities, were selected from two sites for detailed evaluation of SE Cameroon and Gamba. The most salient points from the analysis of these data are: The intensity of survey effort in specific sites has been immense, however, with the exception of Lobéké, there has been no replication in time and large areas of the landscape remain unsurveyed. Unfortunately, despite this huge effort in terms of fieldwork, and the excellent spatial and temporal replication in Lobéké NP, the quality of line transect data was poor, with the fundamental errors of rounding perpendicular distances close to the line to zero, being prevalent particularly in the elephant dung data. Data quality did not appear to improve over time from 2002 to 2009, and these methodological errors lead to problems in the data and unreliability in the modeling results with very different potential estimates from the same data set. These types of problems when they occur make it nearly impossible to draw any conclusions about the validity of density estimates from any given survey and therefore preclude trend detection. Thus the huge investment in effort and good spatial replication is wasted by basic methodological errors that likely come from insufficient appreciation of the underlying principles of distance sampling and insufficient training of field staff. The data management system used in Lobéké is exemplary – the Cybertracking system allows for standardisation at the time of data entry, huge savings in transcription and error checking, and an efficient system for the transfer of data form the data management system into analysis programmes such as Distance. The suspicion that monitoring teams require more training in methodology was evident from their analysis of line transect data – frequently default analyses were carried out rather than appropriate model selection, while in other cases poor choices regarding truncation and other data manipulations were made. This sometimes resulted in very considerable differences between reported density estimates and those generated during this evaluation.
9. WWF need to act quickly if they are going to be able to evaluate their management effectiveness in the central African region between now and 2020. First they need to invest immediately in staff. At global level, WWF needs to provide consistent and high quality interactive support to the WWF CARPO team in terms of strategy, technical backstopping and training. The Conservation Science unit in DC would seem well placed to do this though we did not consult with them during this work. Regionally, a core team is needed to develop and manage a conservation performance monitoring plan, consisting of a Biomonitoring Coordinator, a GIS/database manager and a regional technical support officer, all at PhD level with proven track records. These must be qualified, competent and motivated staff with strong theoretical and practical skills sets. At landscape level, a monitoring coordinator is required at every site where WWF intends to be involved in performance monitoring.
10. Training and standards of survey design and execution must be improved in most sites. Inadequately trained staff will not understand why they are asked to carry out specific tasks according to a carefully defined protocol that aims to meet the assumptions of the method, and therefore will not be rigorous. Solid backstopping and insistence on quality are also fundamental, which can only come from senior staff with enough time to devote to these issues. Failure to effectively train, motivate and manage staff will render investments in implementation futile. Avenues for funding and realizing professional development for WWF

CARPO staff with universities and research institutions that have demonstrated excellence in the field should be developed.

11. Landscape scale design un-biased line transects are recommended across the landscape suite are recommended as a first step toward establishing monitoring norms, production and decay rates. Other methods offer considerable promise to improve the efficiency of field methods, including DNA or camera trap based capture-recapture and occupancy methods.
12. Landscape scale surveys of the kind we have suggested and the support personnel and services required to maintain them will be expensive, however they are no more so than the scale of investment already deployed by WWF. We estimate between 3-6% of the WWF CARPO budget would, if appropriately spent, ensure the way forward to effective monitoring cross the entire suite of the CARPO priority landscapes for apes and elephants. Without more knowledge at site level full business plan development grounded in reality is difficult.
13. To be most effective in the success of monitoring conservation management effectiveness, WWF must strive to collect spatially and temporally explicit information on management interventions at the landscape scale. This will require careful planning of what data to collect, when and how, but will dramatically improve the likelihood of trend detection in biodiversity targets in time and space.
14. Depending on the management strategy within each landscape and the management context, more surveys could be tailored to evaluate specific management interventions. In theory this could be scaled up across the Congo Basin to evaluate the success of management interventions at this scale. To this end WWF should revisit their new strategy, preferably converting it, and landscape strategies to MIRADI format. This will help WWF CARPO specify more systematic biodiversity targets, direct threats, and management interventions articulating causal chains that link these levels. Designing appropriate monitoring programs that span these levels making them more efficient at site level and facilitating scaling up to the regional level..
15. WWF has eager partners to help then with this effort. WCS in particular could, in partnership with WWF, help dramatically increase the performance monitoring success of WWF. They share a number of landscapes, have considerable overlap in their goals, and strong technical capability. However, WCS has a small core conservation support staff, but capacity is stretched to the limit. The Max Planck Institute of Evolutionary Anthropology and the TEAM Network would also be capable and willing collaborators.

INTRODUCTION

The World Wildlife Fund (WWF) has been actively involved in conservation in the Congo Basin since at least the mid 1980's. Pioneering studies by Richard Carroll identified the Dzanga-Sangha region of southwestern Central African Republic (CAR) as a world class stronghold for intact tropical forest containing western lowland gorillas, forest elephants, bongo and other wildlife (Carroll 1986; Carroll 1988a; Carroll 1988b). Subsequently this site was developed as a protected areas complex largely thanks to the efforts of WWF working with the government of CAR. The mid to late 1980's also saw the first large scale wildlife prospection surveys ever conducted in the Congo Basin, under a collaborative programme designed to estimate the abundance, distribution, and conservation status of elephants in Africa's equatorial forests (Barnes, Blom & Alers 1995). These surveys, conducted in all six countries of the central African block (Equatorial Guinea, Cameroon, Congo (Brazzaville), Democratic Republic of Congo (then Zaire), Gabon, and CAR) were funded in part by the EEC/WWF African Elephant Programme and coordinated by the Wildlife Conservation Society (WCS). The results of the surveys, along with a suite of publications from the IUCN (e.g. Gartlan 1989; IUCN 1989; Hecketsweiler 1990) set the scene for the evolution of the conservation movement in central Africa that has occurred over the last two decades. These early surveys also set up the basis of a biological inventory and monitoring methodology that has, with numerous updates and refinements, endured as the principal wildlife monitoring tool used by conservation programmes throughout central Africa (Barnes & Jensen 1987; Barnes 1989; Michelmore 1989; Barnes *et al.* 1991; Alers *et al.* 1992; Barnes & Barnes 1992; Barnes 1993; Barnes *et al.* 1994; Michelmore *et al.* 1994; White 1994; Barnes, Blom & Alers 1995; Barnes *et al.* 1995; Ekobo 1995; Barnes 1996; Barnes *et al.* 1997a; Barnes *et al.* 1997b; Hall *et al.* 1998; Walsh & White 1999; Walsh *et al.* 2000; White & Edwards 2000; Barnes 2001; Thibault *et al.* 2001; Walsh *et al.* 2001; Walsh *et al.* 2004; Blake *et al.* 2007).

In 1990, WWF confirmed its commitment to conservation in Central Africa when it opened a regional coordinating office in Cameroon to oversee its Central African Regional Plan (CARPO). The CARPO conservation strategy focuses on forest conservation through developing and managing protected areas, while promoting sustainable forestry practices and community conservation for the benefit of human populations. From its early beginnings, today CARPO is active in nine large conservation landscapes, which cover a combined area of some 672,200km^2 spread across all six central African nations, from the Albertine Rift of Eastern DR Congo to the Atlantic Ocean[1] (Table 1). It is through management of these landscapes and their network of protected areas that WWF hopes to deliver its conservation strategy, the Green Heart of Africa Initiative (GHoA). The vision of GHoA for the year 2020 is that the Congo Basin's forests, freshwater landscapes, and species are sustainably managed. Conservation of this biodiversity will be achieved with commensurate efforts to maintain healthy ecosystems, as well as addressing economic growth, sustainable development, climate change pressures and the livelihoods of the peoples of the Congo Basin.

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[1] There is some discrepancy between the area figures provided in the WWF strategy document and that according to shapefiles that define the landscapes.

After 20 years of programme development and implementation that has overseen this dramatic expansion in mission and scope, WWF-CARPO is at a critical point in its evolution – WWF-CARPO not only has to deliver conservation solutions, but now, more than ever, it (and every other conservation organisation) needs to demonstrate its effectiveness in the delivery of those solutions. This must be achieved via the development and implementation of a coherent performance monitoring plan that explicitly links management activities (Outputs) to the achievement of management objectives (Outcomes) and ultimately to the attainment of conservation targets (Impacts). There are two principal motivations for a renewed commitment to monitoring and evaluation of programme success within WWF CARPO and WWF more generally. Firstly, internally within WWF there is a strong recognition that performance evaluations are required to provide timely, robust information that is directly useful for management and which can be used in an adaptive management framework to improve the delivery of conservation solutions. Secondly, the donor community and stakeholders across the board from local partners to national governments and international institutions are demanding greater accountability from conservation programmes. All stakeholders want to know where management is working, where it is not working, and why.

WWF CARPO has embraced this concept, and as part of their commitment to improving their monitoring systems across the entirety of their strategy, initiated an evaluation of their bio-monitoring systems, upon which this report is based.

OBJECTIVES OF THIS EVALUATION

As stated in the original terms of reference, the overarching goal of this report is to evaluate the current system of biological monitoring for the CARPO/GHoA field programmes and propose a coherent system for CARPO from field level to national and regional levels. Specific core tasks include the following:

Evaluate the biological monitoring component of all major field programs (10) for the CARPO/GHOA-NI affiliated Projects, in close collaboration with staff from all WWF supported Project sites. Given the scale of the current WWF CARPO monitoring systems, the consultants will select a reduced number of representative datasets for use in this analysis. These could include monitoring priorities such as elephant and great ape surveys, and other key management information. The final list will be discussed with and approved by the African Great Ape Conservation coordinator (AFGAP) and Regional Conservation Director. It will be the responsibility of the WWF CARPO teams to provide these data to the consultants. The selected data subset will be validated and formatted in a standard manner, which will be agreed upon by the consultants, select WWF CARPO team members the AFGAP coordinator, and the Regional Conservation Director.

1. Work with 2-3 select field programs to evaluate the potential of the selected data subset to make clear statements about the state of species populations and protected area management effectiveness
2. Facilitate consultation and collaboration with key points of expertise within and outside the WWF network with the aim to get their input and seek harmonization of methodologies and approaches

3. Work with 1-2 select field programs to develop the plans for an appropriate strategy that will lead to centrally stored data for scaling up to the national and regional level
4. Provide CARPO teams with a framework to ensure that their research and monitoring databases (including GIS and other reference databases) can be updated, backed-up, quality-controlled and centrally stored at the regional office
5. Propose a system of electronic storage of reports, raw data and other information
6. Identify potential partners for long term collaboration on survey design, data collection, data management, analysis and distribution of monitoring information

The deliverables requested by WWF CARPO in this report included the following:

1. A full analysis of, and set of recommendations for (at least 2 of) the field sites visited (bio-monitoring data collection methodology, storage, analysis and presentation) assuming the availability of a validated and standardized subset of data from these sites.
2. Desktop summary analysis of, and set of recommendations for, the remaining field sites (bio-monitoring data collection methodology, storage, analysis and presentation) assuming the availability of a validated and standardized subset of data from these sites
3. A desktop summary analysis of large mammal population trends (based primarily on existing data).
4. Initial set of recommendations for future survey design, field protocol, data collection and storage procedures
5. Analysis of potential partners for full future survey design, field protocol, data collection, analysis and distribution, as well as possibilities for adoption of methodologies by national governments
6. Ideal and minimal bio-monitoring survey designs, schedules and field protocols for each field site with an initial focus on 1-2 select sites and progressing to the remaining sites if time allows.
7. Crude cost analysis for 1) bio-monitoring survey costs over the last 5-10 yrs and 2) a cost estimate based on above future recommendations with an initial focus on 1-2 select sites and progressing to the remaining sites if time allows.
8. A basic business plan for implementation of bio-monitoring methodology for CARPO from field level, to national offices and regional office (including staffing needs and qualifications, soft – and hardware).

SCOPE OF THIS EVALUATION

There are many terms and definitions connected to the theme of evaluating change in the status of biodiversity such as bio-monitoring, biological monitoring, and ecological monitoring. Bio-monitoring in the context of conservation usually means measuring and evaluating the effectiveness of management actions to achieve stated goals. While management occurs at multiple levels from logistics, staff, budgeting, operations and reporting, the ultimate goals of biodiversity conservation programmes usually revolves around biological targets, such as maintenance of intact forest cover in a protected area, or ensuring the long term survival of elephants in a national park. All the management interventions of the programme are implemented toward achievement of the principal objective(s).

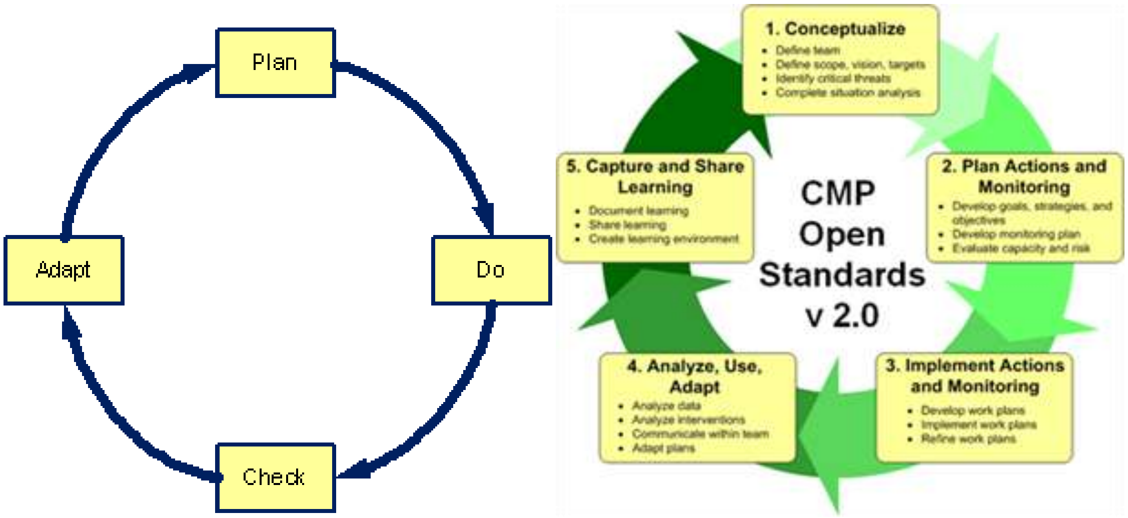
Therefore evaluating the effectiveness of conservation actions ultimately relies on monitoring the status of these targets.

In the context of this evaluation, bio-monitoring includes any and all activities that have attempted to assess the status and trends in priority wildlife populations across the suite of WWF conservation sites. To date, most conservation efforts in the Congo Basin have focused on maintaining large tracts of intact forest wilderness and large charismatic mammals. Therefore, target species include elephants, apes, key bushmeat species, and other priority species of particular interest in certain sites such as bongo and buffalo. However analysis was limited to datasets from line-transect and reconnaissance surveys, which have traditionally comprised the great majority of monitoring effort by WWF in the GHoA region. Monitoring data on the distribution and intensity of human activity in conservation areas have not been included though we realise that human activities, legal and illegal are the principal threats facing ecosystems and the main threats around which management interventions are aimed towards. There was not sufficient time, due in large part to the very late arrival of data and issues with data quality, in the evaluation period to evaluate all monitoring systems within WWF, however the suite of species and methods that were selected should provide an overview of monitoring systems that will be useful material from which to later consider all aspects of monitoring within WWF CARPO.

WHAT IS BIOLOGICAL MONITORING AND WHY IS IT IMPORTANT

Monitoring the effectiveness of management interventions should be central to any conservation programme (or any other results-based endeavour) because it helps determine if objectives are being met, which management actions are working and which are not, where and why, which should in turn provide the information necessary to modify management strategies and practices adaptively to improve performance. The effectiveness of modified management actions is then monitored in what should be a classic performance enhancing feedback loop (Figure 1).

Figure 1. Generic adaptive management loop (from Nick Salafsky's overview presentation at the Conservation Measures Partnership Summit 2010) and the "improved" version from the Conservation Measures Partnership Open Standards for the Practice of conservation.



This is all well-known theoretically, and in 2010 that theory was articulated by some 21 conservation/environmental management organisations (including WWF, WCS, TNC, and others) which signed up to a consensus statement following a meeting organised by the Conservation Measures Partnership (CMP) – the Conservation Measures Summit. A very large investment of thought and effort must have gone into crafting their position statement, and it is worth repeating it here because it sums up the motivation for investment in monitoring and WWF were a crucial partner who endorsed it.

Box 1. CMP commitment to Advance Conservation statement

Measuring Our Effectiveness

Our Commitment to Advance Conservation

Summit Version: 6 May 2010

Our Challenge

The biodiversity conservation community is tackling immense, complex, and urgent environmental problems. The stakes are high. People around the world are counting on us; they trust us, they work alongside us, and they are giving us significant resources to act effectively to save the planet. But we have a problem – we don't have a fully functional system to assess the effectiveness of our actions. It is difficult, right now, to say consistently what is working, what could be improved, and when a change in approach is needed. And that is unacceptable.
Without more rigorous measurement of effectiveness and disciplined recording of our efforts, how will we know if we are progressing as rapidly as needed to achieve our conservation goals? How will we become more efficient? How will we learn from one another? And how will we be able to demonstrate our achievements to build public and political will to expand our resources to really meet the challenges we face? This problem is bigger than any one leader or organization, and that is why we are coming together to develop a shared plan of action. It will be difficult to more rigorously and openly grade ourselves, but the stakes are high and we must act.

Our Vision

Global conservation efforts will be more efficient and effective as we increasingly know how to leverage or replicate what works and not repeat what doesn't based upon credible measurement of our effectiveness and the open sharing of the lessons we learn.

To realize our vision, our respective organizations aspire to:

State our desired results in terms of conservation outcomes, not actions. Effort alone is not sufficient to succeed. We will specify measurable desired results both for the short-term (e.g., funds raised, laws enacted) and long-term (e.g., threats abated, species status improved).

State how our efforts will lead to our desired results. Just as a scientist states a clear hypothesis before designing an experiment to test it, we will articulate and share the "theories of change" behind our actions before implementing them.

Track our progress toward achieving desired results. We will not wait until the end of an action to evaluate it. Instead, we will systematically assess short and long-term indicators to track the effectiveness of our actions, investing in measures appropriate to the risks we are managing.

Adapt our strategies based on what we've learned. Simply measuring effectiveness doesn't fix anything. We will use our data and analyses to guide us toward doing more of what works, and less of what doesn't.

Share our results respectfully, honestly, and transparently to facilitate learning. We are not going to succeed every time, but if we are honest in our appraisals of our efforts, we will learn every time. And if we openly share our assessments of effectiveness with each other and with the public, we will increase broad learning and transparency, ultimately advancing the work of the biodiversity conservation community as a whole.

We will reconvene in one year to assess our progress against these commitments, share lessons learned, and continue the process of building a field committed to rigorous effectiveness measurement and learning.

How does WWF put these lofty ideas and principles into practice in an area as complex as measuring conservation effectiveness over hundreds of thousands of square kilometres of forests in the Congo basin? In the face of chronic underfunding and understaffing of field programmes and sparse technical backstopping, it will be imperative to keep monitoring plans simple, practical and grounded in reality.

Several basin wide inter-institutional biomonitoring initiatives have failed to get off the ground in the past because, while technically appealing, they have simply been too daunting for managers to implement. One, the Congo Basin Conservation Measures monitoring framework (on the development of which one of the authors of this report, SB, was involved) was requested by the NGO partners in the Central African Regional Program for the Environment (CARPE). After some 20-odd iterations of the monitoring framework and presentation at several regional meetings and extensive discussions in Washington DC, the far reaching matrix was whittled down to a pragmatic version that suggested counting elephants, apes, and human activity in conservation areas using standardized line-transect and patrol-based methods. Even this has only met with limited success as this report will show.

Several leading conservation monitoring experts from across institutions have stated that we are collectively suffering from "strategy exhaustion" when it comes to monitoring the effectiveness of conservation in Africa and elsewhere. So what WWF (and everybody else) needs is a theoretically solid, technically and statistically defensible but practical and feasible monitoring programme that allows them to track their progress toward key management goals without spending all their time and effort monitoring instead of doing management interventions. The greatest challenge to this goal is the huge heterogeneity in ecological and human behavioural systems in time and space in the region, much of it unknown, that render it extremely difficult to quantify progress toward conservation targets (e.g. how many chimpanzees are there?) and the direct threats and contributing factors (illegal killing, habitat loss, population biology, ecology, environment, socio-economics at local to global levels) over time and space.

Ultimately, the strategies and methods used in any bio-monitoring plan need to be explicitly linked to management objectives if managers are to learn what works and what does not, and to provide timely, high quality information from robust data as simply and efficiently as possible to feed into adaptive management planning. ***The difficulty for WWF and for this evaluation team is that simple and efficient do not go hand in hand with monitoring rare, shy, endangered wildlife facing multiple threats from multiple sources over millions of hectares of forests with little or no infrastructure.***

Standardised evaluation of the management success of conservation lags far behind most other areas of private and public policy, which demand prompt evaluation of management outputs (Ferraro & Subhrendu 2006) (one can imagine the time interval NIKE demand on feedback to know if their latest advertising campaign is effective!!). As these authors state, "*For far too long conservation scientists and practitioners have depended on intuition and anecdote to guide the design of conservation investments*". This means that conservation managers have rarely been able to robustly demonstrate their success or failure towards their objectives and argue effectively and transparently for and against particular strategies. Statements of project success then become exercises in hand-waving and waffle. In short most conservation projects and programmes fail to demonstrate what management works, when, where and why. This then puts conservation managers at a disadvantage on several fronts: First, biodiversity conservation is often an unpopular management strategy in comparison to alternative policies such as economic development, plans for which usually always come with carefully articulated and quantitatively supported projected costs, benefits, and risk assessments. If conservationists cannot demonstrate that they are succeeding, or at least making the right decisions, they will likely be outcompeted in lobbying for political support and funding over other possible land uses. If donors are to continue to fund conservation activities, they increasingly require a transparent means of verification on how their money has been spent and what the outcomes were for conservation. Second, scarce resources for conservation need to be spent as effectively as possible, on the most appropriate policies and activities. If managers are to confidently allocate resources appropriately, they need objective un-biased criteria on which to base their decisions, otherwise they may continue with management strategies that do not improve the situation.

CONSTRAINTS TO EFFECTIVE MONITORING

Among the reasons for the poor development of conservation monitoring programmes in general and bio-monitoring in particular include the following taken loosely from Ferraro and Subhrendu (2006) who did a good job of summing them up:

1. Programmes are usually self-evaluated which requires considerable political will from within the project, and strong ethics of transparency, accountability and honesty (for example, a programme that honestly demonstrates its own failure is likely to be more heavily penalized than one which argues for its success but presents no robust data).

2. Conservation programmes often have a plethora of goals and objectives spanning multiple disciplines, not just conservation, making the evaluation of collective progress appear to be overwhelmingly complex.

3. Conservation managers and staff are often absurdly busy, and do not have the time or staff resources to invest in monitoring. This can lead to a self-fulfilling prophesy in that the monitoring data that do get collected are often of poor quality, not useful for decision making, and therefore no incentive is generated to put more resources into their collection.

4. Conservation managers are often not aware of the methods and analyses that are available, nor are they aware of problems such as bias and inefficiency in current methods.

5. The cost of monitoring and evaluation is often seen as prohibitive when there are seemingly many more pressing priorities that need immediate attention.

6. Conservation of ecological systems is complex and identifying trends and chains of cause and effect can seem daunting to the point of stifling the incentive to really think through how monitoring of targets can be achieved. To really link cause and effect in credible way may require manipulation of systems to identify whether a particular management intervention is working or not.

7. Many grants for conservation are short term - usually 1-3 years – however biological systems usually respond on much longer time scales than this, particularly for recovery. A poaching event can halve a population of elephants in months, but the maximum rate at which the elephants can recover if all poaching ceases is about 4% per year.

For these reasons **we will argue throughout this report that bio-monitoring (assessing status and trends of target species and populations) needs to be planned and executed within the framework of overall, comprehensive project performance monitoring at all levels, not just monitoring biological variables.**

The above reasons for lack of performance monitoring in conservation are generic and could apply almost anywhere. The specific context of conservation in central Africa causes particular challenges beyond these for executing meaningful biological monitoring. Most important perhaps is logistics. Many protected areas are huge – Salonga NP is some 35,000 km^2, Odzala NP is over 13,000km^2, Minkébé is over 7,500km^2. However, these are dwarfed by the landscapes in which they are situated, some of which are truly enormous: TRIDOM is close to 0.2 million km^2 – or ca. one-tenth the surface area of the entire central African forest block. These vast management units are embedded in a region of particularly low infrastructure development (though this is changing dramatically in some sites as roads and other developments expand). Quantifying how wildlife populations are changing in these vast areas is a daunting technical challenge. Second, security is a major concern in some areas of the Congo Basin – particularly in DR Congo. For many years field teams were, and in some cases are still unable to access the parks of eastern DR Congo, and parts of the Salonga NP were off limits to monitoring teams in the mid-2000s. Third, capacity to do robust monitoring remains extremely weak in the Congo Basin. In Congo and DR Congo, civil unrest and war have resulted in a highly degraded education system across all age groups, and a strong pool of well-educated, motivated young recruits is simply not available. Fourth, and related to capacity is the extreme physical difficulty of carrying out extensive field work deep in the forest. Few technicians continue to be motivated after several years of fieldwork, particularly as competent conservation employees can earn more money for less work in more stable jobs in the private sector. Fifth, funding of conservation programmes is particularly limited in central Africa compared to most of the world.

These challenges are real and they are significant impediments not just too monitoring but to the entire conservation and natural resource management movement. But they are not insurmountable, and effective monitoring is one way to help promote the conditions necessary to improve the playing field for conservation. Without it we will never be able to say with conviction “we are doing a good job, we are winning, we are meeting our objectives, we have the capacity to spend more money and grow our programmes”, or the reverse “we are not meeting our objectives, but at least we can tell you why and we need x dollars and y policy change to make a difference”.

MONITORING MANAGEMENT EFFECTIVENESS

The ultimate conservation goal in a project is the one that really matters. In their strategic plan WWF state that the following biodiversity goal: **By 2020, priority populations of target species within priority landscapes are either increasing or stable from 2014 levels.** This is what they will be judged by and what their biomonitoring programme should be geared towards. This will require a robust estimate of population size by 2014 and again in 2020, with both population estimates within some credible bounds of precision (e.g. the ability to detect, say, a 10% decline in that time). However, monitoring the conservation goal in a landscape or across landscapes is both the most difficult and most costly to implement, and takes the longest time to measure an impact of management. There are numerous management interventions and contextual changes that will take place within the CARPO landscapes in that six years, some of which will be causally linked to the change in population size of the target species. Some, or hopefully all, of those management interventions will be implemented under the assumption that they are increasing the likelihood of achieving the conservation target (some explicit causal chain between the intervention to reduce a threat and relax pressure on the target population). If monitoring is limited only to two biological surveys six years apart, it will be very difficult to link any particular management intervention or other contextual change in the landscape suite to the trajectory of those priority species. Managers will at best have an estimate of change in target species status but will not have a good understanding of the mechanisms, including management interventions that may have been responsible for the change.

Monitoring should not therefore be limited to estimating the abundance of target species, but rather to monitor over all levels of the conservation project in a spatially explicit framework from the implementation of management actions to changes in the geography and intensity of threats and ultimately to the conservation targets.

If "bio-monitoring" includes monitoring actions, threats, and conservation targets, the integrated plan will not only provide much more timely information that monitoring wildlife populations alone, but will also allow a mechanism with which to test the efficiency of management interventions, its impact on threat reduction and the response of the target population, i.e. test the assumptions of a causal chain – more guards should reduce illegal killing of wildlife which should allow wildlife populations to grow). In operationalizing this as a monitoring plan, there are some important considerations (Figure 2).

Firstly, the only surefire way to know how a bonobo population is changing over time and in response to management interventions in Salonga NP is to go out and count bonobos, but as said above this is costly. A possible proxy for direct counts of bonobos is to measure the change in the threat level bonobos face –how many illegal hunters are in the forest trying to kill bonobos. A manager will probably deploy ecoguards intensively in areas they suspect or know to be heavily hunted, fewer guards in a low intensity hunting area, and perhaps guards and no guards in a hunted area. This immediately sets up a pseudo-experimental framework in which to test the efficiency of management interventions and assumptions by measuring in a spatially explicit way (1) the patrol effort by zone, (2) the response of hunting intensity to the patrol effort, and (3) the response of the bonobo population (Figure 3). Monitoring the number or patrols per month is relatively straightforward and cheap, and the information is available immediately, however the level of confidence these data provide on whether the conservation target is being achieved is weak, and reliant on correct assumptions. Next easiest to monitor is the level of illegal hunting – and if a reduction in illegal hunting sign can be demonstrated in the high management effort area, this would be suggestive that the bonobo population is doing better. On the other hand if there is no change in illegal hunting, the effort put into management is insufficient and most likely bonobos are continuing to be poached. Finally a test of the assumption of the causal chain is needed: is the bonobo population responding to reduced hunting levels caused by effective patrolling? With an intrinsic rate of population growth of a few per cent per year, it will take a long time to measure an increase in the population size and the same is likely true for anything but a catastrophic decline in abundance. Therefore it is not appropriate to monitor the bonobo population annually, but rather every few years. But it is entirely feasible and important for measuring management effectiveness to monitor actions and threats on much shorter time scales.

A lot of time and effort has been put into developing these apparently simple concepts of monitoring by the CMP and others, and there is a large suite of resources available to help managers develop appropriate monitoring plans that take advantage of data collection at all levels of the management process. Later in this report, these principles are applied to the CARPO strategy. What is amazing is now few conservation projects, not just in WWF or Central Africa, but across the spectrum of NGOs and other groups have implemented this form of conservation monitoring, even in wealthy countries with relatively large budgets for wildlife management and deep scientific expertise (Yoccoz, Nichols & Boulinier 2001; Sutherland *et al.* 2004; Nichols & Williams 2006; Howe & Milner-Gulland 2012).

The MIRADI software (miradi.org)does an excellent job of extending the conceptual model into a network of causal chains which requires very clear expression of suspected cause and effect from which real testable hypotheses related to management interventions can be generated.

Figure 2. Monitoring should involve measuring change across all levels of a programme (from N. Salafsky's overview presentation at the CMP Summit 2010).

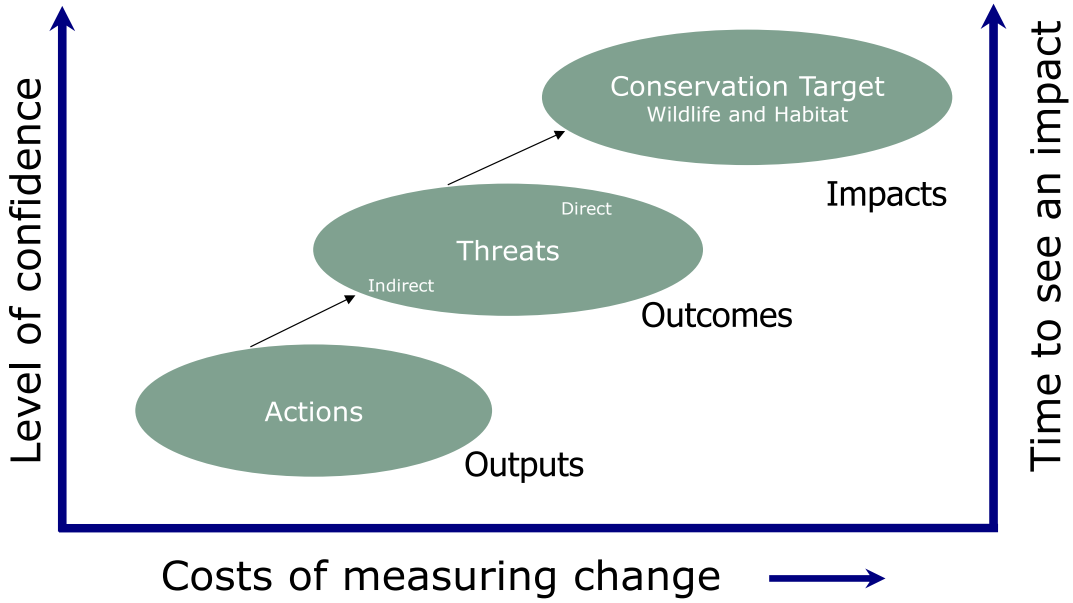
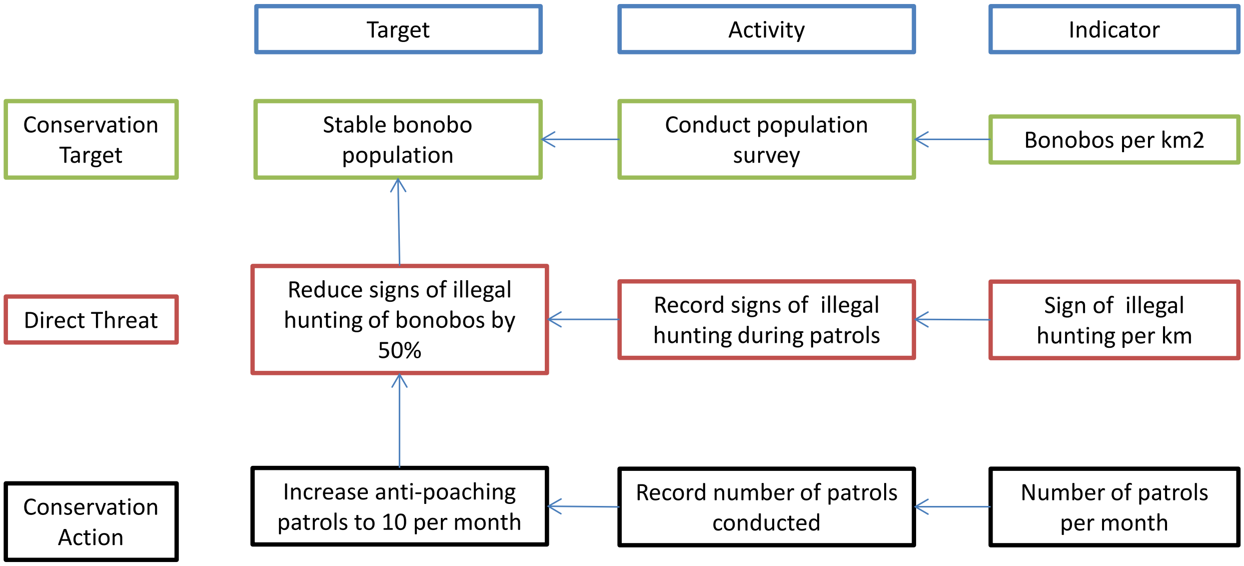


Figure 3. An example of a monitoring framework for bonobo conservation within a landscape



CAUSATION VERSUS CORRELATION

Recently, Yuccoz et al (2001) in their paper called ”monitoring of biological diversity in space and time” quoted Charles Krebs who said that “*monitoring of populations is politically attractive but ecologically banal unless it is coupled with experimental work to understand the mechanisms behind system changes*”. The same is true for conservation monitoring, monitoring wildlife and detecting change is better than nothing, but would be much more useful if we could understand what is driving the trend and then how to manage adaptively. Should a conservation manager spent $50,000 more per year to double the number of anti-poaching patrols or should they rather invest that money in outreach and education? What would be the effect of either strategy on illegal killing – would it go down, up or would there be no effect and what would have happened had they done nothing? Good monitoring of management interventions should shed light on these sorts of questions even in complex management environments like the Congo basin.

Obviously in the Congo Basin we need to understand what is feasible given the massive constraints on budgets, trained staff, security, logistics, etc. Some applied scientists have suggested that conservation programmes set up genuine design-biased experiments in their sites (using statistically robust treatment and controls) to measure the impact of management (Ferraro & Subhrendu 2006), though most managers would be horrified if we suggested they spend money counting wildlife in areas where they are not working. However a landscape scale approach to monitoring, with spatially explicit interventions and threats assessments can set up something close to a scientifically valid experimental framework. Setting up monitoring in this way is not theoretical scientific mumbo jumbo for the sake of it, but quite the contrary - a very practical way to help answer critical management questions.

We return to this theme later in the report.

THE CONTEXT OF BIO-MONITORING FOR WWF CARPO

The CARPO site based conservation programme in central Africa consists of nine priority landscapes spread across five countries (Gabon, Republic of Congo, Democratic Republic of Congo, and Cameroon), which cover a combined surface area of some 67 million hectares. This represents ca. 17% of the entire surface area of the six central African nations, and 37% of the central African forest block (Figure 4). The CARPE GHoA landscapes are our of these landscapes that traverse international borders (Table 1), which generates huge opportunity in terms of managing coherent ecological units, but can add to management complexity when operating across borders within multiple national legal frameworks. Seven of the CARPO landscapes are based within the suite of conservation landscapes recognised by the Central African Regional Program for the Environment (CARPE), which were established in 2002. In prioritising their activities in central Africa, WWF defined two additional landscapes outside of the CARPE framework; Campo-Ma'an and Mount Cameroon – Korup-Bakossi. Collectively, these landscapes hold among the most ecologically intact tropical forests on earth, large tracts of wilderness, and a high diversity of charismatic megafauna. In many cases human populations are low, and most of the protected areas within the landscapes are without any permanent human settlement. Full site descriptions are provided in the "State of the Forest" report of 2008 (de Wasseige et al. 2009), and are not worth repeating here.

In all landscapes, WWF are one of a consortium of management entities that work in partnership, and which include governmental institutions, the private sector other large NGOs (notably WCS, CI and Africa Parks), and local inhabitants, all of which must be taken into account as WWF defines and pursues its management objectives. Some landscapes are divided into management sectors by tacit agreement between NGOs and governments, such that in the Sangha Tri-National landscape for example, WCS assumes responsibility for conservation management and monitoring on the Congolese side, while WWF does so in collaboration with government partners in CAR and Cameroon. Thus while WWF has management objectives over all 672,220km^2 of landscape territory it may have some level of management mandate or authority over only a portion of that area.

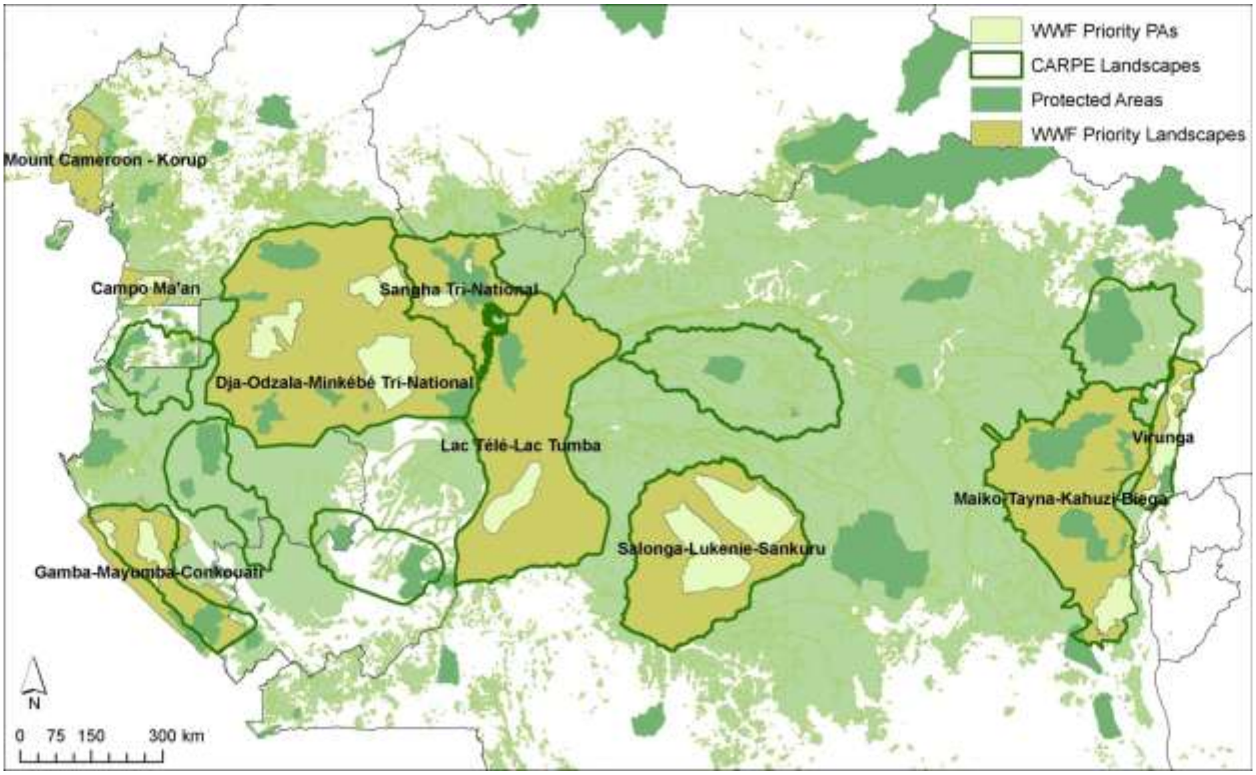
Table 1. WWF Priority landscapes in Central Africa

	Landscape	Area^1 (km^2)	Area^2 (GIS)
1	Mount Cameroon - Kourp - Bakossi (Cameroon)	20,635	15,443
2	Campo-Ma'an (Cameroon)	7,000	7,782
3	Gamba, Mayoumba, Conkouati (Gabon, ROC)	34,258	47,584
4	Dja-Odzala-Minkebe Tri-National (Cameroon, Gabon, ROC)	141,000	191,560
5	Sangha Tri-National (CAR, Cameroon, ROC)	36,236	43,927
6	Lac Tele-lac Tumba (ROC, DRC)	126,440	130,900
7	Salonga-Lukenia-Sankuru (DRC)	102,847	105,268
8	Maiko-Tayna-Kahuzi Biega-Itombwe (DRC)	67,121	111,219
9	Virunga (DRC)	15,000	18,537
	TOTAL	**550,537**	**672,220**

[1] Area given in WWF strategy document,

[2] Areas were calculated according to GIS shapefile Congo_basin_WWF_PLS_wgs84.shp provided by WWF

Figure 4. WWF priority landscapes in the central African forest block, showing the (best guess) current protected areas network, and the suite of WWF priority protected areas.



Embedded within these landscapes are a suite of protected areas, of which 17 are considered priority protected areas by WWF in their 2020 strategy (Table 2). These protected areas cover ca. 76,984km^2 , almost all of which is moist tropical forest. The size of some of these areas is enormous – the combined area of Salonga NP in the heart of DRC is some 34,945km^2, in one of the most isolated areas of the Congo Basin. By contrast, Mount Cameroon NP is only 580km^2, yet lies within 20km of one of the largest ports and cities in Central Africa. The diversity of size, isolation, human population pressure, land use and socio-political context render effective management of these landscapes and protected areas almost insurmountably complex. Measuring the effectiveness of management (monitoring), within the bounds of feasible budgets, human resources and logistical reality is a similarly difficult task, and providing some sensible, practical suggestions to how WWF can improve its current monitoring strategy is the core of this report.

Table 2. Priority protected areas within priority landscapes

	Name	Country	Area (km2)
1	Mount Cameroon NP	Cam	580
2	Campo Ma'an NP	Cam	2,640
3	Korup NP	Cam	1,250
4	Bakossi NP	Cam	300
5	Lobeke NP	Cam	2,170
6	Nki NP	Cam	3,090
7	Boumba Bek NP	Cam	2,380
8	Loango NP	Gab	1,550
9	Moukalaba Doudou NP	Gab	4,500
10	Minkebe NP	Gab	7,570
11	Ngiri Reserve	DRC	1,000
12	Tumba Lediima	DRC	2,600
13	Salonga NP	DRC	34,945
14	Virunga NP	DRC	7,844
15	Itombwe NR	DRC	2,000
16	Odzala NP	Congo	13,600
17	Dzanga-Sangha NP/SR	CAR	6,865
	TOTAL		**76,984**

OVERVIEW OF MONITORING PRIORITIES AND MONITORING CAPACITY BASED ON INTERVIEW RESPONSES

A questionnaire was sent out to field sites through the WWF head office to improve our understanding of the current state of biomonitoring priorities and resources in the region. Nine sites completed the questionnaire. Below we briefly summarise the salient points of the responses.

What are the target conservation species in your conservation area?

Elephants were conservation targets in all 9 landscapes, followed by great apes in 8 sites. Marine turtles were cited as important in the two coastal WWF sites and a variety of species were prioritised at local level in one or two sites (e.g. bushmeat species, okapi, drill, manatee).

Do you have a monitoring strategy for your site?

Six sites of nine stated that they have clear monitoring strategies, though no examples were provided. however in one site (Virunga) the emphasis is not on bio-monitoring. Only one monitoring strategy document was made available to us which outlines a monitoring proposal for monitoring management effectiveness in across WWF Cameroon (Tchamba *et al.* 2007).

Do you have written monitoring objectives?

Interestingly, only four sites said that they had monitoring objectives, which seems at odds with the answer to the previous question. We did not receive any examples, however we did not specifically ask for them.

Do you have partnerships with other organizations for monitoring? If so with which institution(s)?

The dominant WWF partner involved in monitoring activities is WCS, with whom there is collaboration in four sites. The MIKE programme was only cited once, though MIKE and WWF share common site areas in many large sites in the Congo Basin.

Monitoring related infrastructure

Internet

All sites that responded have internet access, with a reasonable connection in eight sites, and a good connection in just one site. Bandwidth ranges from just 128kB/sec in four sites, to a 2mB connection in the Gamba landscape (Tchibanga site).

Data management

Six sites have a functional bio-monitoring archive, two have partial systems, and one site, Virunga, has no bio-monitoring data archive at all. All archives are digital, with either hard drive or CD backup storage. The Cameroon sites all have a database system for storage, while all other sites use specially designated folders in windows explorer. Very surprisingly, no sites send back up copies of their data to the WWF regional offices, presumably meaning that all data are stored in the WWF site level offices.

Four sites are currently using MIST software, though four more sites expressed an interest in using it in the future. Of those sites using MIST, only one incorporates some form of biological research data, though no details were given on how these data have been integrated.

Personnel

Four sites (Cameroon) said they did not have a formal GIS technician, though members of the field team have at least some GIS expertise. Two GIS specialists have Masters level degrees in Environmental Information management. No site had an information technology manager on site. The Gabon site has a specialist in Libreville who is available for site level needs, and the CARPO regional HQ in Yaoundé has a proficient IT manager.

Five of the nine sites have trained biologists, while five sites have trained field technicians, though only two sites had more than one technician available, while in Campo Ma'an, the field technician's role is performed by a local volunteer.

Law enforcement

Ecoguards are present at all sites, and while WWF does not directly engage in law enforcement, it does fund and or support logistics law enforcement activities in all sites. The level of investment in some sites is very significant – an estimated 250,000 and 225,000 Euros are spent annually in Gamba and Dzanga-Sangha respectively.

WWF is involved in law enforcement monitoring (LEM) in eight of nine sites. WWF does not engage in LEM in Virunga but does support patrols financially, and could become more involved. WWF has access to LEM data in Cameroon, Congo and DR Congo, but has increasing difficulty accessing these data in Gabon. However in only one case (Campo Ma'an) was a formal agreement reported on LEM data management involving WWF and MINEFOF.

Discussion

There is a high level of agreement in conservation target species across sites which is helpful when considering the integration of site level with regional scale wildlife monitoring. It is encouraging that 6 sites stated that they have written monitoring strategies, though this is inconsistent with the volume of data that were made available for this evaluation, and suggests that strategies are not being implemented in most sites.

WCS emerged as the most consistent monitoring partner, and interestingly only two site (Virunga and Boumba Bek and Nki) cites a national institution (the ICCN and MIKE respectively) as a monitoring collaborator.

While all sites have internet capability, no site routinely sends their data to a central storage facility at WWF-CARPO HQ. This suggests potential problems for data security, but also the the ability to quality control data collection and also perform regional analyses.

Human capacity in GIS, IT, statistical analysis and biological sciences are generally weak at site level.

EVALUATION OF THE EXISTING WWF MONITORING PROGRAM BASED ON DATA AND REPORTS RECEIVED

SURVEY COVERAGE IN TIME AND SPACE

The following section provides an estimate of the total survey effort deployed by WWF CARPO in terms of line transect survey data. The first salient point is that at three landscapes, as far as we can detect, no line transect survey work has been completed by WWF (Maiko-Tayna-Kahuzi Biega-Itombwe, Lac Tele-Lac Tumba, and Virunga). In Virunga, it has been WWF policy to devolve all biological monitoring to the WCS teams who have been operational on the ground in the region for over two decades. In Lac Tele-Lac Tumba, there has been a considerable amount of line-transect survey work carried out by WCS on the Congo-Brazzaville side of the landscape where WCS has primary responsibility. However, in the Lac Tumba segment in DR Congo WWF are responsible for management implementation. For Maiko, we were provided with no data and do not know what, if any, survey work has been completed.

Figure 5. The area covered by line-transect surveys carried out by WWF in priority landscapes

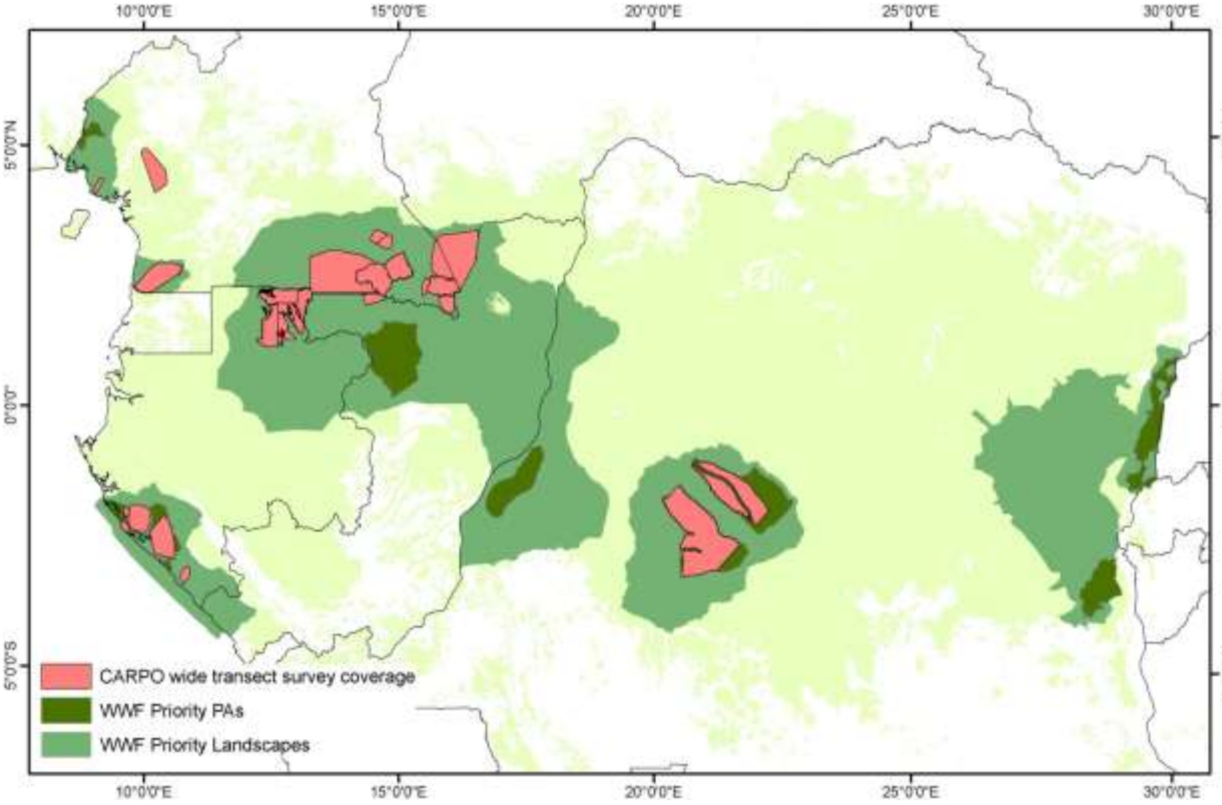


Figure 5 and Table 3 demonstrate that despite considerable efforts in some sites, the total sampling coverage across the landscape network is extremely small – the surface area of sampling since 2002 (including repeat surveys in some areas) is just 69,892km^2 out of a total landscape area of 672,220km2. Most of this sampling effort has taken place in two bursts – the first in 2004 and the second in 2011 (Figure 6). The 2004 peak is as a result of the region wide implementation of MIKE surveys, which focussed largely on MIKE sites where WWF has a strong management interest (Boumba Bek, Minkébé, Dzanga-Sangha, Salonga), while the 2011 peak is due to the surveys in Ngoila-Mintom, Campo Ma'an, and the almost complete survey coverage of the Dzanga-Sangha site. Sampling coverage in other years only exceeded 5,000km^2 once, in 2005, largely due to the WWF Max Planck Institute joint ape survey of Moukalaba-Doudou National Park. In only one case has survey coverage exceeded 50% of landscape area – in Campo Ma'an, however at only 7,000km^2, this is by far the smallest of the WWF landscapes. We appreciate that there are clearly some surveys that have not been included. These are either because (1) we have not been made aware that they were ever done, or (2) data were provided in an unusable format (in several cases we received summaries of data only with no spatial or raw data. One important example of (2) is a dataset collected in the late 1990s in the Gamba complex which provided data for several critical papers for the development of biodiversity monitoring theory and practice in the Congo Basin (Walsh & White 1999; Walsh *et al.* 2000; Thibault *et al.* 2001). These data were not collected strictly under the management auspices of WWF, but do represent an early status assessment on the abundance of priority taxa and might have been incorporated into trends monitoring over time. We return to discuss these data later in the report, as they represent a good example of poor data archiving and loss of institutional knowledge.

When considering only those landscape sectors in which WWF is the primary implementing NGO, coverage is rather better. However here, the total coverage of all surveys conducted since 2002 rarely exceeds 20% of the landscape sector, with the exception of the same sites mentioned above. Importantly, there is very little spatial replication over time, with most surveys being one-off efforts. The ability to detect and inference of trends in populations of priority species are therefore impossible in the great majority of the priority protected areas and priority landscapes.

Important exceptions to this are the Lobéké and Dzanga Sangha sites. In the Lobéké NP, there is a long history of line-transect work dating from the late 1980s (Stromayer & Ekobo 1991), through 1995 (Ekobo 1995) and into the 2000s with three high intensity surveys in 2002, 206 and 2009 which are reviewed in detail later in this report. In Dzanga-Sangha, low intensity design biased surveys in the 1980's revealed high elephant and ape densities (Carroll 1986; Carroll 1988a; Fay 1989b; Fay 1989a; Fay & Agnagna 1991). Subsequently a variety of surveys to measure ape and elephant surveys were completed by WWF (Blom *et al.* 2001; Blom *et al.* 2004) and several independent researchers all of which were reviewed by Walsh (2009b). Most of these surveys had low spatial coverage and were not subsequently re-surveyed so again trend detection over time is problematic. However, wide ranging design un-biased surveys conducted by the MIKE teams in 2004 and by Todd et al in 2011, for which the data are as yet unavailable, provide the best opportunity for comparison in abundance over time and space for elephants, though poor precision in ape density estimates by the MIKE team may preclude trend detection.

Table 3. Total survey coverage using line-transects generated from data provided by WWF (exceptions not included are cited in the text)

Year	Country	Landscape	Site	Total Landscape area (WWF estimates)	Area of WWF as lead sector	Area surveyed (km2)	% of landscape surveyed	% of wwf landscape sector surveyed
2011	Cameroon	Campo Ma'an	Campo Ma'an NP	7,000	7,000	3,644	52.1	52.1
2002	Cameroon	Ebo (non-priority)	Yabassi			2,683		
2005	Gabon	Gamba	Moukalaba Doudou NP	34,258	29,264	3,415	10.0	11.7
2006	Gabon	Gamba	Loango NP	34,258	29,264	357	1.0	1.2
2007	Gabon	Gamba	Loango NP	34,258	29,264	187	0.5	0.6
2008	Gabon	Gamba	Kivoro	34,258	29,264	2,332	6.8	8.0
2010	Gabon	Gamba	Mavoungou	34,258	29,264	495	1.4	1.7
2003	Cameroon	Mount Cameroon - Kourp - Bakossi	Mount Cameroon	20,635	20,635	318	1.5	1.5
2004	DRC	Salonga-Lukenia-Sankuru	Salonga NP	102,847	102,847	7,778	7.6	7.6
2002	Cameroon	Sangha Tri-National	Lobeke NP	36,236	15,003	2,161	6.0	14.4
2003	Cameroon	Sangha Tri-National	UFA10-13_2003	36,236	15,003	423	1.2	2.8
2004	Cameroon	Sangha Tri-National	UFA10064	36,236	15,003	1,037	2.9	6.9
2004	CAR	Sangha Tri-National	Dzanga Sangha Reserve	36,236	7,376	1,309	3.6	17.7
2004	CAR	Sangha Tri-National	Dzanga NP	36,236	7,376	499	1.4	6.8
2004	CAR	Sangha Tri-National	Ndoki NP	36,236	7,376	746	2.1	10.1
2005	Cameroon	Sangha Tri-National	UFA_10-008-09-10-12	36,236	15,003	2,917	8.0	19.4
2006	Cameroon	Sangha Tri-National	Lobeke NP	36,236	15,003	2,161	6.0	14.4
2009	Cameroon	Sangha Tri-National	Lobeke NP	36,236	15,003	2,007	5.5	13.4
2011	CAR	Sangha Tri-National	Dzanga Sangha Reserve	36,236	7,376	6,732	18.6	91.3
2003	Cameroon	TRIDOM	UFA_10-021	141,000	59,005	609	0.4	1.0
2004	Cameroon	TRIDOM	Boumba Bek NP	141,000	59,005	2,383	1.7	4.0
2004	Cameroon	TRIDOM	NKI NP	141,000	59,005	3,256	2.3	5.5
2004	Gabon	TRIDOM	Minkeke NP	141,000	67,689	9,320	6.6	13.8
2006	Cameroon	TRIDOM	UFA10023	141,000	59,005	658	0.5	1.1
2011	Cameroon	TRIDOM	Messokdja	141,000	59,005	825	0.6	1.4
2011	Cameroon	TRIDOM	Ngoila Mintom	141,000	59,005	11,642	8.3	19.7
Total						**69,892**		

Figure 6. Area surveyed using line-transects per year since 2002

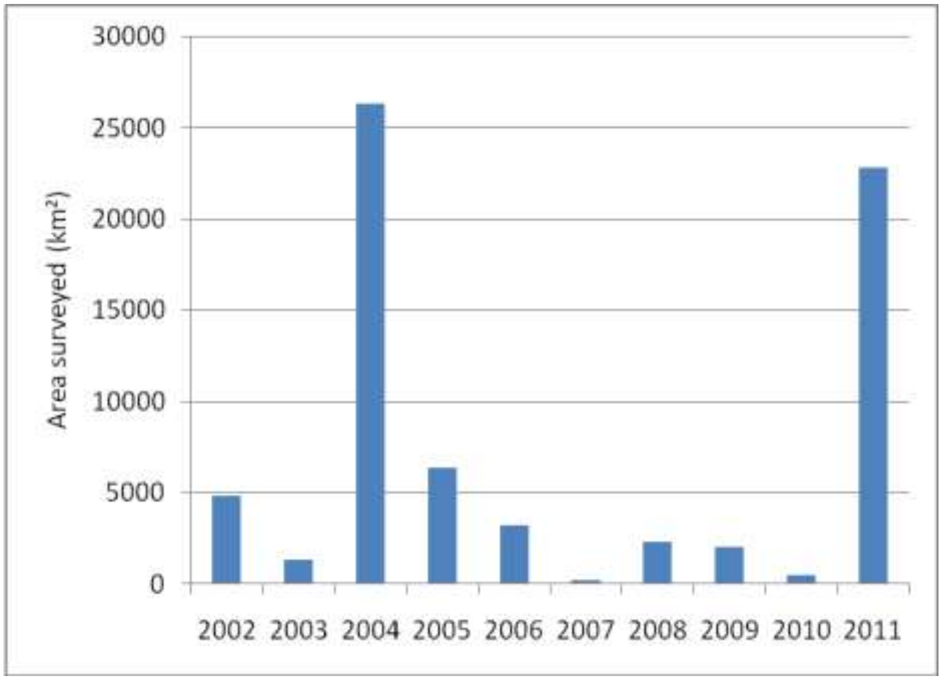


Table.4. Break down of survey coverage as a percentage of landscape area in which WWF has primary NGO responsibility

Landscape sectors	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Campo Ma'an										**52**
Cameroon										52
Gamba				**12**	**1**	**1**	**8**		**2**	
Gabon				12	1	1	8		2	
Mount Cameroon - Kourp - Bakossi		**2**								
Cameroon		2								
Salonga-Lukenia-Sankuru			**8**							
DRC			8							
Sangha Tri-National	**14**	**3**	**42**	**19**	**14**			**13**		**91**
Cameroon	14	3	7	19	14			13		
CAR			35							91
TRIDOM		**1**	**23**		**1**					**21**
Cameroon		1	10		1					21
Gabon			14							

Reconnaissance surveys have been used more extensively than line-transect surveys across the WWF priority sites, most notably in Minkébé. Northeastern Gabon had been identified as an outstanding site for elephants by Barnes et al in the late 1980s (Barnes *et al.* 1991; Barnes *et al.* 1995) which prompted WWF to invest in the Minkébé site. With no up to date information on the distribution of wildlife or hunting in the region, WWF initiated extensive recce surveys in 1998 and 1999 (Figure 7). In most other sites, recces have accompanied line-transect surveys, with recces carried out between transects following methods based largely on the methods manual of White and Edwards (2000).

Figure 7. Spatial coverage of recce data collected within priority landscapes by WWF-CARPO

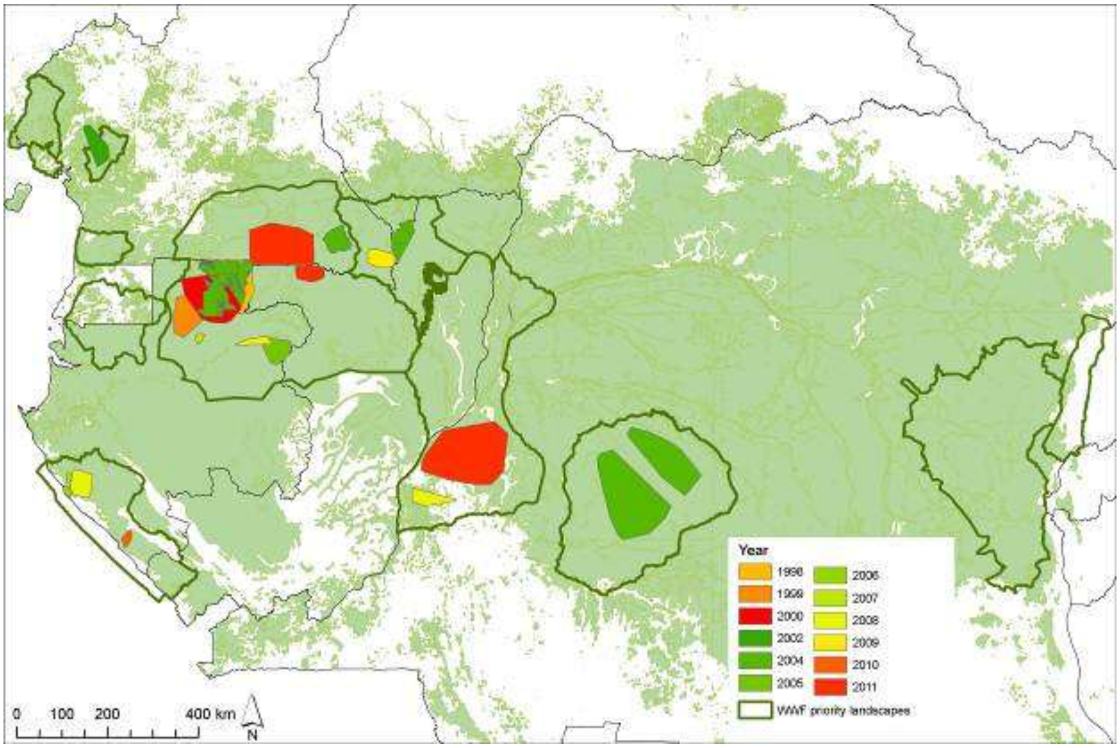


Table 5. Area covered by WWF led reconnaissance surveys by landscape based on datasets provided by WWF.

Year	Country	Landscape	Landscape area km^2	Site	Area surveyed (km^2)	% of landscape
2002	Cameroon	Ebo	6095.4	Yabassi	2,683.0	44.0
2009	Cameroon	TNS	44,620.9	Lobeké	2,006.6	4.5
2011	Cameroon	TRIDOM	192,859.2	Ngoila Mintom	11,641.8	6.0
2004	Cameroon	TRIDOM	192,859.2	Boumba Bek	2,382.7	1.2
2004	CAR	TNS	44,620.9	Dzanga Sangha Reserve	1,308.6	2.9
2004	CAR	TNS	44,620.9	Dzanga NP	499.2	1.1
2004	CAR	TNS	44,620.9	Ndoki NP	746.4	1.7
2011	DR Congo	Lac Télé-Lac Tumba	133,656.8	RLT_eq	19,839.9	14.8
2008	DR Congo	Lac Télé-Lac Tumba	133,656.8	South Tumba	2,113.4	1.6
2005	DR Congo	Lac Télé-Lac Tumba	133,656.8	Bomongo-Lobengo	56.1	0.0
2004	DR Congo	Salonga	108,808.9	Salongasouth	17,976.1	16.5
2004	DR Congo	Salonga	108,808.9	Salonganorth	10,121.4	9.3
2010	Gabon	Gamba	47,346.3	Mavoungou	508.2	1.1
2008	Gabon	Gamba	47,346.3	rabi	2,337.2	4.9
2006	Gabon	Gamba	47,346.3	Loango	313.3	0.7
2007	Gabon	Gamba	47,346.3	Loango	188.8	0.4
1998	Gabon	TRIDOM	192,859.2	Minkébé	8,853.4	4.6
1999	Gabon	TRIDOM	192,859.2	Minkébé	4,446.8	2.3
2000	Gabon	TRIDOM	192,859.2	Minkébé	11,933.5	6.2
2005	Gabon	TRIDOM	192,859.2	Mwanga	2,768.6	1.4
2007	Gabon	TRIDOM	192,859.2	Minkébé	308.5	0.2
2009	Gabon	TRIDOM	192,859.2	Mwanga	928.7	0.5
2011	Gabon	TRIDOM	192,859.2	Messok Dja	1,948.1	1.0
2004	Gabon	TRIDOM	192,859.2	Minkébé low	2,518.9	1.3
2004	Gabon	TRIDOM	192,859.2	Minkébé medium	4,520.6	2.3
2004	Gabon	TRIDOM	192,859.2	Minkébé high	2,306.4	1.2

WILDLIFE SURVEY METHODS FOR OBTAINING BASELINES AND MONITORING TRENDS OVER SPACE OR TIME

OVERVIEW

When little is known about the intensity or location of threats or the status of a conservation target of interest within a site, baseline surveys are conducted to inform conservation management. Once the conservation context has been defined and strategies formulated to get conservation activities underway, a monitoring program to assess the status of conservation targets with respect to specific goals are conducted (CMP 2007). The results from monitoring surveys are used to determine whether the activities are working or need to be adapted (Salafsky et al. 2001). In addition, further research on the conservation targets may be carried out to refine either the conservation strategies and associated activities or the monitoring program itself.

Once conservation targets have been selected, deciding what to monitor is determined by the objectives of the monitoring program. The general recommendation is that objectives should focus on “state variables” and “rate parameters” that characterize the system dynamics (Williams et al. 2002). With a focus on species, the state variable may include abundance, density or occupancy (area in which the species is present); with a focus on biodiversity, species richness may be appropriate (Magurran 1998, 2003). Rate parameters could include birth, death, immigration, emigration, extinction or colonization. Abundance can be measured directly (numbers or biomass of the species) or indirectly (occupancy for a species). Estimates of abundance can be obtained from survey data collected on the animals themselves or on their sign.

Whichever state variable or rate parameter is selected (for a general wildlife monitoring decision tree see Strindberg and O’Brien 2012), the ideal is to then use a survey method to estimate those parameters that explicitly accounts for detectability (referred to as sightability or catchability for some methods). Efforts can be made to standardize field procedures, which will reduce variation in detectability. However, it is impossible to control or identify all factors that might influence it (Conroy and Nichols 1996), thus applying survey methods that provide estimates of detectability and account for it when estimating the state variable or rate parameter are much preferable. For example, reconnaissance (recce) type surveys (Walsh and White 1999) provide measures of relative abundance generally expressed as encounter rate of specific cues per kilometer walked. With recce surveys that are frequently used in Central Africa and other tropical forest settings, as one can cover large areas much more quickly, it is unknown what proportion of the species (or their sign) is detected. Recces or other catch per unit effort methods are potentially useful during the initial phase of obtaining information at a site that is unknown (although even here improvements could be made to the method to permit analysis in an occupancy framework, which provides estimates of detectability – see below). However, in the context of a monitoring program, such indices are difficult to use. Interpretation of the index to determine trends over time or space relies on an assumption that is unlikely to be true, namely, that detection remains constant over time or space.

THE PROBLEMS OF *RELATIVE ABUNDANCE*

The term *relative abundance* is used heavily in the Central African monitoring context as a catch all term to justify many methodological variations and apparently render data compatible. However to be useful, it is critical to know what the estimated value of a variable is relative to. Ideally, an indicator should have no bias or a systematic bias (where the abundance of the indicator is directly proportional to the population of interest). In these cases the term relative abundance can be used appropriately. However relative abundance is often loosely used, with the inherent assumption that biases and either not present or uniform, when in fact they are not. Rarely are common assumptions of uniformity tested, for example observer ability. Imagine two recce surveys used in 2000 and 2010 to estimate elephant abundance in a population that was perfectly stable. If the observer in survey 1 happened to be twice as good at spotting dung as the observer in survey 2, the encounter rate of dung would be twice that in 2000 compared to 2010, and therefore the relative abundance of elephants in 2010 is halved compared to 2000. The monitoring team assumes therefore that the elephant population has declined by half. This may sound far-fetched, however trials in the Ndoki forest indicate that there can easily be a two-fold difference in observer efficiency between observers, and this can have nothing to do with training or experience (Blake, pers. obs.).

Similarly we use relative abundance frequently to "account" for the fact that other forms of bias have not been quantified. In the central African context these include dung and nest decay and production rates. Wing and Buss, who worked in the Kibale Forest dealt with these issues appropriately as far back as 1970, and until quite recently, many survey analyses were still using their estimates of elephant dung decay and defecation rate. It is sobering to think that Richard Barnes first discussed the impact of variable dung decay and defecation rates on elephant population estimates based on dung counts at length in 1987 (Barnes & Jensen 1987) and many times subsequently (Michelmore 1989; Barnes & Barnes 1992; Barnes *et al.* 1994; Barnes 1996; Barnes *et al.* 1997a; Barnes *et al.* 1997b; Barnes 2001; Barnes & Dunn 2002). Other conservation biologists with much experience in Central Africa have done the same (Walsh & White 1999; Walsh *et al.* 2000; Walsh *et al.* 2001; Kuehl *et al.* 2007; Kuehl *et al.* 2008; Todd *et al.* 2008; Walsh 2009a; Walsh 2009b). Further sources of bias in detectability come from failure to adequately differentiate between chimp and gorilla nests (Sanz *et al.* 2007) Yet most monitoring programmes, including those within WWF and WCS continue to fail to adequately measure these variables. Indeed the last published multi-site evaluation of forest elephant conservation status (Blake *et al.* 2007) did not estimate either elephant defecation or decay rates at all, rather they guesses values and plugged them into their elephant population estimates with no idea of their accuracy. All MIKE surveys not only failed to measure nest decay rates for apes, but in most cases they also failed to correctly identify ape nests to species or to provide the necessary data to do so after fieldwork. The WWF CARPO analyses are full of similar errors. There are mitigating circumstances and strong reasons for not quantifying these variables (lack of funds, time and personnel), but not taking them into account means that there are certainly large sources of unknown error in estimates of animal abundance, and our "relative abundance" becomes dependent on the strength of these biases.

The potential strength of decay rates to bias estimates of ape abundance was illustrated by Walsh & White (2005), who found that variation within and between survey sites over time could change the decay rate of nests by tens of percent from the mean decay rate. Normal variation in rainfall over time can therefore produce wildly inaccurate estimates of ape abundance.

The issues of bias and potential solutions are discussed further below.

DISTANCE SAMPLING METHODS

In forested Central Africa, distance sampling methods that account for detectability and provide estimates of density and abundance have been used successfully (Buckland *et al.* 2001). When applying these methods, observers traverse a series of line transects or visit point transects and record the perpendicular distance from the line transect to each observation (or the radial distances for points). A detection function is fitted to these distance data and can be used to estimate both the proportion of animals or sign detected and counted and the proportion of the survey area covered. Ideally transect lines or points are located randomly with respect to the distribution of the animals, which helps ensure valid statistical inference. Additional assumptions when using the standard method include that objects of interest on the line or point are detected with certainty, animals are detected at their initial location, measurements are exact, and that detections are independent events. Distance sampling can be very efficient and cost-effective for large populations (in contrast to capture-recapture methods, for example, where a large proportion of the population needs to be sampled to obtain reasonable precision), populations at low or medium density, or sparsely distributed over large geographic regions. In particular, point transects might be most appropriate for populations at high density, for multi-species surveys (e.g. songbirds), or when habitat is patchy or terrain is difficult, making it problematic to walk along predetermined lines. In contrast to occupancy or capture-recapture methods (described below), advantages of distance sampling are that the detection function is robust to unmodeled heterogeneity and repeated surveys are not required. Distance sampling methods are continually evolving with innovations in spatial modeling using distance sampling data, incorporating covariates into the detection function, combining distance sampling with mark-recapture methods, automated survey design, for example (Buckland *et al.* 2004). The freely available Distance software exists to help with distance sampling design and analysis (Thomas *et al.* 2010). It comes with a comprehensive online users' guide and can be downloaded from the Distance website (www.ruwpa.st-and.ac.uk).

Ground-based line transect surveys for elephants, apes and ungulates are focused on sign, because direct observations of these animals are relatively infrequent, as they are difficult to detect in forest habitat (also movement away before they are detected would be problematic given distance sampling assumptions). Methods are well known, and survey standards and best practices exist for both elephant and ape surveys (Hedges & Lawson 2006; Kuehl *et al.* 2008; Hedges 2012). The higher sighting frequency of sign provides larger sample sizes, where otherwise a prohibitive amount of survey effort would be required to obtain adequate sample sizes and precision. The drawback, of course, is the difficulty of obtaining estimates of actual animal abundance from sign-based surveys due to the biases discussed above. Either standing crop or accumulated/marked sign surveys can be used. Standing crop surveys require a single visit to the sampling site and rates of creation and decay to convert estimates of sign density to estimates of animal density. Accumulated/marked sign surveys require repeat visits to count new sign that accumulates between visits under the assumption that the time between visits is shorter than the shortest time it might take sign to decay. Only rates of creation are then required to obtain estimates of animal density from estimates of sign density. Ideally, only survey-specific and rates of creation and decay should be used with representative spatial distribution of samples. In practice, given the additional resources this requires it is not always possible, and more often than not the rates are used from the same site from different time periods or from different sites altogether are the norm. This brings with it similar caveats as using a survey method that does not take account of detectability.

For sites where gorillas and chimpanzee co-occur, additional information to determine nest builder is needed. Ape nests on the ground can be assigned to gorillas, but with tree nests it is only possible to reliably assign ape species in the field, if dung is present under the nest (Arandjelovic *et al.* 2010). Certain characteristics of the tree nest or the habitat it is found in can be used to found to reliably predict the ape species which constructed the nest (Sanz *et al.* 2007). To successfully do this, a sufficient number of nests in the sample need to be attributed to each species with certainty, and in addition information on nest height, habitat type, whether the undergrowth under the nest is closed or open, and tree species in which the nest has been constructed has to be collected in the field (Kühl et al. 2007).

Given the issues with conversion rates from sign to animal density and the fact that for many species that might be conservation targets distance sampling is unlikely to work well, we can consider the advantages and disadvantages of other potential monitoring techniques.

CAPTURE-RECAPTURE METHODS

Capture-recapture techniques comprise a continually evolving set of methods to estimate state and rate parameters (Otis *et al.* 1978; Pollock *et al.* 1990; White & Burnham 1999). The methods require recaptures (active or passive) of animals that can be individually identified or sub-populations that can be recognized either through tags or natural marking (or through DNA). A key assumption is that marked animals are representative of the entire population of interest and that marks are not lost (or do not change in the case of natural markings). Unmodeled heterogeneity in capture probabilities create biases in the estimates and every attempt must be made to account for this heterogeneity that may be due, for example, to reactions to physical trapping, differences in the natural behaviour of individuals or changes in behaviour over time. Some of the most well known capture-recapture methods include known fate models, Cormack-Jolly-Seber models, closed models, band recovery/exploitation models, multi-state models or combinations of these (Williams, Nichols & M.J. 2002; Amstrup & McDonald 2005). The Mark software that offers an astonishing list of analysis options is the state of the art software for the analysis of capture-recapture data (White and Burnham 1999). Mark's online help is comprehensive and in addition the e-book compiled by Evan Cooch, Program Mark: A Gentle Introduction, provides a wealth of information (http://www.phidot.org/software/mark/docs/book/).

Innovation in the form of spatially explicit capture-recapture (SECR) uses the locations where each animal is detected to fit a spatial model of the detection process, and hence to obtain estimates of population density unbiased by edge effects and also dealing with heterogeneity in capture probabilities caused by spatial movement of the animals (Borchers & Efford 2008)(Efford 2004). Previously, the conventional approach to convert estimates of abundances to densities used a wide range of essentially ad hoc methods. SECR methods are more reliable than previously used capture-recapture methods in terms of monitoring changes in abundance over time, but due to their additional complexity require more data and thus also more survey effort to obtain those data. The Density software uses maximum likelihood to estimate the density of animal populations from spatially explicit capture-recapture data (Efford et al. 2004, www.otago.ac.nz/density). The SECR library developed for the R statistical software implements an even wider range of spatially explicit capture-recapture analysis options using maximum likelihood methods (Efford 2012). The SPACECAP library for R implements a set of Bayesian spatially explicit capture-recapture models (Gopalaswamy et al. 2012). It was originally developed for tiger camera trap data.

In forested Central Africa capture-recapture surveys using camera traps have been less frequently employed, even though it has been shown that they can provide reliable results (Ahlering et al. 2011). This is perhaps due to the fact that line transect surveys appear to be more cost-effective over large landscapes that tend to be the norm. Also, populations of many species in many conservation areas are still abundant enough to make it prohibitive to sample a large proportion of the population of interest using capture recapture methods in order to achieve adequate precision for monitoring purposes. Camera trapping methods have been used in Central Africa mainly to answer specific conservation related research questions (Henschel et al. 2011) or to survey populations in small study areas (Arandjelovic et al. 2010, 2011). Aside from the application of capture-recapture methods to leopard (photo-identification; see Henschel and Ray (2003), as well as Ancrenaz et al. 2012) it has been shown that the application of the method via camera trap photo-identification surveys is possible for bongo (Elkan 2003) and okapi (Nixon and Lusenge 2008), because of their distinctive markings.

Capture recapture methods using fecal DNA or DNA from hair are offering some promise as viable alternatives to line transect surveys for small populations. Lori Eggert and colleagues found that fecal DNA methods gave a more precise estimate of elephant abundance than dung counts based on line transects for a small population in the Kakum NP in Ghana (Eggert, Eggert & Woodruff 2003). Similarly, DNA-based capture recapture provided a smaller confidence interval in an abundance estimate of gorillas in Loango NP than traditional methods would have done (Arandjelovic *et al.* 2010), and are recommended as an appropriate technique for “small” populations (up to a few thousand individuals) in the Best Practice Guidelines for Surveys and Monitoring of Great Ape Populations (Kuehl *et al.* 2008).

Particularly encouraging is the recent work by Simon Hedges and colleagues who compared elephant abundance estimates from line-transect surveys and simultaneously conducted fecal DNA capture recapture over an area of > 5,000 km^2 (Hedges *et al. in review*). They concluded that the capture recapture method provided a more precise estimate of elephant abundance than dung counts, and provided very useful data on population structure and genetic diversity. Furthermore the fecal DNA method required less time in the field, and was cheaper to execute than a line-transect study. Importantly for applications in the conservation landscapes of the Congo Basin, Hedges et al. argue that fecal DNA capture recapture methods may be feasible for small populations over large landscapes (>25,000km^2).

OCCUPANCY METHODS

Another area that has developed rapidly in terms of new techniques and wide-ranging applications is that of occupancy methods that estimate the proportion of a habitat occupied when detection is incomplete, making them promising for poor visibility and elusive animals in tropical forests (Mackenzie et al., 2002, Mackenzie et al., 2003, Mackenzie et al., 2006). The method allows for three states: occupied and detected, occupied and not detected, and not occupied. It provides estimates of the probability that a sampling unit is occupied and the probability that an animal (or sign, if sign surveys are used) is detected. Occupancy methods require repeated observations on each sampling unit, but it has the flexibility to allow varying numbers of repeats across the sampling units and that repetition can be temporal, spatial or observer-based. Occupancy allows for variables that might affect occupancy or detection to be incorporated into the analysis. The basic method assumes demographic and spatial closure during a sampling period (referred to as a season) such that the occupancy status does not change and that sampling units states are independent. Additional assumptions include no errors in identifying species and that observations are independent. There are analysis options that relax most of these assumptions should this be needed. A variation on regular occupancy models that only requires detection/non-detection data, uses the variation in detection probability of a species in space to estimate its abundance at each sampling point (Royle and Nichols 2003). An issue with this model is interpretation of the results, as it is generally unclear how to translate the estimates of abundance at each sampling point into a meaningful estimate for the entire study area. Occupancy models can be implemented using either the Presence software (Hines 2006) or the 'unmarked' package in the R software (Fiske et al. 2011). While using 'unmarked' requires you to be familiar with R, the package is more stable than Presence and gives you more flexibility to work with the model output. Donovan and Hines (2007) provide an extensive introduction into occupancy modeling and many worked examples for Presence online. The Mark (White and Burnham 1999), better known for capture-recapture analysis, can also be used for occupancy modeling.

Given methodological advances, occupancy methods that provide estimates of occupancy and species distribution (also potentially relative abundance), as well as estimates of extinction and colonization rates over time have real potential as a monitoring method should be considered, where distance sampling or some other method that provides an estimate of absolute abundance is not feasible to implement. Occupancy provides estimates of detectability, which makes it a robust method for monitoring over time, and can potentially be applied in conjunction with carefully designed recce type surveys that take account of the assumptions underlying occupancy methods. In the Central African context, occupancy methods could be adapted for the rarer species, including hippos, carnivores, and rarer ungulates, giving adequate precision for monitoring purposes, as long as detectability is reasonable and occupancy falls approximately in the 30-80% range.

Patch occupancy methods based on detection of elephant dung have been successfully used in the Gamba landscape to monitor the impact of multiple covariates (season, fruit availability, road infrastructure, and settlement) on the distribution of forest elephants.

SURVEY DESIGN

In general, given that an objective of the monitoring surveys is to assess whether the conservation management activities are having any effect, survey sites selection, stratification of the survey area, and effort allocation should aim to detect changes due to management interventions. If conditions within a landscape (typically habitat type, hunting pressure, or a combination of both) suggest that wildlife is likely to be at very different densities or occupancy in different parts of that landscape, then precision of the overall estimate of density or occupancy can be improved by means of stratification.

For distance sampling surveys in particular, survey effort should be allocated in proportion to suspected abundance in each survey stratum to improve precision. Also, to reliably estimate detectability roughly 60-80 (80-100 for point transects) observation overall are needed, however this will depend strongly on the variance in the abundance of sign and the variance in detectability (from habitat differences for example open versus closed forest), and observer variability. Ideally there should be a least 25 transects per stratum, although 15-20 may suffice, to obtain a representative sample and a reliable estimate of variance in the density estimate. Within each survey stratum line transects should be placed parallel to suspected density gradients, e.g. perpendicular to rivers, roads, habitat edges and when conducting point transects, these might be placed systematically along similarly placed lines. However, if nothing is known about potential density gradients or it is not possible to find an optimal line orientation for a multi-species survey, then a north-south or east-west orientation may facilitate field work. Various design options can be investigated and transect locations can be generated using the Distance software. Generally, some version of a systematic design with a random start option is preferable as this tends to improve precision (Strindberg et al. 2004; see also chapter 7 in Buckland et al. 2001 for design considerations). Encounter rate of the least common species in a multi-species survey will dictate the amount of effort required for a desired precision and to obtain sufficient observations to fit the detection function, with relatively more effort required as sign becomes less common. Clearly, for a multi-species survey compromises may have to be reached in terms of stratification or allocation of effort per stratum. However, even if this is less than ideal for any particular species, it may lead to a loss of precision, but not introduce any biases, if the other assumptions underlying the method are met. Similarly, if the objective is to produce results for management, the stratification is likely to be linked to management activities, which may or may not be optimal in terms of improving precision. If additional variables that might influence detectability or the spatial distribution of the animals are collected during the survey or can be retrieved from a GIS, then these can be incorporated into a standard analysis or used to develop spatial models using the distance sampling data (Stokes et al. 2010).

Capture-recapture study design is informed by the home range size of the species of interest, keeping in mind that it is advantageous to increase both the number of individuals captured, as well as the capture and recapture probabilities. Thus, a compromise much be reached between extensive (generally, the larger the area covered the more unique individuals are included in the sample) and intensive sampling (the greater the sampling effort per unit area the higher the capture and recapture probabilities). Thus sampling is frequently conducted in a fairly systematic manner across the study area with sufficient flexibility in the design protocol to sample areas likely to maximize capture probabilities. In the case of camera traps this may include placing cameras on animal trails or other areas of frequent use, and using aggregation points such as water holes to collect dung for studies using fecal DNA. Another consideration for multi-species surveys is that optimal placement of cameras for one of the species of interest may be less than optimal for the other target species. For example, when monitoring carnivores in Central Africa it seems to be the case that golden cats tend to avoid areas with leopards, which needs to be taken into account when designing the survey.

For the design of occupancy surveys the size of the sampling units is generally determined by the characteristics (home-range size, territoriality) of the target species to ensure that the measure of occupancy is meaningful, although it may also be influenced by the scale of management or of the threat being mitigated. Ideally sampling sites should be selected using a probabilistic sampling scheme, unless the entire landscape is covered. The presence of multiple species (including humans) is always recorded on Central African surveys because the high cost of logistics in the region precludes otherwise. Care must therefore be taken in designing occupancy surveys to allow sufficient survey effort per sampling unit. The Presence software includes a simulation routine that calculates the degree of bias and precision likely to occur for a given number of sampling units and sampling effort when true occupancy and detection probability are known. Thus different scenarios can quickly be evaluated. For more complex sampling designs, the GenPres software can be used to inform the design process.

HUNTER "CATCH PER UNIT EFFORT" METRICS

Professional, expert-based monitoring systems such as those discussed above can, if implemented correctly, fulfil the requirements of scientific rigour, adequate spatial and temporal coverage, and transparent analysis, but they can be extremely costly in terms of quantified staff, logistics, and analytical requirements. An intrinsically appealing alternative is participatory or community based monitoring. In some situations these approaches may prove more financially sustainable, and results may be easier to understand by local stakeholders who may be directly involved in the monitoring effort (Danielsen *et al.* 2000). One example of such an approach that has been used in some form for at least the last three decades in tropical forests is to quantify catch per unit effort by hunters to monitor the sustainability of bushmeat harvesting systems (Caldecott 1988; Rist *et al.* 2010). The methodology relies on either a designated researcher or the hunting community themselves recording relevant data from hunting expeditions that form a normal part of their routine subsistence hunting lifestyle. Early attempts to in Congo were promising (Blake 1994; Eves & Ruggiero 2000) based on an index labelled the estimated rate of return (ERR). These studies suggested strongly that hunter catch per unit effort varied as expected – i.e. increasing efficiency of hunting with distance from the nearest village. This method not only proved useful as an index of hunter efficiency, but also provided valuable information on the geography of hunting, prey species, hunting methods, as well as establishing fruitful relationships between managers, researchers and hunters.

However, those early trials did not assess the critical issues of whether this method stands up as rigorous monitoring tool over the long term, across sites, and with variable personnel. Good reviews of this question have been carried out in relation to the use of catch per unit effort (CPUE) from commercial fisheries, a notoriously difficult form of resource exploitation to monitor, and one with often far reaching ecological and socio-economic consequences. One high profile controversial paper published in *Nature* (Figure 8) used CPUE data to suggest that overfishing was causing a rapid worldwide decline in predatory fish communities (Myers & Worm 2003), which is supported by a wide array of other publications and datasets. Critiques of that paper and its approach (mostly from within the fishing industry) say that methods are flawed, biased and misinterpreted (Maunder *et al.* 2006).

Figure 8. Figure 1 from Myers and Worm (2003) illustrating declining fish stocks around the world as industrial fishing increases. The results are based on CPUE methods.

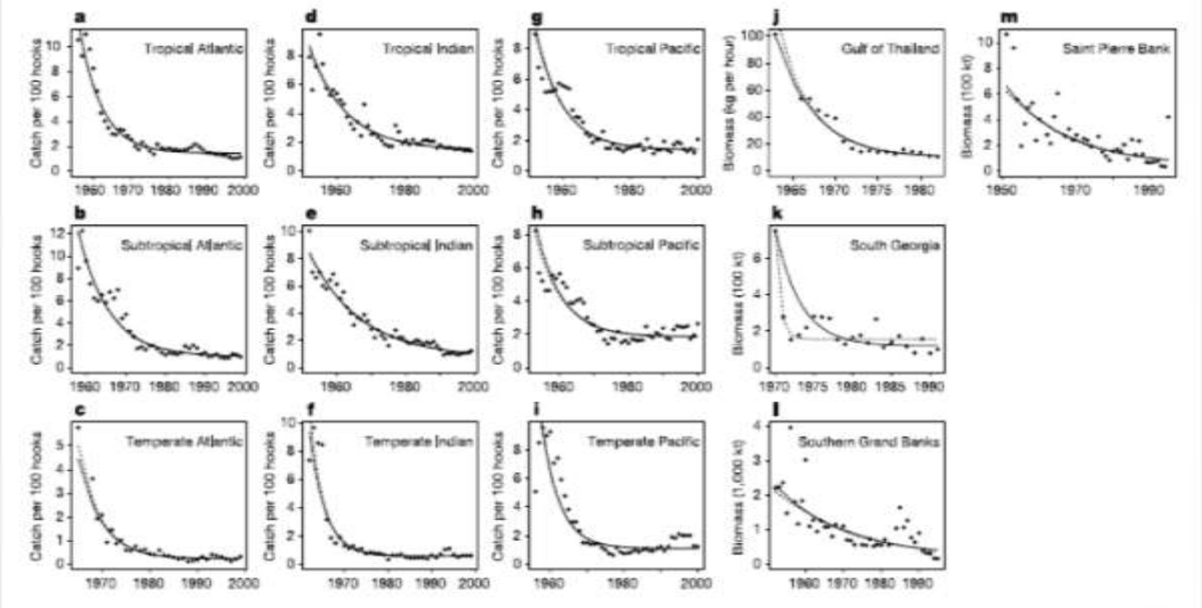


Figure 1 Time trends of community biomass in oceanic (**a**–**i**) and shelf (**j**–**m**) ecosystems. Relative biomass estimates from the beginning of industrialized fishing (solid points) are shown with superimposed fitted curves from individual maximum-likelihood fits (solid lines) and empirical Bayes predictions from a mixed-model fit (dashed lines).

Several studies have argued that CPUE data can provide sound information on hunting offtake, health and management of harvested species in south American tropical forests (Hill, McMillan & Fariña 2003; Puertas & Bodmer 2004), and recent support for using CPUE methods in central African forests comes from a paper by Rist et al. (2010) in which the authors describe their study of a bushmeat harvesting system in Equatorial Guinea. The researchers gathered data on hunting trips using "professional techniques" and "locally-based" methods and compared the two. The professional technique relied on a researcher accompanying hunters while hunting and recording effort and catch details, while the "local" method relied on either weekly hunter interviews and/or camp diaries in which one hunter in a camp collected all the hunting information for the group.

Problems with all methods and their interpretation are discussed at length by Rist et al. (2010) but the bottom line was that locally based methods can give reliable catch and effort information. However the authors caveat this with the assumption that biases in effort remain constant over time, something that is unlikely to be true. The authors go into some detail describing how to improve their methods, and there is a lot of room for periodic checks of assumptions inherent in the methods. Several particularly salient points came from the study:

1. The approximate number of hunts required using their methods and analysis needed to detect a 20% change in CPUE was about 1000– better geographical coverage and other feasible improvements to methods would perhaps reduce this number.
2. Locally based methods were much more cost effective than the professional method. Professional methods required about 6000 person-hours to monitor 1000 hunts, whereas camp diaries cost 39 person hours, and only 25 person-hours was required to record the data from 1000 hunts using weekly hunter interview methods.
3. The locally based methods were less precise than the professional method, however, because they are so much cheaper, local methods provide a more effective way of collecting CPUE data.

It must be understood that the measure of CPUE used in the Equatorial Guinea example was based on the total weight of wildlife harvested, rather than a CPUE on a species by species basis. Depending on the variety of species being hunted, a considerably larger dataset than the nominal 1000 hunts would likely be needed to assess change in CPUE for a single species. Furthermore, a stable CPUE does not necessarily mean that the wildlife resource base is being harvested sustainably, unless the species composition is taken into account. Hunters who would usually hunt red duikers, may switch to hunting pigs of the efficiency of duiker hunting declines to low levels, yet the CPUE in terms of animal mass may remain the same following the change in hunting practise. These and many other sources of bias and issues of data reliability and interpretation need to be identified and quantified before moving forward with a monitoring scheme involving CPUE.

Nevertheless, given the importance of Community Based Natural Resource Management (CBNRM) in the WWF strategy (a 2020 strategic goal is stated as: Targeted CBNRM interventions in priority landscapes deliver innovative alternatives that reduce hunting, commercial trade and consumption of illegal wildlife products (e.g. alternative employment, income, protein.), locally-based simpler methods that ideally estimates detectability/catchability, such as occupancy, rather than relying on untestable assumptions as CPUE methods do could be an appropriate methodology that delivers data that are robust enough to include in a quantitative monitoring programme, but which also engage local communities in data collection involving their own resource base.

BAI MONITORING

Bai monitoring has intrinsic appeal. Animals are very difficult to see in forests and therefore difficult to monitor directly. All methods are labour-intensive methods, involving multiple sources of bias and significant expense needed to overcome them, and mostly only work for moderate population sizes because precision is too low to be valuable when animal density becomes very low. Bais provide an opportunity to see animals directly, which immediately reduces several sources of bias involved with abundance estimation, and provides unique opportunities to assess metrics like population structure, physical condition, health, behavior, as well as individual recognition which may be useful for capture recapture abundance estimates, and a range of biological information otherwise unavailable – reproductive rates, calf mortality, social relationships and mating systems, etc. There is also the added value that bai monitoring provides excellent protection and opportunities for tourism, which add significantly to on the ground conservation (Turkalo & Fay 2001; Fishlock, Lee & Breuer 2008; Fishlock 2010).

Despite these positives, bai obsevations have many inherent sources of bias including: (1) point location – the usual premise of valid sampling is representative sampling across the target population. Bais are tiny ultra-high quality point resources, (2) unknown fraction of the population uses bais – elephants, bongo, buffalo and sitatunga frequent bais in large numbers, but the proportion of bai visitors relative to the total population in unknown, (3) social bias – bais are social arenas where competition for mates and resources is high (Fishlock 2010) which most likely skews visitors towards a biased sample of the total population, (4) bais are subject to ecological change over time – drainage changes may lead to substrate and vegetation change, mineral concentrations, etc. These biases need not cripple population monitoring – but as with any other method, they need to be recognized, understood, and quantitatively factored into adaptive designs of bai monitoring programmes.

It is premature to go into detail of the merits of bai monitoring here, because a handbook will be finalized in the coming months based on a workshop involving leading bai researchers and outside scientists and managers.

THE SPECIAL CASE OF SMALL POPULATIONS

For distance sampling survey costs start to become prohibitive when encounter rates drop below 2 per kilometre if a 10% CV is desirable, as then survey effort of more than 150km is needed. For other survey methods, such as capture recapture methods, smaller populations may make them more attractive. This is only the case if the population in question is not spread over too large a geographic area. Otherwise, the costs of sampling the large proportion of the population needed to attain good precision again becomes prohibitive. If an assessment of abundance becomes too costly, then a reasonable alternative is to consider the use of occupancy methods – potentially in conjunction with appropriately modified recce surveys - under the assumption that changes in occupancy are related to abundance to abundance (even if this relationship is not linear and the strength of the relationship depends on the characteristics of the species and the particular occupancy survey design). Occupancy methods have the advantage of being very flexible (being able to accommodate data collected in different ways), providing better precision relative to abundance estimation methods for potentially similar amounts of effort. The crux of the matter is whether occupancy is a reasonable monitoring metric for the species of interest or makes sense given the characteristics of the species. For example, if elephants effectively occupy the entire landscape, then one certainly wouldn't expect an increase in occupancy over time, in contrast to estimates of abundance over time that would be more informative. Although the metric might be useful if occupancy was less than 80% or expected to decrease over time, for example.

DETAILED ANALYSIS OF PRIORITY SITES IN CAMEROON AND GABON

INTRODUCTION

From WWF's conservation work in Cameroon, survey data were available for Lobéké National Park, Nki National Park, Ngoila Mintom and Yabassi sites, as well as for several UFAs (Figure 9). Information was also included from the MIKE surveys in Boumba Bek. Analyses were conducted and summaries were obtained for both line transect distance sampling and recce data sets that were available for most sites. From WWF's conservation work in Gabon line transect data were similarly analyzed for Loango, Mavoungou and Kivoro in the Gamba Landscape (Figure 9). Information was also included from the MIKE surveys in Minkébé. Temporal trends were considered in particular for the surveys over three time periods for Lobéké NP and spatial trends when contrasting the results for Lobéké to the three UFAs surrounding it, as well as the three sites in the Gamba landscape. For both distance sampling and recce data survey area and effort summaries were obtained (Table 6), as well as encounter rates summaries for a subset of targets: elephant dung, ape nests, chimpanzee nests, gorilla nests, bongo dung, red river hog dung and forest buffalo dung (Table 7 and 8). For distance sampling data type additional summaries on detection, effective strip width and density, and the associated precision of different parameters were also obtained (Table 7).

During review of the application of the distance sampling technique, additional distance sampling analyses were completed for elephant dung, ape/chimpanzee/gorilla nest groups. Small sample sizes seldom permitted this to be done for bongo dung, red river hog dung and forest buffalo dung. Note that occasionally decay and production rates were available in the distance sampling projects, but all summaries shown here are for dung or nests.

For the recce data additional encounter rates summaries were obtained for certain types of human sign, namely, tracks or trails (also camps, snares, and hunting sign when recorded).

For the 2009 Lobéké NP transect data, interpolated kernel density maps were created using data values at the mid-point of each transect.

OBSERVATIONS & RECOMMENDATIONS

Survey Design

- For the survey data considered, the survey effort was generally intensive leading to reasonable precision for monitoring purposes for elephant and sometimes gorilla, but usually not chimpanzee, bongo, red river hog or forest buffalo. A survey design process should be used that explicitly considers the effort required to obtain adequate precision to enable trend detection over space and time. Additional thought needs to be given to monitoring the rare species such as bongo, red river hog or forest buffalo, since line-transect methods appear unlikely to provide adequate precision.
- The spatial coverage of the survey effort was generally excellent within the sites surveyed, which is important in terms of obtaining a representative sample and also achieving good precision; critical to detecting wildlife trends over time. With additional care in the design process this feature of the monitoring surveys can be further improved.

- The survey designs did not seem to be random, which means one needs to assume that the wildlife is randomly distributed with respect to the sampling units, which is generally unlikely to be true. Ideally systematic designs with a random start should be used, as these tend to provide better precision.
- The spatial location of threats and management activities needs to be considered in the survey design process if the results of the monitoring surveys are to inform management and adapt activities over time. It is unclear whether or not this was the case for the surveys considered here, i.e., were gradients in density and potential stratifications to improve precision or assess management effectiveness considered?
- Over the years the length of the line transects seems to have increased. For example, for the Lobéké 2002, 2006 and 2009 surveys, the average transect length was 0.5km, 1km and 2.5km, respectively. Although the general rule of thumb is that more shorter transects are better than fewer long transects, some compromise needs to be reached in terms of what is practical in the field and generally a transect length and spacing that facilitates the field logistics is preferable. Thus the design with 2.5km transects is likely to be fine. In addition, with an adequate spacing between transect sampling units there will be no spatial dependence between units, which avoids underestimates of variance which can result from this type of dependence in the data.

Field Protocol

- The use of the Cybertracker system has aided in data validation and reduced transcription errors. In addition, there seems to be a good system in place that permits the data exported from Cybertracker to be formatted for import to the Distance software in a manner that maintains data integrity and reduces errors (for example, perpendicular distances are correct and distances to the centroid of ape nest groups are correctly calculated from raw distances – although see point below about using nests rather than nest groups as the unit of observation). The use of Cybertracker is highly recommended across WWF landscapes, particularly given this proven effectiveness in SE Cameroon and recent advances in hardware reliability.
- The survey teams followed a traditional protocol of ape species identification for all surveys, based on the presence of at least one nest at ground level to signify a gorilla nest group, versus all nest in trees with supporting sign such as dung or hairs, which signified chimp nests. Remaining nest groups were considered simply "great apes". This general protocol was standardized until more recent methods suggested ways to improve ape species classifications (e.g. Sanz et al. 2007). Many of the variables used to determine which ape species is the builder of a particular nest are already collected, so it would require little additional effort and allow for a critical component in the analysis of the ape data where gorilla and chimpanzee co-occur.
- For ape nest data collection, the unit of observation should be the ape nest, i.e. perpendicular distance and all other data on nest characteristics should be collected for each nest rather than for the nest group. This will permit the type of ape nest builder discriminant analysis described above. It will also increase the sample size for analysis, which should facilitate fitting a detection function and potentially reduce bias and improve precision (the latter may in part be an artefact of variance possibly being underestimated due to the dependence between observation, i.e., those nest that comprise a single group). Another advantage is that it avoids the problem of having to estimate group size, which for gorillas, for example, is especially problematic, as group size tends to be underestimated with ground nests disappearing more rapidly than tree nests (it also avoids the problem of group size not being recorded sometimes, which clearly hampers estimation of group size). For both chimpanzees and gorillas assigning group membership is also fraught with error once the nests are older and it becomes impossible to distinguish between two nest groups in the same spatial location. This also has implications for accurate group size estimation.
- Extra care and training is needed to ensure that measurements are recorded accurately. It is absolutely critical not to record observations close to the line as zero, although those that do fall on the line (or whose centre point does in the case of a dung pile of several boli) should be assigned zero distance. It

should be emphasized that observers need to focus at areas on or close to the line as these are critical to fitting a good detection function. Observations far from the line are of far less importance for fitting the detection function.

- It is also important not to round values, although this can be dealt with during data analysis to some extent (see Data Analysis below).
- Dedicated observers are needed to look for dung (or other sign on the ground) and ape nests, as the search process is completely different.

Data Analysis

- Discrepancies in the survey effort were noticed in most of the data sets considered here. To avoid biased results effort data must be carefully recorded and calculated. To obtain accurate estimates of encounter rate from either the line transect or recce data, in analyses actual distances covered in the field should be used rather than those proposed by the design prior to the field work.
- For almost all data sets there was heaping at zero, which has the potential to bias estimates. If heaping is not too severe, the problem can be dealt with during analysis by grouping the data into intervals and conducting a grouped data analysis rather than using the exact distances. Left truncating the data to remove entries with zero distance values, is not recommended as this is an ad-hoc fix that can produce very different estimates with just small changes to the analysis. Generally, when different truncation distances, groupings and or detection function models given substantially different results this is indicative of problems in the data due to issues with the field protocol. “Well-behaved” distance data tend to produce fairly similar results irrespective of how the data are truncated or grouped and which model is selected.
- For many of the data sets there was rounding to convenient values (100 cm, 200 cm, etc.). Although not ideal, this problem can be dealt with to a large degree during analysis by conducting a grouped data analysis rather than using the exact distances and ensuring that intervals are defined such that the rounded distance values fall approximately at the midpoint of such intervals.
- Right truncating the data to improve model fit is recommended. An approximate rule of thumb is to truncate 10% of the data, although this will depend on the characteristics of the data in each case. Similarly, grouping data into intervals for analysis to improve model fit should be considered if there are potential issues with the accuracy of the distance measurements.
- In some of the original analyses it does not appear that model selection was conducted, as only the default model option appears among the model definitions. Looking at other projects, it was clear that the original analyst had a good understanding of distance sampling and what to look at in the data to assess potential violations of the method’s assumptions. Mechanisms for those who understand the methods and use them well to train others who have less experience should be considered.
- It is unclear why the maximum distance for ape observations is frequently very small (5m, 6m, or 10 m, etc). IN most other surveys from central Africa nests are observed well beyond these distances. Is the habitat very dense? Was there not a dedicated observer for ape nest observations?
- For some of the elephant dung data it was also unclear why there was sometimes such a rapid drop in detectability, often before a distance of 1m from the transect line.
- Considerations should be given to pooling data across species with similar detectability when dealing with small sample sizes. For example, fitting a single detection function to all the ape data with separate encounter rate estimates by ape species might lead to more robust results and some improvements in precision.
- Similarly, for species such as bongo, forest buffalo and red river hog, pooling data across several sites or several surveys at the same site, with stratified encounter rate estimates for a site or time period, might provide adequate sample sizes to fit a robust detection function. Something which is currently only

occasionally possible for a single survey. However, pooling the data in such a way is unlikely to provide results with adequate precision for monitoring purposes.

- Even with exceptional precision for wildlife distance sampling surveys power analysis shows the difficulty of detecting trends for populations with low growth rates common to target species such as large mammals. In addition, to attain this precision requires extraordinary amounts of effort for species that are only infrequently encountered.

Recce Data

- Human sign encounter rates were low in Lobéké NP and mainly found away from the center of the study area in 2009, even though they had been more wide-spread in earlier surveys. Human sign was prevalent throughout the UFAs.
- Although the number of observations per km is significantly higher for recces, it is difficult to correctly interpret the recce data to assess whether or not the data show trends over time, as they provide indices that do not account for likely changes in detectability over time.

Interpolated Kernel Density Maps

- Interpolated kernel density maps created from line transect data from the Lobéké NP 2009 survey for elephant, apes, chimpanzee, gorilla, bongo, red river hog, and forest buffalo provide a spatially explicit overview of the data.
- The maps show the possible distribution of the target species and may highlight areas for attention, e.g., that might need further investigation or additional protection.
- Changes in distribution over time could also be used to define management activities.
- Distance sampling densities per transect should be used to create the interpolation maps, unless effort per transect is the same, in which case the raw counts can be used. For recces encounter rates should be used, unless recces are split into segments of equal length with associated counts.
- To facilitate correct interpretation of the interpolated density maps, holes in spatial coverage that occur if survey effort is not spread out throughout the study area (not the case here), should be masked out from the area of interpolation or at a bare minimum the survey effort (transects or recces) should be overlaid on the map.
- Spatially explicit statistical models could be used to create maps that are visually similar, but that explicitly consider the potential ecological or human influence factors that drive the distribution of species of interest.

ANALYSIS METHODS[2]

Line Transect Data

For the line transect data, density of target objects D was estimated as:

$$\hat{D} = \frac{n\hat{f}(0)}{2L} \qquad (1),$$

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[2] Looking at the distance projects provided, it was not always clear which analysis contained the "final" result. Thus we assumed the last analysis done was also the final analysis.

where L denotes the aggregate length of the transects, n is the number of observations, and $f(0)$ is the probability density function of observed perpendicular distances evaluated at x = 0 (Buckland et al., 2001). Thus, density estimates are obtained from estimates of $f(0)$ and encounter rate n/L. $f(0)$ is equal to $1/\mu$, where μ represents the effective strip half-width, corresponding to the perpendicular distance from the transect line within which the number of undetected objects is equal to the number of objects detected beyond it. This equation (1) can also be written as:

$$\hat{D} = \frac{n}{2\hat{\mu}L} \qquad (2).$$

Data were analyzed using Distance 6 (Thomas et al., 2010). The variance of the encounter rate was estimated empirically using the replicate transect lines as samples, while maximum likelihood methods were used to estimate the variance of the effective strip width. Exploratory analyses were first conducted to examine options for truncation and grouping intervals to improve model fit for the detection function. Following Buckland et al. (2001), a variety of key functions and adjustment term combinations were considered to model the detection function (e.g., uniform + cosine or simple polynomial, half-normal + cosine or simple polynomial, hazard rate + cosine or hermite polynomial). Goodness of fit tests were used to identify violations of assumptions. Akaike's Information Criterion (AIC) was used in model selection, with particular attention paid to model fit at distances near zero, since the fit of the shoulder near zero is most import for robust estimation (Buckland et al., 2001). For ape nest group data, density of nests can be obtained from density of nest groups by multiplying be average group size. However, there may be a tendency for smaller nest groups to be missed more often than larger groups at further distances from the transect line, which can lead to size bias if the average group size is used (Buckland et al., 2001). To test for bias in the estimate of group size we applied a statistical hypothesis test at the 15% a-level to the regression of natural logarithm of group size against the probability of detection at distance x from the line, using Distance. If the regression is statistically significant, the expected group size is used, otherwise average group size is used to estimate nest density.

Recce Data

Recce effort (in km) was calculated by summing up the distances between all fixes for each recce sampling unit and then aggregating (this avoided overestimating effort by accidentally including the transect effort given that recces "sandwich" transects). The total number of observations, as well as the overall encounter rate, precision and range of encounter rates was calculated.

Interpolated Kernel Density Maps

For illustrative purposes, interpolated kernel density maps were only created using the raw dung counts from line transects for elephant, bongo, red river hog and forest buffalo and raw nest group or nest counts for apes, chimpanzee and gorilla for the Lobéké NP 2009 survey. In this case using raw counts was equivalent to using encounter rates or densities, as each of the line transects was 2.5 km in length and was covered a single time. Raw counts allow for comparisons among all the target species, including red river hog and forest buffalo with insufficient sample sizes for a distance sampling analysis. For these two species additional maps were created using all sign to see if this might provide a better picture of species distribution. Including all sign can be a risky approach and lead to incorrect distribution maps, if there are issues with correctly assigning different sign to species. For the ape, chimpanzee and gorilla nests, interpolation maps were created using both nest group and individual nest counts.

The transect lines were spread throughout Lobéké NP, thus there is good spatial coverage and no "holes" in the effort that might be misinterpreted as a low density area for a particular target species. When effort varies per transect or different effective strip widths are used for different transect subsets (as might be the case for a stratified survey, for example), then densities rather than raw counts should be used. For recces, encounter rates should be used, unless recces are split into segments of equal length with associated counts. When there are holes in spatial coverage, these areas should be masked out from the area of interpolation or at a bare minimum the survey effort (transects or recces) should be overlaid on the map and shown together with the interpolated density surface to facilitate correct interpretation.

The counts were associated with the mid-point of each of the 87 transects. As the coordinates for 4 of the transects were missing (Transects 393, 73, 74, 75), interpolated midpoint coordinates were used.

The 'Calculate Density' function in Spatial Analyst, with a 5 km search radius and the 'Kernel' option selected, was used to create a continuous density surface at a 100 by 100 meter resolution. Each grid cell value corresponds to the number of occurrences of the count of interest per km^2 and is calculated by summing the counts of points (that have been distributed out from each point for the Kernel option to give a smoother looking result) within a 5km radius.

Note that the density map is simply and interpolation of the counts rather than the result of a statistical model. Interpolation basically smoothes across the data and for any location not covered during the survey shows a type of average value given the neighboring values, whereas a statistical model with explanatory variables fit to the survey data counts looks of the potential drivers of the distribution of a species and can be used to predict values for each location in the study area given values for the explanatory variables (see Stokes et al. 2010, for example).

ANALYSIS RESULTS

Line Transect Data

An overview of the line transect and recce effort for the survey conducted by WWF staff is shown in Table 6. Of the sites considered here, the largest was Ngoila Mintom, which also had the most survey effort (an astonishing amount of effort at over 900km of transects with 376 transects with mean length of 2.5km). Transect lengths varied between sites and for some sites, such as Lobéké NP has changed from 0.5 to 1 to 2.5 km for the 2002, 2006 and 2009 surveys. Careful recording and calculation of survey effort is crucial to obtaining accurate estimates of encounter rates for distance sampling and recce data analyses. In several cases there were discrepancies in the survey effort that were cause for concern. Often the number of transects listed in the Distance projects did not match up with those found in the original data. An extreme example of this was noticed in the Lobéké 2002 data where a subset of the transects (mainly those with observations it seems) were used for the ape analysis leading to extremely positively biased encounter rates and nest density estimates. Most Distance projects had a constant value across all transects, which is unlikely to be true. For the Nki NP 2004 survey, for example, 1 km lengths were associated with all the transects, however, although most transects lengths were within a few hundred meters of 1km, some were as small as a few meters, suggesting errors of georeferencing in the field.

Species specific results are described below with line transect and recce data summaries shown in Tables 7 and 8, respectively. For some sites there were so few observations for the target species that distance sampling analyses were not possible and even the basic recce encounter rate summaries were not informative. An example of this is the UFA 100-21 site surveyed in 2003 with only 22 dung and 17 nest observations for elephants and apes, respectively, distance sampling analyses were not possible. Even on the recces only 95 elephant dung piles and 68 ape nests were observed with no bongo or forest buffalo dung (some tracks), but 38 forest river hog dung (and hundreds of tracks). Most of the 195 human observations were tracks or trails with 26 direct encounters with people with a similar pattern for the recces. This was also the case for the UFA 100-23 site surveyed in 2006, with only 48 dung and 20 nest observations for elephants and apes along transects (with only one bongo dung and tracks for the other species of interest and almost all the 358 human observations being tracks or trails (372 on recces).

Elephant dung: Plotting the data it is evident that for many surveys there is heaping at zero, as well as too few observations at the smaller distances (see Figures 10a & b, for example). The latter is not very problematic, as it can potentially be dealt with by appropriate grouping of the data into intervals for analysis. However, heaping has the potential to cause serious bias in the density estimate. For Lobéké 2009, the original analysis right truncated at 6m, which is appropriate to improve model fit (Figure 10c). However, model fit can be further improved by more severe truncation, such as the application of the general guideline of right truncating 10% of the data (at approximately 3m for these data – see Figure 10d, which also further highlights the extreme heaping in the data).

The original Lobéké 2009 analysis also left truncated the data to remove entries with zero distances (see Figure 10e & f). Left truncation removed the heaping in the data, and reduced the effective strip width and the encounter rate, both of which result in a smaller density estimate (Table 7). Dealing with positive bias introduced by heaping by means of left truncation is ad-hoc and can result in negatively biased estimates. An alternative for addressing this problem is to group the data into intervals and to analyse the data as grouped rather than using the exact perpendicular distances. When heaping is extreme, as is the case here, even with a grouped analysis an unknown amount of bias may still remain in the estimates. However, more attention to correct methodology in the field will immensely improve density estimates.

Two of the models considered when completing a grouped analysis and right truncating 10% of the data are shown in Figures 10g & h. Although, the AIC value for the half-normal model is slightly smaller (by 1.23) the uniform model is likely to be better due to its fit close to the line and the results for this revised analysis are also shown in Table 7. In the original Lobéké 2009 analysis it does not appear that model selection was conducted, as only the default model option appears among the model definitions. Note that although we do not report results for elephant densities, in the original distance projects the conversion rates of average time to decay and a production rate of were used.

The problem of severe heaping and some rounding is also evident in the earlier 2002 and 2006 surveys for Lobéké, with a very surprising drop off in detectability of elephant dung piles before 1m distance from the transect in 2006. This is certainly not due to the true distribution of elephant dung, but an artifact of either field methods or some form of data manipulation error. The elephant data collected in some of the UFAs looks better and suffer less or not at all from these issues of heaping or rounding. For UFA 100-13 collected in 2003 does have too many observations at zero distance, but heaping is not too severe to preclude a reliable analysis. For the UFA 100-64 in 2004, there was no heaping at zero, though rather strangely not a single observation was at zero distance or closer than 10cm, but a large number at around 20cm!. Possibly this was due to field teams overcompensating for heaping errors made in earlier surveys, though detectability again drops off rapidly before 1m distance from the transect line. The drop off in detectability is so rapid that truncation at 95cm makes sense to avoid unnecessary over fitting of the detection function at the tail (note that observations were made out to 16m). For the data collected for group of UFAs 100-08/09/10/12 in 2005, almost no elephant sign was detected in UFA 100-08. The data from UFA 100-09 exhibited no heaping or rounding with detectability dropping off more gradually from the line, but still not certain detectability up to 1m, which might be expected. It can be advantageous to stratify the data and fit separate detection functions, especially when detectability varies by stratum, as one might expect it to do. However, given the poor quality of the data in UFAs 100-10 UFA 100-12 of the strata, pooling the data improved the structure of the data and permitted a more robust fit of the detection function in this case. With only 45 observations from Yabassi for 2002 the distance results are unlikely to be reliable. For the Nki 2004 data there is also extreme heaping at zero which precludes a proper analysis (with detectability dropping off rapidly even before 1m, even the attempted "data rescue" strategy of assuming perfect detection up to a small distance and fitting a uniform with no adjustment terms to the data truncated at 30cm is a dubious strategy). The rapid drop-off in detectability was in stark contrast to observations being made out to beyond 20m. The original analysis used right truncation as the "data rescue" strategy, which as mentioned before is not recommended. For the Ngoila Mintom 2011 survey there is still heaping at zero which makes for a difficult, but perhaps not impossible analysis by grouping into intervals - in part to the large sample size. Detectability does drop of before 1m, but not too rapidly in general, which is important as it makes it easier to fit a detection function to the data.

For the Gabon surveys considered here, the elephant dung data was variable in its characteristics. Considering the data in more detail by means of QQ-plots (figures 15a-d) and histograms (figures 15e-h) of the data truncated at 6m it emerges that there is some heaping at zero for the Loango 2006 data and to many observations a short distance from the line for Loango 2007. For both these data sets given that sample sizes are large and the proportion of data that exhibit this feature is not overwhelming, it is possible to group the data into intervals and find models that fit the data well (see Figures 15i & j). The Kivoro 2008 data does not exhibit any major problems except for a little heaping at zero, which again permits the fitting of models to interval data (Figure 15k). For Mavoungou 2010 there are too many observations at some small distance from the transect line and the problem is more extreme than for the Loango 2007 data, which make model fit especially at the smaller distances, where it is important, more problematic (Figure 15l).

Ape/Chimpanzee/Gorilla nests: Plotting the 2009 Lobéké data it is evident that for the ape data in general there is heaping at zero, as well as too few observations at the smaller distances (see Figure 11a & b). Compared to the elephant dung data the heaping does not appear to be as severe, although this may simply be a function of sample size. The original analysis right truncated at 7m, which improved model fit (Figure 11c, Table 7). An alternative additional model using data grouped into 5 equal intervals and the same right truncation at 7m is Figure 11d (Table 7). In particular for the chimpanzee data, the problems caused by small sample sizes become very evident; plotting the data, the previous patterns became even more is evident (see Figure 12a & b). The original analysis right truncated at 8m, with no real improvement to model fit (Figure 12c). An additional analysis without truncation is shown in Figure 12d. It is generally recommended that distance analyses are done using individual nest groups rather than nest groups, as this avoids issues with group allocation, group size estimation, and increases the sample size. Issues of dependence that are introduced do not bias the density estimates, although standard variances may be underestimated. Switching to individual nests underscores the results of the nest group analysis, also showing no drop-off in detection out to 10 m. The results for these additional models are almost identical (Table 7). For the gorilla data the same problems in the data also showed up (see Figure 13a & b). The original analysis right truncated at 5m, with some improvement to model fit (Figure 13c). An additional analysis grouping into 4 equal intervals and truncation 5m is shown in Figure 13d. The results for these models are fairly similar (Table 7).

For the earlier Lobéké date, in 2002 as well as the previously mentioned issues with the ape data there was heaping in the data, although not as severe as for elephant dung. This was also the case for 2006 with the additional feature that no nest groups were seen beyond a distance of 9m from the transect line, which seems strange, unless the vegetation is very dense. Note that no dung and nest decay and production rate studies were carried out, and instead a nest production rate of 0.842 and a time to decay of 113.6 days used in the original analysis for chimpanzee and 1.09 and 90 days for gorilla. There is little way to know how close to the true values these figures were.

For the 2003 UFA 100-13 survey only the gorilla data were considered due to the detection of only 8 chimpanzee nest groups. Although there were a few more zero distance observation than expected, the problem was not severe and the data looked good. Given relatively small number of observations the model results seemed pretty stable. The data looked excellent for the 2003 UFA 100-13 survey (again analysis was restricted to gorillas, as almost no chimpanzee nest groups were seen). The detection function had a good fit even with smallish number of observations of 58 nest groups, which highlights the fact that it is possible to get reliable results even with smaller sample sizes than the recommended 60-80 observations, if the quality of the data is good. Although a similar question arose as with ape data from other sites as elsewhere: why was the maximum distance to a nest group just 6m? For the data collected in UFAs 100-08/09/10/12 in 2005 strangely the maximum distance was only 5m.

For the 2002 survey at the Yabassi site were mainly chimpanzee sign was found, the data looked good and observations were made out to 33m, which seems more similar to other distance sampling ape data collected in the region. For the ape data from the 2004 survey in Nki NP, although observations were made out to 25m, detection probability drops rapidly to very little at about 3m (seems to be due to gorillas – for chimps detectability drops off beyond 10m). There is some noticeable heaping at zero, but probably not too severe to preclude a reasonable analysis result. For the 2011 data from Ngoila Mintom, there are distances to chimpanzee and gorilla nests to 90m and 56m, respectively! For both there is considerable heaping at zero distance, however, due to the large sample sizes the proportion of zeroes is not overwhelming and a reasonable analysis result still seems possible.

For the Gabon surveys considered here, there were insufficient sample sizes for a distance analysis for Loango and Minkébé. However, for the Kivoro 2008 and Mavoungou 2010 surveys, although the sample sizes were small, especially when considering just the gorilla nest groups (Figure 16a & b show the observations for gorilla and unknown apes at Kivoro and Mavoungou, respectively), when these combined with unknown apes it was possible to fit some reasonable models to the data. In general, the data looked reasonable, but it was difficult to very reliably assess its quality and model fit given the limited sample sizes and number of intervals. For both sites models were selected based on smallest AIC value (Figure 16c & d). A major issue with the data was that, aside from potential coding problems for sign type, nest group size was not always recorded either for gorilla or unknown ape species, which makes it impossible to get a reliable estimate of nest density from nest group density. In addition, the variables that would permit identification of ape species for those entries recorded as unkown ape during analysis were not recorded. Note that no nest groups were ever attributed to chimpanzee for any of the Gamba Landscape surveys considered here.

Bongo dung: An analysis was only attempted for the Lobéké 2009 data, and even for this survey, the sample size was borderline for a reliable analysis. Plotting the data it is evident that there is heaping at zero, as well as too few observations at the smaller distances (see Figure 14a & b). The problem of heaping is probably further exacerbated by the marginal sampling sizes, (that might have provided robust estimates without problems in the data). The original analysis tried different grouped analyses and also left truncated the data to remove entries with zero distances, but the final model was fit to data grouped into 3 intervals and truncated at 3m (see Figure 14c and Table 7). Another option considered during the revised analysis uses data grouped into 4 intervals and truncated at 1m (see Figure 14d) with results of the revised analysis shown in Table 7. In the original analysis it does not appear that model selection was conducted, as only the default model option appears among the model definitions.

Red river hog dung: Sample sizes were insufficient for a distance analysis for almost all the surveys considered here, and an analysis that pools the data across surveys could be considered in these cases. The exception was the line transect dung data for red river hog collected during the 2006 survey of Loango NP and 2008 survey of Kivoro in the Gamba Landscape. With a moderate sample size of 43 it was difficult, but still possible to obtain an estimate of dung density, as the data was of good quality with no obvious severe problems (Figures 17a-d), except for potentially some rounding at 2m (Figure 17c). The model with the lowest AIC shown in Figure 17e was fit to grouped data on 4 intervals. Although, the sample sizes (68) for Kivoro 2008 data were somewhat larger, the data seemed to exhibit some problems, such as potential heaping at zero (Figure 17d), which made it harder to fit a reliable detection function. The model with the lowest AIC is shown in Figure 17f and is fit to data right truncated at 5m.

Forest buffalo dung: Sample sizes were insufficient for a distance analysis for almost all the surveys considered here, and an analysis that pools the data across surveys could be considered in these cases. The exception was the line transect dung data for forest buffalo collected during the 2006 survey of Loango NP in the Gamba Landscape. Even with a moderate sample size of 56 and right truncating 10% of the data, it was possible to obtain a reliable estimate of dung density with all models considered producing very similar estimates (the model with the lowest AIC shown in Figure 18b). This was due to the good quality of the distance data that did not exhibit any problems, such as heaping or rounding (Figure 18a).

Recce Data

The data summaries for the available recce data are shown in Table 8. Compared to the encounter rates for the raw (untruncated) distance sampling data, the recce encounter rates reflected similar patterns in relative size for the target species. However, the raw encounter rates were on average between 1.5 and over 2 times larger for the various target wildlife sign categories for data collected on transects compared to those collected on recces, which is not surprising given the different protocols. The recce data generally provided more insights into the human activities, as is frequently the case. During the 2002 Lobéké survey, human sign was distributed mainly in the north-east and south-west of the NP, but there was encroachment even to the center of the NP (although the three encounters with people occurred at the extreme southern edge of the NP on the same stretch of recce, but at different times). People were heard in the central part of the south-western sector of the NP. In 2006, again human sign was distributed in a similar manner, although there were more direct encounters with people from the southern edge all the way to the center and north-east of the NP (where people were also heard).

For the 2003 UFA100-13 survey there was human sign throughout, even though people were neither seen nor heard (and elephant sign was found more in the north). Human sign was seen throughout UFA 100-64 in 2004 (with people seen 8 times & heard 6), but elephant sign tended to be found closer to NP. Both transect and recce data indicated that UFA100-08 had almost no animal sign, but the largest proportion of human related observations. Although UFA 100-09 had the second highest number of human related observation it also had the highest proportion of animal sign across all species with smaller numbers found in UFA 100-10 and UFA 100-12. Overall there were 12 encounters with people and they were heard 6 times.

Interpolated Kernel Density Maps

For the Lobéké 2009 data, interpolated kernel density maps created using raw counts of elephant dung (Figure 19a) showed similar spatial patterns to those using counts truncated at 3m (or equivalently the transect specific densities estimated using distance sampling, as a single effective strip-width was estimated for the pooled data set). Higher densities, particularly in the north, south-west and east of the study area may indicate important resources for elephants in those areas. The fact that the highest densities do not just occur towards the center of Lobéké National Park perhaps indicate the effectiveness of law enforcement in this area?

The ape nest interpolation maps seemed to indicate that the western portion of the study area was preferred for nest building and within this sub-region the gorillas seemed to be distributed more towards the north and chimpanzees to the south. There were a few smaller medium density patches scattered in the eastern portion of the study area. Perhaps there are ecological patterns that explain these distributions. Contrasting the nest group and individual nest count interpolation maps for apes, chimpanzee and gorilla (Figures 19b-g) the overall spatial patterns are approximately the same; However, the potential relative importance of some areas changes. Deciding whether to use interpolation maps from nest group or individual nest counts may depend on whether the priority is on individual ape (chimp/gorilla) groups or on the number of apes overall.

Given the small number of bong dung overall it is possible that the areas of potentially higher density in the interpolation map for this species (Figure 19h), might simply be an artefact of small sample size. For red river hog although just using dung counts highlighted potentially high use areas in the north and south-west of the study area, with all sign these areas were further expanded and highlighted with areas in the east also emerging as potentially important for this species (Figures 19i & j). Forest buffalo distribution seemed much more limited than that of red river hog, but there were also some shifts and changes in relative importance of areas when contrasting interpolation maps from dung and all sign counts (Figures 19k & l).

Differences in Densities over Space and Time

Not only can we look at the results in tables 7 and 8, we can also consider the results of the distance sampling analyses for a subset of species, namely elephants and gorillas, graphically (Figure 20). Keeping in mind the caveats highlighted in the data analysis, it appears that Lobéké NP and Nki NP have relatively higher densities of elephant dung, as do the UFAs surrounding Lobéké that have been surveyed (with the exception of UFA 100-08), while elephant dung density in Yabassi and Ngoila Mintom is at very low levels. In the Gamba landscape for the surveys considered, the south-east of Loango NP surveyed in 2006 has the highest elephant dung densities followed by the densities for Kivoro in 2008 and then Mavoungou in 2010, with the north-east of Laongo NP having the lowest densities. For gorillas, Nki NP and UFAs surrounding Lobéké (especially UFA 100-64 and 100-13) have relatively higher densities of nests with somewhat lower densities in Ngoila Mintom followed by Lobéké. The nest density estimate shown for Yabassi is for chimpanzees, as none could be obtained for gorillas. The chimpanzee nest density is at a low level, but this is not unexpected, as chimpanzee nest density where it could be estimated is always significantly lower than that for gorillas across all the survey sites considered here (keeping in mind the potential issues associated with discriminating between gorilla and chimpanzee nests).

For Lobéké NP and the UFAs surrounding it, we compared density estimates produced from the line transect surveys over time (for the three Lobéké surveys) and space (Lobéké contrasted to the UFAs) for elephants and gorillas (the species where estimates were available for all these sites) to determine whether there were statistically significant differences. We used a z-test at a 5% significance level (see Buckland et al. 2001, p.84).

The density estimates for elephant dung for Lobéké were significantly different from each other. The dramatic increase in the density in 2006 could either be an artifact of the problems with the data or due to an influx of elephants into the area (or potentially unusual weather conditions or seasonality that left more dung on the ground compared to 2002 or 2009). For the UFAs surrounding Lobéké, only UFA 100-64 and UFA 100-09/10/12 were significantly different from each other in terms of elephant dung density. If one contrasts the UFAs surrounding Lobéké to the Lobéké survey closest in time to when each UFA was covered, then the differences were all statistically significant.

In the Gamba Landscape the Loango 2006 density for elephant dung was significantly different to the densities from the other three surveys. In addition, the Loango 2007 density was just significantly different to the Kivoro 2008 density.

The density estimates for gorilla nests for Lobéké were not significantly different from each other. When contrasting the UFAs to each other only UFA 100-13 and UFA 100-08/09/10/12 were significantly different from each other in terms of gorilla nest density. Contrasting the UFAs surrounding Lobéké to the Lobéké survey closest in time to when each UFA was covered, then the differences were all statistically significant, except for the 2006 Lobéké survey results compared to 2005 UFA 100-08/09/10/12 (although it was at the cusp with a p-value of 0.057).

Careful thought needs to be given as to what these results mean in terms of management, if one looks at the conservation activities that have been conducted in or around these survey sites considered here, as well as how the results here compare to sites in other landscapes in terms of regional prioritization of conservation resources.

Table 6: The surface area, number of replicate transects and total survey effort for sites in Cameroon, falling in two WWF Landscapes of interest, where line transect distance and recce sampling was conducted (dashes indicate the information was not available).

Landscape	Site	Area (km^2)	Survey Year	Data Type	Replicates	Effort (km)
Cameroon Sangha Tri-National	Lobéké National Park	2,173.5	2002	Transects	261[3]	130.5
				Recces	272	280.1
			2006	Transects	194	194.0
				Recces	198	219.1
			2009	Transects	87[4]	217.5
				Recces	93	354.3
	UFA 100-13	507.8	2003	Transects	52	52.0
				Recces	55	57.9
	UFA 100-64	1,159.2	2004	Transects	93	93.0
				Recces	130	298.7
	UFA 100-08/9/10/12	2,909.1	2005	Transects	312[5]	312.3
				Recces	287	180.1[6]
Cameroon TRIDOM+	Yabassi	1,997.1	2002	Transects	27	124.3
				Recces	-	-
	Boumba Bek	2,383.0	2003/04	Transects	47	47.0
				Recces	-	473.0
	Nki NP	3,093.9	2004	Transects[7]	258	258.0
				Recces	291	446.7
	Ngoila Mintom	9,420.0	2011	Transects	376	920.0
				Recces	-	-
	UFA 100-21	661.8	2003	Transects	120	60.0
				Recces	122	132.8
	UFA 100-23	580.0	2006	Transects	86	86.0
				Recces	89	65.8
Gabon TRIDOM	Minkébé NP	9,320.0	2004	Transects	60	60
				Recces	-	659
Gabon Gamba Complex	Loango	357.0	2006	Transects	47	47
		188.8	2007	Transects	32	32
	Kivoro	2,337.2	2008	Transects	169	169
	Mavoungou	508.2	2010	Transects	82	82

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[3] In the original analysis only 98 transects for were used for apes and 269 for the chimpanzee for unknown reasons.

[4] Transect start and end coordinates were only available for 83 transects.

[5] 314 transects of 1km each in distance projects.

[6] Likely an underestimate of effort as recce segment start and end locations were not available.

[7] There were problems with the coordinates of three transect whose lengths were calculated as very large compared to the 1km distance they were supposed to be, so replaced these with 1 km length values, which was supported by surrounding tracklog data.

Table 7: Distance sampling analysis results for original and additional analyses for the target species. Results include detectability $\hat{p}$*, effective strip width* $\hat{\mu}$*, encounter rate* n/L*, and dung or nest density estimates* $\hat{D}$*, as well as percent coefficients of variation for these estimated parameters (dashes indicate the information was not available).*

Site	**Target**	**Sign**	**Analysis**	**Raw counts**	$\hat{p}$	$\hat{\mu}$ **(m)**	n/L **(km^{-1})**	$\hat{D}$ **(km^{-2})**	**%CV ($\hat{\mu}$)**	**%CV (n/L)**	**%CV ($\hat{D}$)**
Lobéké 2002	Elephant	dung	original	1,073	0.44	0.89	5.72	3,204.1	4.4	7.5	8.7
			new	1,073	0.56	1.12	5.72	2,541.8	9.6	7.5	12.2
	Ape[8]	nests	original	117	0.28	2.90	2.40	764.6	10.1	3.8	12.3
			new	117	0.40	2.59	2.16	801.8	10.8	5.1	14.0
	Chimpanzee	nest groups	original	50	0.75	7.51	0.37	48.1	13.2	14.0	20.9
			new	50	0.72	3.61	0.22	60.8	17.9	18.5	28.9
	Gorilla	nest groups	original	67	0.41	3.51	0.51	101.3	8.3	13.7	17.6
			new	67	0.43	3.42	0.51	103.4	9.5	13.7	18.0
	Bongo	dung	-	16	-	-	-	-	-	-	-
	Red river hog	dung	-	18	-	-	-	-	-	-	-
	Forest buffalo	dung	-	10	-	-	-	-	-	-	-
Lobéké 2006	Elephant	dung	original	1,696	0.21	1.65	8.74	2,644.4	2.6	8.3	8.6
			new	1,696	0.42	0.51	4.89	4,802.0	5.0	8.0	9.6
	Ape	nests	original	98	0.29	1.46	0.47	181.6	11.0	12.0	16.9
			new	98	0.37	1.47	0.46	175.3	10.0	12.0	16.6
	Chimpanzee	nest groups	original	34	0.47	2.33	0.15	65.9	13.0	20.0	25.3
			new	34	0.41	1.83	0.15	88.5	21.0	20.0	30.4
	Gorilla	nest groups	original	64	0.35	1.27	0.28	149.2	13.0	15.0	20.4
			new	64	0.53	1.45	0.27	124.9	11.0	15.0	20.3
	Bongo	dung	-	29	-	-	-	-	-	-	-
	Red river hog	dung	-	15	-	-	-	-	-	-	-
	Forest buffalo	dung	-	7	-	-	-	-	-	-	-

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[8] Only 98 out of the 261 transects were included in the Distance project file. Excluded transects did not have ape nest observation. Thus the encounter rate is biased high and the estimate of density is incorrect and artificially high.

Site	Target	Sign	Analysis	Raw counts	$\hat{p}$	$\hat{\mu}$ (m)	n/L (km^{-1})	$\hat{D}$ (km^{-2})	%CV ($\hat{\mu}$)	%CV (n/L)	%CV ($\hat{D}$)
Lobéké 2009	Elephant	dung	original	1,259	0.33	1.95	5.37	1,376.2	3	9	9.4
			new	1,259	0.46	1.39	5.12	1,838.8	4	9	9.5
	Ape	nests	original	98	0.52	3.61	0.40	106.7	8	16	18.9
			new	98	0.51	3.60	0.40	106.1	9	16	19.6
	Chimpanzee	nest groups	original	29	0.96	0.77	0.11	12.2	20	21	31.8
			new	29	1.00	9.95	0.13	12.0	0	19	22.4
		nests	new	52	1.00	9.99	0.24	12.0	0	22	22.3
	Gorilla	nest groups	original	69	0.52	2.59	0.29	117.8	10	19	22.6
			new	69	0.53	2.65	0.29	114.1	6	19	21.3
	Bongo	dung	original	58	0.37	1.11	0.26	117.7	15	21	25.8
			new	58	0.35	0.35	0.18	254.8	17	18	24.6
	Red river hog	dung	-	18	-	-	-	-	-	-	-
	Forest buffalo	dung	-	14	-	-	-	-	-	-	-
UFA 100-13 2003	Elephant	dung	original	152	0.32	1.85	2.92	788.4	6	26	26.4
			new	152	0.40	0.69	2.04	1,470.3	10	24	26.4
	Ape[9]	nest groups	-	81	-	-	-	-	-	-	-
	Chimpanzee	nest groups	-	8	-	-	-	-	-	-	-
	Gorilla	nest groups	original	73	0.60	3.74	1.40	310.2	10	24	26.8
			new	73	0.66	3.43	1.33	310.7	10	24	27.0
	Bongo	dung	-	3	-	-	-	-	-	-	-
	Red river hog[10]	dung	-	0	-	-	-	-	-	-	-
	Forest buffalo	dung	-	15	-	-	-	-	-	-	-

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[9] With so few chimpanzee observations, just considering the results for gorilla where sample sizes were adequate for distance sampling analysis.

[10] Tracks and aural observations were made for this species.

Site	**Target**	**Sign**	**Analysis**	**Raw counts**	$\hat{p}$	$\hat{\mu}$ **(m)**	n/L **(km^{-1})**	$\hat{D}$ **(km^{-2})**	**%CV ($\hat{\mu}$)**	**%CV (n/L)**	**%CV ($\hat{D}$)**
UFA 100-64 2004	Elephant	dung	original	436	0.26	0.91	4.09	2,255.3	6.0	12.0	13.2
			new	436	0.67	0.67	2.77	2,073.6	11.0	12.0	16.4
	Ape	nests	-		-	-	-	-	-	-	-
	Chimpanzee	nest groups	-	3	-	-	-	-	-	-	-
	Gorilla	nest groups	original	58	0.38	2.25	0.62	375.5	13.0	16.0	22.8
	Bongo	dung	-	11	-	-	-	-	-	-	-
	Red river hog	dung	-	4	-	-	-	-	-	-	-
	Forest buffalo	dung	-	2	-	-	-	-	-	-	-
UFA 100-08/09/10/12 2005	Elephant[11]	dung	original	562	0.3/0.2/0.2	1.4/0.9/8.2	1.4/2.1/3.5	1,148.0	11-18	~17.0	13.2
			new	562	0.56	0.67	1/1.4/2.6	1,147.0	4.0	~18.0	11.2
	Ape	nests groups	-	129	-	-	-	-	-	-	-
	Chimpanzee	nest groups	-	17	-	-	-	-	-	-	-
	Gorilla[12]	nest groups	original	112	0.26	1.28	0.36	199.7	8.7	11.5	15.1
			new	112	0.48	1.09	0.31	201.9	8.0	12.0	15.6
	Bongo	dung	-	11							
	Red river hog	dung	-	9	-	-	-	-	-	-	-
	Forest buffalo	dung	-	24	-	-	-	-	-	-	-

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[11] UFA100-08 (727.3km^2) was excluded as it had no elephant observations and only data from UFAs 100-09 (922.9km^2), 100-10 (666.9km^2) and 100-12 (592 km^2) with a total of 237 transects was analyzed. Data were stratified to estimate encounter rate and also detectability (in the original analysis), but pooled to fit the detection function in the new analysis. Density estimates in both cases were obtained per stratum and the overall density estimate was a mean weighted by stratum area.

[12] There were also 4 Distance software projects with separate analyses done for each UFA for gorillas and apes. The results are not shown here.

Site	Target	Sign	Analysis	Raw counts	$\hat{p}$	$\hat{\mu}$ (m)	n/L (km^{-1})	$\hat{D}$ (km^{-2})	%CV ($\hat{\mu}$)	%CV (n/L)	%CV ($\hat{D}$)
Yabassi 2002[13]	Elephant	dung	-	45	0.54	1.61	0.27	85.20	24.0	74.0	77.9
	Chimpanzee	nest groups	-	61	0.57	4.87	0.23	23.94	16.0	36.0	39.7
	Red river hog	dung	-	29	0.48	15.79	0.49	27.57	9.0	38.0	39.6
	Forest buffalo[14]	dung	-	0	-	-	-	-	-	-	-
Boumba Bek 2003/04	Elephant[15]	dung	-	115	-	-	2.4	-	-	-	-
Nki NP 2004	Elephant	dung	original	1,299	0.28	1.38	4.40	1,589.63	4.0	6.0	7.6
			new	1,299	1.00	0.30	1.28	2,131.78	0	9.0	9.1
	Ape	nest groups	original	246	0.27	2.15	0.89	350.84	6.0	9.0	11.8
			new	246	0.38	1.92	0.83	392.67	7.0	9.0	12.7
	Chimpanzee	nest groups	original	53	0.29	7.37	0.21	27.33	12.0	22.0	25.9
			new	53	0.78	7.78	0.19	23.17	15.0	23.0	28.8
	Gorilla	nest groups	original	172	0.48	1.66	0.59	299.26	6.0	10.0	12.9
			new	172	0.52	1.57	0.57	322.23	6.0	10.0	13.8
	Bongo	dung	-	5	-	-	-	-	-	-	-
	Red river hog	dung	-	17	-	-	-	-	-	-	-
	Forest buffalo	dung	-	9	-	-	-	-	-	-	-
Ngoila Mintom 2011	Elephant	dung	original	1,595	0.21	2.20	1.73	394.07	3.0	9.0	9.6
			new	1,595	0.47	1.86	1.60	430.00	4.0	9.0	9.6
	Chimpanzee	nest groups	original	372	0.37	10.96	0.39	43.13	6.0	8.0	10.9
			new	372	0.53	10.53	0.37	41.25	4.0	9.0	10.3
	Gorilla	nest groups	original	455	0.33	3.01	0.48	171.02	6.0	7.0	9.9
			new	455	0.45	2.73	0.45	178.26	6.0	7.0	10.1

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[13] Note that the results for elephants and red river hog are unreliable due to the small sample sizes. Although recce data were not available for Yabassi to evaluate human activities, 286 human signs were found on the transects in total, including 1 camp, 25 snares, 9 shotgun shells (with gun shots heard 4 times) and 102 trails.

[14] Only 3 forest buffalo tracks found.

[15] There were issues with the data collection described in the MIKE report that precluded a distance sampling analysis.

Site	Target	Sign	Raw counts	$\hat{p}$	$\hat{\mu}$ (m)	n/L (km^{-1})	$\hat{D}$ (km^{-2})	%CV ($\hat{\mu}$)	%CV (n/L)	%CV ($\hat{D}$)
Minkébé NP 2004	Elephant -overall	dung	967	-	-	-	5,347.60	-	-	9.5
	- low impact		306	0.26	1.47	19.1	6,498.30	-	-	11.6
	- medium impact		243	0.22	1.23	12.3	4,980.90	-	-	16.3
	- high impact		398	0.29	1.65	15.9	4,807.80	-	-	21.5
Loango NP 2006	Elephant	dung	502	0.65	2.77	9.19	1,656.40	4.39	11.10	11.94
	Apes	nest groups	5	-	-	-	-	-	-	-
	Gorilla	nest groups	0	-	-	-	-	-	-	-
	Red river hog	dung	43	0.50	2.00	0.87	217.67	12.86	26.23	29.22
	Forest buffalo	dung	56	0.46	2.28	1.06	232.57	22.43	24.16	32.96
Loango NP 2007	Elephant	dung	145	0.65	2.87	3.63	651.98	8.47	14.80	17.05
	Apes	nest groups	5	-	-	-	-	-	-	-
	Gorilla	nest groups	0	-	-	-	-	-	-	-
	Red river hog	dung	1	-	-	-	-	-	-	-
	Forest buffalo	dung	5	-	-	-	-	-	-	-
Kivoro 2008	Elephant	dung	617	0.41	1.77	3.45	974.47	4.82	5.94	7.65
	Apes	nest groups	39	0.57	11.32	0.0002	15.30[16]	6.25	29.08	34.74
	Gorilla	nest groups	24	-	-	-	-	-	-	-
	Red river hog	dung[17]	68	0.55	2.76	0.40	71.66	6.3	39.56	40.06
	Forest buffalo	dung	11	-	-	-	-	-	-	-
Mavoungou 2010	Elephant	dung	393	0.64	2.75	4.38	796.88	9.25	11.05	14.41
	Apes	nest groups	38	0.48	9.63	0.0005	24.04[18]	13.17	17.24	21.69
	Gorilla	nest groups	7	-	-	-	-	-	-	-
	Red river hog	dung	2	-	-	-	-	-	-	-
	Forest buffalo	dung	4	-	-	-	-	-	-	-

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[16] This estimate of nest density is incorrect, as nest group size was not recorded for most observations.

[17] There were some potential issues with the coding of the data in terms of sign type with only data coded as “dung” (or “nest” for the ape analyses) used in the analysis.

[18] This estimate of nest density is incorrect, as nest group size was not recorded for most observations.

Table 8: Recce data summaries for the target species sign and some categories of human sign (these changes by site and over time). Results include total number of observations, overall encounter rate, as well as the standard deviation and maximum encounter rate values (the minimum was always zero). Dashes indicate the information was not available.

Site	**Target**	**Sign**	**Total**	**Encounter rate (km^{-1})**		
				Average	**Std Dev.**	**Maximum**
Lobéké 2002	Elephant	dung	2893	10.32	9.75	53.83
	Ape	nest groups	238	0.85	1.53	12.45
	Chimpanzee	nest groups	81	0.29	0.71	4.65
	Gorilla	nest groups	157	0.56	1.07	5.36
	Bongo	dung	29	0.10	0.48	5.42
	Red river hog	dung	21	0.07	0.32	2.75
	Forest buffalo	dung	15	0.05	0.22	1.79
	Human	tracks	47	0.17	0.51	4.61
		trails	40	0.14	0.42	2.73
Lobéké 2006	Elephant	dung	1776	8.11	10.44	77.50
	Ape	nest groups	67	0.31	0.73	4.66
	Chimpanzee	nest groups	15	0.07	0.30	2.68
	Gorilla	nest groups	52	0.24	0.60	3.74
	Bongo	dung	43	0.20	0.62	5.19
	Red river hog	dung	13	0.06	0.29	2.91
	Forest buffalo	dung	6	0.03	0.18	1.74
	Human	tracks	69	0.31	1.09	9.75
		trails	66	0.30	0.66	3.15
Lobéké 2009	Elephant	dung	1140	3.22	4.10	25.48
	Ape	nest groups	105	0.30	0.38	1.62
	Chimpanzee	nest groups	26	0.07	0.14	0.64
	Gorilla	nest groups	79	0.22	0.35	1.62
	Bongo	dung	48	0.14	0.20	0.85
	Red river hog	dung	18	0.05	0.17	1.16
	Forest buffalo	dung	12	0.03	0.11	0.64
	Human	camps	2	0.01	0.06	0.48
		snares	20	0.06	0.18	0.90
		hunting sign	7	0.03	0.15	1.28

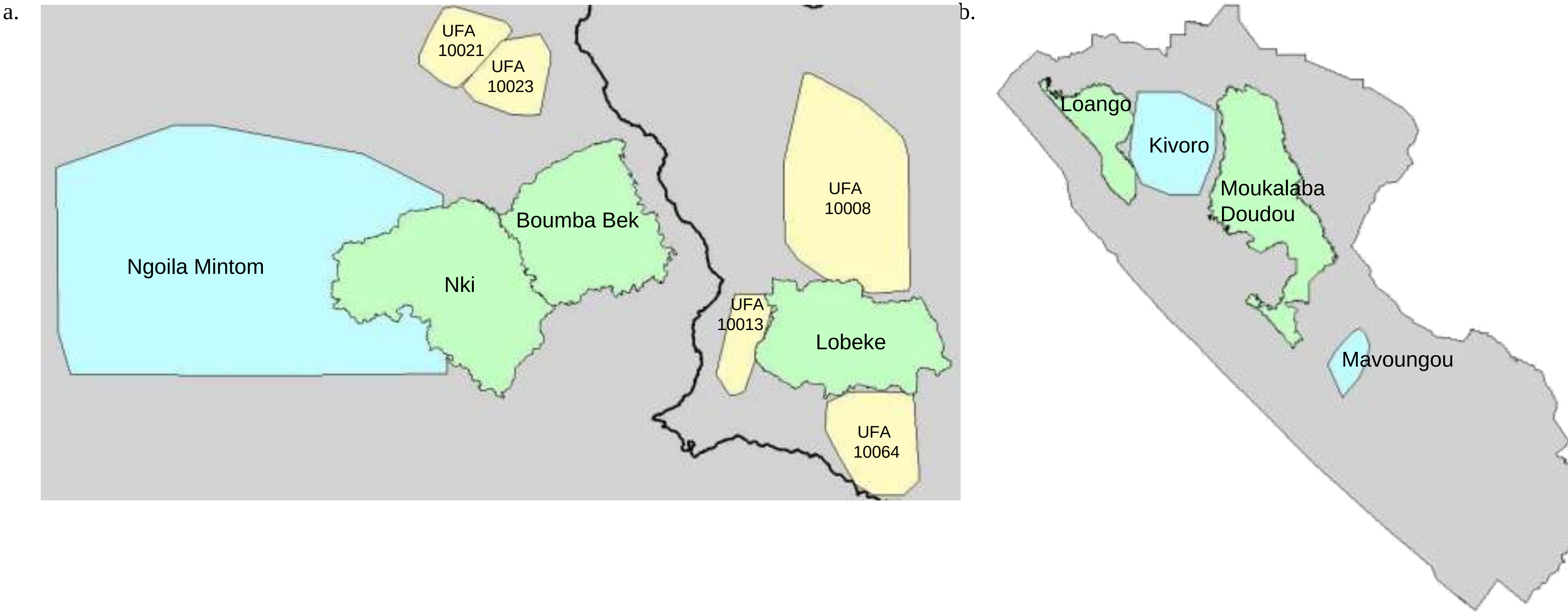
Site	Target	Sign	Total	Encounter rate (km^{-1})		
				Average	Std Dev.	Maximum
UFA 100-13 2003	Elephant	dung	126	2.18	3.32	17.47
	Ape	nest groups	64	1.11	1.44	5.76
	Chimpanzee	nest groups	4	0.07	0.32	1.97
	Gorilla	nest groups	60	1.04	1.56	6.35
	Bongo	dung	3	0.05	0.21	1.07
	Red river hog	dung	0	0	0	0
	Forest buffalo	dung	15	0.26	0.91	4.69
	Human	tracks	40	0.69	0.88	3.22
		trails	28	0.48	0.68	2.06
UFA 100-64 2004	Elephant	dung	733	2.45	4.66	17.76
	Ape	nest groups	55	0.18	0.73	3.88
	Chimpanzee	nest groups	1	0.00	0.09	1.00
	Gorilla	nest groups	54	0.18	0.71	3.94
	Bongo	dung	8	0.03	0.23	1.11
	Red river hog	dung	2	0.01	0.11	0.98
	Forest buffalo	dung	6	0.02	0.38	4.17
	Human	tracks	65	0.22	0.67	2.99
		trails	48	0.16	0.60	3.20
UFA 100-08/ 9/10/12 2005[19]	Elephant	dung	661/560	1.79	85.14	1504.41
	Ape	nest groups	101/99[20]	0.32	0.81	6.98
	Chimpanzee	nest groups	18/15	0.05	0.25	2.26
	Gorilla	nest groups	83/84	0.27	0.65	4.88
	Bongo	dung	14/11	0.04	0.20	2.09
	Red river hog	dung	2/9	0.03	0.19	2.00
	Forest buffalo	dung	22/24	0.08	0.51	7.28
	Human	tracks	239/276	0.88	1.05	7.50
		trails	126/115	0.37	0.74	5.62

---

[19] Only counts entered from recce data, as the effort data was unreliable with locations only taken when observations were made and not at set intervals or at the start or end of each recce unit.

[20] Does not quite match up with the 112 in the distance sampling project.

Figure 9: The landscape of interest in Cameroon (a) and (b) Gabon with details where transects (or their endpoints) are shown in dark purple and recces in light purple of: (c) Lobéké survey 2002, (d) Lobéké survey 2006, (e) Lobéké survey 2009, (f) UFA 100-13 survey 2003, (g) UFA 100-64 survey 2004, (h) UFA 100-08/09/10/12 survey 2005, (i) Yabassi 2002, (j) Boumba Bek 2003/04, (k) Nki National Park 2004, (l) Ngoila Mintom 2011, (m) UFA 100-21 survey 2003, (n) UFA 100-23 survey 2006, (o) Loango 2006(south-east)/2007(north-east) and Kivoro 2008, and (p) Mavoungou 2010.



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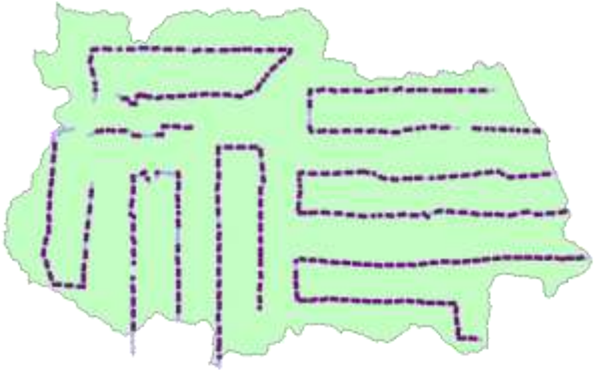

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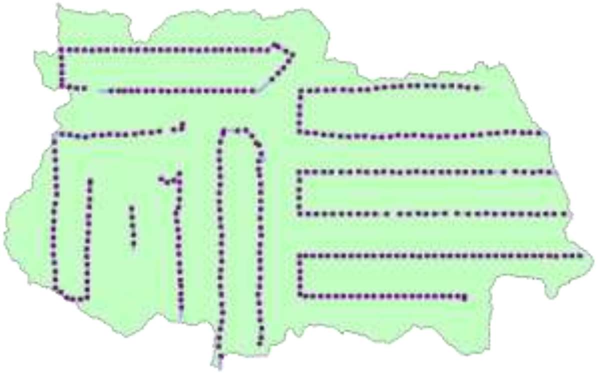

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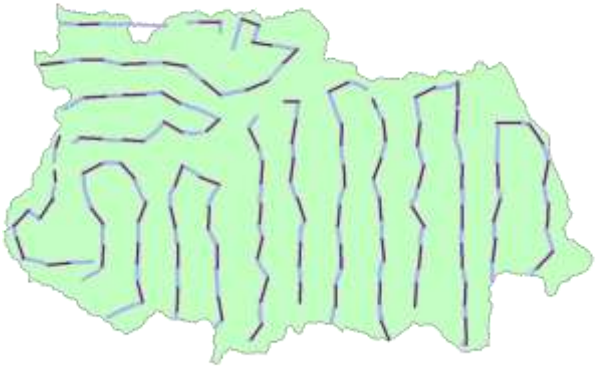
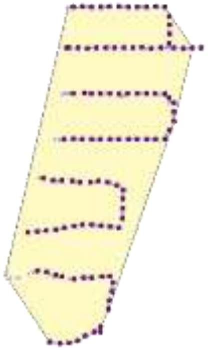
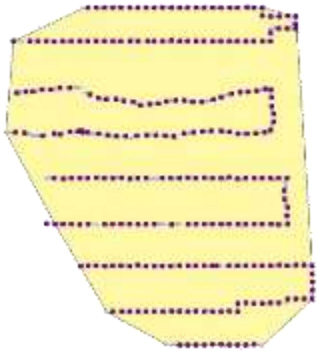


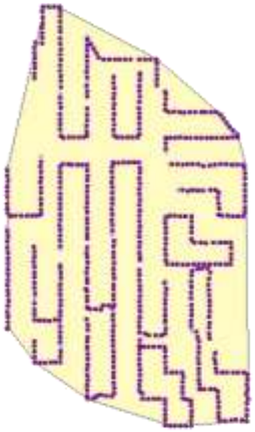
f.



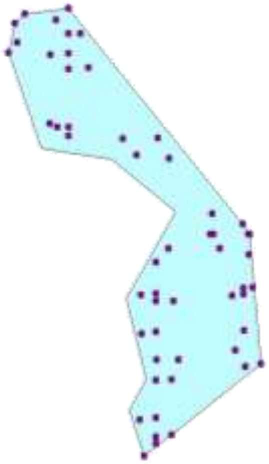
g.



h.

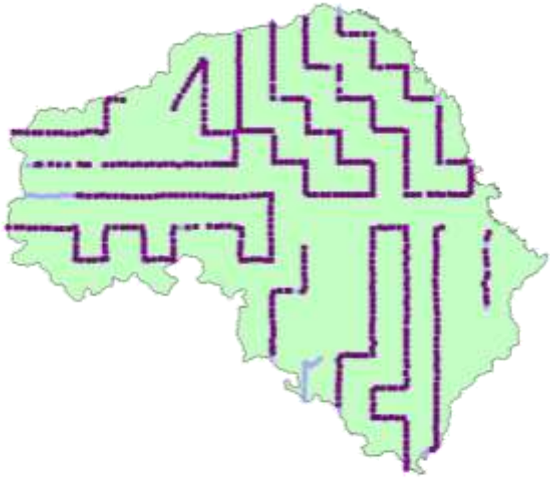


i.

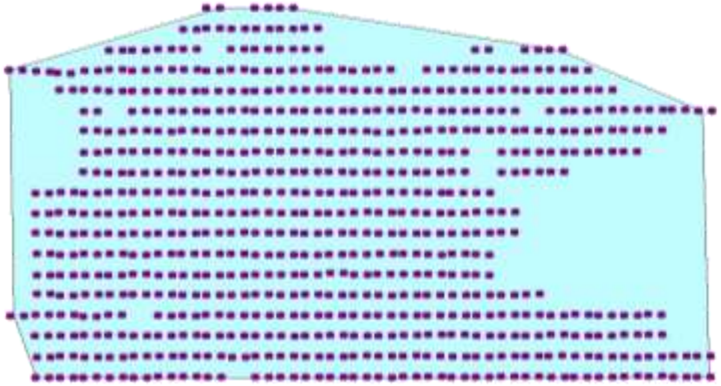


j.

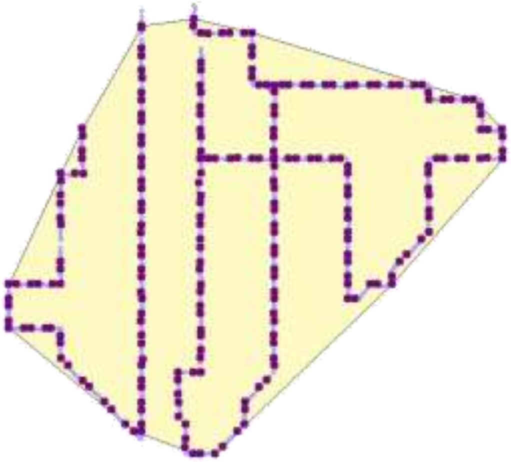
kj.



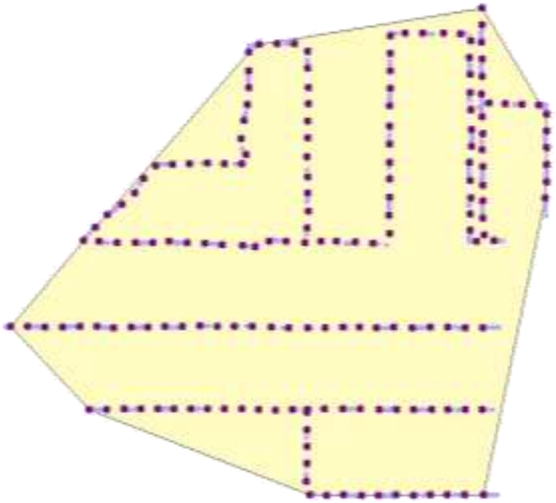
l.



m.



n.



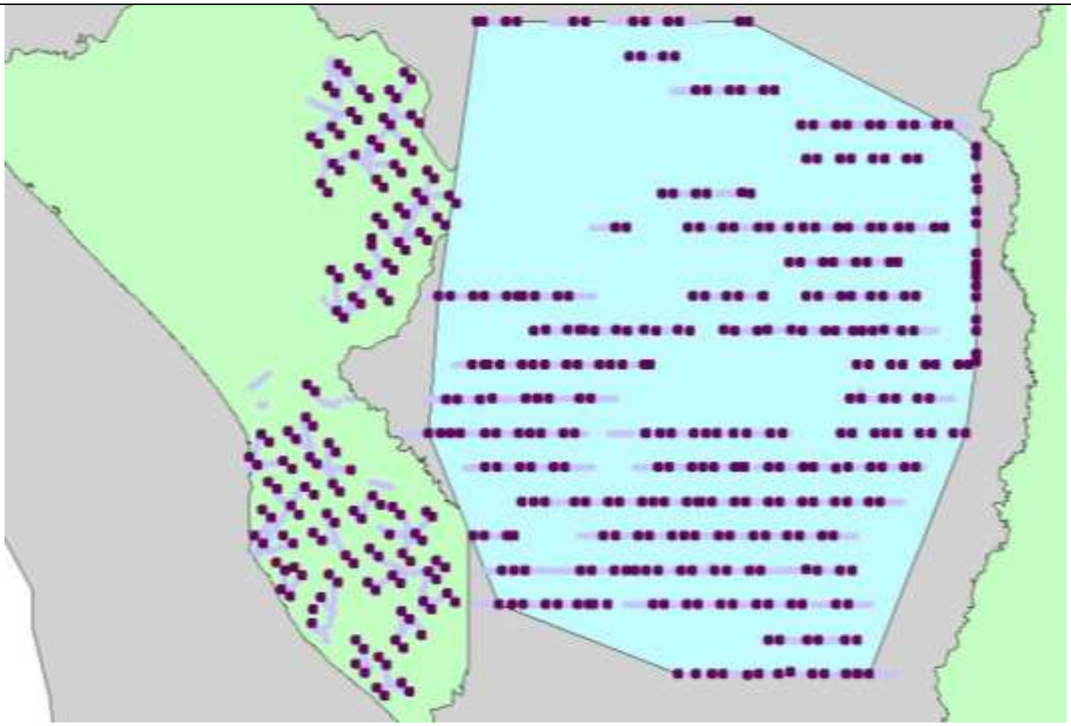
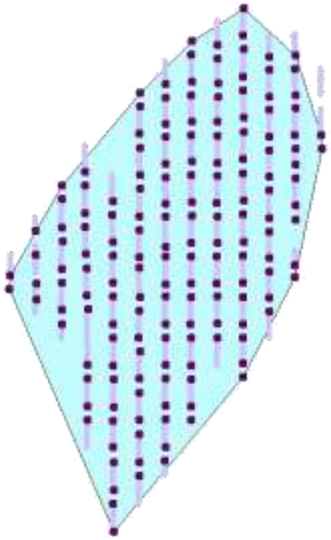
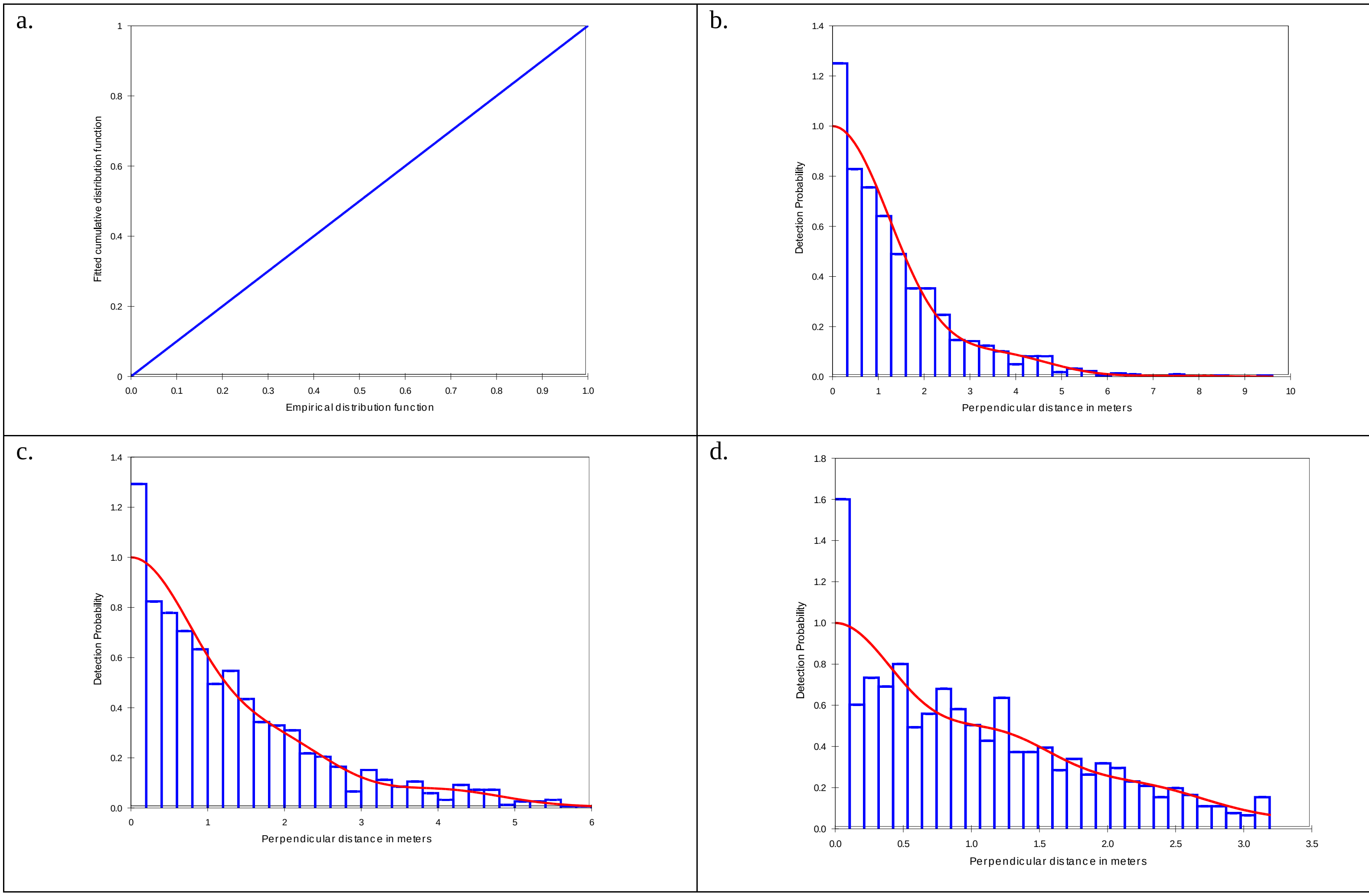
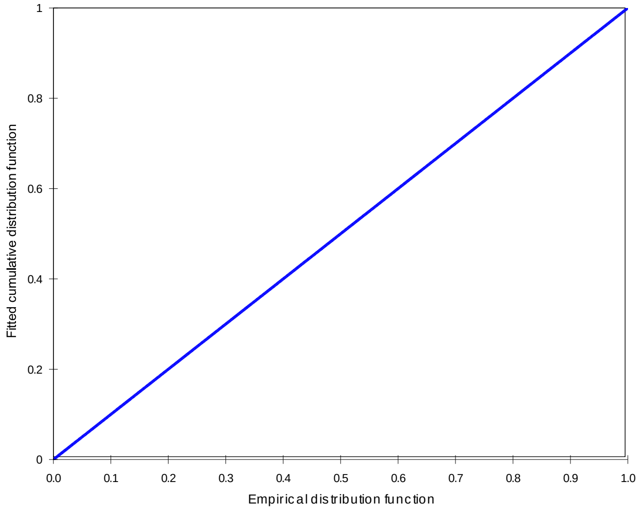
o. 	p. 

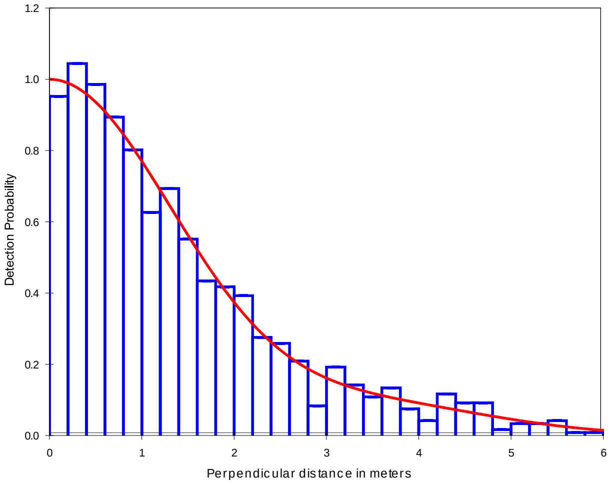
Figure 10: Graphical display and analysis results for the elephant dung data collected at the Lobéké site in 2009. Shown for all the data are (a) a QQ-plot and (b) a histogram showing the frequency of observations with respect to distance from the transect line. Histograms are also shown for (c) right truncation at 6 meters and (d) right truncation of 10% of the data. Left truncating to remove zero distance observations and right truncating at 6 meters results in a QQ-plot and frequency histogram shown in (e) and (f), respectively. Detection function (key plus adjustment terms) fitted to the perpendicular distances of observations (g) Half-normal+cosine, and (h) Uniform+cosine.



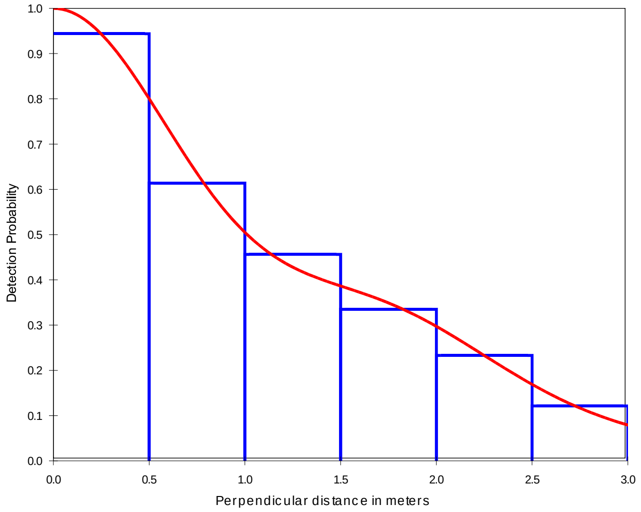
e.


1
0.8
0.6
0.4
0.2
0
Fitted cumulative distribution function
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Empirical distribution function

f.


1.2
1.0
0.8
0.6
0.4
0.2
0.0
Detection Probability
0
1
2
3
4
5
6
Perpendicular distance in meters

g.


1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Detection Probability
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Perpendicular distance in meters

h.

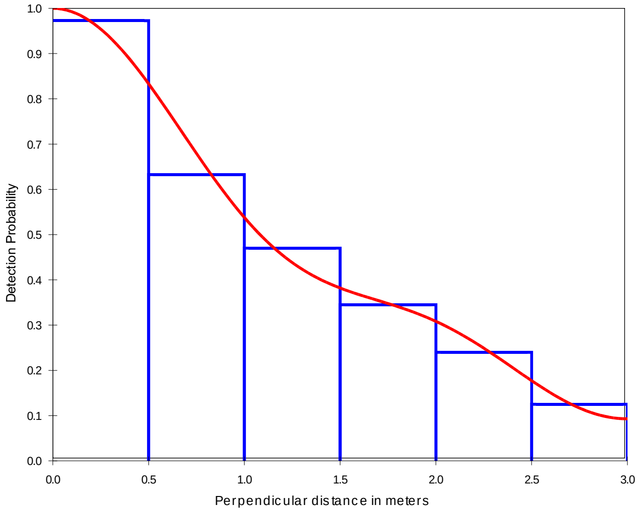

1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Detection Probability
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Perpendicular distance in meters

Figure 11: Graphical display and analysis results for the ape nest data collected at the Lobéké site in 2009. Shown for all the data are (a) a QQ-plot and (b) a histogram showing the frequency of observations with respect to distance from the transect line. Detection function (key plus adjustment terms) fitted to perpendicular distances of observations when (c) Half-normal+cosine – using exact distances with right truncation at 7m, and (d) Half-normal with no adjustment terms – using 5 equal intervals to with right truncation at 7m.

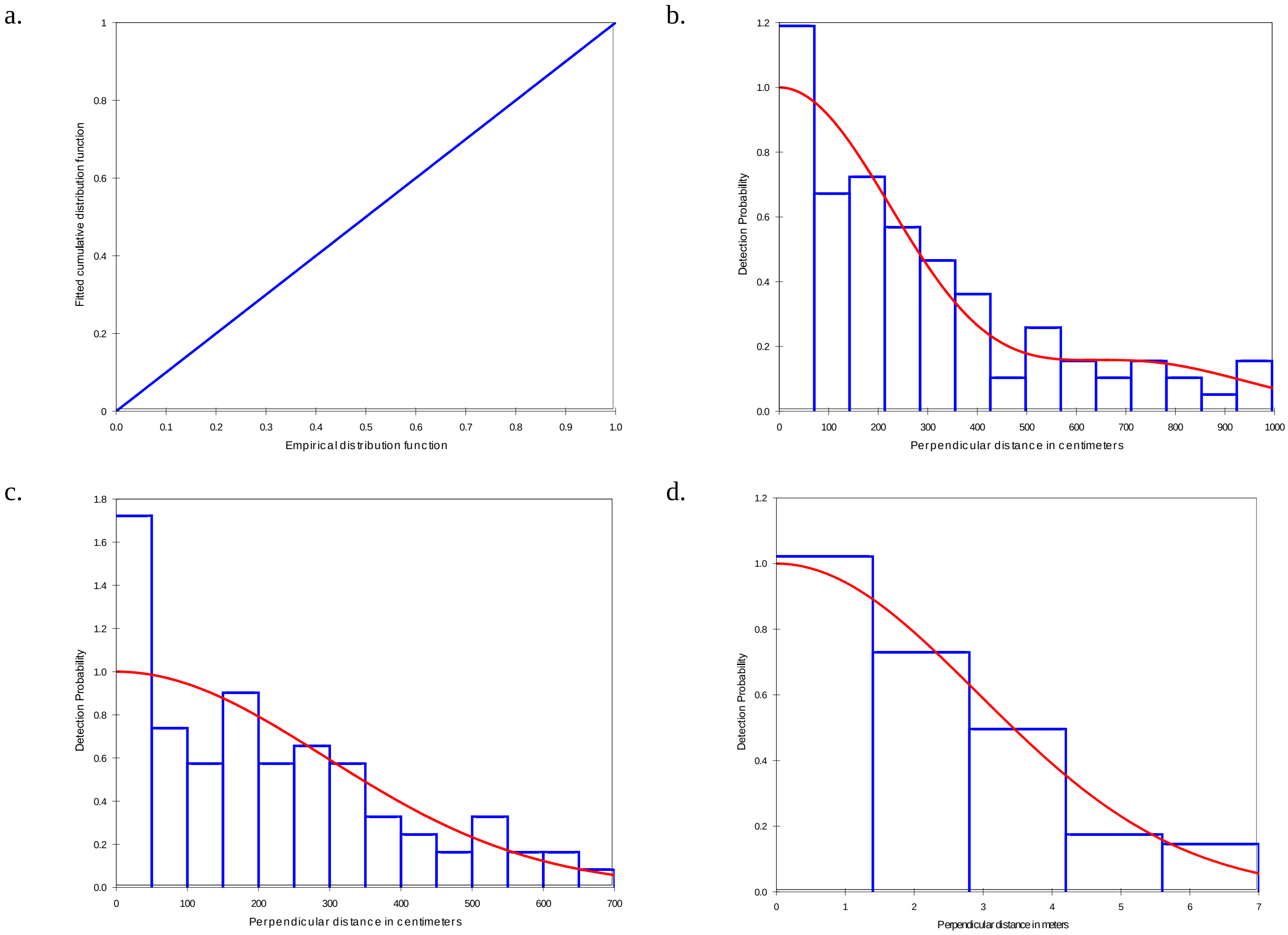
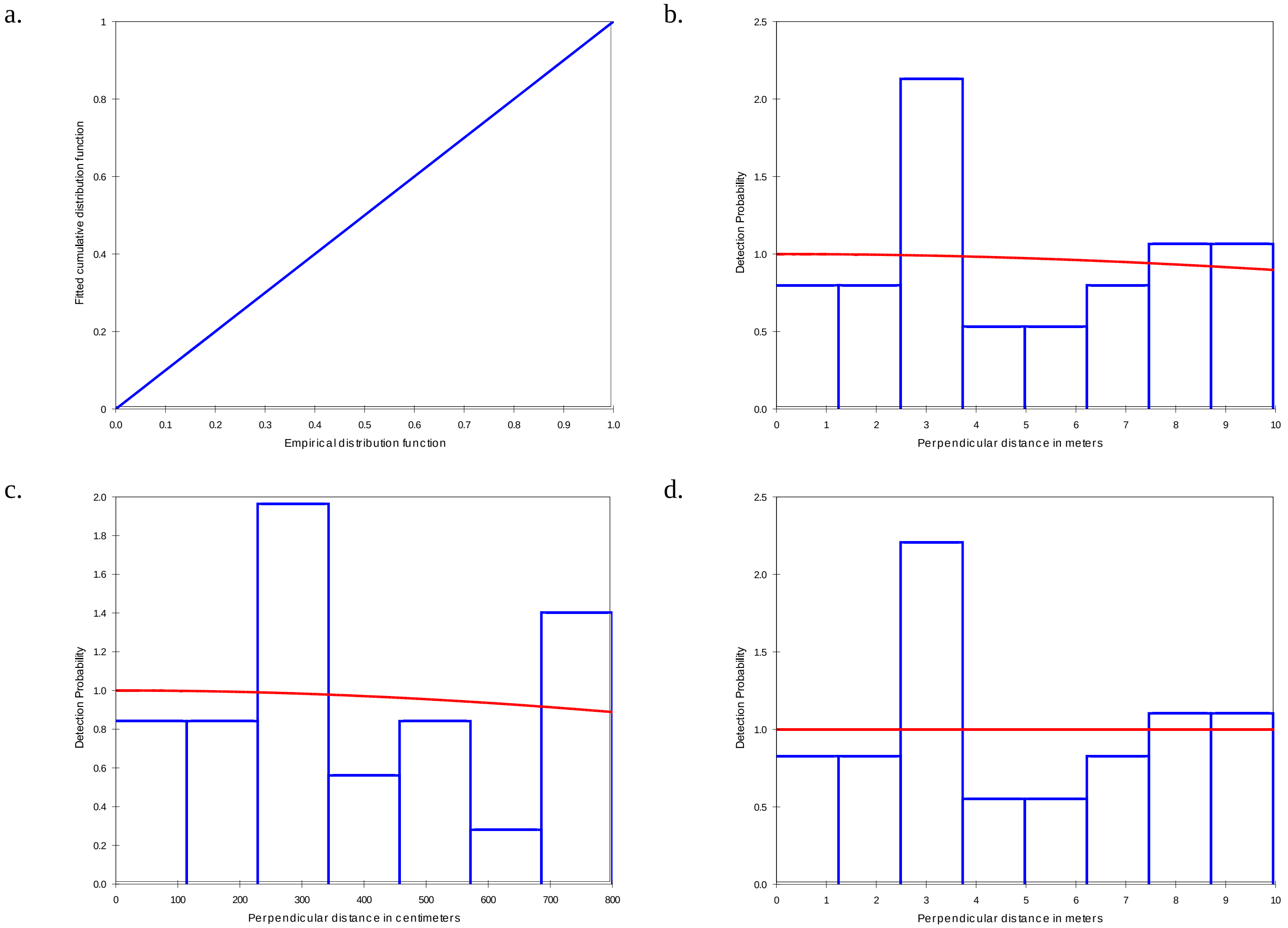
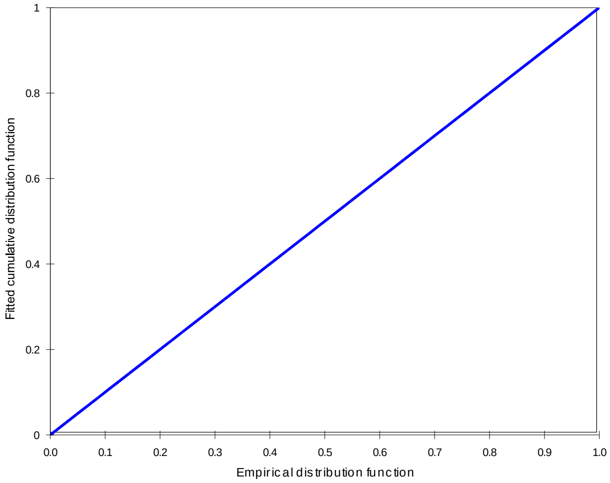


Figure 12: Graphical display and analysis results for the chimpanzee nest data collected at the Lobéké site in 2009. Shown for all the nest group data are (a) a QQ-plot and (b) a histogram showing the frequency of observations with respect to distance from the transect line. Detection function (key plus adjustment terms) fitted to grouped perpendicular distances of observations when (c) Half-normal+cosine – using exact distances with right truncation at 8m, and (d) Uniform with no adjustment terms – using exact distances and no truncation. Shown for all the individual nest data are (e) a QQ-plot and (f) a histogram showing the frequency of observations with respect to distance from the transect line.

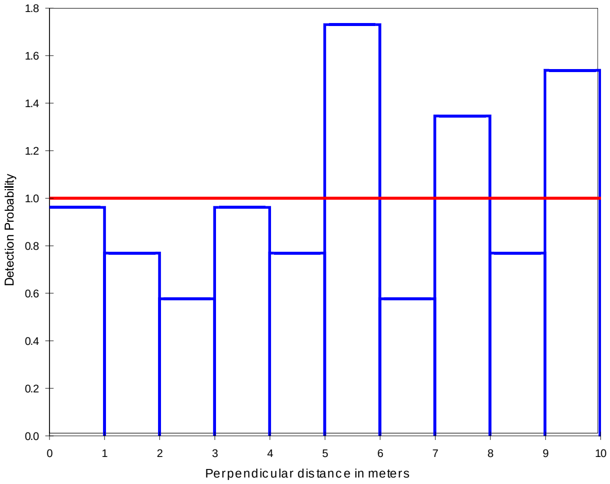


e.



Fitted cumulative distribution function
1
0.8
0.6
0.4
0.2
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Empirical distribution function

f.



Detection Probability
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
5
6
7
8
9
10
Perpendicular distance in meters

Figure 13: Graphical display and analysis results for the gorilla nest data collected at the Lobéké site in 2009. Shown for all the nest group data are (a) a QQ-plot and (b) a histogram showing the frequency of observations with respect to distance from the transect line. Detection function (key plus adjustment terms) fitted to perpendicular distances of observations when (c) Half-normal+cosine – using exact distances with right truncation at 5m, and (d) Half-normal+cosine – using 4 equal intervals to with right truncation at 5m.

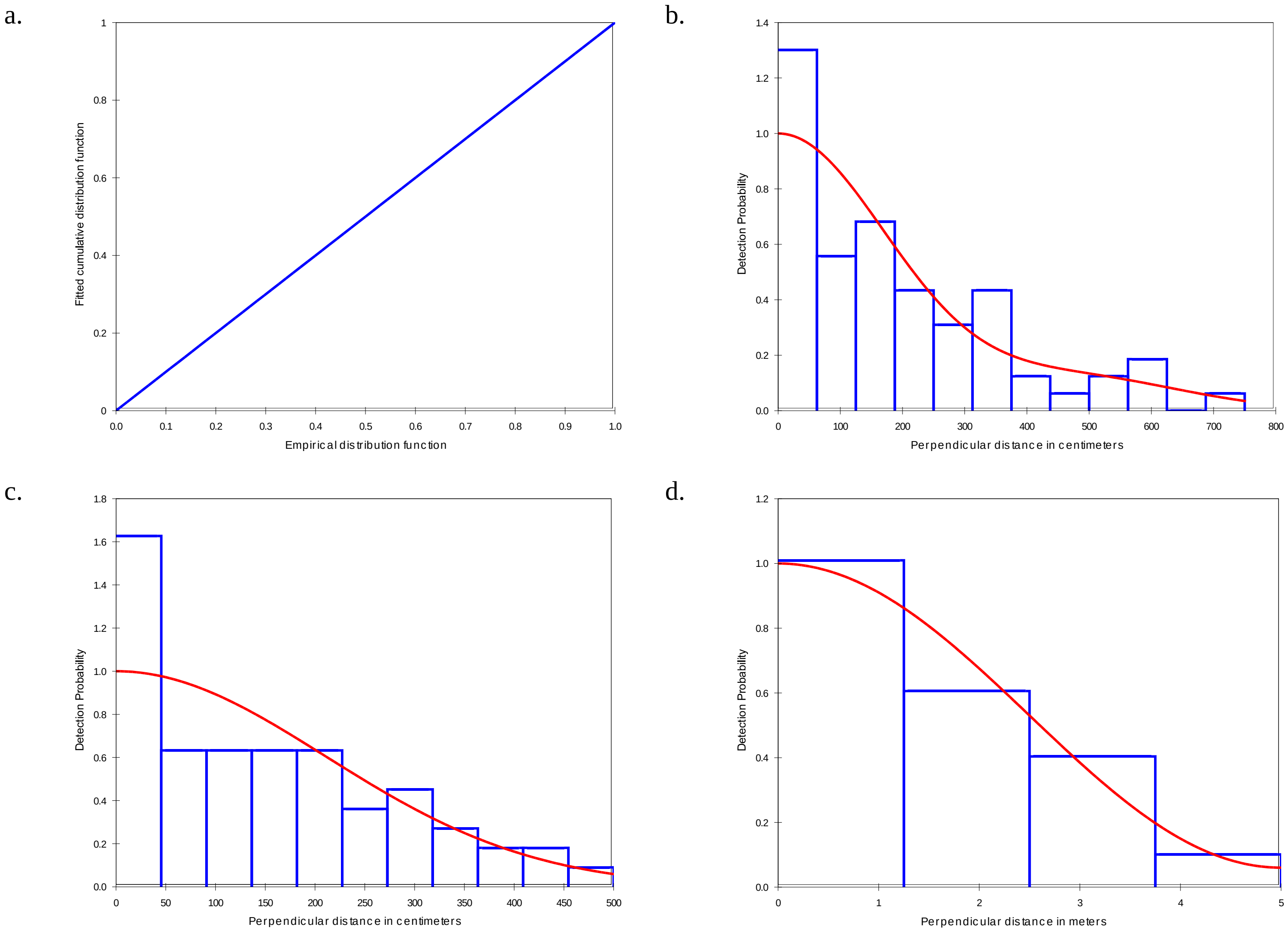


Figure 14: Graphical display and analysis results for the bongo dung data collected at the Lobéké site in 2009. Shown for all the data are (a) a QQ-plot and (b) a histogram showing the frequency of observations with respect to distance from the transect line. Detection function (key plus adjustment terms) fitted to grouped perpendicular distances of observations when (c) Half-normal+cosine – using 3 equal intervals to with right truncation at 3m, and (d) Half-normal+cosine – using 3 equal intervals to with right truncation at 3m.

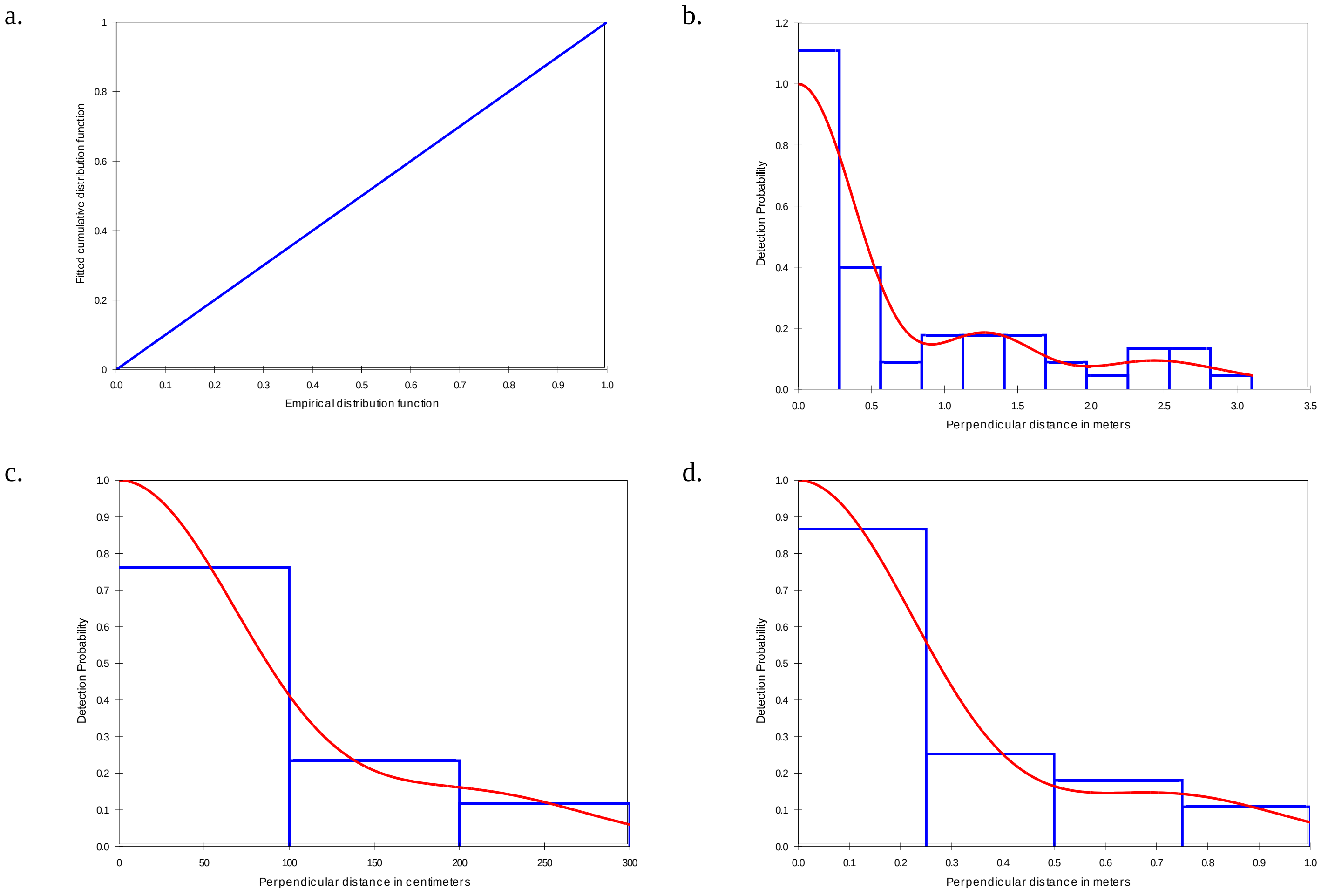
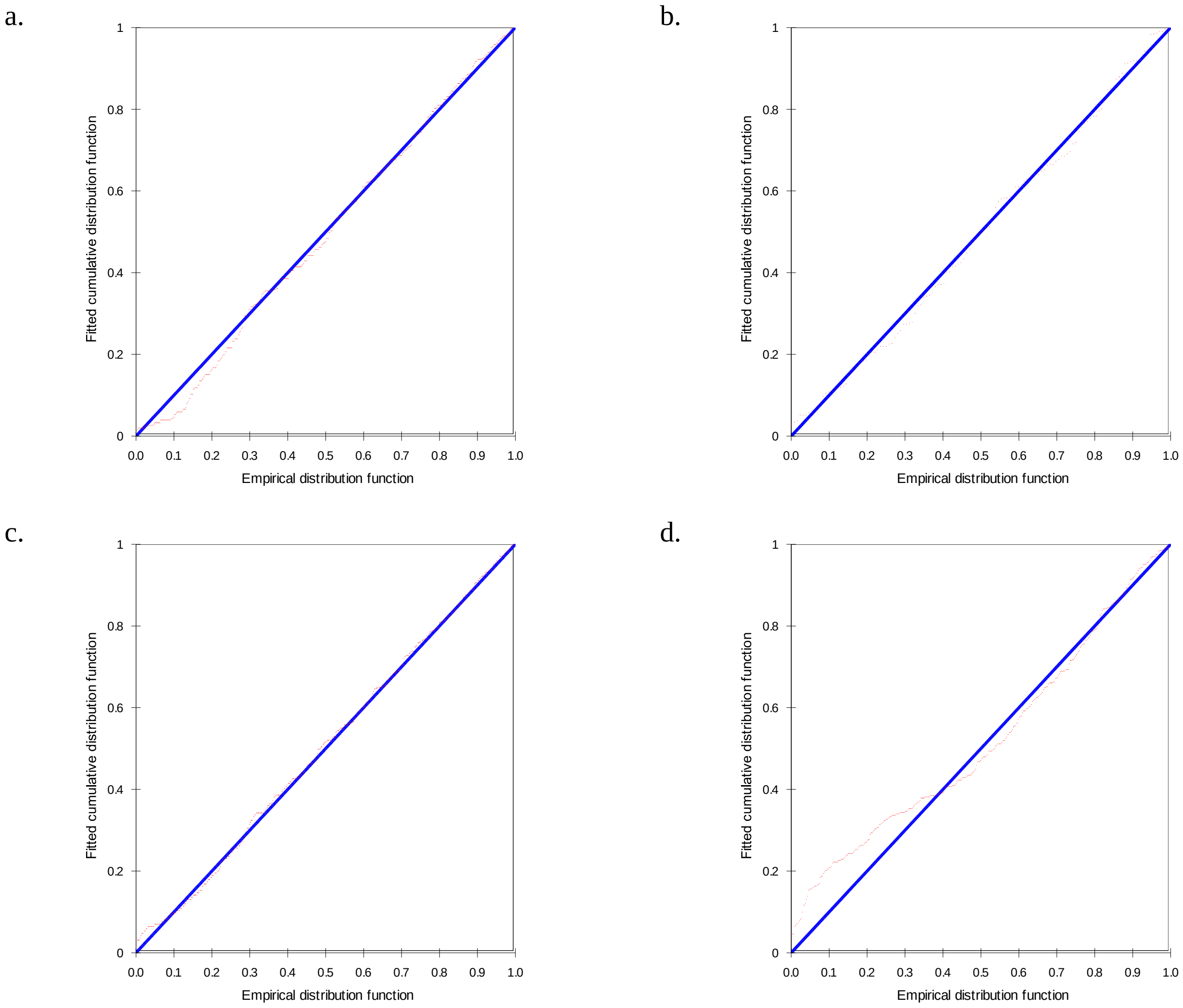
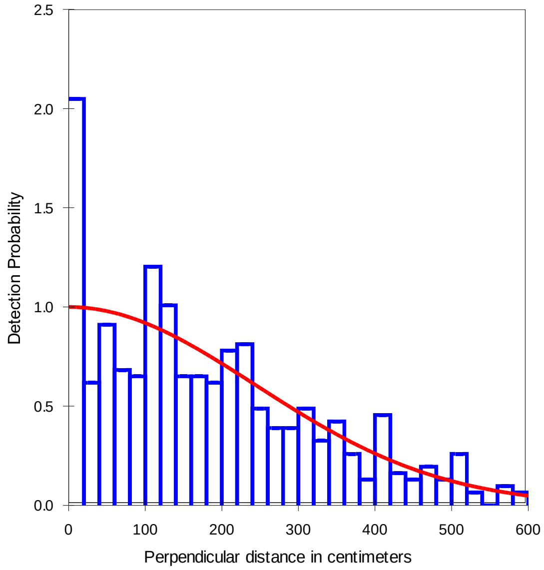


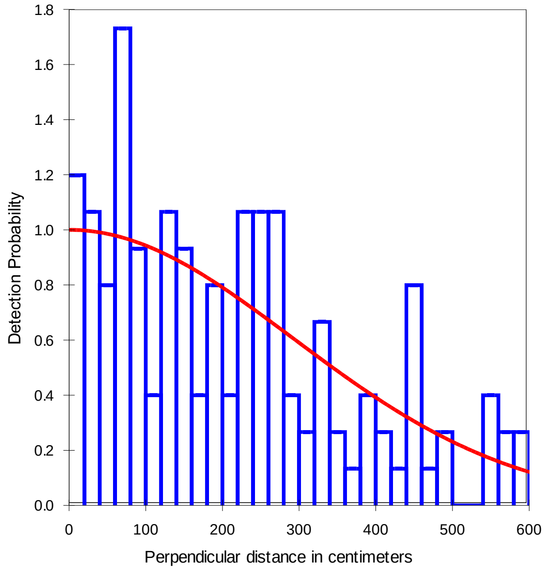
Figure 15: Graphical display and analysis results for elephant dung data collected in the Gamba Landscape. Shown for data truncated at 6m are QQ-plot for (a) Loango 2006, (b) Loango 2007, (c) Kivoro 2008, (d) Mivoungou 2010, and the corresponding histograms showing the frequency of observations with respect to distance from the transect line for (e) Loango 2006, (f) Loango 2007, (g) Kivoro 2008, (h) Mivoungou 2010. Shown also are half-normal+cosine detection functions – using 5 equal intervals to with right truncation of 10% of the data for all 4 sites (h-l).



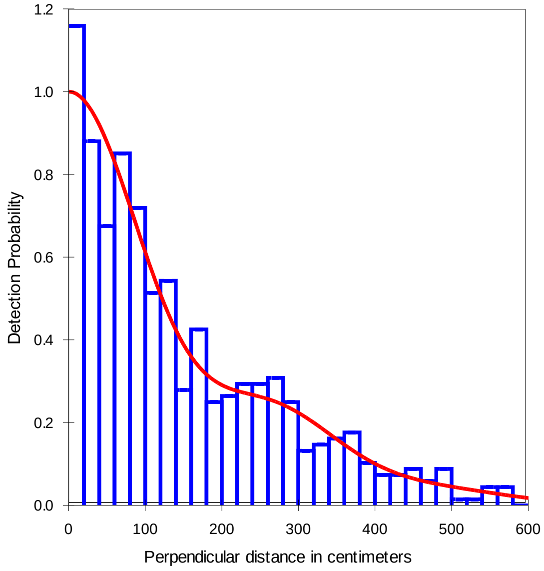
e.


Detection Probability
2.5
2.0
1.5
1.0
0.5
0.0
0
100
200
300
400
500
600
Perpendicular distance in centimeters

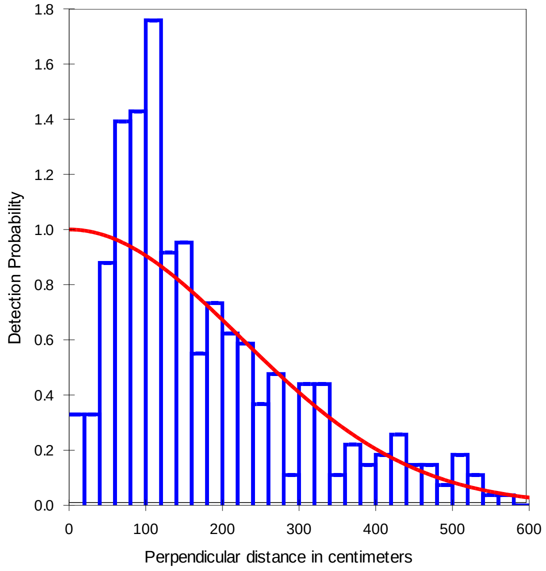
f.


Detection Probability
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
500
600
Perpendicular distance in centimeters

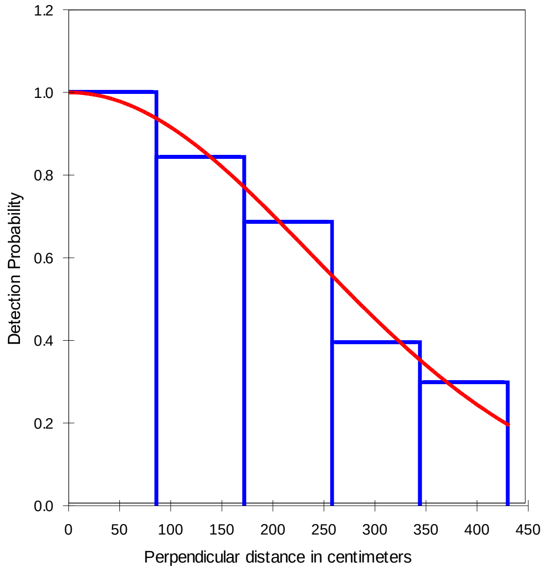
g.


Detection Probability
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
500
600
Perpendicular distance in centimeters

h.

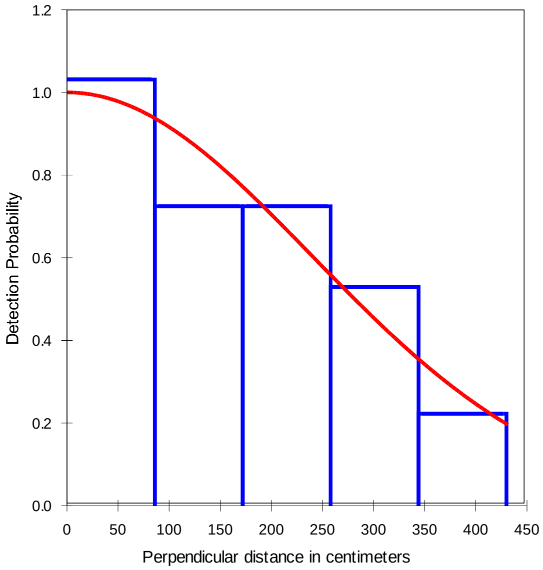

Detection Probability
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
500
600
Perpendicular distance in centimeters

i.



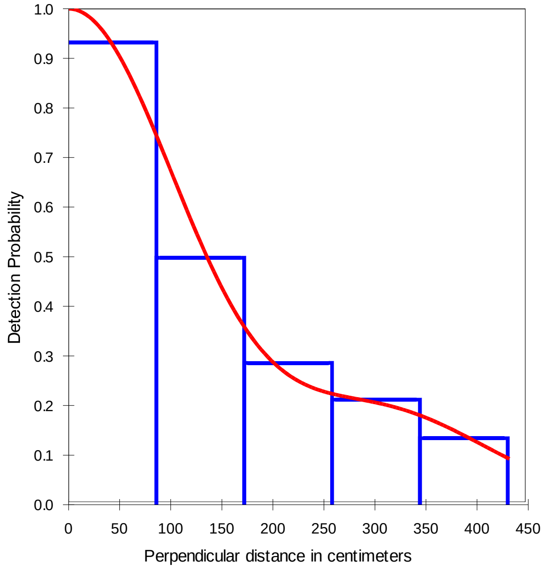
Detection Probability
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
250
300
350
400
450
Perpendicular distance in centimeters

j.



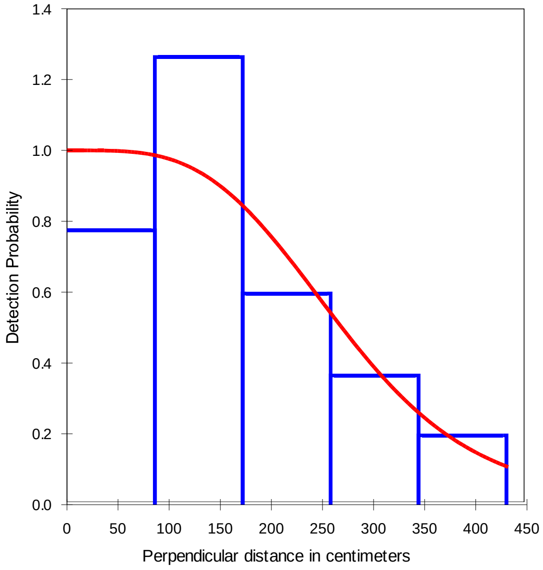
Detection Probability
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
250
300
350
400
450
Perpendicular distance in centimeters

k.



Detection Probability
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
50
100
150
200
250
300
350
400
450
Perpendicular distance in centimeters

l.



Detection Probability
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
250
300
350
400
450
Perpendicular distance in centimeters

Figure 16: Graphical display and analysis results for the ape nest group data collected in the Gamba Landscape. Shown are histograms showing the frequency of observations with respect to distance from the transect line for all (a) gorilla nest group observations during the Kivoro 2008 survey and (b) unknown ape nest group observations during the Mavoungou 2010 survey, (c) a half normal with no adjustment terms detection function – using 4 equal intervals with right truncation at 20m for all ape (gorilla + unknown ape) nest group observations during the Kivoro 2008 survey, and (d) a hazard rate with no adjustment terms detection function – using 4 equal intervals with right truncation at 20m for all ape (gorilla + unknown ape) nest group observations during the Mavoungou 2010 survey.

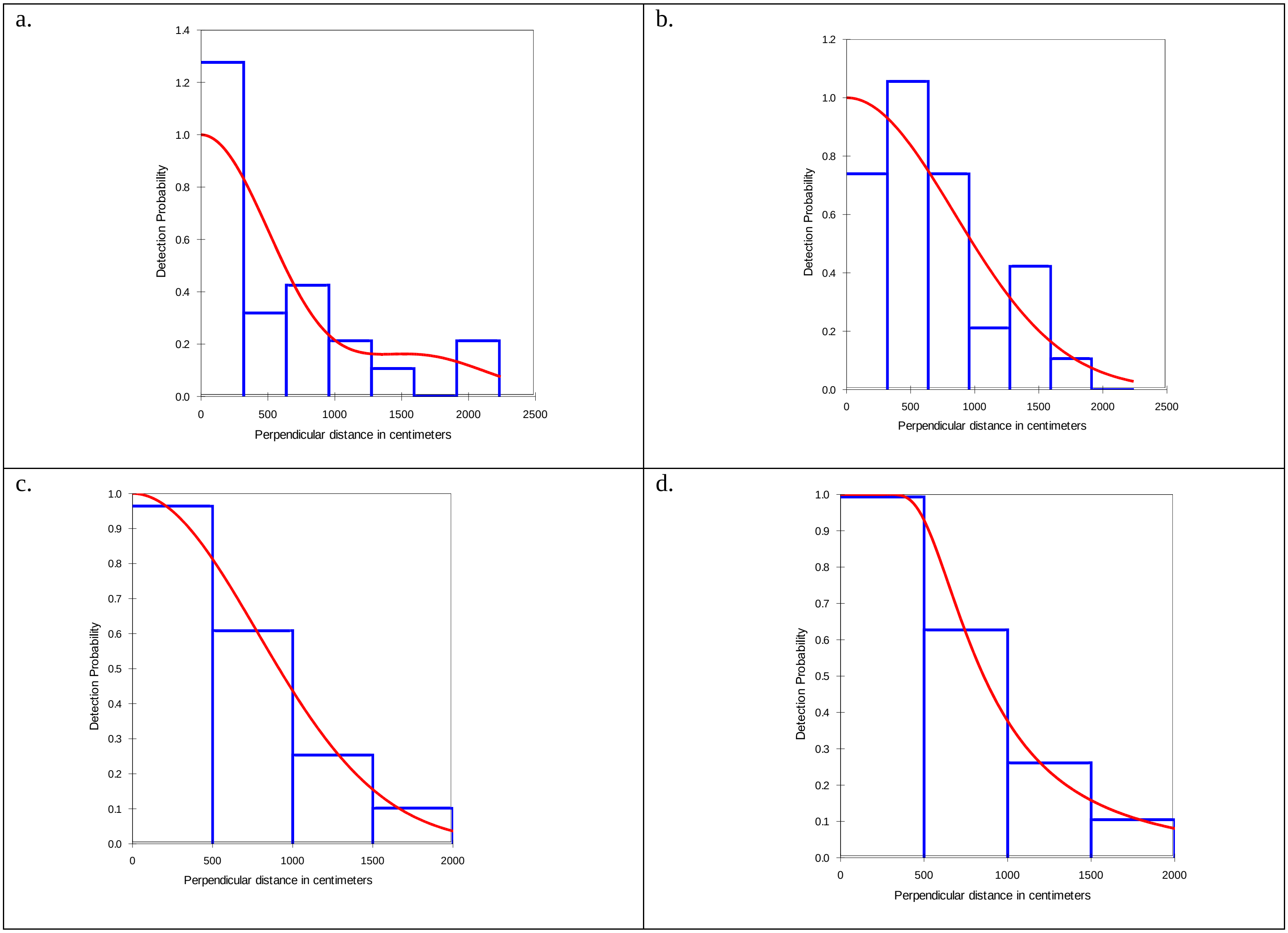
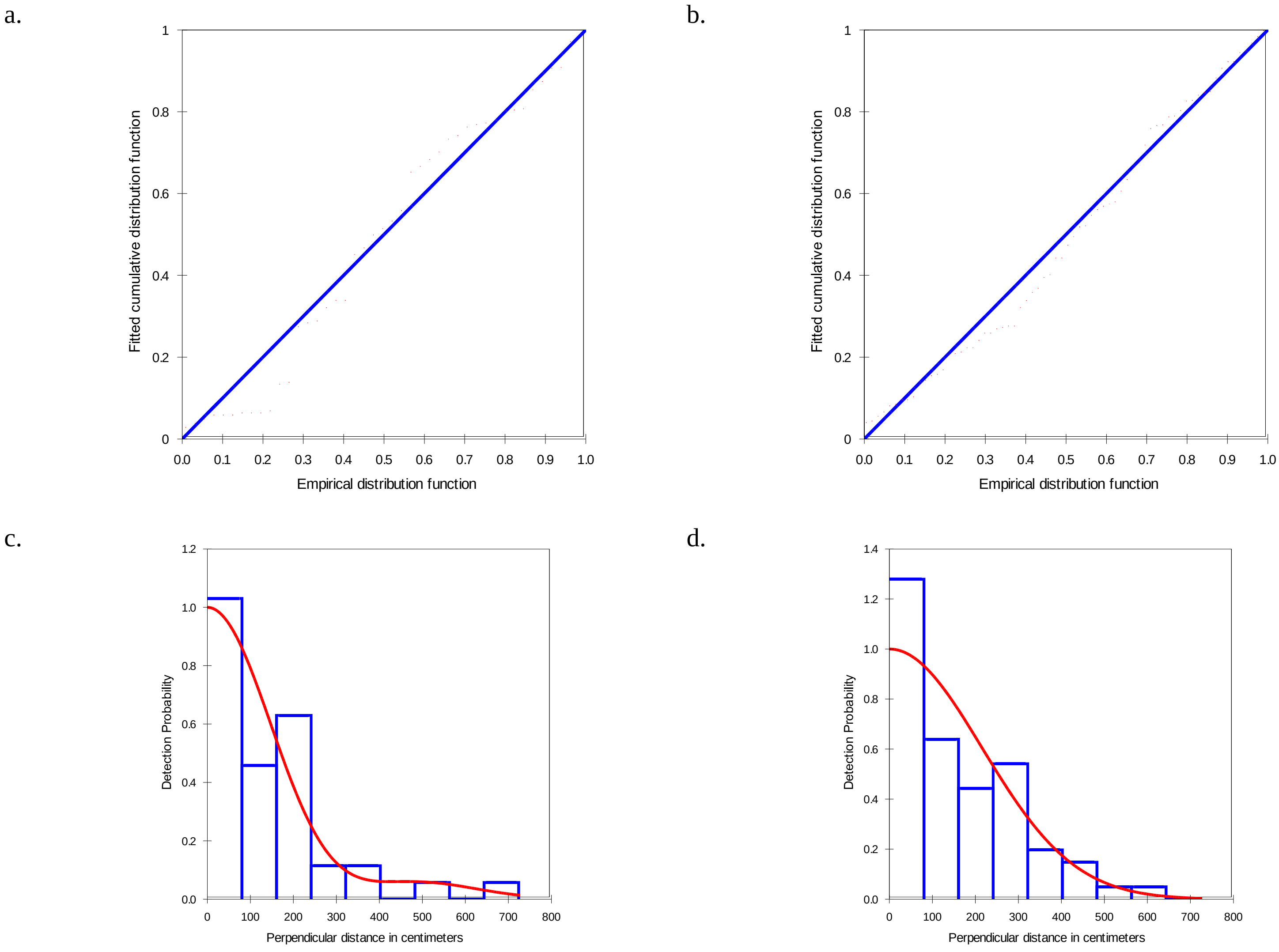


Figure 17: Graphical display and analysis results for the red river hog dung data collected at the Loango site in 2006 and Kivoro 2008. Shown for both sites are QQ-plots for all the (a) Loango 2006 and (b) Kivoro 2008 data,histogram showing the frequency of observations with respect to distance from the transect line for all the (c) Loango 2006 and (d) Kivoro 2008 data, and (e) a half-normal with no adjustment terms detection funtcion – using 4 equal intervals with right truncation at 4m for Loango 2006 and (f) a uniform+cosine detection funtcion – with right truncation at 5m for Kivoro 2008.



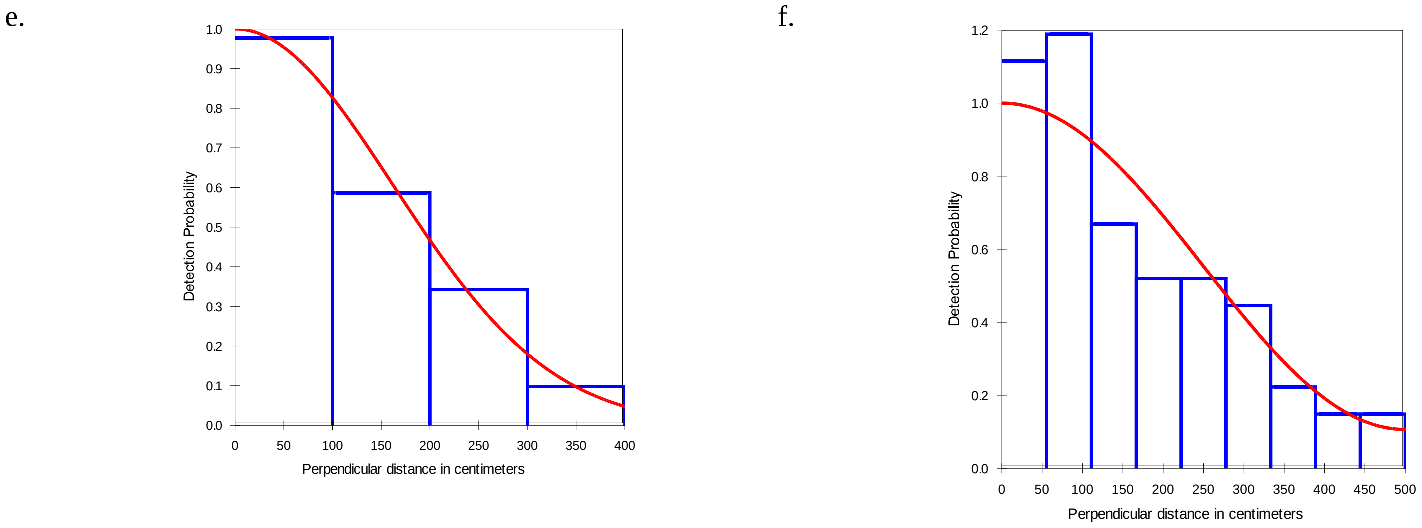


Figure 18: Graphical display and analysis results for the forest buffalo dung data collected at the Loango site in 2006. Shown are (a) a QQ-plot for all the data and (b) a histogram showing the frequency of observations with respect to distance from the transect line and a hazard rate+cosinedetection funcion – with right truncation 10% of the data.

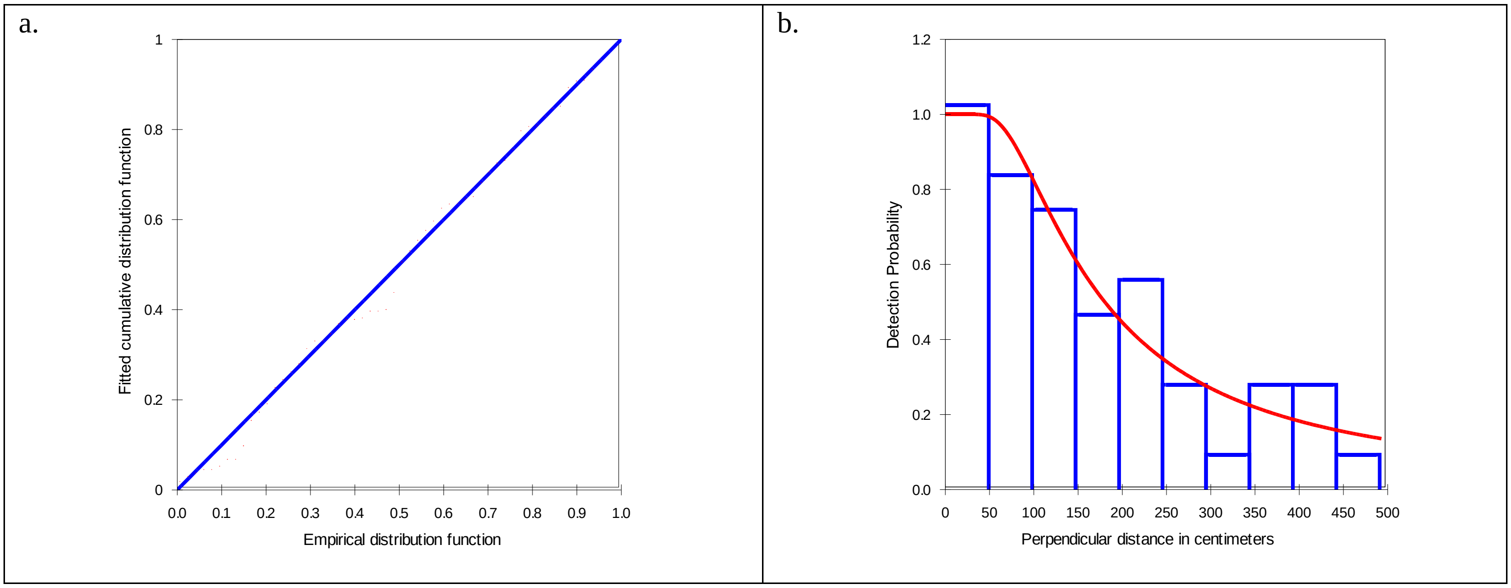
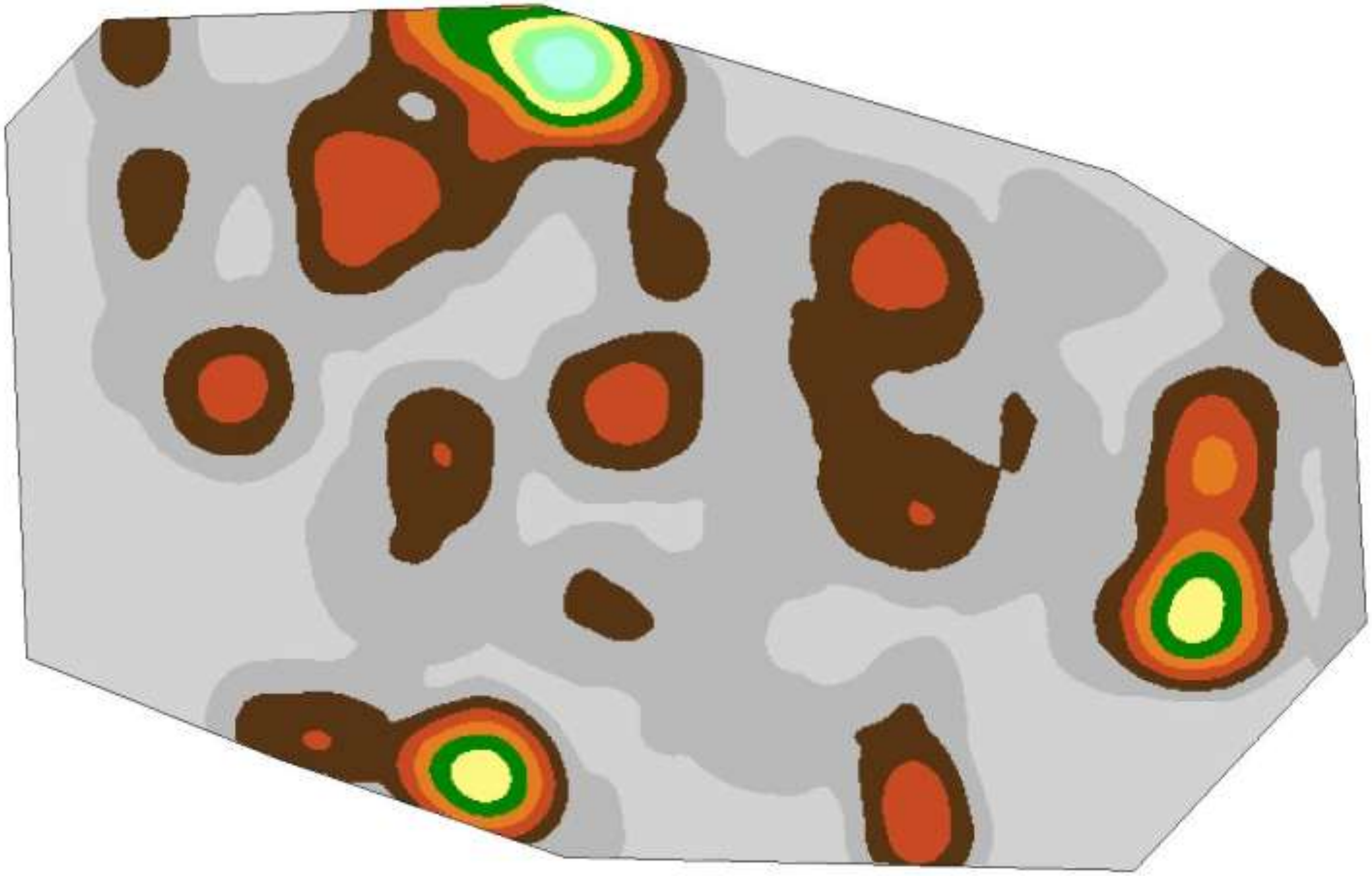
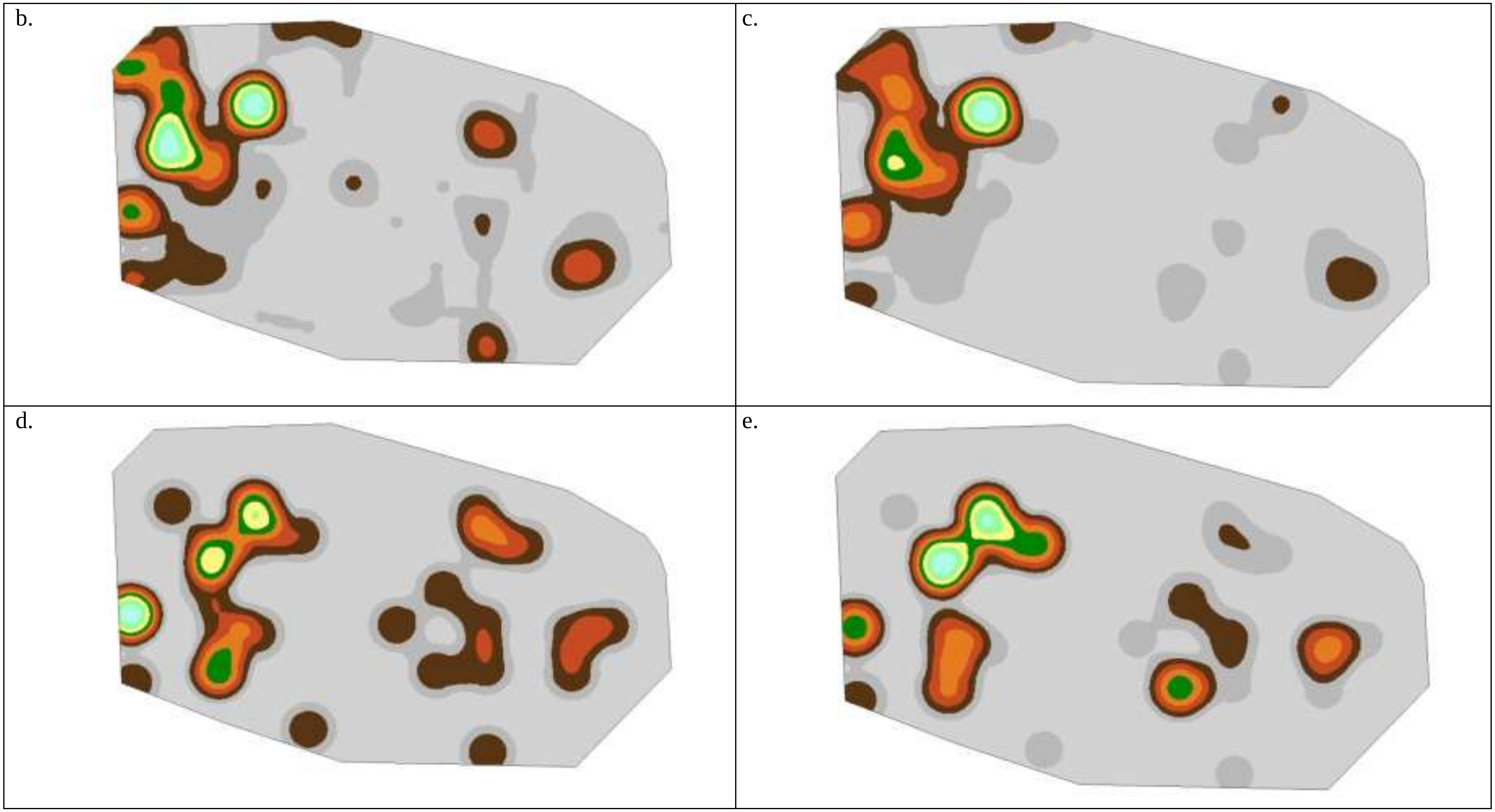


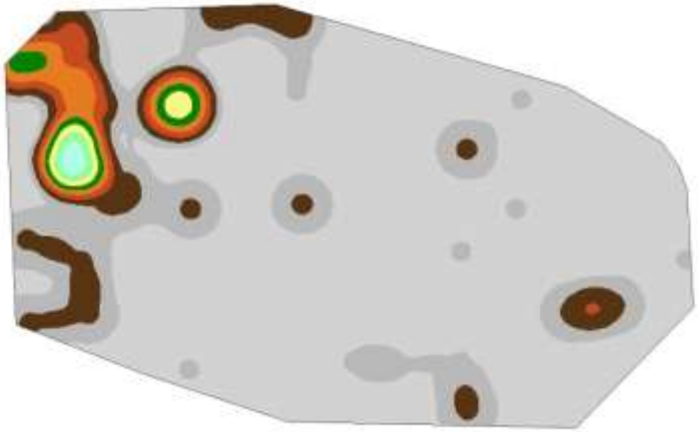
Figure 19: Interpolated kernel density map created using the raw dung counts at the mid-point of each of the 87 transects of 2.5km length for the Lobéké 2009 survey. Lowest densities correspond to areas shown in light grey and highest in light blue. Shown are the results for (a) elephant dung with a density range of 0-2.99/km^{-2}, (b) ape nest groups with a density range of 0-0.32/km^{-2}, (c) ape nests with a density range of 0-0.80/km^{-2}, (d) chimpanzee nest groups with a density range of 0-0.12/km^{-2}, (e) chimpanzee nests with a density range of 0-0.24/km^{-2}, (f) gorilla nest groups with a density range of 0-0.32 /km^{-2}, (g) gorilla nests with a density range of 0-0.59/km^{-2}, (h) bongo dung with a density range of 0-0.425/km^{-2}, (i) pig dung with a density range of 0-0.12/km^{-2}, (j) pig all sign with a density range of 0-0.65/km^{-2}, (k) forest buffalo dung with a density range of 0-0.15/km^{-2}, and (l) forest buffalo all sign with a density range of 0-0.51/km^{-2}.

a.

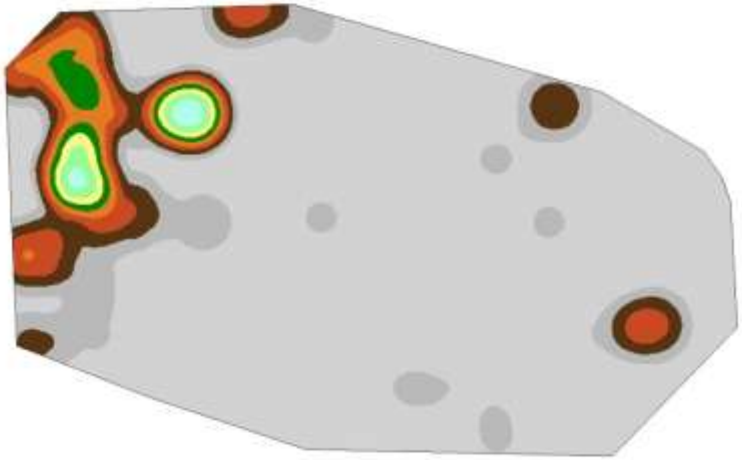



b.
c.
d.
e.

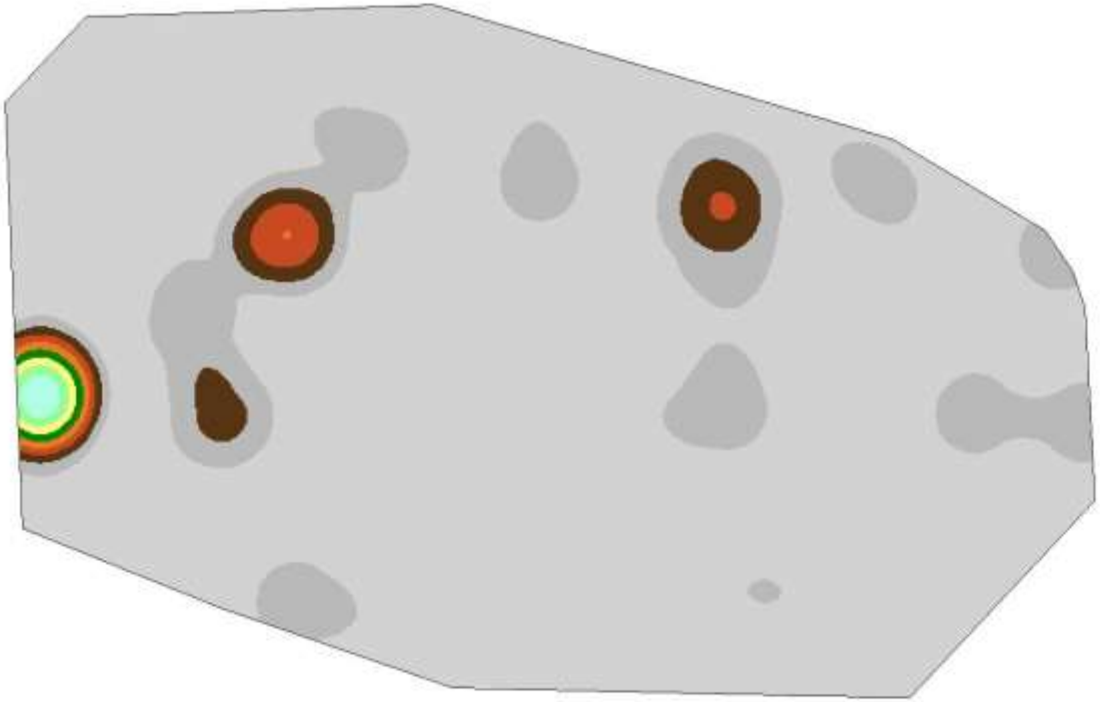
f.



g.



h.



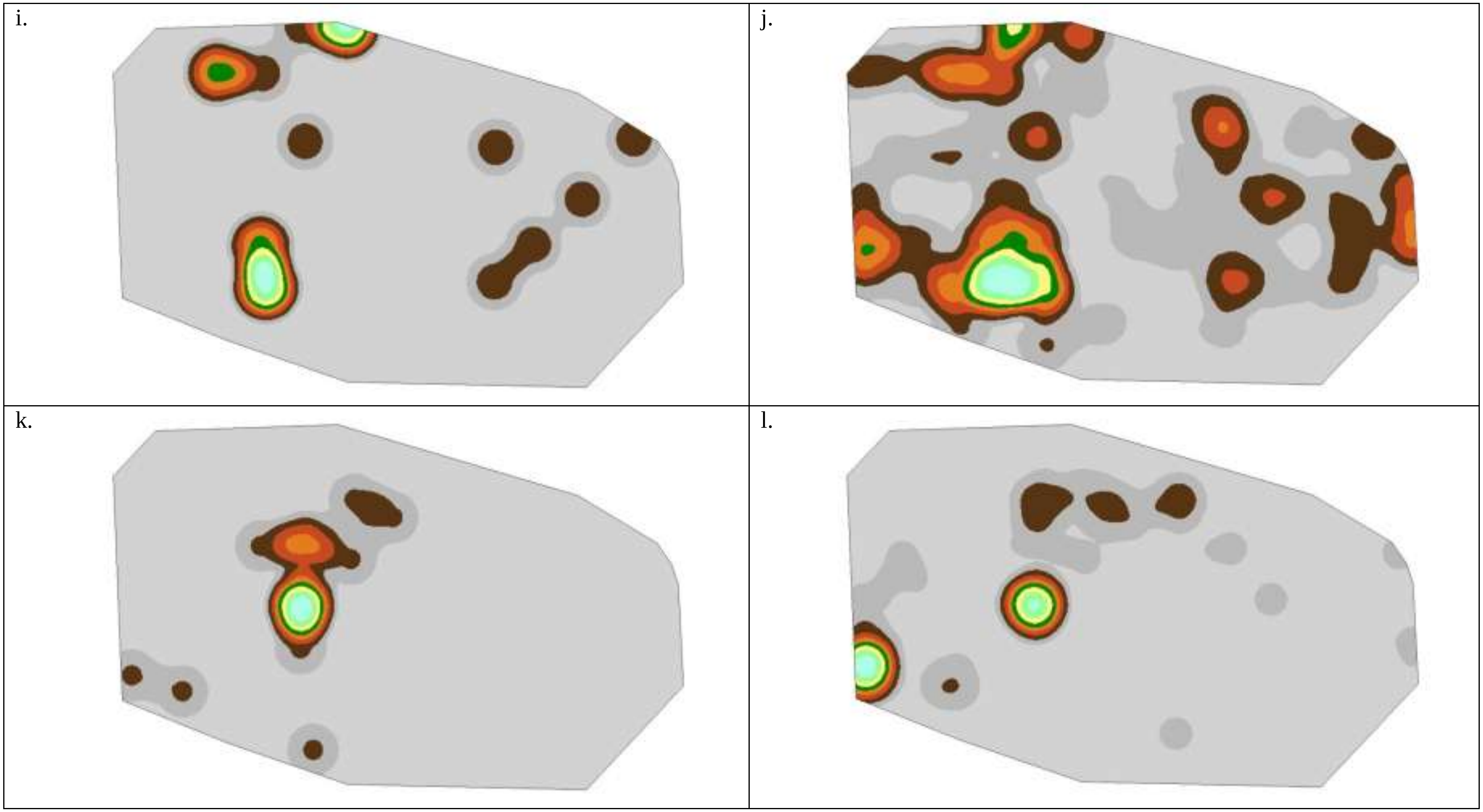
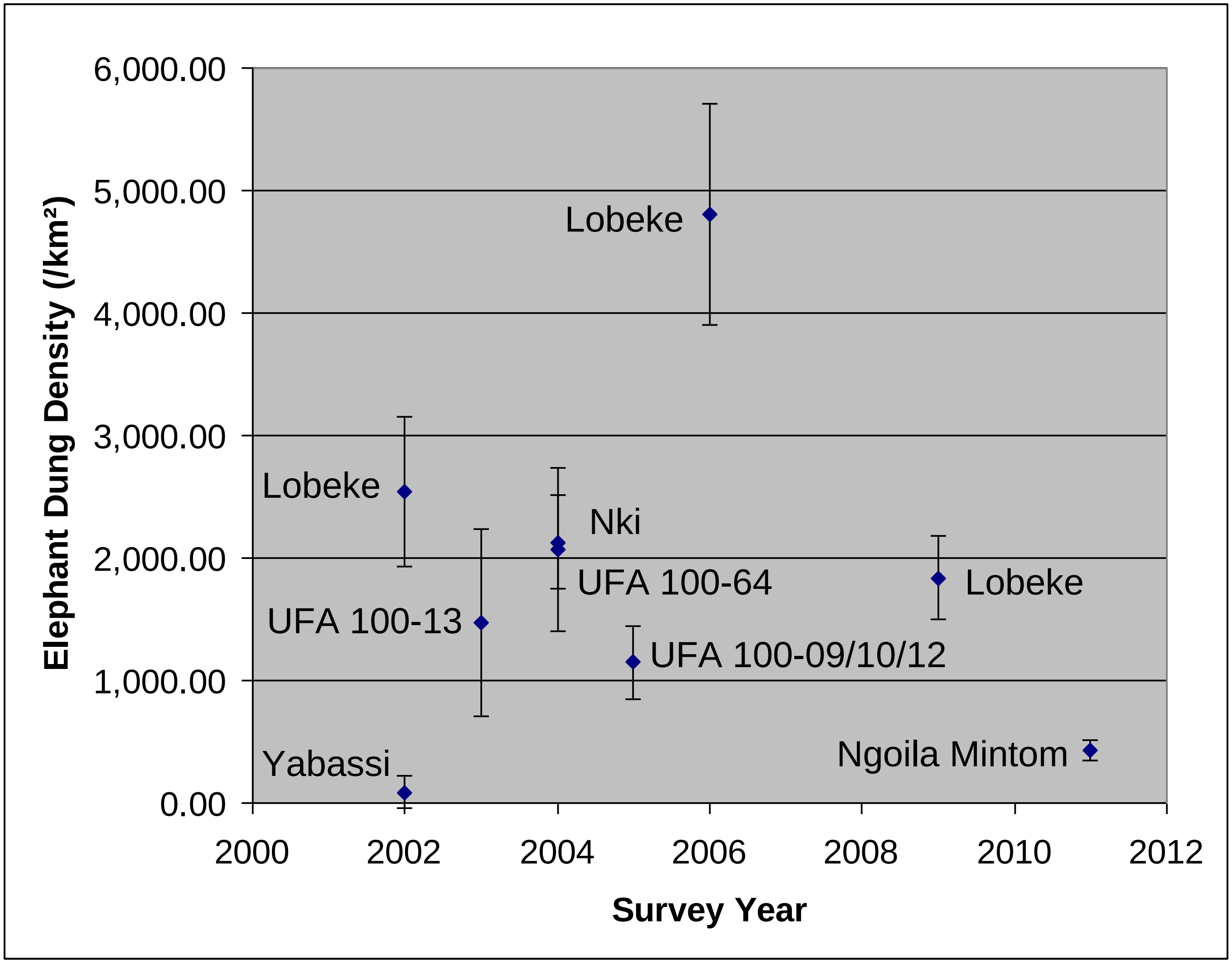

i.
j.
k.
l.

Figure 20: Shown are density estimates for (a) elephant dung and (b) gorilla[21] *nests with their 95% error bars for survey sites in Cameroon, as well as (c) elephant dung for survey sites in the Gamba Landscape.*

a.



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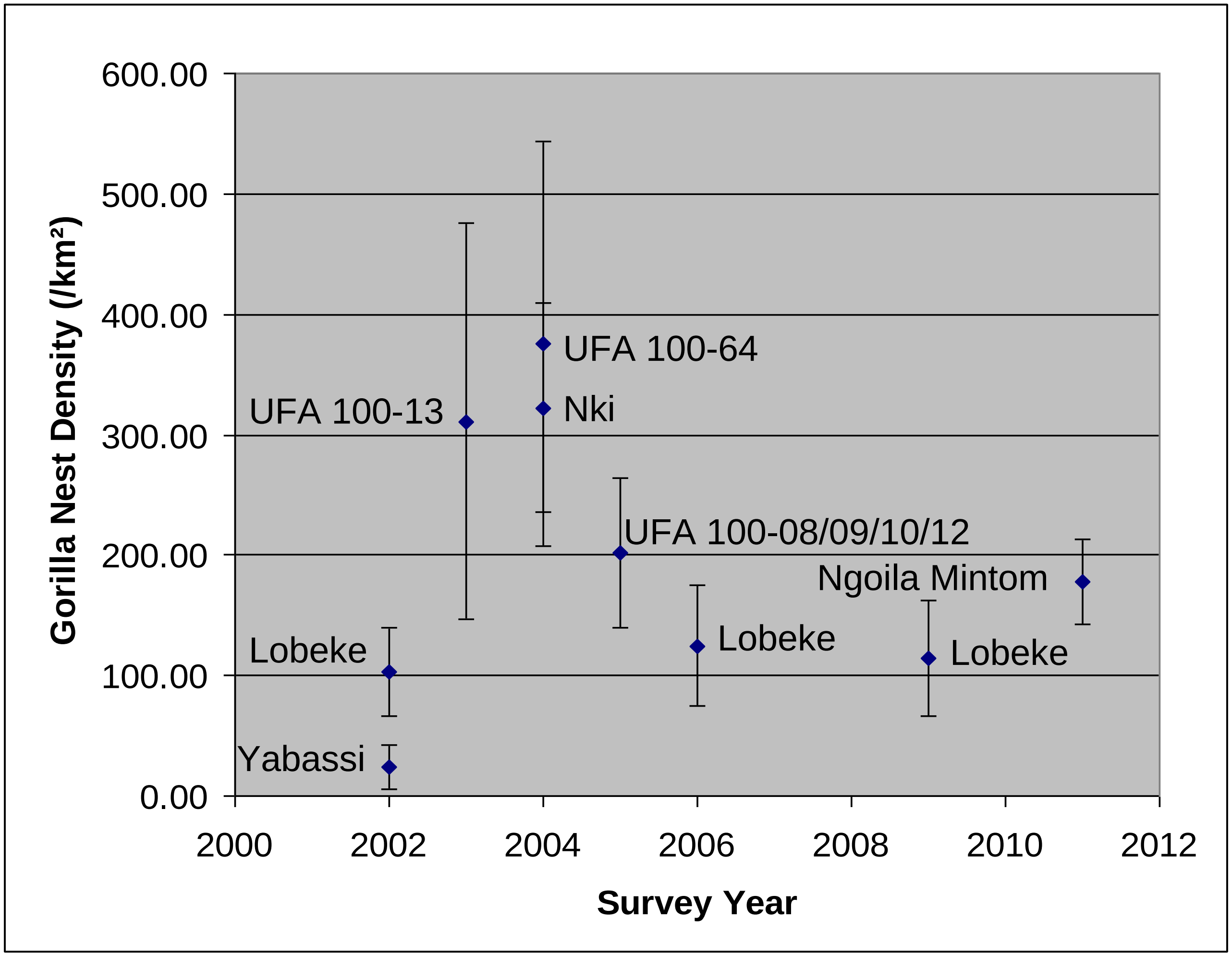
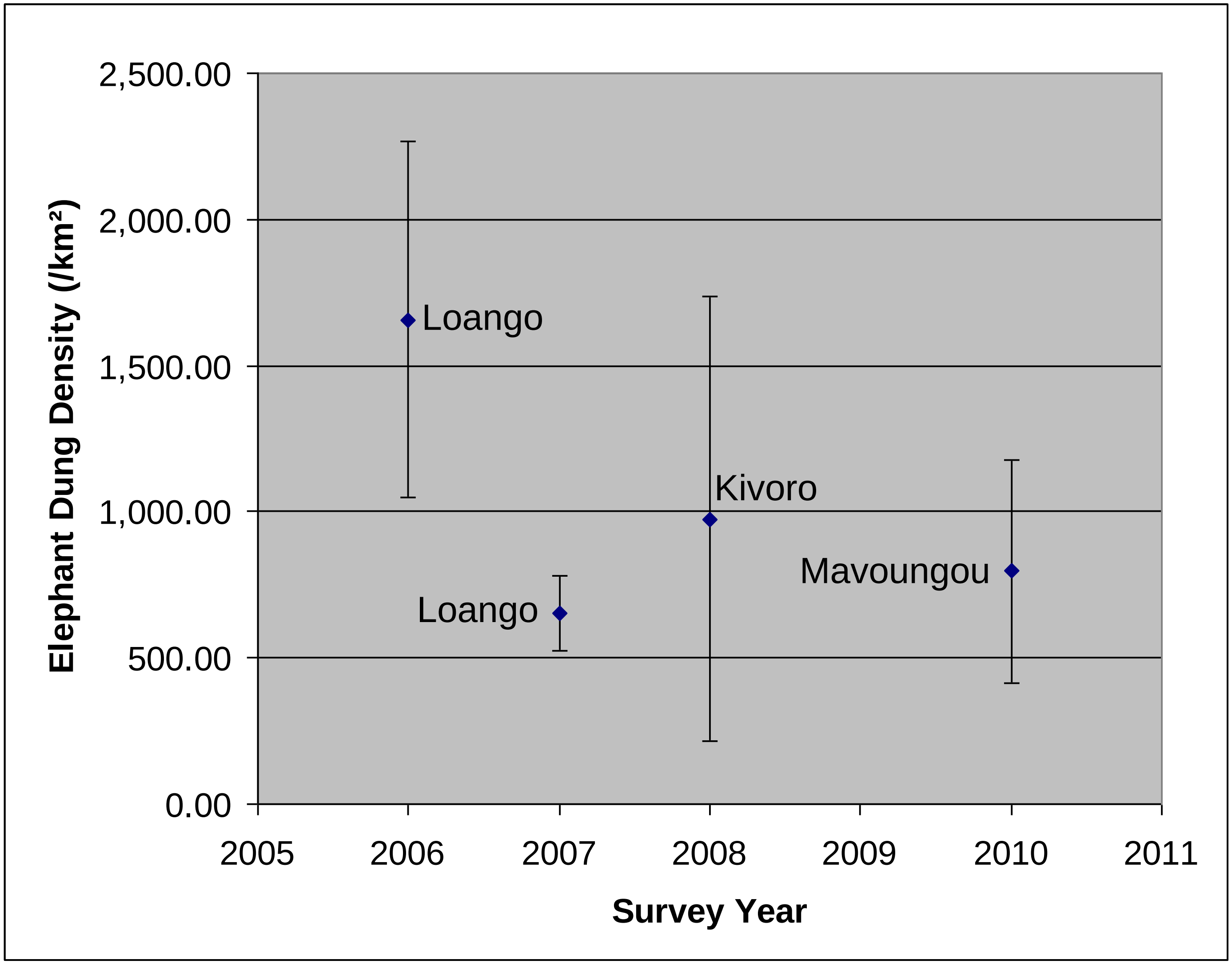
[21] For Yabassi the results are for chimpanzee as no results could be generated for gorilla.

b.


600.00
500.00
400.00
300.00
200.00
100.00
0.00
Gorilla Nest Density (/km²)
UFA 100-64
Nki
UFA 100-13
UFA 100-08/09/10/12
Ngoila Mintom
Lobeke
Lobeke
Lobeke
Yabassi
2000
2002
2004
2006
2008
2010
2012
Survey Year

c.


Elephant Dung Density (/km²)
2,500.00
2,000.00
1,500.00
1,000.00
500.00
0.00
2005
2006
2007
2008
2009
2010
2011
Survey Year
Loango
Kivoro
Loango
Mavoungou

PRECISION VERSUS AVAILABLE RESOURCES: CALCULATING SURVEY EFFORT REQUIRED FOR MONITORING PURPOSES

When using distance sampling or other techniques, one can consider precision of the density estimates obtained and the potential statistical power to detect trends over time for the target species. Power increases with increasing sample size, and increasing size of the effect or response, and decreases as the variance increases. Power analysis is most useful when planning a study or monitoring program, as ideally one wants monitoring survey results with sufficient sensitivity to be used as a basis for management decisions Although power analyses placed in a hypothesis testing framework are perhaps not ideal (Gerrodette, 2011), they do promote more careful thought about the data requirements for a monitoring program and are very informative in terms of illustrating how difficult it may be to show that conservation actions are effective. For example, one can make use of the Trends software (Gerrodette, 1993) that implements a power analysis for detecting trends in abundance using linear regression described, as described by Gerrodette in Ecology 68: 1364-1372 (1987) and Ecology 72: 1889-1892 (1991). Note that this software is limited to situations in which monitoring occurs at one site and does not allow for arbitrary patterns of variance, detection of nonlinear patterns, and correlation among estimates. The significance level was set 10% for a 2-tailed test assuming a constant coefficient of variation (generally appropriate for distance sampling surveys), a linear model and equal intervals between sampling occasions were assumed.

Given the results of these illustrative power analyses, thoughts are given to increases or reductions in effort might influence estimates and potential considerations for future designs. Generally, when designing a distance sampling or other type of survey a balance has to be found between the precision of the density estimate and the resources available for the survey in terms of time and money. The trade-off between desired precision and the cost of implementing the survey usually dictates the survey effort and design used in sampling a particular study area. A pilot survey is the best way to estimate the amount of survey effort required to achieve a desired precision. The time and cost constraints associated with a particular type of survey in a given study area will usually dictate whether the desired precision is feasible and which survey design is most suitable for the given circumstance.

The coefficient of variation (CV) is a useful unit-less measure of precision that can be used to compare different studies. Assume that we want to conduct a line transect survey for a species where groups are the objects of interest and detection on the line is certain. Then for line transect surveys by applying the formula

$$L = \left(\frac{b + \left[s\hat{t}d(s) / \bar{s} \right]^2}{\left[CV_t(\hat{D}) \right]^2} \right) \left(\frac{L_0}{C_0} \right)$$

we can estimate the total length of transect line required for a given encounter rate $\frac{C_0}{L_0}$ and a desired target CV for the density estimate $CV_t(\hat{D})$.

The standard deviation of group size is $\hat{std}(s) = \sqrt{\sum_{i=1}^{C'} (s_i - \bar{s})^2 \Big/ (n-1)}$, where $\bar{s}$ is the mean group size and s_i the size of the i^{th} group, which assumes group size is independent of detection distance. If observations are of individuals rather than of groups of objects, then just omit the quantities related to group size from the equation.

The parameter b is known as the dispersion parameter or variance inflation factor and is approximately given by $\frac{\text{var}(C)}{C} + C\frac{\text{var}(\hat{f}(0))}{[\hat{f}(0)]^2}$. The dispersion parameter generally takes a value in the range 1.5-3. If the spatial distribution of the animals were random then $b \cong 1$ as one would expect the count on each line to approximately follow a Poisson distribution (i.e. $\hat{\text{var}}(C) \cong C$). If the population is highly aggregated then b takes on larger values. To avoid underestimating L for planning purposes it is suggested that one use a value of 3 for b (assuming it is not possible to estimate b from a pilot study or use a value calculated previously from a similar study).

Ideally a pilot study would be carried out to estimate the encounter rates to be expected during the actual survey and the mean and standard deviation of group size. These values can then be plugged into the above equation to estimate the amount of effort required to achieve the desired precision. A simple pilot study during which distances to the objects of interest are not measured can be conducted to estimate these values. If the pilot study is more comprehensive, and also includes distances to detected objects then the dispersion parameter b can be approximated by $C_0 \cdot \left\{CV(\hat{D}_0)\right\}^2$, in which case this value can also be plugged into the above equations.

If the available resources determine the total effort in terms of line length L, then it is possible to estimate $CV(\hat{D})$ using

$$CV(\hat{D}) = \sqrt{\frac{(b + [\hat{std}(s)/\bar{s}]^2)L_0}{LC_0}}$$

Again, if observations are of individuals rather than of groups of objects, then just omit the quantities related to group size from the equation. If $CV(\hat{D})$ is too large, then it may not be worthwhile conducting the survey. Similarly, having calculated the amount of effort L required to achieve our desired precision $CV_t(\hat{D})$ and possibly conclude that we do not have the resources to achieve that precision and decide whether a reduction in precision is feasible given the goals of the survey (or alternatively whether we can find more resources for the survey).

All of these equations assume that the lines are distributed randomly (or systematically with a random start) within the study area. Additionally, if detection on the line is not certain and $g(0)$ or other multipliers need to be estimated (decay or production rates), then greater effort is required to achieve a target precision (equivalently the same amount of effort will give lower precision). For more detailed explanations, similar formulae for point transects, and example calculations see Buckland et al. (2001: pp. 241-4).

Table 9: Consider a monitoring program with a 5 or 10 year duration with yearly distance sampling surveys. Below is the power (the probability of being able to detect a certain change – with values in bold indicating acceptable power) for a range of different positive or negative changes (% change/year) in population size with different potential percent coefficients of variation (%CV).

%CV	Duration (yrs)	Power	%change/year
10%	5	0.11	+1
		0.14	+3
		0.30	+5
		0.11	-1
		0.39	-5
		0.90	-10
		1.00	-20
	10	0.21	+1
		0.71	+3
		0.96	+5
		0.23	-1
		1.00	-5
		1.00	-10
		1.00	-20
15%	5	0.10	+1
		0.14	+3
		0.19	+5
		0.10	-1
		0.24	-5
		0.63	-10
		1.00	-20
	10	0.15	+1
		0.43	+3
		0.72	+5
		0.16	-1
		0.97	-5
		1.00	-10
		1.00	-20

Table 10: Shown is the required amount of effort L to attain a desired precision (%CV) for a wide range of encounter rates n/L.

%CV	n/L (km^{-1})	L (km)
10%	0.05	6,000
	0.10	3,000
	0.25	1,200
	0.50	600
	1.00	300
	2.50	120
	5.00	60
15%	0.05	2,667
	0.10	1,333
	0.25	533
	0.50	267
	1.00	133
	2.50	53
	5.00	27
20%	0.05	1,500
	0.10	750
	0.25	300
	0.50	150
	1.00	75
	2.50	30
	5.00	15

EXAMPLE LINE TRANSECT SURVEY DESIGN:

SANGHA TRI-NATIONAL LANDSCAPE AS A MODEL

Let's consider a hypothetical line transect design that could be used as part of a monitoring program to assess conservation effectiveness in the Sangha Trinational landscape over time. For this example the target species is forest elephants. With an interest in demonstrating that conservation activities are working or in adapting activities over time, the landscape was stratified according to different land use types, management units and considering degrees of human influence, as these would dictate the type of conservation activities and the scale of conservation investment (Figure 21a).

Separate strata were defined for the national parks given the assumption that these should be strongholds for elephants and have considerable conservation investment (strata 1-3 and 9 in Figure 21a). Logging concessions in the Republic of Congo were kept separately as they are larger than those across the border and the logging companies operating in each have varying degrees of commitment to potential conservation activities, e.g., low impact logging or law enforcement activities (strata 4-6 in Figure 21a). The logging concessions in Cameroon were aggregated into a single survey stratum (stratum 10 in Figure 21a), as the individual concessions are relatively small and there was no information available on the conservation interest of the logging companies for Cameroon in this area. No logging stratum was defined for the Central African Republic (CAR), as it seems no logging concessions have been attributed. In both Cameroon and CAR there are hunting concessions that have been aggregated per country, assuming different conservation activities and investment in each (strata 11 and 12 in Figure 21a). For Cameroon the aggregated logging stratum that has been defined (stratum 10 in Figure 21a) also permits hunting, while the aggregated hunting concession (stratum 12 in Figure 21a) is not attributed as a logging concession. Although, there are community hunting areas on the Congo side, these are smaller and subsumed into the larger logging concession strata. The original Trinational Landscape has been extended along its south-eastern edge to include a swamp area that is potentially important for elephants (stratum 8 in Figure 21a). We are unlikely to be very interested in the change in elephant populations in the areas of high human influence in the landscape, given that the level of conservation investment in these areas is presumably small or none. However, we are interested in contrasting the status of the elephant population in these highly impacted areas to those where there is heavier investment. Thus, as part of this design high human influence areas – effectively control sites - have been defined in each country (as it is also of interest to have this information by country; strata 7, 13 and 14 in Figure 21a). Note that the Mokabi logging concession in the north-east of the landscape was classified as the high human influence stratum for Congo (stratum 7 in Figure 21a), as it already presents a very high threat area for elephants.

Looking at the results of the power analysis (Table 9), where ideally one aims for upward of 90% power, for a 10% or 15% coefficient of variation (CV) for either a 5 or 10 year monitoring program where distance sampling surveys might be conducted on 5 year cycles, the difficulty of detecting trends is clear. For populations with low intrinsic growth rates it becomes almost impossible to detect a change with any degree of certainty during a 5 year monitoring program and only for populations with slightly higher growth rates can changes be detected even after 10 years of monitoring. Catastrophic declines are easier to detect, however, it is worth keeping in mind that “even” a 5% yearly decline results in loss of almost 23% of the population after 5 years and over 40% after 10 years. These power analysis results are for a CV of 10% or 15%, which is extremely optimistic if one considers the amount of effort required to attain this precision, especially for areas with low encounter rates (Table 10).

Assuming certain constraints on the amount of survey effort that could be invested in this landscape as part of a monitoring program, we aimed for a CV of approximately 10% in the national parks which potentially have the highest level of investment and are likely to be elephant strongholds. We speculated that there might also be considerable conservation investment in some of the logging concessions (strata 5, 6 and 10 in Figure 21a) and aimed for reasonable CVs in these (<15%). Stratum 4 (Loundougou logging concession) is critical for the integrity of NNNP (stratum 1) and stratum 11 (CAR aggregated hunting concession) for the national parks in CAR, thus one can assume that quite some conservation investment with be made in these too. However, given the lower elephant population densities in these strata, the amount of effort that would be required to obtain reasonable precision in these strata is enormous (potentially 600 km and 1,000 km of effort, respectively, to obtain 10% CV, see Table 11) and thus a trade-off has to be made. Similarly, to obtain even moderate precision in the high human influence strata would require astronomical survey effort and thus it is not even reasonable to consider it as an option. However, given that our intention is to contrast the state of elephant populations in these strata to those where we are conducting activities, as long as our methods are providing unbiased results we can still contrast the density estimates in order to show with reasonable confidence that our conservation investments are paying off. Other assumptions can of course be made and the design revised accordingly.

In the design process we used encounter rates from previous surveys in the strata under consideration (Table 11). Where this information was a few years old, we pessimistically adjusted the encounter rate downwards (assuming declines in the elephant populations and thus more survey effort to detect changes in status over time). The design was done using the Distance software (Thomas et al. 2010). Line transects were placed systematically with a random start within each survey stratum, using the ‘’Systematic Segmented Trackline Sampling’’ design class within the automated design component of the software, as this tends to improve precision (Strindberg et al. 2004). A 3km length setting was selected for transects, although the option to allow for shorter transects where these intersect stratum boundaries was chosen (this is a better option from a statistical point of view, as it provides the same sampling intensity throughout, which is assumed during a standard distance sampling analysis). With this type of design, shorter transects have sometimes been used in the past in part to facilitate logistics, with one transect covered per day and transit to the start of the next transect on the same day. However, given the unfortunately lower encounter rates compared to previous surveys and either the increased accessibility (in survey strata where there is access, which has potentially increased in the last few years) or the cost of access in remote areas of some strata, a 3km transect provides more survey effort overall, i.e., is cost-effective, while still being logistically feasible. We aimed for at least 15 transects and ideally upwards of 25 transects per stratum to ensure sufficient replication for a representative sample and to get a good estimate of variance. The spacing between the transects in each stratum was a function of the desired survey effort and the size of the stratum. To improve precision in density estimates, transects were placed perpendicular to potentially gradients in elephant density (generally associated with varying degrees of human influence such as access and settlements).

The Sangha Tri-national Landscape is at an appropriate scale when considering elephant movement and conservation and ideally monitoring it as a unit should be considered. Just having information on much smaller scales, for example, Lobéké NP even with survey information from the surrounding logging concessions is at a moderate scale for elephant conservation when one considers population sizes and movement patterns of this species.

However, even if a similar design to the one proposed here for the larger landscape were put in place, its successful implementation very much relies on substantial and continuous training to ensure that field staff understand the critical assumptions underlying the distance sampling methodology and apply the technique correctly in the field. Although, the field staff at Lobéké NP have put a remarkable amount of dedication and effort into their surveys, the results for elephants are difficult to interpret due to critical problems with the collection of the data (extreme heaping at zero distance from the line). The problems in the data leads to unreliability in the modelling results and very different potential estimates from the same data set (the difference in density estimates produced by the different models varied by over 150% for the 2006 Lobéké transect data). Thus the spike in the 2006 estimate compared to 2002 and 2009 for elephants are quite possibly just an artefact of the data collection problems rather than related to a real increase in the elephant population. Considering the untruncated encounter rates for elephant dung, these are 8.22, 8.74 and 5.79 from transects and 10.32, 8.11 and 3.22 from recces for 2002, 2006 and 2009. Thus, although the encounter rates from transects seem to indicate some increase in elephant dung in 2006 (without accounting for detectability), this is not reflected in the recce encounter rates, even if for both transect and recce data there does seem to be indication of a potential decline by 2009.

Without the critical foundation of well-trained field staff, the data resulting from surveys will be difficult (due to inherent biases), if not impossible to use for monitoring purposes and adaptive management, even with the best possible design, great precision for the monitoring surveys and the adequate resources to conduct the field work over time. In addition, thought needs to be given to not only training field staff to apply the proper field protocols and to conduct the standard analyses well, but to potentially conducting more sophisticated spatial modelling analyses (or have personnel elsewhere who can provide such technical support to the field). To use the survey data (both transect and recce data) to their full potential to inform management activities, it is important to conduct analyses that consider the possible drivers of species distributions and how these change over time and under different management regimes This is not a trivial task, as it requires technical expertise and aside from the survey data itself also explanatory variable data (usually extracted from GIS data layers if not collected directly in the field, which requires another range of technical skills).

Table 11: Details of the hypothetical Sangha Tri-National Landscape design. For each survey stratum whose identifying number (ID) corresponds to that in Figure 21, the site type is listed (NP = National Park, LC = Logging Concession, HC = Hunting Concession, HHI = High Human Influence). If a survey was conducted there previously, then the year and resulting encounter rate (n/L) are detailed (assuming a decrease in elephant numbers over time, a lower encounter rate was used for the design with older results), as well as the amount of effort that would be required to obtain a coefficient of variation (CV) of 10%, which is good for monitoring purposes. The actual design effort is given together with the number of transects in each stratum and the spacing between them. Finally the percent CV that can be expected for the given design effort is detailed.

ID	Stratum	Site type	Area (Km^2)	Previous Survey	Previous n/L (km^{-1})	n/L (km^{-1}) used	Effort (km) for 10% CV	Design Effort (km)	Transects	Expected %CV
1	NNNP	NP	4,089.05	2010	3.63	3.60	83	81	30	10
2	Ndoki NP	NP	751.31	2003	8.50	6.00	50	54	22	10
3	Dzangha NP	NP	499.73	2003	9.86	7.00	43	51	23	9
4	Loundougou	LC	4,228.95	2010	0.56	0.50	600	42	16	38
5	Pokola	LC	4,515.28	2010	2.19	2.00	150	64	24	15
6	Kabo	LC	2,887.82	2010	5.78	5.50	55	51	18	10
7	Mokabi	LC	3,471.16	2006	0.10	0.05	6,000	39	15	>100
8	Bailly	Nothing	5,890.74	2010	1.47	1.40	214	75	26	17
9	Lobéké NP	NP	2,160.98	2009	5.79	5.00	60	74	28	9
10	Cameroon Logging	LC	3,633.22	2003-05	3.93[22]	3.00	100	81	32	11
11	CAR Hunting	HC	3,325.43	2003	0.63[23]	0.30	1,000	78	30	36
12	Cameroon Hunting	HC	3,888.83	2005	1.75[24]	1.00	300	78	28	20
13	CAR High Influence	HHI	2,991.23	-	-	0.01	30,000	39	15	>100
14	Cameroon High Infl.	HHI	5,042.06	-	-	0.01[25]	30,000	42	15	>100

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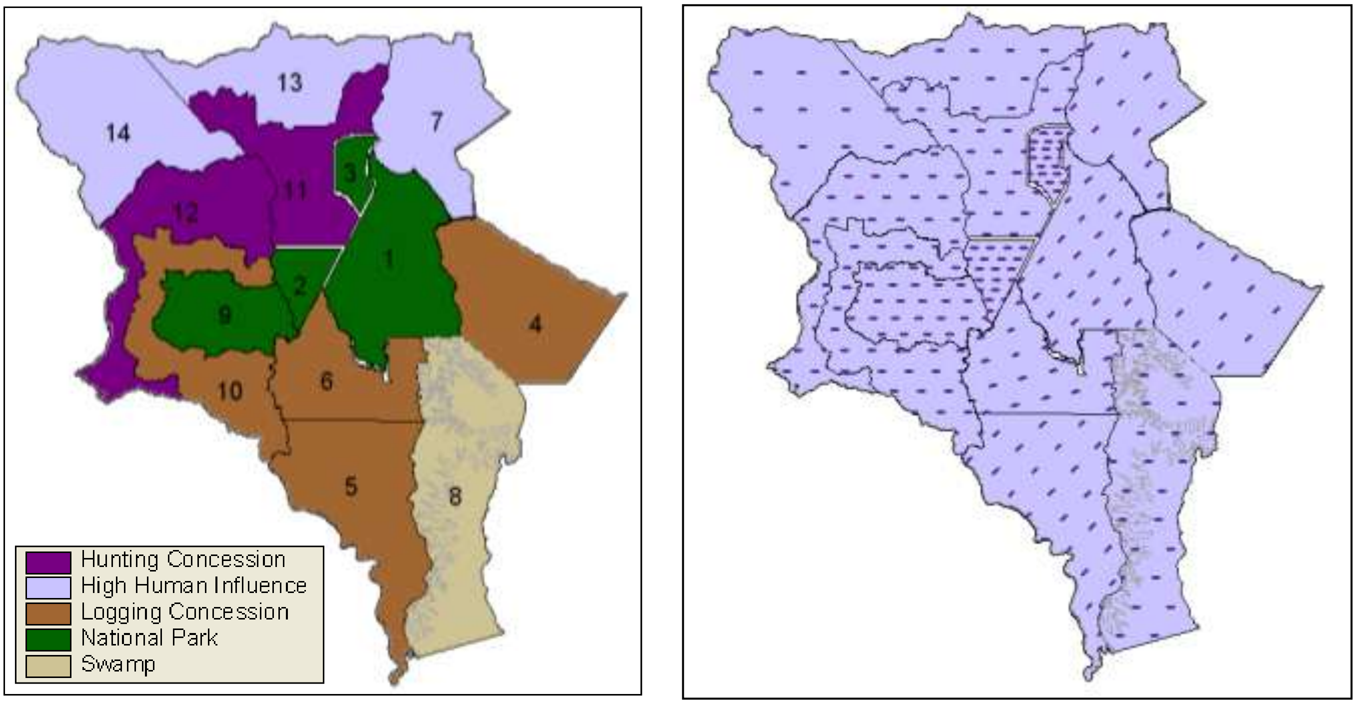
[22] This is an average based on the encounter rates from UFA 100-12, 100-13 and 100-64 that overlap with the Cameroon Logging stratum.

[23] The Dzanga Sangha Special Reserve survey results were used (the SR overlaps in part with the CAR Hunting stratum).

[24] This is an average based on the encounter rates from UFA 100-09 and 100-10 that overlap with the Cameroon Hunting stratum.

[25] During 75km of transect surveys no elephant dung was encountered in UFA 100-08 that overlaps with the high human influence stratum in Cameroon (1 elephant carcass & 2 abandoned elephant paths were observed on recces). Thus, it was assumed that the encounter rate would be very low. A similar assumption was made for the high human influence area of Cameroon, although no survey information was available.

Figure 21: The stratification used for the Sangha Tri-national Landscape design (a) and the possible line transects (b). The survey strata corresponding to the numbers on the map are detailed in Table 11, as is the survey effort, spacing between transects and replication. Note that the grey edge in stratum 8 is the actual boundary of the landscape, which was extended into the swamp areas in the south-east to capture potentially important refuge habitat for the elephants.



APPROXIMATE BUDGET NECESSARY TO ACHIEVE THIS SURVEY DESIGN

An estimated budget is itemised in Table 12. DO NOT DISMISS THESE FIGURES AS OUT OF THE QUESTION JUST YET!! Using rough figures provided by Fiona Maisels from WCS on the relative costs of survey work per line transect per landscape per country, we estimate that realising the survey above will cost ca. **$280,750.** We feel that it no longer acceptable to conduct line transect surveys if we are not going to invest in appropriate studies of decay and production for ape nests and elephant dung, and since we do not have figures to hand on these expenses, we estimate that this will require doubling the survey costs if using the retrospective decay methods of (Laing *et al.* 2003) as suggested in the MIKE dung survey standards of MIKE (Hedges & Lawson 2006). Training costs, which we have shown are absolutely fundamental to collecting analysable data, will cost ca. $80,000 for a training workshop and the equipment needed to complete the survey. Site level coordination and data management will require another $126,000, and coordination and quality control from regional staff will cost an additional $18.833 (not including site visits from regional monitoring staff). All told this comes to a grand total of **$705,833**.

Table 12. Effort and associated budget of recommended landscape scale line transect survey of the Sangha Tri-National Landscape

ID	Stratum	Area (Km^2)	Transects	Expected %CV	Cost per transect	Stratum costs ($)
1	NNNP	4089.05	30	10	$750.00	$22,500
2	Ndoki NP	751.31	22	10	$900.00	$19,800
3	Dzangha NP	499.73	23	9	$900.00	$20,700
4	Loundougou	4228.95	16	38	$750.00	$12,000
5	Pokola	4515.28	24	15	$750.00	$18,000
6	Kabo	2887.82	18	10	$750.00	$13,500
7	Mokabi	3471.16	15	>100	$750.00	$11,250
8	Bailly	5890.74	26	17	$750.00	$19,500
9	Lobéké NP	2160.98	28	9	$1,000.00	$28,000
10	Cameroon Logging	3633.22	32	11	$1,000.00	$32,000
11	CAR Hunting	3325.43	30	36	$900.00	$27,000
12	Cameroon Hunting	3888.83	28	20	$1,000.00	$28,000
13	CAR High Influence	2991.23	15	>100	$900.00	$13,500
14	Cameroon High Infl.	5042.06	15	>100	$1,000.00	$15,000
Total		**$47,376**	**322**			**$280,750**

Ballpark for retrospective nest and dung duration and production rate study	**$280,750**
Total to achieve the 2013-2014 survey	**$561,500**

Training

Initial training course for 20 people	$30,000
Scientific and field equipment for training and survey	$50,000

Landscape level salaries[26]

Monitoring coordinator	$30,000
Team Leaders x 5	$60,000
Assistant team leaders x 5	$36,000

Porters and guides salary factored into transect costs

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[26] Salaries here are estimated over 6 months, because the coordinator will have other responsibilities, and the salary of team leaders and assistant leaders is included in the unit transect cost. The entire salaries of local porters and guides is included in the per transects costs

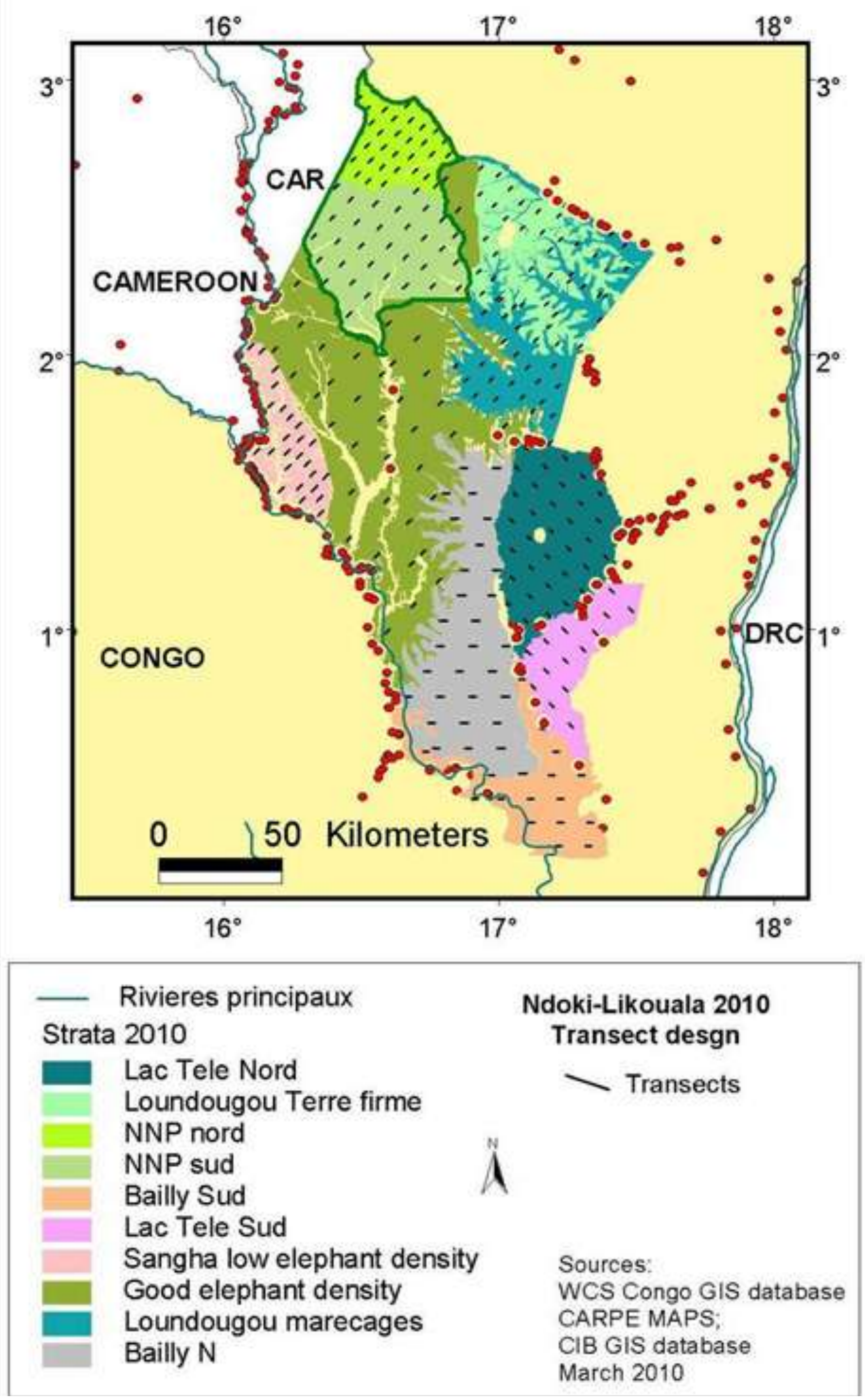
Landscape level monitoring staff	**$126,000**
Regional technical support	
Regional monitoring coordinator	$6,667
Regional GIS database expert	$5,833
RegionalTechnical Advisor	$5,833
Regional Assistance subtotal	**$18,333**
Grand total	**$705,833**

So Can WWF (along with WCS, the main NGO landscape collaborator) afford to do this kind of survey? Three piece of evidence suggests that they can. Firstly, a general rule of thumb is that a project or programme should spent between 10-15% of its budget on performance monitoring (ref). According to figures published on the CARPE web site, budget estimates for the totality of landscape management in the TNS in 2011 was $1,256,400 (which includes USAID funds and matching funds. If we assume that this survey design will be repeated twice over the lifetime of the 2020 CARPO vision (once to obtain the baseline in 2014 and again in 2020) WWF would need $1,412,000 over an eight year period (2013-2020). The total budget at current rates for the TNS over those eight years would equal $10,051,200. Thus the 2 survey conservation target monitoring would cost ca. 14% of the total budget. This is on the steep side, especially considering that other monitoring must also be carried out (at the threats and conservation actions levels, such as LEM), but the costs of these are relatively small to implement.

Taking this a step further, WWF state in their 2020 strategy that by 2015 they will be raising 21,000,000 Euros annually to achieve their conservation targets. Current exchange rates put this at about $27.5 million. If we take this as the mean CARPO budget, from 2013-2020 (eight years) WWF will spend $220 million. If we now take the costs of the TNS biological monitoring plan above and replicate this across all nine landscapes (admittedly a big generalisation, however in the ballpark since TNS is a little below the mean landscape size), the total budget would be $12.7 million over the 8 years, or 5.8% of the total CARPO operations budget. Finally WWF is not in this alone – yet we have said that for ca. 6% of the total CARPO budget full landscape survey coverage can be achieved. WCS has similar management needs, budgets, and monitoring needs as WWF for their landscape segments. Effective cost sharing and partnerships will reduce the WWF contribution to these surveys to roughly half…Our point is clearly not to give hard budget projections, but simply to day that although the numbers sound shocking at first reading, they are WELL WITHIN the capacity of WWF on budgetary terms.

The second piece of information comes from the fact that large sections of this landscape have already been surveyed. All of Dzangha-Sangha was surveyed with similar intensity in 2001, and also in 2011, WCS completed a landscape scale survey involving the TNS and Lac Tele Lac Tumba landscapes (Figure 22) which involved 281 line transects spread out over the landscape. Thus from a technical, logistical, and financial perspective, it is possible – it has been done!

Figure 22: The stratification and transects for the 2011 landscape survey completed by WCS in 2011.



Third, the effort levels we suggest is less than half that expended by WWF for surveys that have already completed. In SE Cameroon, survey teams have put in an astonishing amount of effort in terms of transect kilometres, but the spatial coverage of these surveys across the landscape has been poor, and temporal replication has only occurred in Lobéké. What we are recommending will provide complete coverage of the entire landscape, for a fraction of the effort in terms of number of transects that WWF has already deployed. For example, WWF Cameroon deployed 906km of line transects over four management blocks with a combined area of 6750km^2, whereas we are suggesting an effort level of 497km over an area of 14,725km^2.

The reality is that the data collected so far have very limited value for measuring the effectiveness of management interventions.

Table 13. Effort suggested by recommended survey design compared to the effort already realised by WWF in CAR and SE Cameroon.

TNS sector	Our design Effort (km)	Our Suggested design n transects	Effort (km)	WWF designs completed effort n transects
Ndoki NP	54	22	52	26
Dzangha NP	51	23	52	26
Lobeke NP*	74	28	181	181
CAR non-park	117	45	268	134
Non-park Cameroon	201	75	457	457
Total effort	**497**	**193**	**1,010**	**823.5**

*This is the mean effort of the three surveys (2002, 2006, and 2009).

QUALIFICATIONS AND CAVEATS

This survey was designed based on elephant dung pile encounter rates from previous WWF and WCS data aimed at achieving a 10% CV in at least some survey strata (see Table 9 how inadequate the power to detect changes in the population over successive surveys is likely to be even for this precision). More effort would be required to achieve similar precision in ape abundance. Furthermore, this level of effort will be woefully inadequate for rare species such as bongo and forest buffalo. Other methods, such as fecal DNA or photo-identification based capture-recapture will be necessary for these species, if abundance or other rate parameters are required (or occupancy methods if this state variable and rates of extinction and colonization are viable alternatives in terms of the monitoring objectives). And of course as populations of currently rarer species decline, the cost of monitoring them increases as per our power estimations in Table 9. For species such as duikers and diurnal monkeys, which do not range over large areas, survey designs more geographically targeted over smaller scales than the entire landscape would be appropriate, as long as designs include the usual caveats – i.e. that bias is correctly accounted for (detectability, decay and production rates of sign, etc.). For monkeys there is the additional caveat of extensive training and experience to correctly identify species.

Spatial modeling offers much promise to both increase precision and provide information on how environmental and management related factors, influence spatial patterns in abundance (Walsh & White 1999; Walsh et al. 2000; Walsh et al. 2001; Blake et al. 2007; Stokes et al. 2010; Yackulic et al. 2011). They potentially provide better precision for the same sample effort, which is critical in terms of a monitoring program (or achieve the same precision for less survey effort, saving time and money). The problem lies in the fact that there is no way to evaluate how well the models represent reality – a precise output with estimated strength of explanatory variables could be wildly inaccurate. By contrast, a design-based estimate will provide accurate estimates of population size if the survey methods are correctly applied. In this survey design we have tried to marry the two approaches: effort is adequate in most strata to provide the desired precision, but only just! (and in some strata, no realistic amount of effort would ever be possible). The data would be ideal for spatial modeling techniques because probability sampling is used, and the results of the standard design-based analysis could be used to check the validity of spatial model predictions of density and abundance.

Our example design is specifically geared toward population estimation rather than quantifying the effect size of any particular management intervention. We chose this approach because of the fundamental question of the WWF CARPO strategy. Depending on the management strategy within each landscape and the management context, more surveys could be tailored to evaluate specific management interventions. For example, a specific test of the impact of protection on roads and the distribution of elephants abut roads could be done with appropriate sampling along the distance from road gradient and in areas of varying levels of protection, e.g. none, low, medium, and high levels of protection.

DATA MANAGEMENT

PREVENTION OF DATA LOSS

Biomonitoring data are usually expensive to collect and should be valuable for managing protected areas. The loss of such data means loss of valuable information and wasted funds. Unfortunately loss of data is common and can occur at various stages of the monitoring process. This section discusses the various ways that data can be lost, and how to prevent such a loss. The different types of data loss described here are based on results of interviews with WWF project managers.

DATA LOSS

Researchers generally safeguard their data, that have been collected and collated in field books or data sheets, during the period of field surveys and analyses. These books are the primary source of information and should be properly stored after the survey and analyses have been completed – even when all the data are stored on computer.

Although humidity, insects and rodents can cause tremendous damage to data on paper, computers are not free from problems. This also accounts for handheld computers that are used in the field in combination with the CyberTracker software.

LIMITED LIFE-TIME

Computers have a limited life-time (3-5 years). This especially applies to hard disks. One day they will simply fail to work. Although the hard disk can be replaced, all the data on the old one will be lost if no preventive measures have been taken. Moreover, the harsh environmental conditions in field camps and field stations (such as high humidity, high temperatures, thunderstorms and small insects) can considerably reduce the life-time of computers or their components, and failure always happens unexpectedly! For example, lighting in the vicinity of the offices in Bayanga (CAR) in 2009 damaged various computers and internet equipment. Strong lighting conductors have been installed since then. But it is not a full-proof guarantee - the area around the Bayanga offices was hit twice by lightning in May 2012. Electrical surges heavily damaged switches, ethernet cables and some of the computers that were attached to the network by cable.

Dust can create damage over a longer time as cooling fans in computers draw in air from the outside. Moreover, dust created by logging trucks for example can reach a much wider area than the width of the road. For example, red dust reaches the offices on the road-side of the WWF office in Mambele (Cameroon) which is located some 100-200 meters and partly shielded from the road.

COMPUTER VIRUSES

To date tens of thousands of computer viruses that can affect computers, especially those that use the Windows operating system, have been identified, and each day new ones are created. The time when these viruses were relatively harmless e.g. displaying an unwanted message when the computer is activated, is over. Many viruses will silently delete files and some even prevent the computer from starting-up at all. Modern computer viruses are complex and cannot easily be removed from the hard disk without cleaning the entire hard disk and reinstalling Windows (and all other programs). This can, in the worst-case scenario, result in a total loss of data.

For example, various computers at the Bayanga offices were infected in 2010. Some of these virus infections were simply due to expired licenses or not updating regularly anti-virus software. The latter also depends on the quality of the internet connection as the update may fail during a weak connection. But even some computers with valid licensed anti-virus software were infected (with different viruses), thus that not all anti-virus software was efficient in detecting viruses.

See the section “Prevention” for procedure that can reduce virus infections.

“PRIVATE” DATA

Data from ecological surveys that have been carried out by external researchers (e.g. PhD students) can also be lost when those researchers consider these data as “private” and do not make these data available until results have been published in a thesis and/or in scientific journals – often several years later. It is often difficult to trace the original data when researchers have left the field site.

This type of loss also applies to staff who have used their private computer and leave without leaving data copies behind.

THEFT

Laptops and notebooks are convenient for travelling, whether from office to home, field site or to a meeting abroad. In many places it is also the only type of computer that is used by individual staff. However, this convenience of light-weight computers also makes them more prone to theft (during travelling) than a desktop in a locked office. A big complaint by new staff in the Tab Tumba site was that no biological monitoring data, either in paper or electronic form, were present at the field site.

LACK OF META-DATA

Data files stored on computers or hard disks which are used as an archive often have cryptic names and file structures with no additional information (meta-data) that reveals the origin, version, location or even species involved. Such naming systems ensure that even that the person who created the files cannot accurately identify these files several years later (when the data needs to be used in retrospective studies).

Cryptic file names can also lead to unintentional removal of files during activities such as freeing up space on a hard disk. Such files may be identified as non-important when meta data are missing.

An good example of this comes from one of the most important datasets ever collected in the Gamba Complex in the late 1990’s. The first extensive survey over much of the complex was carried out, analyses were conducted and several peer reviewed papers resulted from the work. However the data that WWF managers have that came from that excellent survey are almost completely indecipherable.

Understand the data would require finding the people who did the surveys and entered the data, and going through the data column by column, and even then it is likely that many problems with the data would remain unanswered.

PREVENTION

Several measures can be taken to prevent (or at least reduce) loss of data stored on paper and/or computer whether due to hardware failures, virus attacks, theft or 'disappearing' data.

PHOTOCOPIES

Copies of pages of field of notebooks can be made by a photocopier – if available – when returning from an expedition. But again the copy is on paper. Furthermore, photocopies may produce faint copies that are difficult to read. Moreover, such copies are made after returning from the field. Highest chances to lose a notebook is especially when in the field. A good choice is to use a water-resistant digital camera to make a photo of the field notes every day after finishing a survey. But don't leave it with a copy on the camera. Make sure these photos are uploaded to a computer once back at the (field) offices.

BACKUP

The most important measure to prevent data loss is making a backup of the dataset on an external hard disk, second computer (local archive) or CD and DVD.

It is strongly recommended to make regular backups during the period of entering data as hardware failures and virus attacks can happen unexpectedly. Therefore, do not wait until the last transect data have been entered. Make a backup after every day's work. Note that computer programs can also crash and corrupt the data. A recent backup copy will minimize such loss.

GPS readers are small computers and thus can – though more equipped for field conditions – fail. Ecological survey protocols generally recommend also writing important GIS coordinates in field books and/or uploading these data to a computer on a daily basis (or at least when returning from a field trip). Do not forget to backup the computer after uploading GIS data.

The previous also refers to handheld computers, even the rugged ones, as used with CyberTracker.

ANTI-VIRUS PROGRAMS

Many users are not aware or ignore the malicious effects of computer viruses. But viruses are nowadays perhaps the most common cause of data loss. Given the vast number of viruses that have been created, there is a great risk of infection when preventive measures are not taken. Therefore it is essential to install an anti-virus program.

Given that new viruses are created almost every day, it is equally important to update – preferably daily – these programs with the latest protection measures. Some of these viruses are created with the assumption that many computer users forget to update regularly. They take over the control of the anti-virus program and let the user 'believe' that the anti-virus program has been updated. Meanwhile the virus continues to cause damage. Installing an anti-virus program or updating after a virus has infected a computer is therefore too late!

The detection of computer viruses differs per anti-virus program. Since this quality aspect can change over time it is strongly recommended to ask advice of the IT department at WWF-CARPO. One of us (FP) has experienced that old viruses showed up in a modified version and were not detected by most anti-virus programs. The main reason that this virus could continue was because no one informed the vendor(s) of these programs of the existence. Thus informing these vendors is essential.

The vast majority of viruses target computers running the Windows operating system. The major reason is that Windows is widespread among home users who often – with lack of IT support - are not always aware of the serious threats of viruses. Both the popularity of Windows and this large user group make it 'attractive' to virus developers. This does not mean, however, that users of Apple computers with the Mac OSX operating system (or computer running Linux) should ignore anti-virus programs.

E-mails can include attachments which are infected with a Windows based virus. Although such a virus does not affect an Apple or Linux computer, forwarding the e-mail or later sending the attachment to a Windows computer transfers the damage too. Therefore, users of these operating systems should install an anti-virus program to prevent distribution of Windows based viruses. Furthermore, given the increasing popularity of both Apple computers and Linux based computers it is only a matter of time before someone manages to create a damaging virus.

SECURITY UPDATES

It may be clear that developers of Windows, Mac OS X and Linux implemented software that prevents viruses (that are new or not detected) to breach the security of their operating systems. But unfortunately this a constant battle as those who create computer viruses look for weaknesses. Therefore, it is important to download (often automatically) the latest security updates from Microsoft, Apple or Linux vendors.

USB MEMORY STICKS/DISKS

USB memory sticks are convenient to store files as a (temporary) backup medium and/or to transfer files between computers. The latter has become a source of virus infections as they are not always scanned for viruses. Since the capacity of USB memory sticks has dramatically increased, 16 and 32 GB are almost standard, it takes several minutes to scan these disks. This waiting time is felt like a 'nuisance' for simply transferring a single file. Therefore, many people disable this option in the anti-virus program (or are not aware whether the program disabled this option). A USB stick that has been used on a virus infected computer can contain a small program that is automatically passed to another computer that has virus scanning of USB sticks disabled. In the worst case this enables a virus to detect and disable the anti-virus program! The same problems count for USB hard drives which now can hold easily 2 TB and are used as backup drives. Scanning these disks can take considerable time, and the best prevention is not to use them to transfer files between computers. And in the case one needs to transfer a large amount of documents: SCAN FIRST!

COMPUTER QUALITY

Most computers are manufactured to function under moderate temperatures and lower levels of relative humidity. A rule of thumb is that computers do well under conditions that are being considered 'comfortable' for humans. These climate conditions are certainly not met at field sites and non-air-conditioned offices in tropical rainforest regions.

Do not save budget on computer quality. Cheaper computers may work well under moderate conditions but are more likely to fail under higher temperatures/humidity. The more expensive range of computers generally use higher quality components that are more likely to cope with extreme climate conditions. Contact the IT department at WWF-CARPO for information on preferred brands and models.

MEMORANDUM OF UNDERSTANDING

The availability of data can be – as mentioned previously – difficult when ecological monitoring has been carried by external researchers without direct or indirect involvement of WWF. However, it would be fair to state that external researchers could carry out their independent studies thanks to the effort and investment of WWF to protect the area which has become 'the study site'. Furthermore, they may hire trackers and field guides who have been trained by or who are WWF staff.

This means that external researchers would be obligated to provide managers of protected areas with copies of their relevant data and results, including sufficient meta data to interpret raw results on the short term i.e. before publication. Clearly the work of the researchers need to be respected but not to the detriment of the protected area. Thus unpublished data and results that have been provided should not be published without approval.

It is recommended to develop a standardised Memorandum of Understanding with regard to data sharing and uses for external researchers who carry out a study at WWF sites.

REGIONAL ARCHIVE

Raw data as collected during previous ecological monitoring are not available i.e. missing for various WWF sites. The reasons for this loss of data have been discussed in the section "Prevention of data loss".

Creating a regional archive on a computer (server) placed in a secured and air-conditioned environment, either at the WWF CARPO office in Yaounde or at an external (internet) provider is an important step in preventing data loss. A mirror site in Europe or the USA should also be installed as a third backup.

A regional archive does not only serve as a backup of data for field sites (and as an extra backup for national offices), but also serves as a resource for ecological research. To date, researchers who intend to study population trends in the GHoA region require to contact each single project site to acquire raw data. A regional archive would stimulate a more proactive approach in studying trends by making data available in a single location.

This section discusses the use of Google Docs and a regional server for a regional archive purposes. Google Docs is already used by WWF and therefore it provides an easy short term solution. WWF CARPO is in the process of installing a regional server at their office in Yaounde (Ahmadou M. Bello, pers. comm).

GOOGLE DOCS

Google Docs can be best described as an on-line "office suite" which includes a word processor, spreadsheet and presentation program that are compatible with Microsoft Office. These documents can be stored on-line. Furthermore, documents can be uploaded from personal computers and stored on-line, as can they be downloaded. Documents stored on-line can be shared with others who have a Google account. The owner of the document has full control whether documents are shared and can be edited. Google Docs is available for private users and organisations (with adopted features).

WWF uses the services of Google for both e-mail and Google Docs. This allows to easily share documents between employees. It seems logical to use the WWF/Google Docs services as a shared archive for biomonitoring and patrol data and reports.

A basic folder structure to upload survey data for each WWF-CARPO/GHoA site has already been created for this consultancy. This system could easily be extended to a collection per WWF site. Each of these site-specific collections can be subdivided in, for example, monitoring, patrol and report data.

Figure 23 presents an example of such a directory (collection) structure. These site collections can include backups of MIST and/or CyberTracker databases (i.e. files with extensions .FDB and .CTX, respectively) for ecological monitoring and patrol data. Excel compatible spreadsheets which contain subsets of data that can be imported by analyses programs such as Distance and survey designs are included as well.

Information on data and document files on Google Docs can be provided as meta data in a simple document or spreadsheet file. Information on each file is stored in a single line. For example:

Date	Country	Site	Description	File name
20120301	CAR	APDS	Survey design	Monitoring/APDS_Survey.DST

Figure 23: Example of directory/Google collection) structure of a CARPO archive on Google Docs or regional server.

```
BioMonitoring
|   MetaData.doc
\---Country
    \---WWF Site
        |
        +---Monitoring
        |   |   Distance survey design 2011.DST
        |   |   Line transect data 2011.XLS
        |   |   Monitoring.CTX
        |   |   Recce data 2011.XLS
        |   |
        |   \---Distance survey design 2011
        |           DistData.MDB
        |           Transect.DBF
        |           Transect.PRJ
        |           Transect.SHP
        |           Transect.SHX
        |           WWF_Site.DBF
        |           WWF_Site.PRJ
        |           WWF_Site.SHP
        |           WWF_Site.SHX
        |
        +---Patrol
        |       MIST.FDB
        |       Patrol.CTX
        |
        \---Reports
                Patrol 2011.PDF
                Survey 2011.PDF
```

Since Google Docs supports on-line editing of both Excel and Word documents new information is added directly on-line to a single (shared) meta data file, which resides in the main Biomonitoring folder on Google Docs. This on-line editing avoids the problem of having multiple copies of different versions of the meta data file.

SHARING DOCUMENTS

The archive as discussed above is based on sharing documents that are stored on-line. Google Docs provides full user control of who have access to folders to read and/or to edit documents within it.

Those who have been granted access, will see for example the Biomonitoring folder (which is owned at WWF-CARPO level) as a “Shared Collection” when they logon to Google Docs.

GOOGLE DRIVE

Google will replace Google Docs with the Google Drive suite. A major new feature is the option to synchronise documents between computer and on-line version, i.e without specific instructions to upload/download documents. Furthermore, Google Drive will use the term “Folders” - as used in Microsoft Windows – instead of “Collections”.

REGIONAL NETWORK SERVER

A network computer (=server) based at the WWF CARPO office in Yaoundé could be used as a regional archive for raw data, analyses results and reports. The same structure as described for Google Docs in the previous section could be applied (see Figure 24).

The most basic communication between server and local computers i.e. download and upload files could be based on a (secure) File Transfer Protocol (FTP) over the internet. The shared directories and files on this server can be accessed through Web browsers, special FTP programs or through defining a network drive on which refers to the FTP address. In the latter case, the shared data are 'integrated' and show up as if they are on a local hard disk.

USER INTERFACE

Communication with the regional server through FTP is efficient for uploading and downloading files, but this protocol is not user-friendly. For example, updating the meta information in the archive requires first to download the MetaData file, and then, after adding the information by the owner, upload it again.

Developing a website would benefit user-friendly access to the regional archive (similar to Google Docs). This website could include a special page for uploading files which includes a form in which meta information is entered. Data forms can ensure consistency, e.g. pick-up lists, in entry of meta data, especially when used in combination with a Relational Database Management System (RDBMS).

SEARCH ENGINE

The demand for a search engine increases as the number of files in the archive grows. A great advantage of a relational database system is its inherent search facilities which makes implementation of a search engine relatively simple. In this, the data entry form can already serve as a simple search form.

Figure 25 presents an example of a SQL database scheme for database “search_engine” to store meta data. Table “meta_data” holds the main data. It includes a look-up link (=relation) to table “location” (WWF project sites) which includes a look-up link to table “country”. Look-up links ensure that data are entered – and therefore being searched – in a consistent way.

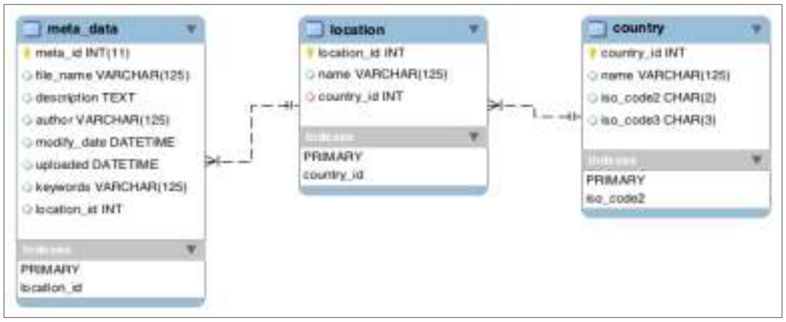


Figure 25: Relational SQL database model for WWF CARPO search engine.

It is strongly recommended to use a RDBMS which supports the Structured Query Language – SQL This shouldn't be too difficult as the SQL language is a standard within both major commercial and open source database products. This means that a database structure developed in one product can easily be ported - including data - to another product, even on different operating systems.

The following paragraph shows the generic commands to create the databases system as presented in Fig. 2:

```
CREATE DATABASE `search_engine`;
USE `search_engine` ;

CREATE  TABLE `country` (
  `country_id` INT NOT NULL ,
  `name` VARCHAR(125) NULL ,
  `iso_code2` CHAR(2) NULL ,
  `iso_code3` CHAR(3) NULL ,
  PRIMARY KEY (`country_id`) ,
  UNIQUE INDEX `iso_code2` (`iso_code2` ASC) );

CREATE  TABLE `location` (
  `location_id` INT NOT NULL ,
  `name` VARCHAR(125) NULL ,
```

```
  `country_id` INT NULL ,
  PRIMARY KEY (`location_id`) ,
  INDEX `country_id` (`country_id` ASC) );

CREATE  TABLE `meta_data` (
  `meta_id` INT(11) NOT NULL ,
  `file_name` VARCHAR(125) NULL,
  `description` TEXT NULL DEFAULT NULL ,
  `author` VARCHAR(125) NULL ,
  `modify_date` DATETIME,
  `uploaded` DATETIME NULL,
  `keywords` VARCHAR(125) NULL ,
  `location_id` INT NULL ,
  PRIMARY KEY (`meta_id`) ,
  INDEX `location_id` (`location_id` ASC) );
```

The website as mentioned in the previous section is also used to embed the search engine and to access the database with meta data.

RECOMMENDATION

Since Google Docs/Drive is already available to all WWF employees it is strongly recommended to maintain using this system as an archive for raw ecological survey data on the short/mid term.

Development of a database with search facilities is recommended when storage of data on a regional network server is preferred.

MONITORING SOFTWARE

CURRENT SOFTWARE

MIST VERSION 2

The “Management Information System” (MIST) database system was developed by Deutsche Gesellschaft für Technische Zusammenarbeit – GTZ to support the Ugandan Wildlife Authority(Schmitt & K. 2002).

MIST has been adopted by the CITES - Monitoring of the Illegal Killing of Elephants (MIKE) program to register data on elephants (live, carcasses) and patrol effort as observed during patrols.

The MIST database system can be installed both as a stand-alone program on a single PC or as a server program in a local network. Data between two or more MIST databases on different computers (or networks), e.g. at local site and national/regional office, can be synchronized. The MIKE programme office uses this feature to collect, store and update data from different sites.

Location data (waypoints) from GPS receivers can be uploaded to MIST and form the basis of records of a single patrol. However, all attribute data need to be entered manually.

The MIST program offers a large variety of reports such as overview reports, calculation of patrol effort and encounter rates. Furthermore, geographic maps of waypoints of patrols and observations, that are (optionally) projected on existing GIS layers e.g. park boundaries, roads, vegetation map, can be created by this program.

CURRENT USERS

The MIST program is used already in MIKE sites across Africa to record law enforcement data, and observations on large terrestrial species and human activities during patrols.

WWF-CARPO is committed to have the MIST software installed for law enforcement at all their project sites within the GHoA region.

The following WWF-CARPO project sites are currently using the MIST software:

Boumba Bek and Nki National Parks (Cameroon), Dzanga Sangha Protected Areas (CAR), Gamba Complex of Protected Areas (Gabon), Minkebe – Mwagna Program (Gabon).

The following sites are planning to implement MIST:

Campo Ma'an (Cameroon), Lobeke TNS Landscape (Cameroon) and the Coastal Forest Programme (Cameroon).

TECHNICAL DETAILS

Availability: freeware (not open source); can be downloaded from <http://www.ecostats.com/software/mist/mistdownloads.htm>

Database system: Firebird SQL relational database system, which is an open source version of Interbase.

GIS system: ESRI shape files.

Programming Language: Pascal (compiled source)

Modifications: as closed source modifications can only be made by original developer(s).

Operating system: Windows 2000, XP and higher; Linux

CYBERTRACKER

The CyberTracker software was developed by Louis Liebenberg and Justin Steventon in 1996. Development of this program was initiated by the wish to capture “the art of tracking animals” by Kalahari bushmen, and other indigenous people (for example Aka Pygmies). Since especially older trackers – who are most experienced – in these groups maybe illiterate, the CyberTracker software is heavily based on using symbols, rather than text, to enter data.

The CyberTracker software consist of (1) a main program with a database to store data on a PC, and to generate various reports, and (2) data entry forms that are installed on devices such as rugged pockets PCs and smart phones with GPS receivers. These devices are use used to collect waypoints and to enter attribute enter data in the field (see http://www.cybertracker.org). These data can be directly uploaded into CyberTracker. This means that the process of manual data entry from field notebooks to computer, which is prone to introduced errors due to misspelling and inconsistency in names and transcription errors, is not necessary.

CyberTracker is freeware, but it comes without a so-called 'application' i.e. database fields, data entry forms for the handheld computers. Users have to create their own application using the various examples and demos. The demo 'Wildlife Application' contains all elements to carry out recces and line transects (including dung) but is geared for savannahs. However, applications for the Central African rainforest exists and have partly be developed by WWF-CAMEROON staff, who are proficient users (see current users).

Data in CyberTracker can be exported to Excel spreadsheets or to text that can be used as import data for the program Distance using view filters (search criteria). View filters allow to restrict export of data to specific species, dates, type of survey etc. GIS data in CyberTracker are plotted on top of user supplied ESRI shape files (e.g. park boundary, rivers and streams) and/or on Microsoft Virtual Earth, when an internet connection is available. These data can be exported as ESRI shape files and to Google Earth (“kml”) files.

CURRENT USERS

WWF-Cameroon uses a customized “patrol” application in CyberTracker for recording and storing law enforcement data. These data can potentially be exported to MIST.

Dr Zacherie Nzooh (WWF/Lobeke NP) has created a CyberTracker application “Inventaire Faune” that is used to record/store data from recce's and line transects. These data can be exported to Distance.

CyberTracker is rarely used outside projects in Cameroon (i.e. within the CARPO region). A major reason is that the available field equipment i.e. Palm tops when this software was released were not suitable for the harsh conditions (humidity and shockproof) in the field. Furthermore data loss occurred when data were not uploaded before batteries lost power (Zacherie Nzooh, pers. Comm.). However, these limitations do no longer exist with the introduction of rugged handheld computers (the Recon Geneq is used in Lobeke NP). Data are stored on memory cards which eliminate data loss due to battery failure.

TECHNICAL DETAILS

Availability: freeware (not open source); can be downloaded from <http://www.cybertracker.org/>.

Database system: Microsoft Access

GIS system: Microsoft Virtual Earth, ESRI shape files, Google Earth.

Programming Language: Pascal (compiled source)

Modifications: the main program cannot be modified, however the program is developed as a tool to customize data entry forms (modules) and reports.

Operating system: Windows 2000, XP and higher.

EXCEL SPREADSHEETS

Ecological survey data within CARPO (line transects and recces) are primarily stored in Microsoft Excel (or compatible spreadsheet programs). The main reasons are that most field technicians are comfortable using spreadsheets, they are ubiquitous, and data stored in this format can be easily exported to analyses programs like Distance.

Although data entry in spreadsheets tables is convenient, this method embeds various problems that make use for analyses difficult, especially when collating data from different spreadsheets,.

Typing error while transcribing field data is one of the most serious problems. For example, a digit difference in GPS data may place observations outside the survey area. Furthermore, misspelled names of species and locations make it difficult to extract the correct data for analyses.

Different teams often use their "own" spreadsheet designs such as column names, order of columns, data format Furthermore, the large amount of data that need to be entered stimulates to using coding systems that are, without clearly described meta-data, difficult to interpret by others Individualised codes for attributes are common within CARPO (one site may use lox to mean elephants, while another may use elephant, etc.)..These differences also have a serious impact on comparing data without extensive "cleaning".

Recce and transect survey data that were made available for this consultancy included the whole range of problems that make sharing data and/or using data for further analyses such as in Distance either impossible or demanded a lot of time to "clean". Therefore, tips for properly using spreadsheets will be discussed in a separate section.

NEW DEVELOPMENTS

SMART

The Spatial Monitoring and Reporting Tool (SMART) program is currently being developed by a consortium of conservation NGOs (Frankfurt Zoological Society, North Carolina Zoo, Wildlife Conservation Society (WCS), World Wildife Fund (WWF) and Zoological Society of London (ZSL). SMART has it uses its own database system, but will be able to use MIST data.

The first official release of SMART version 1.0 is planned for December 2012, but beta versions are already available. The first version is focussed on law enforcement. Implementation of ecological survey data (transects) has been discussed by the development committee and may be included in later releases (Emma Stokes, WCS, pers. Comm.). An option to upload data from high-end GPS receivers, as implemented in CyberTracker, is scheduled to be included in the next release (expected 6 months after the first release (see SMART website)

A workshop to train trainers is scheduled for September 11-15, 2012 in Pretoria (South Africa) for SMART partners.

TECHNICAL DETAILS

Availability: open source; Beta (test!) versions can be downloaded from the SMART website. <http://www.smartconservationsoftware.org>

Database system: Apache Derby SQL database; access to MIST database through Firebird JDBC (Java Database Connector) driver

Program language: Java

Modifications: since SMART is open source new functionality can in principle be added by users with knowledge of Java.

Operating systems: cross-platform, but current beta versions are compiled for Microsoft Windows only; the final first release will be available for Mac OS X and Linux.

MIST VERSION 3

Ecological Software Solutions, who developed MIST, is currently re-writing MIST (version 3), as part of the "Protection Area Management Information System" <http://www.pamis.org>. MIST 3 is being developed as open source.

This new version is programmed in the Python interpreter language (open source and cross-platform) and uses the Firefox browser as graphical user interface (GUI) to enter data and to generate reports. It uses the same database system as implemented in the previous MIST versions.

TECHNICAL DETAILS

Availability: open source; can be downloaded from < http://www.ecostats.com/software/mist/mistdownloads.htm>

Database system: Firebird (see MIST 2)

Programming language: Python version 2.7

Operating systems: Microsoft Windows and Linux (and potentially Mac OS X).

RECOMMENDATIONS

The MIST program is being used by several WWF-CARPO project sites. An important aspect is that training has/is been provided at workshops, even some on-site e.g. in Dzanga Sangha in 2010, in combination with the CITES/MIKE program. However, MIST was developed through GTZ in 2001/2002 as a total management system – including data on tourist activities and revenues, for the Ugandan Wildlife authorities. Although MIST is freeware, modifications could only be made through its initial developers. Meanwhile a group of NGO's, which includes WWF, have started development of a new program called SMART that extends on missing options in MIST.

MIST is currently redeveloped under an open source ("Artistic") license. Nevertheless, it is likely that SMART is becoming the successor of MIST within the WWF-CARPO region for law-enforcement data, as WWF has been committed to the development of this software and the initial workshop to train trainers.

Both MIST 3 and SMART do currently not provide extensive support for entering and managing data that have been collected from ecological surveys (transects, mark/recapture). Implementation of an ecological survey module into SMART is being discussed. However, the timeframe for the actual implementation is not known at the time of writing this report.

Given the problems that have been encountered with spreadsheets for data entry of ecological surveys, the main recommendation is to use software that is based on relational database systems. The CyberTracker software is currently, until SMART is a full-fledged program, being recommend to be used for data collection and data storage of ecological surveys.

The combination of symbol-driven data entry on handheld devices in the field, its flexibility to customize surveys, to generate reports, data export options, and ready available "applications" for both recces and (line) transects, make it currently superior above other programs. Furthermore, the WWF-Cameroon staff at project sites have already experience with CyberTracker. They can assist in training both researchers as field-teams in using the combination of data entry and manipulation

Training:

workshop for those who will use the CyberTracker PC software i.e. use of the symbol driven hand-held devices, and use of standardised applications (either those from Dr Zacherie Nooz, or modified versions from templates)

Training of field staff could be carried out on-site. This staff could later train eco-guards when SMART has implemented these handheld PC features.

Costs of rugged PCs recommend by CyberTracker:

Trimble Juno handheld computers with GPS, digital camera, bluetooth and wireless starts at US$ 749. The top end model SC has cellular phone and extra protection (OtterBox case) costs US $1199.

SPREADSHEETS

Microsoft Excel and other – compatible - spreadsheet programs are widely used, as they provide data entry in a tabular form, to store biological monitoring data. Microsoft Excel is ubiquitous in WWF CARPO – with one exception – line transect from Alard Blom's survey work in Dzanga-Sanngha, every dataset we were given was in MS-Excel. MS-Excel is intuitive, powerful, and used for a variety of normal operations within organisations. Analytical programs like Distance and other commonly statistical packages (Minitab, SPSS, Genstat, Statistica) can either directly import spreadsheet files or read spreadsheet files that have been saved as plain text files in which columns (fields) are delimited by a character e.g. semi-colon, tab, comma or space. Various Geographic Information System (GIS) programs, like ArcGIS and QGIS, and more specialist statistical programs like R, can also import data from such field delimited text files. It is, therefore, not surprising that mainly Excel spreadsheets have been used for ecological survey data in the WWF-CARPO/GHoA region.

The majority of spreadsheets we received for analyses contain data that were entered manually from field notebooks. Spreadsheet programs are very flexible in data entry, but, consequently, offer limited options for data validation – users are free to organize fields as they see fit, and determine their own nomenclature for data. This also means that data entered manually are prone to typing mistakes (e.g. "elephnat") and inconsistencies within the same data-set (e.g. "forest elephant", "ele", "loxo"). These errors and inconsistencies are a problem when data need to analysed within Excel or other software programs: an "elephant", "elephnat" or "ele" are interpreted as different species. Ecological surveys can generate large amounts of data that need to entered in a spreadsheets. Coding of longer names (e.g. abbreviations) is often used in an attempt to reduce the workload or to add consistency. However, these data become obscure whenever explanations (metadata) are missing. Even those who entered the data may not always remember the original names after several years.

Within and across programmes the potential for minor (and major) differences in spreadsheet data for what should be standardized methods is mind boggling. To illustrate, , some of the following issues were encountered with the datasets received:

1. Column names and locations within spreadsheets were often completely different
2. Many different heading names for the same data, e.g. latitude was given as Lat, Lat DD, and Latitude
3. Latitude and longitude were expressed as decimal degrees or degrees minutes and seconds.
4. Decimal points were sometimes expressed as commas when entered by francophones, and as points by anglophones.
5. Dates and times were given in different formats, sometimes together, sometimes separate.
6. Numerous different codes were given for a single datum, e.g. an observation of elephant sign was given as e, ele, elephant, lox, Elephant de Foret. In some cases, particularly in DR Congo, local names were used with no key available to translate into the scientific name.
7. Perpendicular distances of objects from the centerline of transects were given in metres, centimetres, centimetres with a plus or minus sign to indicate which side of the centerline they were found on, some included the units within the cell (ie +138.5 cm) while others were a simple number.

The list could go on and on. The point here is that while any given technician may understand their own data (though in the almost complete absence of metadata of any kind, this will rely on memory which is notoriously inconsistent) and analyse them locally, the task of combining these data into a coherent format for a regional analysis as we have attempted to do here, is gargantuan in scale. Simply to achieve complete consistency in the data received from across the CARPO sites in preparation for analysis would have taken months of work. And data consistency is a fundamental step in combining datasets – there is no way around it.

Spreadsheet programs offer many options to make a table look attractive in print or in a presentation. While borders and lines are discarded when exporting to delimited text files, special characters and summary data (e.g. total count, mean, variance) are included. These features embed the risk that data become unreadable for analyses programs, and, consequently, require extra time for cleaning. Moreover, preliminary analyses such as summarizing data in pivot charts, sub-totals, or graphs are easy to perform in spreadsheets with the result that a single data table can quickly proliferate into many worksheets within the workbook, each showing a summary table that may or may not be meaningful. Where the original raw clean data are located may be known only by the data owner. These and similar issues can render data in spreadsheets almost unusable for all practical purposes unless special attention is paid to data formats and consistency at an early stage.

The following section will provide guidelines to ensure that raw data that has been entered in spreadsheets can also be imported by analyses programs.

GUIDELINES FOR DATA ENTRY

THE COMPUTER ALPHABET

The basic computer “alphabet” is the American Standard Code for Information Interchange (better known under its abbreviation **ASCII**). The ASCII character set consist of 128 characters, of which 96 are printable i.e. 0-9, a-z, A-Z and characters such as “#$%^&*()”.

There are various extensions to the ASCII dataset in order to print e.g. Arabic, Greek, Latin or even Khmer characters. However, many analyses programs assume the basic ASCII character set and have difficulties reading text that have special characters as e.g. **é** or **λ**.

Using ASCII characters for naming columns and for text in rows is still the best bet to make sure that these data can later be imported in an analyses program.

GEOGRAPHIC INFORMATION

Human readable text format of geographic coordinates that include the degree (°), minute (') and second ('') signs (e.g. 1° 23' 45'') cannot be interpreted by most GIS programs. These programs require that geographic coordinates are presented in numerical (decimal) format. The decimal representation of a coordinate in degrees can be calculated as:

degrees + minutes/60 + seconds/3600 .

For example, the decimal format of coordinate of 1° 23' 45'' is 1 + 23/60 + 45/3600 = 1.39583.

Since GIS programs expect numbers, north/south of the Equator and east/west of Greenwich are indicated with +/-. Note: the + sign is not required to indicate north or east.

DATE AND TIME

Spreadsheet programs store date/time internally as numbers of days (and fractions thereof) that have passed since a specific reference date (e.g. Microsoft Excel uses January 1st, 1900 as a reference). This approach prevents ambiguity that can occur between European (day-month-year) and American (month-day-year) date formats (e.g. is 01/08 August, 1st or January, 8th?). This is especially relevant within the international context of conservation.

The importance of this date/time system is that the correct date will not change when spreadsheets are used on different computers (with different language settings). Furthermore, date/time can be presented in whatever format the user prefers.

Spreadsheet programs automatically convert date/time entries to numbers according the language (country) settings of Windows or (overruled) by general settings of the spreadsheet program. Date entries that do not comply with those settings will either be wrongly converted or interpreted as text.

The safe way to enter date/time manually is to pre-format cells or columns using the name of the month as it provides some basic date validation. For example, a date like 31/12/2011 will be displayed as 31 Dec 2012 when European date settings are used, or as a text string when American settings are used (and vice versa).

VALIDATION OF NAMES

Most spreadsheet programs have implemented a feature that will recognize previous entries in columns to provide consistent data entry. This feature works fine unless the first entry of a name contains a typing error. Excel and most spreadsheet programs provide a feature that enables to select a name from a pre-defined drop down list. This feature can means that only the data types from the list may be entered, so for an elephant dung observation, there is only one possible datum option for entering the datum “elephant”. Furthermore, the necessity to use codes or abbreviations to speed up data entry is no longer necessary.

ORGANISING SPREADSHEETS

Analysis programs “expect” raw data to be organised in a consequent format and, in general, to be categorised in columns. Any data file that does not cohere with these requirements will either be rejected or, worse, interpreted wrongly. This also refers to data that are exported from spreadsheets.

The most important recommendation is to keep a spreadsheet with raw monitoring data as plain as possible i.e. the first row contains column headers in ASCII, all other rows contain data in the same format.

Do not include any other information such as summary statistics and/or meta data in this spreadsheet as this will be interpreted as extra columns and/or rows by analyses programs.

Spreadsheet programs allow to create multiple (spread)sheets in a single file. This feature is useful to create a separate sheet that includes any relevant meta-data such as a coding table. Although a separate sheet could be created for summary statistics and other calculations, it is strongly recommended to use a copy and keep raw data and relevant meta-data in a separate data file.

Whatever WWF decides on this issue should be rigorously enforced across all sites in the network. Distance is currently the main program that is used to analyse data from line and point transect surveys. Therefore, it is recommended to use the same column names and order of columns in spreadsheets as described for data import in the Distance manual (Thomas *et al.* 2009).

SPREADSHEET OR DATABASE?

Spreadsheet programs have primarily been designed to create data tables (organized in columns and rows) for the purpose of calculations, statistics and/or presentations. They are flexible in the type of data (dates, numbers or text) that are to be entered. However, the power of flexibility means that spreadsheet programs are not ideal with respect to data consistency and data validation. This weaknesses can be reduced by the guidelines as presented in the previous sections.

Standardisation of data entry within the WWF-CARPO/GHOA region is important to facilitate comparative analyses, either between sites or combined sites. However, merging spreadsheet data embeds the risk that the limit that programs can conveniently handle are reached. For example, merging line transect data from project sites in Gabon resulted in a spreadsheet with nearly 27,000 rows while the Gabon recce data used 87,150 rows. Although recent versions of Microsoft Excel and OpenOffice can handle over one million rows, manipulating such large data-sets are likely to be near impossible. Spreadsheets are simply not designed to store large amounts of data.

On the other hand, database systems are developed to store, query and to manipulate large amounts of data e.g. surveys from different areas and different periods of time. Equally important is that relational database system provide structured designs in which static data such as taxonomic names, locations and transects are included in special tables that serve as pick-lists. This offers consistent data entry and validation of data.

The majority of relational database systems use the Standard Query Language (SQL) for adding, modifying or querying data. The SQL language is very powerful in performing complex queries involving multiple tables and condition. For example, the question “*select all line transect data on fresh dung of forest elephants that were less than 2.5 meter from the line and that have been collected in all sites by Zachari Nzooh during the period 1 Jan 2000 – 31 Dec 2004*” can be transformed into an SQL query. The result of this query can then be exported to a text file in order of columns as used in for example Distance.

The more powerful database systems can be considered as an 'engine' that runs in the background on a computer (whether PC or server computer at another location). The data in these databases are not directly readable by humans, and, thus, require other programs to communicate with the 'engine' to visualise these data. This is not different from spreadsheet programs as the actual data file is generally unreadable in a simple editor such as NoteBook. However, a spreadsheet program - with its limitations – offers an all-in-one package i.e. the spreadsheet program is the data-entry form and report.

The standard programs provided with database systems, especially those in the open source domain like MySQL, PostgreSQL and SQLite, are either command-line utilities and/or graphical programs that require knowledge of SQL. These programs do not in general support development/use of data-entry forms and customized reports. CyberTracker, MIST and SMART use (SQL) database systems and are customized at the level of monitoring whether through patrols and/or surveys. It means that the “ingredients” to use databases for ecological monitoring exist.

ECOLOGICAL SURVEY DATABASE

Recces and line transects are the more commonly used ecological survey methods within the WWF-CARPO/GHoA project sites. Excel spreadsheets are generally used to enter and store these data. The advantages/disadvantages of using spreadsheets and the recommendation to store survey data in relational (SQL based) databases is discussed in the sections Software and Spreadsheets.

The programs CyberTracker, MIST and SMART use relational databases. Whereas MIST or and SMART are the logical choices for patrol data, the CyberTracker software is currently recommended to be used for both recces and line-transects. However, other ecological survey methods, such as mark-recapture, whether by physical capture or cameras, may require specialist software as has been developed by the TEAM Network and others (see section on partnerships below), or certain data may be entered directly in the appropriate analysis programs e.g. MARK (White 2012), PRESENCE (Hines 2006) or equivalent programs.

Using different programs to store ecological survey and patrol data embeds the risk that different, non-exchangeable formats are used. This can complicate comparison of data-sets and or pooling data, for example to create (potential) distribution maps. A solution to these problems is to store raw data from ecological surveys and patrols in a single database, using a relational database management system (RDBMS). Data files for analysis programs such as Distance and MARK are generated, according the specifications of these programs, by the RDBMS.

A proper understanding of the need of users is a prerequisite in design of a database system. Understanding these needs can be helpful to evaluate and, when necessary, adapt existing programs, without going through the process of “re-inventing the wheel”. Furthermore, designers may suggest modifications and additions that could improve existing or newly developed software. Such an approach seems to be appropriate within the context of, in general, limited financial resources that are available for nature conservation.

This document is not intended to design a databases system in detail. It will explore requirements, describe a general framework and evaluate existing programs that could host such a database.

WHY A DATABASE?

The general advantages of databases over spreadsheets, with respect to data consistency, validation and reporting (query) power are discussed in section Spreadsheets. However these pros and cons do not answer the question why a database would specifically be beneficial for holding ecological surveys data.

The reason for designing an ecological survey database finds it base in answering the following questions:

1. Which taxa occur?
2. Distribution of taxa in the protected area?
3. What are the densities either as indices or as the population sizes?
4. What are the threats – qualified and quantified
5. Are protection, including law enforcement, measures successful (also based on changes in 3)?

The answers to these questions will usually require different types of data and analyses. Furthermore, monitoring effectiveness of management measures require comparing data with previous surveys. The advantage of a database system is that both different types of data and historical data can be stored in a single system.

CORE DATA

Table 15 presents different observation/survey methods (including anti-poaching patrols), the minimum data collected and analysis software. The minimal information to be stored is scientific name of taxon, name of location or site indicator. When possible observations should be geo-referenced with a GPS,device. The minimum observed data-set, as extracted from Table 15, can be considered as the core table of an ecological survey and/or patrol database. Princée (2006) developed a relational database “Biodiversity Management Database” (BMD) that follows this concept. The structure of BMD could be used as a blueprint, with modifications, for an ecological survey database.

Table 15: Minimum data collected for different types of ecological monitoring and required analysis software.

Methods of observations	Minimum data per observation	Analysis software
Opportunistic	Taxon, date/time, geo-referenced location name, number of individuals	
Anti-poaching patrols on foot	Taxon, date/time, geo-referenced location, traces, carcasses, number of individuals	MIST (encounter rates/effort)
Net hunting	Taxon, date, time effort, location/area, number of captured individuals	
Recce	Taxon, date/time, geo-referenced location, traces, carcasses, number of individuals	MIST (encounter rates/effort), Presence
Sight/re-sight	Taxon, date/time, geo-referenced location, individual identification	MARK, R/unmarked, Rcapture, R/mrds (Distance),Presence
Point transects	Taxon, date/time, geo-referenced location, traces, carcasses, number of individuals, distance from observer	Distance
Line transect	Taxon, date/time, geo-referenced	Distance, R/mrds, Presence,

Figure 26 shows a representation of the "observation" table with the core data fields *taxon*, *date/time*, *geo-referenced location*, *observer* and *survey method*. These fields refer, except date/time, to functional groups of tables containing data on taxonomy, geography, survey method (and parameters) and observers teams. These "table" groups have the following characteristics:

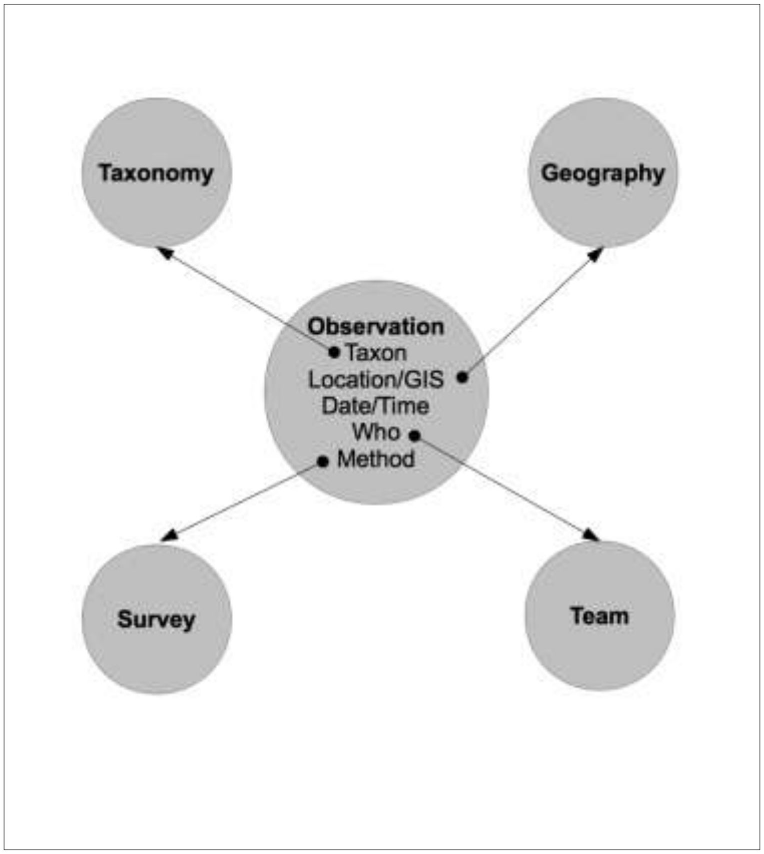
- Taxonomy: a single table with scientific, French and English names of species occurring in the GHoA region; or multiple tables forming a taxonomic tree i.e. kingdom, phylum, class, order, family and genus/(sub-)species.
- Geography: a single table with location names, indicators and/or GIS data; or multiple tables comprising the GHOA landscapes; protected areas, park boundaries, roads, rivers and villages. This requires a database system that is able to store geometry data.
- Survey: a table for each method which includes survey specific data per observations e.g. perpendicular distance on line transects or identification parameters in mark-recapture.
- Team: a table with names and affiliation of observers.

DATABASE REPORTS

The most important reports to be generated by a survey database are column delimited text files that can be imported by analysis programs such like Distance and MARK. These export data can vary from a single survey on a single taxon to data from surveys on several taxa in multiple regions.

SQL databases can perform simple calculations and statistics on data. This allows to calculate for example encounter rates without the need of a special program (other than managing the database).

Figure 26: Observation table of ecological survey database and relations with other (groups) of tables.



USER INTERFACE

SQL is a powerful language to manage and manipulate databases. A “simple” terminal (text based) program to enter instructions and queries, and to retrieve query results is the basic tool that is required. Such tools are provided with most relational database management systems. However, these basic programs are not user-friendly as they require a thorough knowledge of the SQL syntax. Even high-end graphical user interfaces, such as MySQL Workbench or PgAdmin, still require knowledge of SQL for more specialized or complex queries. The power of SQL becomes, paradoxically, its weakness when to be used by the average user.

The above means that a dedicated program which interfaces with the ecological survey database is required.

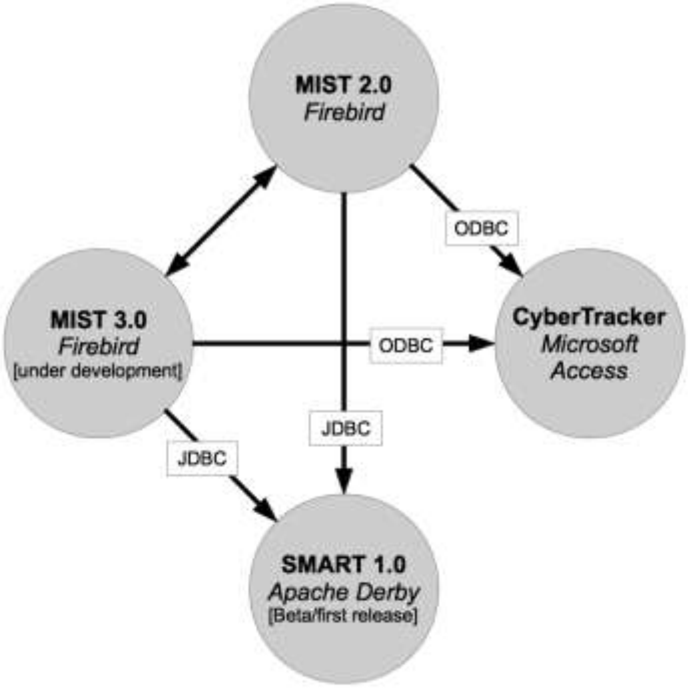
The user interface is generally the most time-consuming/costly aspect in software development. Therefore, it could cost beneficial to explore options to implement the ecological survey database and its user interface within CyberTracker, MIST or SMART. Furthermore, these programs include support of storing GIS data and creating geographic maps. Moreover, implementation of ecological survey data in later releases of SMART are being discussed.

DATABASE CONNECTIVITY

Development of an ecological survey database, especially its user interface, will take time. This means that CyberTracker may be used for ecological surveys, and MIST 2.0 and SMART 1.0 for patrol data It is important to know to what extend these programs can communicate with each other i.e. directly access each others data.

CyberTracker, MIST and SMART each use a different database management system i.e. Microsoft Access, Firebird and Apache Derby, respectively. Although these systems use the SQL language, they cannot access each others databases. However, each of the programs provide (potential) options to access data that are stored in different database systems. Figure 27 presents (potential) database connections between patrol/survey programs as discussed above.

Figure 27: Database connectivity between different ecological survey/patrol programs.



CyberTracker has implemented the Open Database Connectivity (ODBC) that enables to connect to external database management systems. Most database systems, including Firebird, have ODBC drivers. Thus, CyberTracker could use the same database system as MIST 2/3 and, in principle, ecological survey tables could be added to the same database as used for patrol data.

SMART uses the Java Database Connectivity (JDBC), which is similar to ODBC, but can in general only be used by programs that are developed in the Java programming language. SMART will be able to import/convert MIST data – through JDBC - to its default Apache Derby database system (not enabled on the beta version that was available at time of this consultancy).

Since further development of MIST 2.0 has ended, Firebird is the sole database system that can be accessed. However, MIST 3.0 shares the open source and multi-platform approach as SMART does. This means that several open source database drivers (including Firebird) are available for the Python program language that is used for its development.

The main omission in direct data exchange exists between the default databases systems of CyberTracker and SMART 1.0, i.e. Microsoft Access and Apache Derby, respectively. Direct exchange of data between these programs requires a database system is used for which both JDBC and ODBC drivers are available e.g. Firebird, MySQL or PostgreSQL.

RECOMMENDATIONS

SURVEY DESIGNS AND BUSINESS PLANS

STAFF NEEDS, PROFILES AND QUALIFICATIONS

The following discussion is based on the assumption that WWF wishes to develop their monitoring competence to a point where they can design, implement, analyse and report on management effectiveness largely from within the institution. There will always be a need for collaboration and out sourcing for the right kind of technical assistance some of the time (e.g. remote sensing, carbon storage potential, health), but WWF could become semi-autonomous if they invest in capacity.

An alternative approach is that they out-source their monitoring needs to a different institution. In fact this is a perfectly acceptable strategy – indeed technically and philosophically it is a more desirable state than monitoring from within the institution for reasons discussed earlier (and e.g. Ferraro & Subhrendu 2006), since self-monitoring of performance introduces many opportunities for non-objectivity, bias and lack of transparency. However here we assume that WWF wants to develop capacity internally.

If WWF CARPO is to achieve adequate monitoring its progress towards its strategic biodiversity objective, it needs to provide some robust and precise population indicators on priority populations of target species in priority areas by the end of 2014. 2014 status will be the benchmark on which to compare the state of these populations in 2020 on completion of the current conservation strategy. Given all that has been said about the current status estimates for these species across the CARPO sites, achieving this objective will necessitate immediate and significant recruitment, training, and management of key staff at all levels of the organisation. Failure to invest in competent staff will result in failure to deliver appropriate management evaluation. Here we provide a broad assessment of what we consider to be an adequate core biomonitoring staff.

Effective monitoring will require a team that traverses all levels of the institution, from site to international levels (Figure 28). We are aware that WWF already has the kind of structure illustrated in Figure 28 in place, at least on paper, however current staffing levels and competence is not keeping up with the current demands of monitoring, so cannot be expected to expand the workload to meet the challenges of implementing the current CARPO strategy. This may be due to unsustainable workloads, level of technical and management ability of key staff is insufficient to meet the demands of job descriptions, and the level of prioritisation of monitoring given the multitude of other urgent tasks. Here we summarise key roles within a hierarchical monitoring team.

CONTINENTAL/GLOBAL LEVEL

A functional Conservation Science Support Service is urgently needed to provide services at strategic and implementation levels. While WWF US and to some extent WWF International have such services, our impression (which is not based on a detailed evaluation) is that direct interactions with field programmes in the Congo Basin are limited. The condition of data and reporting from the sub-region, including the rather astonishing fact that not a single site in CARPO sends data to the regional office even for backup, suggests that that there lacks a unified approach to monitoring between the field and the science staff based in Washington DC and Gland. Ideally these units, who are removed from the day to day drama of living and working in central Africa could provide the following services to a large regional programme on the scale of CARPO: (1) Strategic planning – particularly in rolling out all of the excellent tools that have been produced by the Conservation measures Partnership, for example MIRADI, which integrates management planning with performance monitoring, but which is largely unknown in CARPO, also development of coherent final monitoring programmes, with appropriate technical underpinnings, methods, analytical procedures and necessary communication feedbacks to management and technical publications (2) Academic liaison – would involve creating opportunities for professional development for technical staff within WWF-CARPO to do advanced degrees at internationally accredited universities, (3) Technical development – to maintain abreast of, and even drive, methodological advances in field techniques an statistical analysis, (4) Training and technical support – provide workshops, seminars and other training to field staff, and provide technical backstopping an trouble shooting, (5) management oversight – ensure that programmes are being implemented according to workplans, that data quality is high, and that communications of results is timely and follows procedures, (6) Larger scale analysis and reporting – in which field derived data play a central role in conservation status evaluation at the larger scale that WWF is required to report at (e.g. the Living Planet Report).

Appropriate staffing at this level should include three core positions at ca. 10% time: a strategic planning specialist, a statistician/landscape ecologist, and a GIS/database specialist. These staff would be part of a vibrant community of conservation biologists, economists, policy specialists, etc. that is necessary to lead a global conservation organisation.

REGIONAL LEVEL

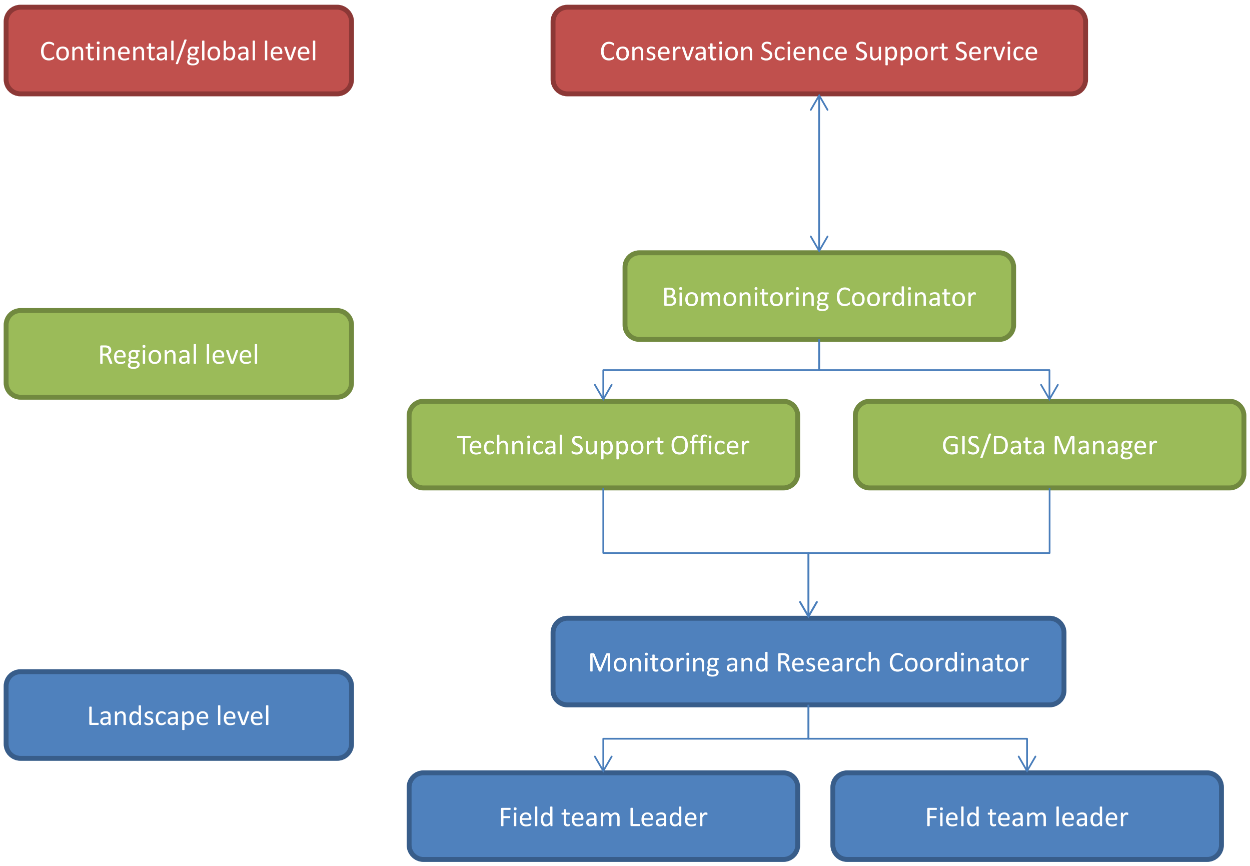
Regional level monitoring support staff will be critical to implementing the monitoring programme. We argue strongly that a three person team is necessary due to the scale of the strategy WWF CARPO has set itself – remember CARPO operates over more than 550,000 km^2 of some of the most biologically and socio-economically complex and challenging environments in Africa.

A full time Biomonitoring Coordinator is essential to managing the programme. The profile of this person would be at PhD level with at least a decade of experience in monitoring and evaluation with a strong background in experimental/monitoring program design and analysis. Necessary core team members at the regional level would include a GIS/database manager responsible for implementing and maintaining data management systems and liaising with collaborators and other institutions to collect and use spatial information. A technical support officer is also needed to bounce around the CARPO sites training, mentoring, assisting with survey designs and implementation, troubleshooting, and ensuring data flow and good communications between the field and the regional coordination group.

LANDSCAPE LEVEL

As a general rule, each landscape requires a monitoring coordinator to ensure the functioning of the programme. There may be scope in small landscapes or landscape segments to double up (e.g. Mount Cameroon and Korup), however other landscapes are so large and complex that they may require 2 coordinators (for example on the Gabon and Cameroon sides of TRIDOM). These landscape level coordinators should be Masters or PhD graduates with proven competence in field research, data management skills, analytical capability and programme management. These, along with landscape level team leaders are perhaps the pivotal positions in the entire structure, because without them, site based monitoring will fail to produce high quality usable results. We cannot estimate the number of team leaders required at site level at this stage, since this depends on final monitoring plans at each site. A general estimate would be 2 per landscape on a permanent basis with more trained up or brought in from other sites for specific needs – such as landscape wide surveys.

Figure 28. Basic staff infrastructure necessary to design, coordinate and implement a WWF CARPO CHoA performance monitoring programme



TRAINING NEEDS

IMMEDIATE NEEDS

The analysis of WWF CARPO line-transect monitoring data revealed than even in the sites with the greatest technical competence, some basic errors continue. This is symptomatic not just of insufficient initial training, but of ineffective subsequent follow up and data quality control during analysis (and is symptomatic of the lack of coordination between bodies like the Conservation Science department and the field).It is clear that even experienced researchers sometimes do not fully understand why methods must be adhered to, and therefore they do not spot check data while surveys are in progress to rectify errors while they can still be corrected. Until they fully understand the concept, the correct method, and the way to detect errors and correct them, line-transects or other types of surveys will continue to be produce poor quality data.

Thus a programme of training will be needed for new recruits to get them up to speed for the 2014 status assessment, but also re-training is needed for more experienced members of the core WWF CARPO team. At the level of key current WWF landscape staff, (at the landscape monitoring and research coordinator level), we would recommend a refresher course in monitoring philosophies and methods, ideally led by an institution from outside the region – the dynamics of training would not be appropriate if local peers were involved in retraining experienced professionals. The course should cover key concepts in monitoring strategies, established methods and innovative approaches, and analytical techniques. Data management would also be a key module. The goal would be to widen the horizon for field staff to new approaches, refresh traditional techniques, and establish core competence.

Training programmes in field methods for recce-transect style new recruits are now very well established in central African forests. Fiona Maisels, the monitoring coordinator for WCS has led numerous training sessions all over the basin based largely on the methods manual of White & Edwards (2000). These courses are tailored to the provide growth to field staff as their core competence grows. The first course for new recruits usually lasts ca. 8-10 weeks often with follow up on the job training thereafter. This course prepares recruits as assistant team leaders, who can transition to leader status in 1-2 years. This time is required less to develop technical skills, but rather to become proficient in management and logistics of survey implementation. WWF CARPO will need to train a cohort of new staff in order to kick start a programme geared to monitoring the management effectiveness toward achievement of their strategy.

ConservationTraining is an open and free learning community that offers conservation-based training materials from The Nature Conservancy and partner organizations (www.conservationtraining.org). Example of free courses available include an introduction to Geographic Information Systems (GIS) - concepts, tools, and functionality in a conservation context, as well as a self-paced online course geared towards teaching the initial steps of the Open Standards. The combination of these in person and online courses, the experience gained from 1-2 or more actual surveys with on the job follow up training result in a high level of competence among dedicated staff.

We will not go into the details of the training programmes here, but highly recommend them as appropriate for training new staff and re-training existing team leaders who can provide instructor support on the course to develop their own teaching ability.

Depending on the methodological approach taken, there may be other training needs, for example camera trapping, fecal DNA capture recapture, occupancy methods [27], etc. Much of the core competence required for any of these methods at team leader level is in understanding scientific methods and basic field skills, so there is considerable overlap with current programmes. Collaboration with partners (see next section) would likely result in options for training in these relatively novel methods in central Africa.

CONSERVATION SUPPORT FOR PROFESSIONAL DEVELOPMENT

To be sustained a culture of science-based monitoring needs to be established within WWF. Traditionally, WCS has been the NGO regional leader in science-based conservation because they have invested more strongly in (1) hiring academically and scientifically trained field staff compared to WWF, (2) they have provided some excellent opportunities for professional development for technical staff through programmes such as the Beinecke and Christiansen scholarships for young professionals from Africa and indigenous groups respectively. Some of these opportunities provide grants for training throughout graduate programmes lasting for five years and more. WWF has similar programmes (e.g. the Prince Bernhard Scholarships) but few that are available for long term graduate level study. We have not evaluated the effectiveness of these programmes, and this would be a very worthwhile exercise, however our feeling is that without a long term approach to training and career building in applied science the quality of conservation monitoring will suffer.

We recommend seeking not only longer term specific funding partnerships for academic training, but also that WWF seek a close collaboration with a leading university that specializes in Conservation Biology. The two go hand in hand – a long term collaboration between WWF CARPO with a world leading conservation biology institute specializing in monitoring would strengthen funding opportunities. Peter Walsh, in a detailed assessment of monitoring needs at Dzanga-Sangha recommended DICE at the University of Kent, with whom WWF has an existing strong relationship, however there are numerous other options. William Sutherland in Ecology and Conservation Science at Cambridge University, E. J. Milner-Gulland at Conservation Science, Imperial College, and James D. Nichols, USGS Patuxent Wildlife Research Centre would be among the top choices. People and institutions such as these could make amazing progress with WWF CARPO.

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[27] There are some excellent resources, especially for occupancy methods on the University of Vermont website: http://www.uvm.edu/rsenr/vtcfwru/spreadsheets/

PARTNERSHIPS

WILDLIFE CONSERVATION SOCIETY

With its long history in the region, proven bio-monitoring capacity and on-going strong collaboration with WWF, WCS is well placed as a potential partner for WWF as it moves forward with its bio-monitoring programme. The technical assistance WCS is currently providing in Dzanga-Sangha and Minkébé, plus the strong role they play in coordinating monitoring in the Gamba Complex has proven highly beneficial. In the mid-2000s the surveys coordinated by WCS as part of the Monitoring of the Illegal Killing of Elephants (MIKE) programme provided some of the first, and in some cases the only, park wide estimates of the abundance and distribution of elephants and apes in several core WWF sites.

The WCS Africa Programme team is motivated to partner with WWF in building monitoring capacity for several reasons. Firstly they realize that improving landscape level monitoring in priority conservation areas can only improve conservation by providing more timely information on trends in wildlife populations and human activities. Second, they feel confident that they can bring solid expertise to WWF which helps them demonstrate their competence and relative success in biomonitoring. Third, such collaboration will strengthen the overall ability of both groups to obtain funding for biomonitoring.

James Deutsch, the Director of the WCS Africa Programme, indicated that while WCS is ready to work with WWF, they cannot do so at the expense of their own activities. WCS generally receives less funding than WWF, and always have difficulty maintaining core salaries in technical roles, and therefore they cannot subsidize the WWF monitoring efforts by providing their time at no cost. However with cost sharing and clear goals, roles and responsibilities, WCS are keen to engage.

We therefore recommend that a planning workshop be organized between WCS and WWF as soon as possible, to develop a collaborative plan that serves the interests of both organisations. This report is not the place to go into the details of such a workshop, but we would suggest the main structure of the workshop as follows:

Short term items

1. Agreement on monitoring goals in relation to management objectives
2. Immediate harmonisation of “best practices” for bio-monitoring across conservation landscapes where the two organisations have a presence
3. Develop a three year plan for 1) fund raising 2) capacity building, 3) monitoring design harmonisation, 4) a monitoring implementation plan to include including logistics, personnel, data management and analysis that will result in a basin wide assessment of priority species in shared landscapes in relation to management interventions.
4. Assign roles and responsibilities to key personnel, and develop accost sharing strategy for these individuals.

Longer term items

1. Building sustainable mechanisms within WWF CARPO that will result in full WWF capacity to implement bio-monitoring across CARPO with activities strongly coordinated with WCS and other regional actors

MAX PLANCK INSTITUTE FOR EVOLUTIONARY ANTHROPOLOGY

The Department of Primatology investigates issues related to the evolution of social systems, culture, and ecology in primates, with a special emphasis on apes. Within the spectrum of research conducted, biomonitoring and conservation is one of the key themes. The MPI-EVA is however dedicated to scientific research and not on the practical side of conservation, therefore the approach they bring is and will continue to be using applied research to support conservation efforts. Using this approach and by establishing links to on the ground conservation organisations, national governments, and other bodies, the MPI-EVA has demonstrated a very positive contribution to ape conservation, and tropical forest ecosystem conservation in general (e.g. Kuehl *et al.* 2008; Rabanal *et al.* 2010; Tranquilli *et al.* 2012). The MPI-EVA also developed and manages the APES database, a repository for varied datasets on distribution and conservation status of apes and their environment. The focal point for much of this work, Dr. Hjalmar Kuehl, has conducted field work in a number of WWF sites, and has collaborated strongly with field programmes through central and west Africa.

Several years ago, the MPI-EVA tried to initiate a Congo Basin wide conservation monitoring programme, which was to include WWF, WCS, and other groups. According to the MPI-EVA this initiative, which would have initiated coordinated monitoring of key species across the basin in key sites, failed to develop into a functional programme in part because the managers at WWF thought that it was too scientific with few practical applications, and that it would be too costly to justify given their other priorities. Secondly, it was easier to work with an institution like WCS which is centrally managed and relatively well coordinated, rather than the more diffuse structure with WWF in which numerous branches of WWF must come together and agree before things can move forward. There were other factors behind the decision mostly based on mistrust, including some suspicion of the motives of the MPI-EVA, the amount of control they could potentially have and their moves to develop the APES database that would be managed by them but would contain data collected and funded by others.

However the APES database has generally been well supported by conservation groups in the Congo Basin (Figure 29), and there are now datasets from some 124 surveys from the central African region, of which 10 were provided by WWF. The potential power of amassing large region wide datasets is evident in the most recent scientific paper to come from the APES database called "*Recent decline in suitable environmental conditions for African great apes*". Better coordination of surveys and data sharing within APES would dramatically improve the analytical options toward understanding trends in abundance and distribution of apes and other wildlife. Dr. Kuehl is very interested in exploring options to re-invigorate moves toward a more integrated approach toward monitoring for Evidence-Based Conservation at WWF sites in the Congo Basin, and suggests several main ways in which MPI-EVA can provide practical applied scientific support.

1. Methodology development

MPI-EVA have made a number of improvements to traditional survey design, methods, and implementation, and Dr. Kuehl was the principle authors of the IUCN Best Practice Guidelines for Surveys and Monitoring of Great Ape Populations (Kuehl *et al.* 2008). Recently in the Tai Forest they have shown how evaluating wildlife abundance survey data with law enforcement monitoring data can improve the distribution of future Law enforcement patrols into the most needed areas – a classic example of using solid data in adaptive management. MPI-EVA is also developing field and analytical tools that take advantage of remote monitoring using either camera traps and or automated sound recording units. Promising MPI-EVA funded research is demonstrating the use of these tools in population structure and abundance monitoring, including automating species and individual recognition, as well as automating identification of species human activities such as quantifying gun shots.

2. Coordination and analytical support

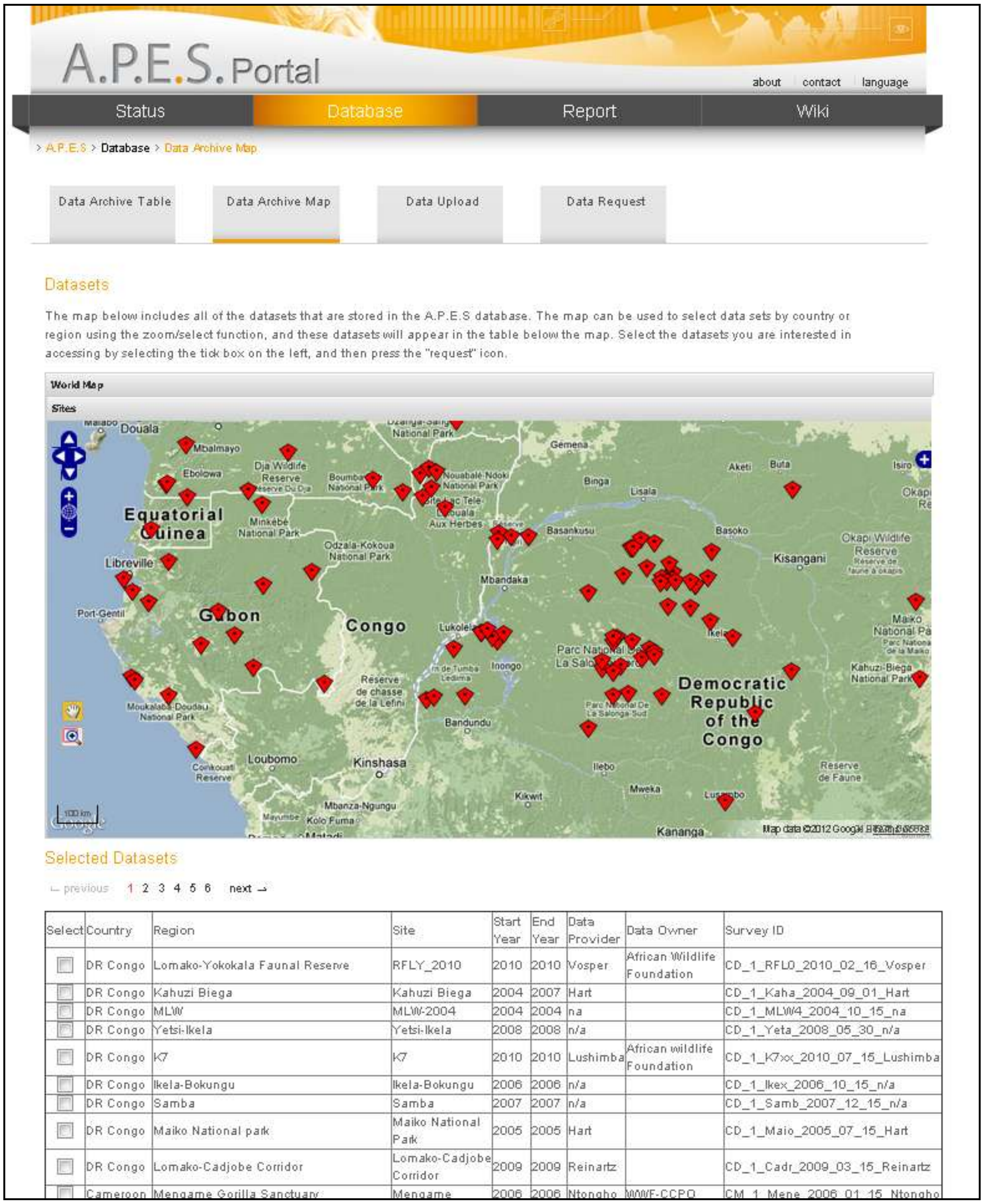
MPI-EVA have has some success with WWF CARPO in this domain, particularly in the Gamba Complex. More recently they have assisted with the design, methods and analysis of ape population surveys cross four west African nations with a variety of site-base partners which has led to an unprecedented level of understanding of ape rage and conservation status in the region.

3. Joint publishing

Publishing papers is not a high priority for most conservation practitioners, and given the crisis management conditions facing most practitioners in the Congo Basin, it probably should not be. However peer review of some kind still provides one of the most objective ways to evaluate the technical merit of a piece of work. Partnerhips between say a conservation NGO and a research institute can be particularly productive since the institution can provide the time that the NGO cannot, However the process of analysis and evaluation critical to producing a final paper brings the practical and technical sides of the process together synergistically.

We recommend strongly that WWF consider redefining its relationship with Dr. Kuehl's research group within MPI-EVA. The MPI has huge institutional strength, it has person-power, and a growing desire to engage directly with conservation (a Max Planck Institute for Conservation Biology may be formed in the near future), and importantly it has funding security. All of this means that if the ground rules are established, and adhered to, MPI could be a stable long term collaborator for not just WWF, but for the conservation community in Central Africa.

Figure 29. The APES online database shows an impressive repository of datasets from the Congo Basin, however of some 124 surveys only 10 appear to have been provided by WWF



The map below includes all of the datasets that are stored in the A.P.E.S database. The map can be used to select data sets by country or region using the zoom/select function, and these datasets will appear in the table below the map. Select the datasets you are interested in accessing by selecting the tick box on the left, and then press the "request" icon.

Select	Country	Region	Site	Start Year	End Year	Data Provider	Data Owner	Survey ID
☐	DR Congo	Lomako-Yokokala Faunal Reserve	RFLY_2010	2010	2010	Vosper	African Wildlife Foundation	CD_1_RFL0_2010_02_16_Vosper
☐	DR Congo	Kahuzi Biega	Kahuzi Biega	2004	2007	Hart		CD_1_Kaha_2004_09_01_Hart
☐	DR Congo	MLW	MLW-2004	2004	2004	na		CD_1_MLW4_2004_10_15_na
☐	DR Congo	Yetsi-Ikela	Yetsi-Ikela	2008	2008	n/a		CD_1_Yeta_2008_05_30_n/a
☐	DR Congo	K7	K7	2010	2010	Lushimba	African wildlife Foundation	CD_1_K7xx_2010_07_15_Lushimba
☐	DR Congo	Ikela-Bokungu	Ikela-Bokungu	2006	2006	n/a		CD_1_Ikex_2006_10_15_n/a
☐	DR Congo	Samba	Samba	2007	2007	n/a		CD_1_Samb_2007_12_15_n/a
☐	DR Congo	Maiko National park	Maiko National Park	2005	2005	Hart		CD_1_Maio_2005_07_15_Hart
☐	DR Congo	Lomako-Cadjobe Corridor	Lomako-Cadjobe Corridor	2009	2009	Reinartz		CD_1_Cadr_2009_03_15_Reinartz
☐	Cameroon	Mengame Gorilla Sanctuary	Mengame	2006	2006	Ntongho	WWF-CCPO	CM_1_Mene_2006_01_15_Ntongho

THE TEAM PROJECT

Judging by its name and acronym, the Tropical Ecology Assessment and Monitoring Network Early Warning System for Nature (TEAM) sounds like a perfect group to lead the charge toward monitoring management effectiveness of conservation in the CARPO region. Their mission is: ***To generate real time***

data for monitoring long term trends on tropical biodiversity through a global network of field stations providing an early warning system on the status of biodiversity to effectively guide conservation action. Semantics aside, this is exactly what WWF CARPO wants to do and should be doing.

The TEAM network currently operates in 18 sites across the new world and old world tropics, including three sites in central Africa. The network seeks to implement standardized protocols across all these sites to monitor biodiversity. Data collection focuses on climate variables, vegetation, and terrestrial vertebrates. The network has developed a very impressive suite of infrastructure and management tools, as well as scientific tools such as survey design modules, PDA data collection interfaces, data and spatial data management systems, analytical tools and a project collaboration tool. They have also developed a range of very detailed protocols to guide implementation of data collection on three indices of ecosystem health – terrestrial mammal and bird diversity, tree and liana diversity, and above ground Carbon storage, and two important covariates – land use change and climate.

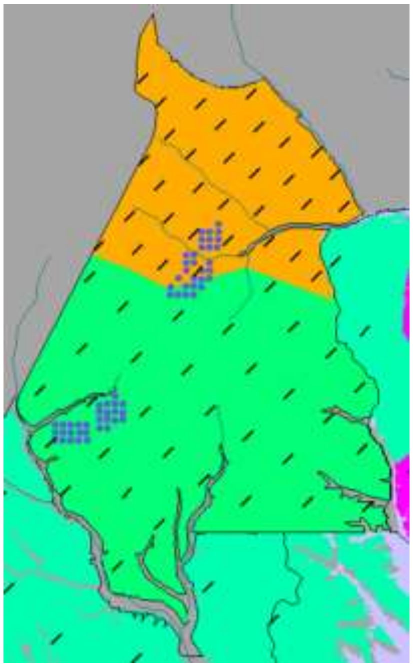
So should WWF just join the TEAM network and implement their protocols across their CARPO sites? We put some questions to leading members of the TEAM network (Jorge Ahumada and Tim O'Brien) in order to understand a bit more about the network and how it works. In general TEAM is implementing. One set of responses is provided in box x below. Some of the most salient points from these discussions can be summarised as follows:

1. TEAM is very interested in developing collaborations with site-based partners
2. They have a solid central coordination unit composed of quality institutions and individuals
3. TEAM can bring some clout to joint fund raising for new sites, and can cost share at sites
4. There is strong overlap between WWF priority species and indicators for TEAM (terrestrial mammals and birds)
5. Protocols are lengthy and take considerable investment in training, but are well standardized and repeatable across sites and over time.
6. Finding good institutional partners and high quality site managers are among the biggest challenges facing TEAM. However TEAM are committed to capacity building.
7. Technological demands can also be problematic in some field sites with poor internet access.
8. Camera trap protocols do seem to be a cost effective monitoring methodology for terrestrial vertebrates – TEAM claim that their camera trapping methodology is more cost effective than other monitoring techniques – however the spatial scale of TEAM may not be suitable for landscape scale monitoring.
9. The TEAM network is interested in providing technical and management assistance to sites and partners, but would need to fund raise with interested partners.

Given that TEAM has established some momentum, and has thought long and hard about many of the same issues that WWF are grappling with, and that they are seeking collaborations, we would advise WWF CARPO to develop a dialogue with the TEAM coordinators to assess where there may be synergies and opportunities.

Current TEAM survey design (Figure 30) may prove be inappropriate for monitoring at the landscape level depending on the management questions, since camera trap arrays are currently highly concentrated into small areas (Figure 30). However methods will certainly evolve and are likely to be adaptable in meeting varied monitoring needs. Rough figures from the Ndoki Forest provided by Patrick Boudjan and Fiona Maisels indicate that it costs ca. \$42,000 (~\$56,700 for 2 years given that equipment costs would have been mainly covered in the first year) to implement the camera trap survey which covers 200km^2 in Figure x compared to ca. \$46,000 to complete a line-transect survey over the entire 4,200km^2 of the Nouabalé-Ndoki National Park. Ideally TEAM will partner with WCS and WWF CARPO sometime in the near future, to complete a full evaluation of the costs and benefits of different methodologies to meet the needs of evidence-based conservation.

Figure 30. Coverage of line-transect survey (black lines) and TEAM camera arrays (blue dots) in the Ndoki Forest, Northern Congo.



BOX 2. JORGE AHUMADA'S QUESTIONS AND ANSWERS

1. How were sites selected in central Africa? Are there plans to increase the TEAM sites and the network? If so where are the priorities for the Congo Basin? Are sites in which WWF is operational being considered?

TEAM is a network by design, and sites are selected based on a number of criteria including: 1) proportion of target sites for each major continental forest block; 2) locations along gradients of expected land cover change, expected climate change and other major environmental gradients (e.g. rainfall, rainfall seasonality, soils); 3) Institutional presence and research history at the site; 4) Political stability and logistical feasibility. There are no immediate plans to increase the number of sites due to funding constraints, but the long-term goal is to increase the number of sites to 40. Korup (a WWF site) is already part of the network through our partnership with Smithsonian. Ituri in the DRC is a site of interest to TEAM.

2. In regard to the central African sites, do you seek collaboration with the NGO's and other institutions (govt, research, private sector etc), and is there interest from potential partners?

Yes, we are committed to working through local partners for implementation. TEAM is composed of four core partners who are responsible for fundraising, maintaining overall network infrastructure and for network management: CI, WCS, Smithsonian and the Missouri Botanical Garden.

3. How does TEAM function within sites? Do you have MOU's with governments and site-based partners? And if so are how are roles and responsibilities for implementation divvied up and are they functioning. What has been the response and level of involvement from WWF in Korup and other sites?

In general, we have agreements with governments in all of the countries where we work. Specific local arrangements vary, depending on the local implementing partner and on what agency has jurisdiction over the land where TEAM is working.

4. Are the TEAM data suitable for monitoring the abundance of NGO high priority conservation target species (elephants, apes, bushmeat species) and populations over time at landscape levels?

The TEAM Terrestrial Vertebrate Monitoring protocol is a cost-effective way to monitor terrestrial species (mammals and birds) relative abundance; species diversity and community composition. They cannot estimate abundance directly, but can track population trends for individual species and also relative abundance. The current design is targeted towards forest species, but can be easily adapted to other terrestrial ecosystems. For example, a variation of this protocol is being used at Mpala ranch in Kenya to monitor the large terrestrial fauna present there. Data are currently used for the Wildlife Picture Index and also TEAM has an MOU with IUCN and the data feed into the Red List process.

5. Do you have any data suggesting what suite of species will be most suitable for monitoring under TEAM, and what constraints are being revealed in terms of ability to monitor change with density and abundance/range/movement characteristics of species?

The TEAM terrestrial vertebrate monitoring protocol can monitor a wide range of species, and particularly aims to monitor the terrestrial vertebrate community as a whole. We do not pick up many species under 250 gm. The spacing of the camera trap points (1 every 2 sq km) is designed to monitor all types of species from wide ranging and rare to common and abundant, however we do not get sufficient data on very rare species to track trends. The number of points is also a key parameter, with a minimum of 60 points per site per year (dry season) for at least 30 days each point. With this effort we can detect annual change in occupancy of most species with adequate power. We are now finalizing a manuscript describing changes of species in Costa Rica using this method which will be available soon. Of course any site can supplement the TEAM protocol with additional camera traps to get targeted data on particular species.

6. What are preliminary data suggesting as to the accuracy and precision of abundance estimates and trend detection?

With 60 points you can detect changes in 10% annual occupancy for most species. Rare species need to be grouped together to detect changes at this level. If the aim is to monitor rare species, then sample size should be increased to 90 points or more.

7. Who owns the data (interesting and relevant given the excellent open access opportunities you offer – is the data set creator also the dataset owner?)?

The data is owned by the implementing partner, but as part of being a node in TEAM, they grant CI the right to freely distribute the data as soon as it is collected. Therefore, the data are publicly available in near real time and can be downloaded by anyone at http://www.teamnetwork.org. However, anyone can use the TEAM protocols without the support of TEAM and of course in this case, there is no requirement to make the data available. Only formal partners in TEAM, who receive financial, capacity building and data management support from the TEAM Network have to make the data freely available.

8. What are the budgets for training, follow up quality control, equipment and operations for the central African TEAM operations. Is there cost sharing or do you fund everything?

The costs of the sites are cofunded by the core partner in charge of that site and CI. CI contributes approximately half of the cost. For example in the case of Nouabale Ndoki in Congo, WCS funds half of the operations and CI funds the other half. In general, local site operations cost about $110K per year, but this varies, depending on local economy, labor costs, etc.

9. What are the financial costs for analysis both at site level and for central analysis?

We do not really track local financial costs for data analysis and data management. We track this at a Network level. These costs are largely covered by the core partners, not by local sites at this time.

10. What are the biggest challenges to successful implementation at site level?

I think the biggest challenge is to find the right local institutional partner and a good Site Manager. The SM is the person responsible for implementing the data collection, maintaining consistency and quality control scheduling the activities, training and managing the personnel and uploading the data to the TEAM servers. In our experience what makes a site is the Site Manager, the more organized, motivated site managers result in excellent sites. We can give you some names of current site managers in Africa if you are interested in contacting some of them to hear about their experiences. We are committed to capacity building for these managers. We aim to have site managers with Ph.D.s, but in some cases (e.g., Uganda and Tanzania, the SM is pursuing a Ph.D. while serving as site manager, and with some support from TEAM).

11. If TEAM protocols were judged to be viable tools to complement, or even replace more traditional methods for monitoring management effectiveness such as line transects, how far can TEAM go in assisting the development of a suite of sites across WWF landscapes (I am thinking about training, coordination, data management and analysis)? Is this something TEAM could be interested in pursuing?

Tim O'Brien and Sandy Andelman are presenting a paper at ZSL in London in November that demonstrates exactly this: that the TEAM camera trapping protocol is more cost effective for monitoring management effectiveness than line transects or other survey methods. We would be interested in the type of activities you suggest, but we would need to work with partners to raise additional funds.

MONITORING OF THE ILLEGAL KILLING OF ELEPHANTS (MIKE)

The MIKE programme is well known to WWF and does not need to be introduced again here. Clearly there should exist many opportunities for synergy, given the primordial importance of elephants across the CARPO region. WWF CARPO and MIKE have a history of effective collaboration in some sites. Notably, this includes the suite of elephant population surveys conducted in 2003-2005 which covered four of the WWF priority sites; Salonga, Boumba Bek, Dzanga-Sangha, and Minkébé. These surveys remain the best estimates of forest elephant and ape abundance in some of these sites. These sites also provide Law Enforcement Monitoring data to MIKE in part due to the efforts of WWF staff on the ground. In the more recent past, WWF support to MIKE had declined – for example the.

MIKE is very interested in re-invigorating the collaboration with WWF, particularly with the development and implementation of SMART. If all the WWF sites adopted SMART across all of its sites, the efficiency of data collection, management and analysis would improve dramatically. MIKE also needs to continue building local site based collaborations where possible due to their minimal staff infrastructure, and in "return" for locally-based support from partners, MIKE can assist NGOs with leverage at government level and in scaling up from site level to regional and global level standards-based monitoring information delivery at international fora such as CITES. Furthermore, MIKE has provided standards for the implementation of population surveys and LEM, which are sufficiently detailed that they can be implemented without specialised training above and beyond field researcher norms.

Unfortunately, the reality is that the international donor community, including national governments, has not committed long term funding for MIKE, even at a minimal level, and MIKE is continually up against funding crunches, and using extensions, bridging funds, and other creative ways to maintain operations. These funding issues have historically resulted in a sense that MIKE is a risky partner in which to invest heavily. At present MIKE runs out of funds in December 2012, and it is unclear whether new funding will be secured. Therefore despite the considerable geographical overlap between CARPO and MIKE, and the complete thematic overlap (elephant management) it is not clear how much mutual support MIKE and WWF can realistically be to each other.

Clearly there are some immediate, low or no cost improvements to current interactions that could be made:

1. WWF should ensure that whenever they conduct elephant population surveys, they adhere to the MIKE standards (Hedges & Lawson 2006) (and other guidelines such as for apes (Kuehl *et al.* 2008))
2. WWF should make their population monitoring and LEM data available to MIKE in all cases (apparently such data sharing has declined in recent years (the Boumba Bek site was resurveyed in 2008, but according to the MIKE Director Julian Blanc, the results were never shared with MIKE).

How much further WWF should engage beyond these measures is unclear, and largely depends on the future of MIKE as a viable programme both in the region and also globally.

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Appendix Small populations

By Frank Princée

INTRODUCTION

Chances to encounter individuals or signs of species which occur at low densities, during a survey, are low. Additionally, detection rates based on visual encounters of individuals or signs in rainforests are generally low due to limited visibility. This means that rare species may not be detected at all during surveys.

The term *rare* is used in both the context of naturally low (population) density and naturally restricted geographic distribution (see e.g. Krebs 2009). For example, African wild dogs (*Lycaon pictus*) were once distributed through most of sub-Saharan Africa, except rainforests and deserts, but always occur(ed) at low densities (Woodruff and Ginsberg 1997). The geographic distribution of a species can be restricted to a single island, which makes it (geographically) rare. However, it maybe abundant where it occurs. The definition of *rare* within the context of low density is used in this document.

Low densities not only refer to rare species, but also to (populations of) species that are *endangered* with extinction due to human intervention. In practice, there is no difference in monitoring between both groups of species. Moreover, a rare species can easily become endangered due to human intervention. Older versions of the Red Data List actually included the category *Rare* for that reason (IUCN 1988).

SMALL POPULATIONS AND EXTINCTION

Small populations are subject to various kinds of natural stochastic processes (i.e. processes in which a variable outcome is random or uncertain) that affect population dynamics. The following broad classes of stochastic processes or uncertainties are generally recognized (Shaffer 1987, Lande 2002) :

1. *Demographic stochasticity*: random events in the survival and reproduction of individuals e.g. shifted sex-ratio at birth or mortality due to accidents.
2. *Environmental stochasticity*: random – or unpredictable – changes in weather, food supply, and populations of competitors, predators, parasites etc.
3. *Natural catastrophes*: e.g. hurricanes, floods, fires, droughts etc., which may occur at random intervals.
4. *Genetic stochasticity*: random changes in genetic make-up due to the founder effect, genetic drift, or inbreeding, which alter the survival and reproductive probabilities of individuals.

Stochastic fluctuations can cause extinction of small populations either directly or through a chain of cumulative events, named the "*extinction vortex*".

This all sounds theoretic, but it is not difficult to imagine real-life scenarios. For example, three forest elephants in Dzanga-Sangha Protected Areas died in 2011when a tree fell on top of them. Such an accident is unrelated to population size, but the impact can be severe for small populations. Just assume that these three elephants were females in their breeding ages, in a remnant population of 100 individuals. Most of the individuals will not have reached the breeding age, so the death of three females will result in a significant decline of births for some years.

The chance that shifted sex-ratios occur increases with decreasing numbers of births i.e. number of males is 0.5^{births}. For example, the chance that four females produce male offspring is $0.5^4 = 0.0625$ (6.25%). This means that is not unrealistic that shifted sex-ratios occur in a small population.

Add the effect of a shifted sex-ratio to the accident, then add an extreme dry year with insufficient food resources; and it is clear that a small population can be rapidly dwindling towards extinction.

Catastrophes can have a serious impact on small populations, making recovery difficult. A good example of a catastrophe is the extreme outbreak of biting flies, *Stomoxys omega*, in northern Congo in 1997. This outbreak resulted in high mortality among adult males (Elkan, 2009)

It is important to realize that populations of endangered/rare species can go extinct - even when successfully protected against human interventions – when population sizes have become small. This also applies to larger populations that have become fragmented, as for example elephants in the Democratic Republic of Congo, where some remnant populations have sizes less than 500 individuals (Hart, 2009). These remnant populations are at risk.

Conservation should, therefore, ensure that isolated (local) populations are sufficiently large to reduce extinction risks due to stochastic processes as described above.

VIABLE POPULATIONS

Conservation managers obviously would like to know what minimum population sizes would be required to prevent rare and/or endangered species becoming extinct in 'their' protected area(s) by chance alone. This subject touches the concept of *minimum viable population* – MVP: the smallest size required for a population or species to have a predetermined chance of persistence for a given length of time (Shaffer 1981).

The MVP concept has been subject to discussion among conservation biologists and has fallen into disfavour (Reed et al. 2002; Reed et al. 2003). However, there is nothing 'wrong' with the concept itself even when it can be difficult to estimate a MVP; or a MVP is interpreted as a fixed number.

It is indeed difficult to calculate an *exact* MVP value as this requires detailed information on population dynamics in the wild. Data that is often not available. Moreover, a MVP differs per species, even between populations, and can change over time when environmental and/or climatic settings have changed. However, it would generally be safe to consider a MVP as a ballpark figure that can help in decision making

A method to estimate a MVP is based on the minimum *effective population size* (N_e) that is required to balance mutation and genetic drift for genetic variants of quantitative characters (on which selection often acts). Franklin (1980) proposed a minimum value of $N_e = 500$ for long-term persistence. Effective population size is defined as “The size of the ideal, panmictic that would experience the same loss of genetic variation, through genetic drift, as the observed population” (Allendorf and Luikart 2007). In more general terms N_e can be described as the number of sexual mature, non-senescent adults (N_B)[28] that have an equal (random) chance to mate and to produce an average number of two offspring (thus the population stays stationary in size).

Effective population sizes are, depending on the social mating structure, in reality much lower than the actual population size. Factors as fluctuating populations sizes, variance in family sizes and unequal sex-ratio reduce effective population sizes. This difference is generally represented by the N_e/N ratio. Frankham (1995) analysed results of studies on N_e/N_A ratio which involved different taxonomic groups, and included the relevant factors that affect N_e . The average value of N_e/N_A in this study is 0.10 - 0.11, which means that long-term effective population sizes are on average 9-10% of the actual adult population sizes.

A first estimate of MVP would be, from a genetic point of view, an adult population size in the order of 5,000 individuals. Such a minimum, however, may not be sufficient as demographic and environmental processes, and catastrophes have impact on population viability.

Reed et al. (2006) estimated MVPs for 102 vertebrate species using Population Viability Analysis (PVA) that takes these factors into account (PVAs will be discussed in the next section). These authors distinguished between MVPs based on adult population size and total population size, which resulted in averages of 7,000 and 11,000, respectively, for a persistence of 99% after 40 generations.

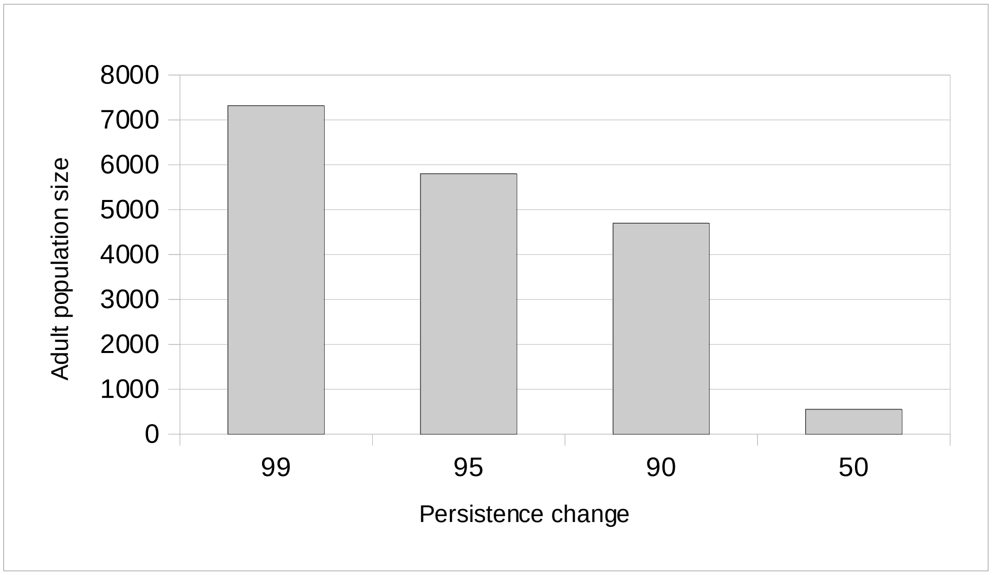

Figure 1: Average Minimum Viable Populations (MVPs) for different changes of

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[28] N_B equals the total adult population (N_A) in species/populations with no post-reproductive age classes.

An important issue that has not been addressed is the impact of management decisions regarding persistence time and chance of persistence on MVPs. Figure 1 shows MVPs for different changes of persistence time over a period of 40 generations. Increasing persistence time will result in an increase of MVPs. Reed at al. (2003) found that doubling persistence time results in ~ 67% increase in MVP.

The use of generations is not that useful in conservation management where goals are expressed in terms of years. Generation time - expressed as "average age at reproduction"[29] - differs per species. The median generation time of the 102 species in the study of Reed et al. (2003) was more than 5 years. This means that 40 generations in this particular study can be expressed in terms of 200 years persistence.

Shaffer (1981) proposed – as a matter of discussion – a 99% persistence after 1000 years. Adoption of these criteria in conservation management has an enormous impact. A rough calculation based on a 67% increase for doubling persistence time, an average (total) MVP of 11,000 individuals for 200 years, implies that enough conservation area needs to be reserved to hold a **total** population of more than 30,000 animals (which is the MVP for 800 years – 160 generations).

Although MVPs are claimed to be in disfavour, more recent studies that include larger datasets and extended population data; and different statistical approaches have been carried out. For example, Brook et al. (2006) estimated and compared MVPs between some 1200 species using different, including density-dependent, population models. Such studies give a better insight into which factors play a key role in determining MVPs.

It may be clear from the previous discussion that MVPs are not fixed numbers written in stone. They differ per species, among populations, and can even differ over time e.g. due to climate change. More over, the required data such as N_e/N ratios, mortality and fecundity rates and other life-history data, are often not available for wild populations. Furthermore, MVPs increase when harvesting (whether subsistence hunting, trophy hunting or poaching) occurs.

Scientists agree that, though MVPs need to be estimated per species/population, values are more likely to be in order of thousands than hundreds. In this, result from analyses on well-studied populations (e.g. Reed et al. 2003) could be used, in the absence of vital life-history data, to set conservative measures e.g. MPVs in the order of 7,000 – 10,000 adults.

POPULATION VIABILITY ANALYSIS

The concept of Population Viability Analysis (PVA) is both a process and a tool to create theory, to analyse data and to project population trends (Beissinger 2002). It existed before Shaffer (1981) introduced the concept of Minimum Viable Populations. PVAs are used to estimate the risk of extinction/chance on persistence of a given population within a specified period of time. It is not surprising that the two concepts are often linked as a MVP could (theoretically) be estimated by manipulating (adult) population size by using a PVA model until the criteria of persistence time and chance are met (as used by Reed et al. 2003; Brook et al. 2006).

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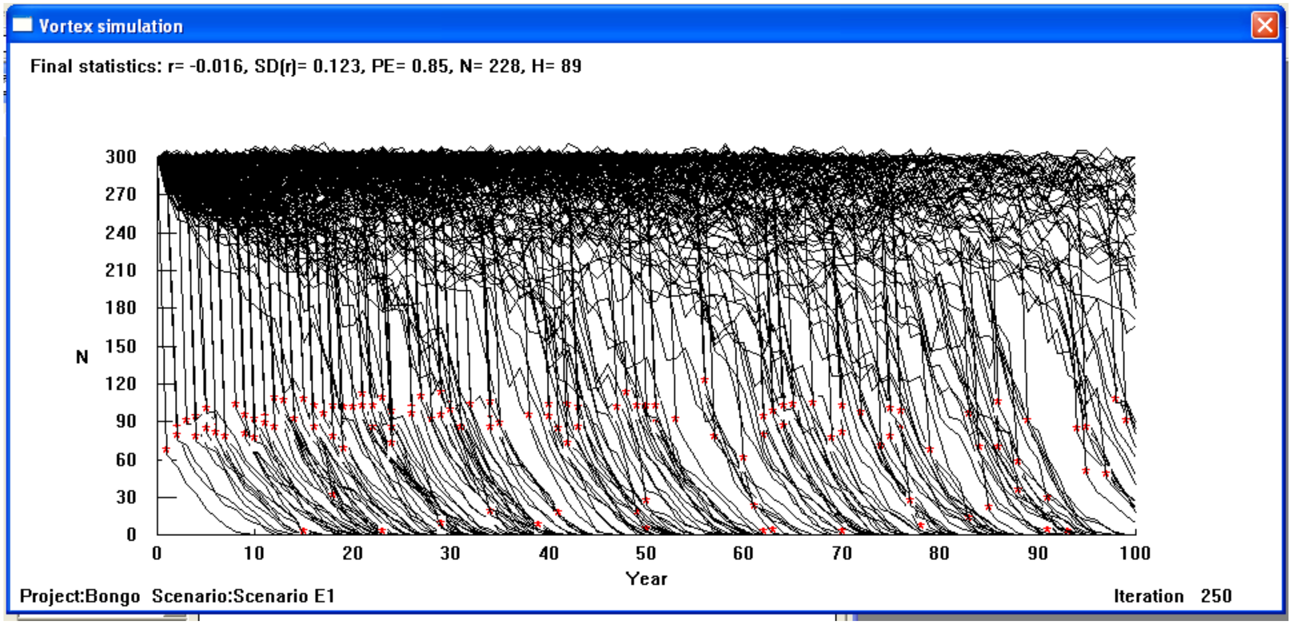
[29] Note that "average age at first breeding" is the proper definition of generation time.

However, this is where the concept of PVA diverts from MVPs: exploring the impact of known, partly known, or even unknown, factors on the viability of populations through modelling different scenarios. In other words: the outcomes of PVAs are often ranges of results (and with each “result” having its own variance).

Software programs like VORTEX (Lacy 2000, Lacy et al. 2009), which is used by the IUCN/SSC/CBSG to assess the viability of small populations, have made the use of PVA models more accessible. This software implements the stochastic (random) processes that affect, especially, small populations as described previously. It is used to determine risk(s) of extinction by 'following' development of population sizes over a period of time (often 50-100 years).

VORTEX is a simulation model, based on Monte Carlo methods, and will by definition result in a range of population sizes per scenario. The extinction risk is based on the number of populations that went extinct on the total of iterations (repeats) of a scenario (model). Furthermore, averages variances and confidence limits regarding population size at the end of the selected period of time is calculated over all repeats. Note that these results are the outcome of a single scenario. Figure 2 shows the results of individual iterations (repeats) of a VORTEX scenario on bongo (in APDS). It shows the essence of predictions: some populations go extinct, some populations are still of the same size (or recovered) as at the beginning.


Final statistics: r= -0.016, SD(r)= 0.123, PE= 0.85, N= 228, H= 89

Project:Bongo Scenario:Scenario E1

Iteration 250

Figure 2: VORTEX simulation results. Red crosses indicate occurrence of a catastrophe.

Since various population data (from initial population size and age structure, mortality & fecundity data, to projected reduction in habitat) are often incomplete or missing, the PVA concept has (similar to MVPs) been under discussion (e.g. Beissinger and Westphal 1998). However these discussions did not reappear profoundly in the last decade. It may be assumed that arguments from pros & cons have been emerged into a consensus. Nevertheless, it is important to point out proper use and limitations of PVA models.

First, to reinforce: a PVA is a model. Although PVA software such as like VORTEX, offer complex population models with many options and parameters, they still partly capture the real world. Second, PVA models project the development of populations under *current* conditions, using *current* knowledge, from life history data, environmental fluctuations, to expected habitat loss. For example, the chance of extreme periods of droughts is based on experiences in the past and, therefore, does not include potential effects of human induced climate change in the future. Third, results from PVAs are expectations, and not hard numbers. The more closely available data and assumptions represent reality, and the projected period of time is modest (e.g. 25-50 years), the more likely it is that the 'true' population size will be in the range of predictions.

However, predicting the 'true' population size and/or estimate extinction risks is not necessarily the primary goal of each PVA, especially in cases where available data are insufficient. PVAs are also used to evaluate relative impact of factors on population development and/or to provide guidelines which data, and thus which type of research or survey, is essential to predict future development.

Modelling is almost a science in itself. Complex models are not necessarily better, depending on the goal, than simple models (see Starfield and Bleloch 1991). Simple models can often better show the impact of a single factors, e.g. increased juvenile mortality or poaching, on population development than complex models in which different factors (e.g. inbreeding depression) can interact. Especially the stochastic components that are implemented in PVAs can make interpretation difficult (see e.g. Fig. 2). Fortunately, programs like VORTEX can also analyse relatively simple models to the extent that it behaves (almost) like a deterministic model with a few parameters.

Discussion PVAs in full depth is beyond the scope of this document. The VORTEX manual includes a comprehensive introduction into the PVA concept (and limitations of both the concept and the software) and can be downloaded (including software) for free (www.vortex9.org).

To conclude: MVPs refer to minimum population sizes that are required to persist for a given period of time. PVAs are used to project viability of a population within a given period and/or to evaluate which studies are important to carry out in order to better predict population viability.

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