Measuring the abundance of wildlife populations in Central African logging concessions

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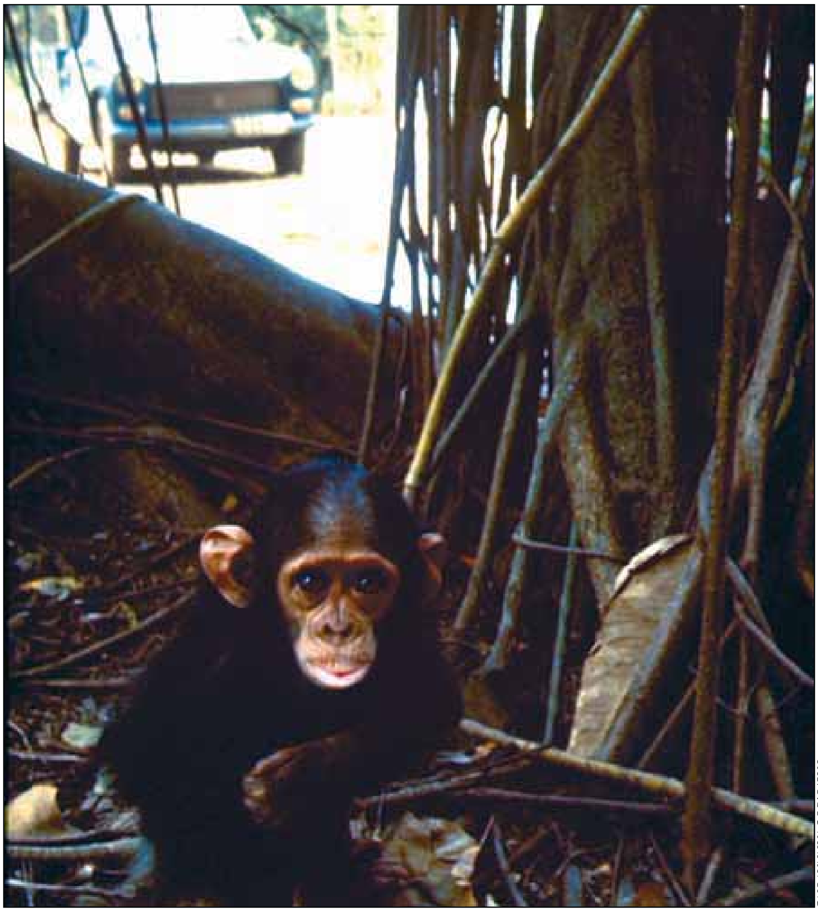
As timber concessions in Central Africa open remote areas to hunting activities, methods for monitoring and measuring wildlife populations bear review.

In Central Africa, selective logging is the most area-extensive extractive industry, with logging concessions occupying 30–45 percent of forests (Nasi, Cassagne and Billand, 2006). The presence of heavy machinery and logging teams has effects on wildlife (Johns, 1997; White, 1994; White and Tutin, 2001), through direct disturbance and modifications of the structure and composition of the habitat. Logging boosts access to remote forests by opening roads in previously inaccessible areas, providing access to markets and increasing population density. Settlements linked to forestry company infrastructures and camps attract large numbers of people, including workers, their families and traders, to areas that have been sparsely populated (Poulsen *et al.*, 2009). Access to remote areas and a rise in population increase hunting activities.



About half of Africa's remaining forest cover is allocated to timber exploitation. Effective wildlife management in timber concessions is critical

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The blue duiker is an important source of protein in Central Africa. According to the IUCN Red List, "[T]his abundant, highly resilient species is suffering some decline in its distribution and numbers as human populations continue to grow and expand"

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Hunting can, in turn, trigger numerous, yet not completely understood, effects that can alter the overall function, structure and composition of the ecosystem. In many cases, these effects are relatively straightforward and easy to predict, especially for those species directly targeted by hunting activities. However, hunting may also have indirect effects, often referred to in the literature as "cascading effects", as several steps of consequential effects may be involved (e.g. Wright, 2003). Among the various systems dependent upon the presence of fauna whose processes are potentially affected by hunting are plant regeneration (loss of pollinators, seed dispersers and seed predators), food webs (loss of top predators or of their prey) and plant diversity (change in herbivory patterns, increased pests) (see Stoner *et al*., 2007, for a review). Hunting, like other extractive activities, may therefore contribute to the degradation of forests. One potential extreme effect is degradation to the stage of quasi-total defaunation[1], in which they become "empty forests" (Redford, 1992).

Although the impact of logging activities and hunting on wildlife is well documented, the role of logging concessions as potential "wildlife reservoirs" compared with unmanaged land is also increasingly recognized (Meijaard *et al*., 2006; Clark *et al*., 2009). As about half of Africa's remaining forest cover is allocated to timber exploitation, wildlife management in timber concessions is critical, particularly as hunting activities press farther into remote areas. Because hunting is about the only source of protein, with fish, insects and grubs, for a large part of the rural population in the tropics, as well as being an important source of income, hunting activities must be managed in such way that they continue to provide protein and income to rural populations, without leading to local extinction of the most vulnerable species (Nasi *et al*., 2008).

Managing hunting activities can only be achieved if appropriate methods to monitor wildlife populations and forest degradation as an impact of hunting are available. This article presents some of the lessons learned from past and recent efforts in assessing the impact of hunting on wildlife populations.

INDICATORS AND METHODS FOR THEIR MEASURE

Indicators

The abundance and density of certain wildlife species appear the most common direct indicators, if not the easiest to measure with any precision (see van Vliet and Nasi, 2008a) of defaunation as an impact of hunting (see Azevedo-Ramos, de Carvalho and Nasi, 2005, for a review on animal indicators and logging). In Central Africa, the abundance and density of large mammals are used as indicators of forest defaunation, with a particular focus on primates and ungulates. The species usually chosen, on the basis of importance as a source of protein and income for rural and urban people living in the Congo Basin, are duikers (*Cephalophus spp.*) and bush pigs (*Potamochoerus porcus*), as well as small diurnal monkeys.

Extent and spatial distribution of roads have been particularly useful for indirect assessment of defaunation (Laurance *et al*., 2006; van Vliet and Nasi, 2008b). Indeed, the distribution of mammals within a forest concession appears influenced much more by roads and hunting than by the direct effects of logging, such as disturbance and modification of habitat (Marshall *et al*., 2006). Most indications of hunting activities are found less than 3 km from logging roads, and there is a strong correlation between hunting signs and distance from roads.

[1] In this article, the word "defaunation" describes a significant decline in animal populations ranging from decrease in numbers or diversity to almost total fauna extirpation.

Other indirect indicators used to assess hunting intensity in logging concessions are: hunters' harvesting profiles, in which data on hunting off-takes are regularly collected for a sample of hunters; hunter effort,[2] which is an economic measure of the effort invested by the hunter; household consumption of bushmeat; and quantity of bushmeat traded in nearby markets.

Survey protocols

Mammal abundance and density

Some studies have used *diachronic* approaches, or approaches in which measurements are taken at two different times at the same site; abundance of mammals is measured before and after logging activities have taken place, and the two sets of data are compared. However, in most cases, data on wildlife abundance before logging activities have not been available. In these cases, researchers have favoured *synchronic* approaches, or approaches in which measurements are taken at one moment in time at different, but related, sites. Using these approaches, data collected from neighbouring hunted and not-hunted sites are compared to assess the impact of hunting.

The most commonly used protocol to survey mammal abundance is line transects, in which data are collected along straight, parallel transects.

In surveys performed by logging companies during their forest management inventories, transects made for vegetation surveys, covering a whole concession, may be used for survey of wildlife and detection of human activity (e.g. hunting). In Central Africa, the inventory of more than 30 million hectares (ha) to comply with national forestry laws (Nasi, Cassagne and Billand, 2006), represents an invaluable data bank that could be used for the assessment of forest degradation (Mathot and Doucet, 2006; van Vliet and Nasi, 2008b).

Studies carried out by individual researchers use shorter, more localized transects of 1–2 km, seeking sites that are similar in terms of habitat and representative of unlogged areas, recently logged areas and areas logged more than a certain number of years before. Data collected during line transect survey protocols usually combine daytime visual counts, pellet counts and nest counts for primates. Transects are walked during the day, early in the morning to maximize direct sightings (from 06.30 a.m. to 10.00 a.m.), at an average speed of 1 km per hour. For duikers, the call count method (van Vliet *et al*., 2009) and night time visual counts (Julve Larrubia, 2005) have also been used.

To obtain data on mammal densities from the line transect records, perpendicular distances of the observations are measured (or estimated). These distances are analysed using distance sampling, in which measurements of the distances of objects observed from a transect line are used to estimate the probability of observing an object (Buckland *et al*., 1993). This method requires a minimum number of 60 direct observations for each species studied, which can be a limitation, given the elusive behaviour of many tropical forest mammals.

For shy and elusive species, dung counts have often proved to be more practical than direct sightings, as the number of observations is often much higher. If data on defecation rates and dung degradation rates are available for each species, dung observations can also be used to assess animal densities using distance sampling. While counting dung pellets is a relatively simple method, there are many possible errors associated with it. Pellet group counts are unworkable, at times, because of variable defecation rates, use of transects and latrines by the animals, variable loss of pellets by beetle attack (van Vliet, Nasi and Lumaret, 2009), extremely dense vegetation or difficulties in identifying pellets of different ungulate species living in the same zone. When the number of observations is scarce, the number of observations per km, or KAI (kilometric abundance index), can be used as a measure of abundance (Mathot and Doucet, 2006). This simple index can be used to compare mammal abundance between sites or over a long-term monitoring period.

As a substitute for line transects, some studies (e.g. Forboseh, Sunderland and Eno-Nku, 2007; Hart *et al*., 2008) prefer census walks or *recces*, where the observer follows a path that offers the least resistance through the vegetation. Recces can be used to register diurnal direct sightings, dung piles and nests. The data obtained are not meant to estimate densities, but can easily be converted into KAI.

Other survey methods besides line transect counts are: capture-recapture methods using nets (Dubost, 1980; Koster and Hart, 1988), in which animals are captured, marked and released, with the marked animals counted, on recapture; net hunting encounters, which involves counting the number of animals seen per searched area (Noss, 2000); and estimating densities from home-range size and population structure (Feer, 1996). These methods have mainly been used for duikers and in relatively small areas because they

Duiker dung pile. Counting dung pellets may be more practical than relying on direct sightings, for certain species

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[2] E.g. number of hunting days for a given yield or game harvested for a given hunting effort (e.g. Rist *et al*., 2008).

are time consuming and usually require the presence of big, well-trained teams.

Capture-recapture methods using non-invasive genetic sampling, for example, from collection of hair and faeces, and camera traps, which are automated cameras that take photographs of wildlife, are currently being tested for some of the Central African species, but the results are as yet unpublished.

Hunting and trading activities

Studies based on data collected at the village or household level use regular (daily, weekly or monthly) semi-structured interviews to assess harvesting profiles, hunter effort or household bushmeat consumption.

Data collected to establish harvesting profiles include species hunted and quantities, hunting technique (gun or snares), number of days allocated to hunting activities, quantities of bushmeat sold or consumed and average price and weight of each animal or piece of animal (e.g. Wilkie *et al*., 1998; Tieguhong and Zwolinski, 2009).

As an alternative to the measure of hunting off-takes, the measure of hunter effort can also be used. Hunter effort may be quantified in units of time such as the number of hours (Franzen, 2006), days (Peres and Nascimento, 2006), or months (Noss, Oetting and Cuéllar, 2005) spent hunting. Hunter effort can also be measured in a number of ways other than in units of time, such as by an index based on the frequency of encounters with hunter signs (Cullen, Bodmer and Valladares-Padua, 2001), by the number of hunters operating in an area (Naughton-Treves *et al*., 2003), in units of hunting equipment such as the number of nets used or traps set per unit time. Other measures are more spatially based, such as the distance of hunting location from human settlement (Rao *et al*., 2005) or nearest point of human access (Hill *et al*., 1997), or the distance travelled by a hunter during the hunt itself (Sirén, Hambäck and Machoa, 2004).

When assessing household consumption of bushmeat, detailed information is recorded about the composition of the principal meal of the day (or of the last few meals), including the unit price of animal protein (fish, livestock or bushmeat), the quantities consumed and the species of bushmeat, if any (Starkey, 2004; Poulsen *et al*., 2009).

Most studies using data collected in bushmeat markets to assess the impact of hunting on wildlife do not focus specifically on logging concessions, but more broadly on a catchment area at a regional scale (Fa *et al*., 1995; 2004). The catchment area is often calculated by evaluation of the total surface covered by all locations mentioned as bushmeat sources by bushmeat sellers, which usually extends beyond the logging concession area. Two main attributes of market dynamics are measured: quantity of and daily availability of each species. These measures are expressed quantitatively as daily abundance of a species and availability of each species in the market. The markets are visited on a regular basis (every day to once a week), and a sample of traders (or all, depending on the size of the market) is interviewed about species sold, quantities and whether meat is smoked or fresh.

DISCUSSION

Line transects provide the possibility to carry out multiple species surveys and have been used largely in the context of logging concessions. However, for regular monitoring, line transects are costly and time consuming. Records from line transects are often too scarce to enable calculating density estimates. These constraints limit the effectiveness of transect surveys as a tool for the monitoring of wildlife population trends. Line transects also imply collateral environmental impacts such as

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Bush pig. Consumption of, and market for, bushmeat can indicate the impact of hunting

the degradation of the understory and the use, by hunters, of these transects to set nets or hunt with guns.

For these reasons, some researchers now prefer to use census walks, or recces. Although this survey approach is attractive when large areas need to be surveyed, as there are fewer logistic constraints, further research is needed to evaluate the quality of the data collected using recces for different mammal species and sign types (including dung, nests, direct observations). More innovative methods, such as capture-recapture methods using non-invasive genetic sampling (Petit and Valiere, 2006) and camera traps, might open new, efficient ways to carry out mammal surveys over large areas. These methods are already used in other contexts for temperate species. With development, they may prove promising for application to tropical species in Central African forests.

Rather than trying to estimate absolute values of densities (with the level of methodological caveats incurred), the aim should be to estimate trends of abundance over time. The KAI offers one simple, but efficient, method to do so. Similarly, methods based on the knowledge of local experts – for example the pooled local expert opinion, PLEO – offer a way to monitor wildlife abundance (van der Hoeven, de Boer and Prins, 2004). In contrast with classical methods, the PLEO method is inexpensive and ensures better local ownership of the results.

Indirect indicators of the role of hunting in forest defaunation are receiving increased attention, although not specifically in the context of logging. The existing literature provides some lessons learned that also apply to logging concessions. For market studies, Fa *et al*. (2004) assessed the efficiency of a number of methods for measuring the volume of bushmeat traded. They found that: useful inferences at a regional scale can be drawn only from a large sample of markets; timing and coordination of sampling may be highly influential on the costs and quality of results; and sampling in blocks of days is as efficient as random sampling in estimating species richness, but not carcass volume. One of the main limitations of market studies is that they generally underestimate the real harvest rate because only a portion of the hunting off-take is sold to markets; the rest is consumed at the village level.

In that sense, hunter interviews for the estimation of harvesting profiles can be more appropriate because they are useful to determine both the quantities kept for own consumption and the quantities sold. Estimations of harvesting profiles and of hunter effort both are time consuming and can only provide accurate results when a certain level of trust exists between the interviewers and the hunters interviewed, limiting the extent of a study to the relatively small scale. Additional challenges associated with measuring hunter effort are: total time estimations can be systematically biased, which can result in overestimation of relevant effort; quantifying trapping effort is problematic because of variable trap checking rates, variable trap group composition and species trap specificity; and economically relevant measures of catch taken from the hunter perspective underestimate the true biological impact of hunting (Rist *et al*., 2008).

CONCLUSIONS

Given the limitations of the different methods discussed in this article, a well-designed survey protocol might imply the use of a combination of approaches with both measures of mammal abundance and measures of hunting and trading activities within a logging concession. Instantaneous measures of these indicators have shown their limits in determining the effects of logging and hunting on wildlife. Instead, long-term monitoring protocols need to be established with the joint effort of governments, logging firms, conservation non-governmental organizations and forest certification bodies.

Van Vliet and Nasi (2008a) show how uncertainty is accumulated in various estimations (especially in those of wildlife populations). Results obtained in different sites are not comparable because different methods have been used to calculate parameters, and each method has different sources of error. Without evaluation of accuracy and standardization of methods, conclusions regarding harvesting sustainability and hunting impacts should be treated with caution.

Further research is needed to lower the human and financial costs of monitoring protocols. The development of innovative methods associated with new technologies, such as non-invasive genetic methods and camera traps, is to be encouraged. Priority for the coming years should be to develop more standardized protocols that would allow comparisons among sites. Until now, most of the studies carried out in different logging concessions of Central Africa have developed their own protocols for the assessment of hunting on forest wildlife populations. The result has been that there are large dissimilarities in the data obtained, and, therefore, there are not comparable results across and within sites. The existence of a more standardized protocol at national or regional levels would provide generalized results that could easily be translated into practical recommendations for more sustainable hunting practices. These recommendations could, in turn, be included in national laws or certification processes to ensure that wildlife is properly taken into account in the management of logging concessions. ◆

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