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Contributed Paper

Hunter Reporting of Catch Per Unit Effort as a Monitoring Tool in a Bushmeat-Harvesting System

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Abstract: *Growing threats to biodiversity in the tropics mean there is an increasing need for effective monitoring that balances scientific rigor with practical feasibility. Alternatives to professional techniques are emerging that are based on the involvement of local people. Such locally based monitoring methods may be more sustainable over time, allow greater spatial coverage and quicker management decisions, lead to increased compliance, and help encourage attitude shifts toward more environmentally sustainable practices. However, few studies have yet compared the findings or cost-effectiveness of locally based methods with professional techniques or investigated the power of locally based methods to detect trends. We gathered data on bushmeat-hunting catch and effort using a professional technique (accompanying hunters on hunting trips) and two locally based methods in which data were collected by hunters (hunting camp diaries and weekly hunter interviews) in a 15-month study in Equatorial Guinea. Catch and effort results from locally based methods were strongly correlated with those of the professional technique and the spatial locations of hunting trips reported in the locally based methods accurately reflected those recorded with the professional technique. We used power simulations of catch and effort data to show that locally based methods can reliably detect meaningful levels of change (20% change with 80% power at significance level (α) = 0.05) in multispecies catch per unit effort. Locally based methods were the most cost-effective for monitoring. Hunter interviews collected catch and effort data on 240% more hunts per person hour and 94% more hunts per unit cost, spent on monitoring, than the professional technique. Our results suggest that locally based monitoring can offer an accurate, cost-effective, and sufficiently powerful method to monitor the status of natural resources. On the basis of our findings, we suggest guidelines for conservation practitioners, such as considering that socioeconomic factors drive use and peoples' incentives for monitoring. To establish such a system in Equatorial Guinea, the current lack of national and local capacity for monitoring and management must be addressed.*

Keywords: biodiversity trends, community conservation, Equatorial Guinea, harvesting, interviews, locally based, participatory, tropical forest

Información sobre la Captura por Unidad de Esfuerzo Proporcionada por Cazadores como una Herramienta de Monitoreo en un Sistema de Cosecha de Carne Silvestre

Resumen: *Las crecientes amenazas a la biodiversidad en los trópicos significan que hay una necesidad imperiosa de monitoreo efectivo que balancee el rigor científico con la factibilidad práctica. Están emergiendo alternativas a las técnicas profesionales que se basan en la participación de los habitantes locales. Tales métodos de monitoreo basados localmente pueden ser más sustentables con el tiempo, permiten mayor cobertura espacial y tomar decisiones de manejo más rápidamente, llevan a mayor cumplimiento y ayudan a estimular cambios hacia prácticas más sustentables ambientalmente. Sin embargo, pocos estudios han comparado los resultados o la rentabilidad de los métodos basados localmente con los de técnicas profesionales o investigado el poder los métodos basados localmente para detectar tendencias. Reunimos datos sobre el*

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esfuerzo y la captura de la cacería de carne silvestre mediante una técnica profesional (acompañamiento de cazadores en viajes de cacería) y mediante dos métodos basados localmente en los que la información fue obtenida por cazadores (diarios de caza y entrevistas semanales a cazadores) en un estudio de 15 meses en Guinea Ecuatorial. Los resultados de esfuerzo y captura de los métodos basados localmente se correlacionaron fuertemente con los de la técnica profesional y los sitios espaciales de los viajes de cacería reportados en los métodos basados localmente reflejaron con precisión los registrados con la técnica profesional. Utilizamos simulaciones del poder de datos de esfuerzo y captura para demostrar que los métodos basados localmente pueden detectar niveles de cambio confiables y significativos (cambio de 20% con 80% de poder en un nivel de significancia (α) = 0.05) en la captura por unidad de especies. Los métodos basados localmente fueron los más rentables para el monitoreo. Las entrevistas a cazadores recolectaron datos de esfuerzo y captura de 240% más cacerías por persona/hora y 94% más cacerías por unidad de costo que la técnica profesional. Nuestros resultados sugieren que el monitoreo basado localmente puede ofrecer un método preciso, rentable y suficientemente poderosos para monitorear el estatus de los recursos naturales. Con base en nuestros resultados, sugerimos lineamientos para los practicantes de la conservación, como considerar los factores socioeconómicos que guían el uso de recursos y los incentivos de la gente para monitorear. Para establecimiento de tal sistema en Guinea Ecuatorial se debe atender la escasez de capacidad nacional y local para el monitoreo y manejo.

Palabras Clave: basado localmente, bosque tropical, conservación basada en comunidades, cosecha, entrevistas, Guinea Ecuatorial, participativo, tendencias de la biodiversidad

Introduction

With growing threats to biodiversity, the need for scientific monitoring is becoming a dominant theme in conservation biology (Bawa & Menon 1997). It is impossible to determine whether conservation efforts have been successful or whether global targets are being met without robust, repeatable systems for monitoring the changing state of nature (Jenkins et al. 2003).

Ideally, monitoring schemes should be scientifically rigorous, allow good spatial and temporal coverage, and be sustainable over extended time scales (Brashares & Sam 2005). Although professional, expert-based monitoring generally meets the requirement for scientific rigor, it is often logistically, technically, and analytically demanding, which makes it difficult to sustain in the long term and across large areas (Danielsen et al. 2005). In addition, it is expensive (Balmford & Whitten 2003; Balmford et al. 2003). Furthermore, professional monitoring may have little influence on conservation decision making at the local level because results are not considered legitimate by resource users or other stakeholders (Owen-Smith 1993). This is a widespread problem in conservation that has resulted in a general shift toward more participatory and inclusive approaches (Kremen et al. 1994).

Consequently, trade-offs in the design of a monitoring system may be needed between scientific rigor and sustainability (e.g., Yoccoz et al. 2001; Danielsen et al. 2003a, 2003b). Alternative approaches are emerging, including locally based monitoring, a general term that includes participatory monitoring, community-based monitoring, hunter self-monitoring, and ranger-based monitoring. Such schemes may be more financially sustainable (Danielsen et al. 2005), and because they involve resource users, management decisions may be implemented more quickly and with greater chance of compliance than if monitoring is entirely expert based (Hackel 1999).

A crucial consideration is whether such locally based methods can detect changes in populations or patterns of resource use accurately (without bias) and with sufficient resolution (with high precision) (Taylor & Gerrodette 1993). Previous investigations of the accuracy of locally based methods have yielded mixed results. Lunn and Dearden (2006) found fishers consistently overreported catch and effort when verified with direct observations, and Gavin and Anderson (2005) found that rapid-assessment interviews were only successful at identifying the species used and not the quantities collected. However, Jones et al. (2008) found rapid assessment interviews to be strongly correlated with more-detailed information on harvesting patterns. In terms of resolution, power analyses have been used to determine whether realistic levels of locally based effort can detect trends with an acceptable degree of statistical confidence. Outcomes so far appear to be case specific; some suggest adequate power is achievable with realistic effort (e.g., Brashares & Sam 2005), whereas others are less optimistic (e.g., Hockley et al. 2005).

To determine whether locally based schemes are accurate and of sufficient resolution, their results must to be compared with professionally derived baselines. Although there is a tendency for bias and low precision in locally based methods, there is cautious support for the ability of locally based methods to detect variation in the status of biodiversity and resource use (Danielsen et al. 2005). However, firm conclusions have yet to be drawn and further comparisons of reliability and cost-effectiveness are needed (Jones 2004; Gavin & Anderson 2005; Gaidet-Drapier et al. 2006). This is particularly vital in developing countries, where in many areas the alternative to locally based schemes is no monitoring at all (Danielsen et al. 2005).

One type of locally based monitoring that may prove useful in developing countries, where rural people meet many of their food and livelihood needs by harvesting wildlife (Pimentel et al. 1997), is that of hunter self-monitoring. Interviews have been conducted to obtain data on wildlife harvesting (e.g., Smith 2008), and there is a growing body of literature that focuses on monitoring relative to the sustainability of hunting (Fa et al. 2004; Noss et al. 2005).

Catch per unit effort (CPUE) is a widely used index of prey abundance and represents an alternative method for evaluating the abundance of wildlife species, determining harvest sustainability (Hill et al. 2003; Siren et al. 2004), and monitoring hunting (Puertas & Bodmer 2004). We investigated the precision, accuracy, cost-effectiveness, and power to detect change of locally based versus professional methods of collecting multispecies catch-effort data. Multispecies CPUE is useful because it relates directly to the production and socioeconomic benefits derived from the system and reflects, at least in part, community-level responses to exploitation (Lorenzen et al. 2006).

We used data from a study of bushmeat hunting in Equatorial Guinea. A professional-monitoring baseline was provided by hunter follows (hunting activities are observed and recorded by researchers and trained assistants), which requires a high input of time, training, and equipment. The alternative locally based methods we tested were hunting camp diaries (where hunters recorded data on catch and effort while working in hunting camps) and weekly interviews with hunters (in which hunting activities were reported and recorded by hunters at the end of a week's hunting once back in the village). We used the results to derive practical recommendations for the selection of accurate, precise, and cost-effective monitoring methods and discuss the feasibility of implementing such a system in Equatorial Guinea.

Methods

Study Location

Our study was carried out in Midyobo Anvom, a village in Rio Muni, mainland Equatorial Guinea (1°N, 10°E), from January 2005 until March 2006 (Fig. 1). Midyobo Anvom has a population of 150–200 people, who practice shifting agriculture and hunting and have little access to alternative livelihoods or food sources. The construction of a logging road in 2001 linking the community to Rio Muni's capital, Bata, allowed a commercial trade in bushmeat to become established. Midyobo Anvom is now one of the main sources of bushmeat in Bata's markets. Further information on the hunting system and offtake is in Rist (2007).

Professional Methods

We conducted hunter follows to obtain data on hunting catch and effort. To record the data we used a Handspring Visor (Palm Inc) personal digital assistant with a Magellan global positioning system (GPS) attachment (MiTAC Digital, Taiwan) and a customized data-collection program written in CyberTracker. Follows were conducted by the lead author or a trained local research assistant. Data on duration of the hunting trip and catch were recorded. Follows were spread evenly across the year, and hunts originated from hunting camps and the village. Scheduling of hunter follows was random where possible and opportunistic when necessary. We made small payments for each accompanied hunt (CFA$1000, US$2). The amount paid was judged sufficient to ensure good will, but not so high as to influence hunting patterns. Neither hunt durations nor prey encounter rates differed between the lead author and trained local assistants (themselves experienced hunters). Therefore we are confident that the presence of observers did not influence hunting decisions or outcomes. A caveat of this method is that hunters might better recall hunts on which they were followed than hunts on which they were not followed. This could result in overestimation of the accuracy of hunter reporting, although it is impossible to test this.

Locally Based Methods

We tested two locally based methods of catch–effort data collection: camp diaries and weekly hunter interviews. Camp diaries were kept by single hunters in each of eight hunting camps (Fig. 1). They recorded the arrival and departure dates and times of hunters in the camp, the date and departure and return times of hunts, the hunting methods used, and details of catches. Data were collected for an average of 20 weeks per camp.

For weekly hunter interviews, all hunters in the community, both those in camps and in the village, were interviewed about their hunting activities at the end of each week throughout the study period. Catch–effort information was reported for all hunting trips conducted, defined as any trip leaving and returning to the village. On the rare occasion that a hunter spent longer than 7 days hunting, all catch–effort data since the previous interview were recorded on his return. Interviews typically lasted 10–15 min and were conducted by the lead author or a local research assistant. The following data were recorded: whether the hunter had been hunting that week, method used, dates spent hunting and times of departure and return, location of the hunt, all animals caught, and method of capture. Hunt locations were assigned to numbered zones on a detailed map of the village and surrounding

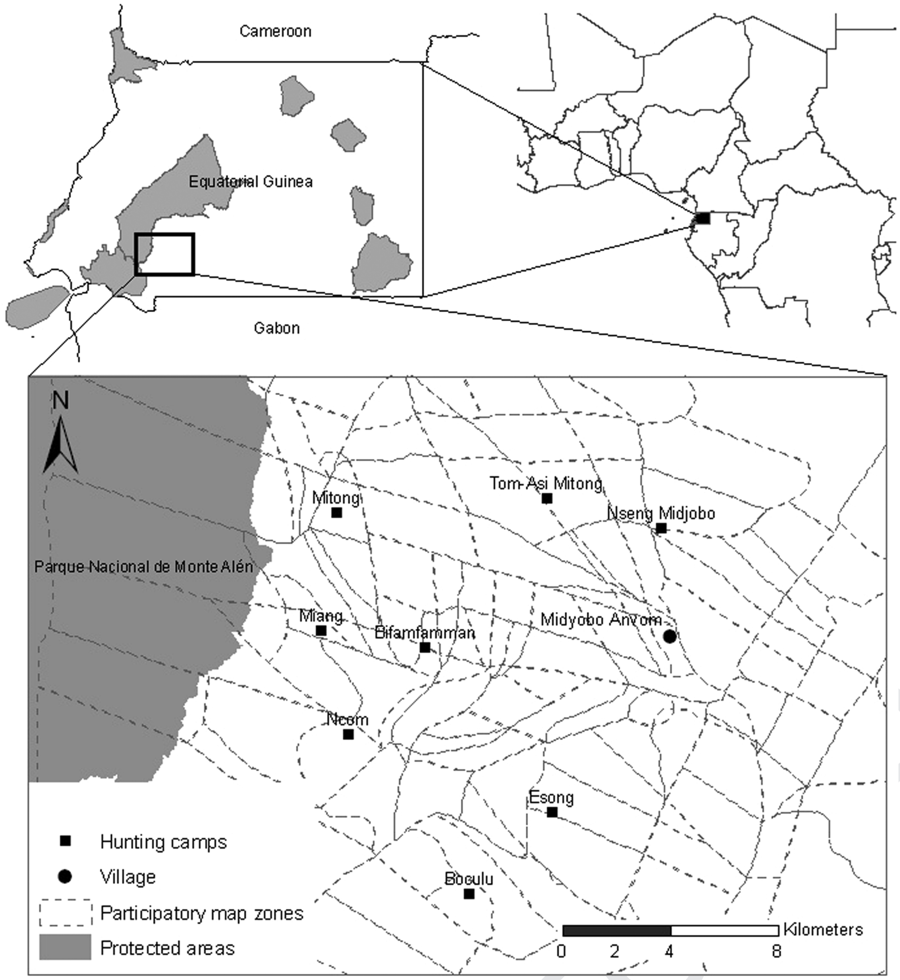

Figure 1. Map of the study area, and its location within Equatorial Guinea and Central Africa, showing community of Midyobo Anvom, protected areas, hunting camps for which hunting camp diaries were collected, and hunting zones from the participatory village map are shown.

area (constructed with participatory mapping methods [Chambers 1994]) (Fig. 1).

Self-reporting of this kind may lead to underreporting to hide illegal hunting activities, or overreporting may occur to impress other community members (Sheil & Wunder 2002; Jones 2004). Hunting was legal in our study area (República de Guinea Ecuatorial 1988). Interviews were conducted in private as far as possible to limit any peer-group effects, and the need for honest reporting of unsuccessful as well as successful trips was explained. We are therefore confident that hunting activity and outcomes were reported to the best of the hunters' abilities.

Comparing Cost-Effectiveness

We compared the costs and benefits of locally based with professional methods of data collection to evaluate their cost-effectiveness. Costs may be defined in terms of money, time investment, or technical expertise required (Gaidet-Drapier et al. 2006; Gardner et al. 2008). We quantified monetary costs (in U.S. dollars) and the time required (in people hours) to collect catch–effort data for each hunt.

Monetary costs include salaries of research assistants and payments to community members for data collection or for participation in data collection. Field equipment was not included in the calculation of monetary cost. Fixed costs such as salary, accommodation, and transport for the project leader were not included in this project-based study and were assumed to be equal across all methods. However, for a monitoring program that is fully institutionalized within a country or area, these costs would need to be incorporated into any assessments of the relative cost-effectiveness of locally based versus professional monitoring methods. Time investment was the time required by salaried research assistants to collect data. Time costs of training by the project leader were not included in the calculation of the time required for data collection

Statistical Analyses

Analyses were performed in the R statistical package (version 2.5.1; R Core Development Team 2007). To assess the accuracy of hunter self-reporting, we compared reported catch–effort data from the locally based methods (camp diaries and weekly interviews) with the catch–effort data recorded by the professional technique (hunter follows of the same hunting trips). Comparisons were therefore made between matched pairs of observations. Catch–effort data were summed per hunter to control for nonindependence of repeated hunts of the same hunter. For comparisons of effort, *t* tests were used, and for comparisons of catch, Wilcoxon rank sum tests were used because of nonnormal errors (Crawley 2007).

To assess the ability of hunters to report their spatial location, we evaluated the percentage of hunting zones correctly reported (accuracy) and compared the distances traveled to hunting locations recorded during follows with distances reported in subsequent hunter interviews for the same hunting trips (precision).

The participatory map used in the interviews was digitized and georeferenced in ArcGIS (version 9.1; ESRI 2006). The GPS positions from hunter follows were imported and overlaid. We calculated reported distance as the straightline distance from the village to the center of each zone identified in the interviews and recorded distance as the straightline distance from the village to the center of the path recorded by GPS during the hunter follow. Matched pairs of recorded and reported distances, with values summed per hunter (to control for nonindependence of repeated hunts of the same hunter), were analyzed with a *t* test and Pearson's product–moment correlation. Spatial accuracy was further evaluated by calculating the absolute distance between recorded and reported hunting locations.

Power Simulations

To investigate the ability of locally based methods to detect changes in multispecies CPUE and determine the influence of sample size and sampling strategy on change detection, we bootstrapped subsamples of the full data set of 3,995 hunting trips recorded in the weekly hunter interviews. We compared three different sampling strategies: (1) random hunter sampling; random sample of the desired size was taken from the full data set of hunts; (2) minimum hunter sampling; hunters were randomly selected and all hunts of these hunters were added to the sample until the desired sample size was met (equivalent to selecting a small number of hunters for intensive sampling); and (3) maximum hunter sampling; all hunters were included with hunts per hunter distributed as evenly as possible between them; thus, every available hunter was sampled but with a lower intensity per hunter.

The sample sizes of hunts were varied systematically from 20 to 3,980 hunts in increments of 20. Sampling was without replacement for all strategies. For each strategy and sample size, mean $2.8 = \frac{R}{\mathrm{CV}\sqrt{1+(1+R)^2}}$ CPUE was calculated for each sample, and the bootstrap function "boot" from the boot package (Ripley 2007) was used to resample (2,000 times) to obtain an estimate of the coefficient of variation (CV) of the mean CPUE estimate. Assuming a desired power of 80% and $\alpha = 0.05$, the equation given by Plumptre (2000) was solved numerically to find the degree of change detectable (% decline, *R*).

Table 1. Pearson's product–moment correlations between professionally recorded hunting catch effort and locally based reporting of hunting catch effort (weekly interviews and camp diaries).

Locally based method	*Catch or effort*	*r*	df	*p*
Weekly interviews	catch	0.67	27	<0.0001
Weekly interviews	effort	0.96	27	<0.0001
Camp diaries	catch	0.40	21	0.06
Camp diaries	effort	0.95	21	<0.0001

Results

Fifty-five of the villages' 80 hunters operated during the study period, and 225 hunter follows were conducted (average 4 [SE 0.4] follows per hunter). A GPS position was recorded for 138 follows due to difficulties in obtaining GPS readings under forest cover. Follows lasted on average 5.85 (0.17) h (approximately 1,315 data collection h in total). Information on 822 camp stays were recorded for 1,960 individual hunts within those camp stays.

Hunter Accuracy

Catch and effort results from hunter follows were strongly correlated with those from weekly interviews and camp diaries for the same hunts (Table 1). Both methods overestimated effort, weekly interviews by 2.50 (SE 0.76) h, or 15% ($t = -3.26$, df = 28, $p = 0.003$), and camp diaries by 2.32 (SE 0.71) h or 17% ($t = -3.25$, df = 22, $p = 0.004$). Catch was not significantly over- or underestimated by weekly interviews ($W = 104.5$, $n = 29$, $p = 0.12$) or camp diaries ($W = 34.5$, $n = 23$, $p = 0.27$).

Only 21% of hunters accurately reported their spatial location to the level of the hunting zone, but nonetheless, average distance between reported and actual locations was relatively small 1.93 km (SE 0.27). Furthermore, the distance of hunting locations from the village recorded on hunter follows was strongly correlated with the distance reported in weekly interviews for the same hunts ($r = 0.98$, df = 45, $p < 0.0001$) (Fig. 2). This indicates a reasonable degree of accuracy in spatial reporting by hunters.

Detection of Changes in Multispecies CPUE

The power to detect a change in CPUE was a function of the coefficient of variation (CV) of the CPUE estimate,

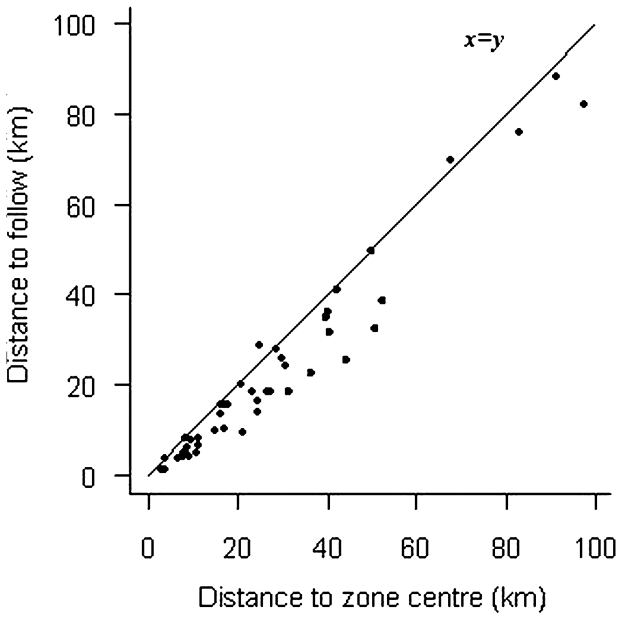

Figure 2. Relationship between the reported distance to zone center and the recorded distance to follow a hunter to a hunting location. Follows are hunting trips where the hunter was accompanied by a researcher. Data points are individual hunters, with distances summed over all recorded hunts.

which was itself a function of sample size and sampling strategy (Fig. 3). In all three strategies, CV initially declined sharply with increasing sample size, but there was little absolute change beyond around 500–1000 hunts. The maximum strategy yielded a slightly lower CV than the random strategy, but the minimum strategy performed much worse than either, with a CV consistently around twice those of the other two strategies.

Differences between sampling strategies were more marked in terms of the power to detect change. The minimum strategy only detected changes three to four times as great as the other strategies. The maximum and random strategies again performed almost equally well. The maximum strategy detected a slightly smaller percent change in CPUE, particularly at small sample sizes. In absolute terms, a sample size of 1,000 hunts allowed change of around 75% to be detected under the minimum strategy, whereas the other strategies detected changes approaching 20%. A large increase in effort, up to around 3,000 hunts, was required to reduce the detectable change to below 10%, even with the best sampling strategy. These results suggest that a sample of around 1,000 hunts is likely an efficient target for most purposes, and that it is best to aim for even coverage of different hunters if possible, but that random sampling of hunters is also adequate if this is easier in practice.

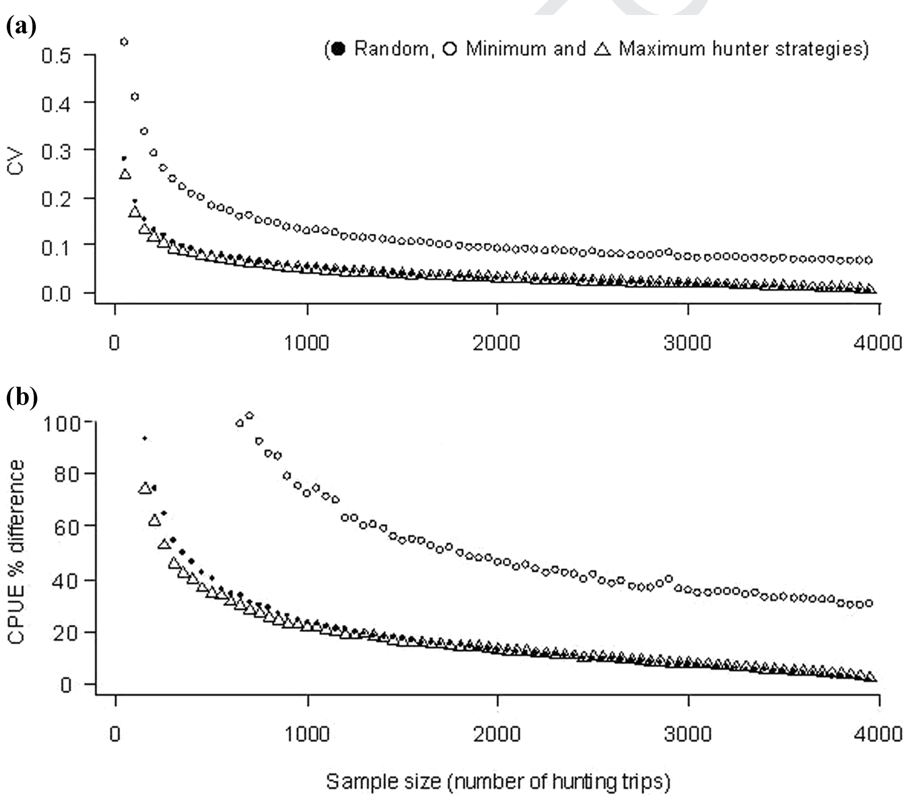

Figure 3. Effect of sample size and hunter sampling strategy on (a) the coefficient of variation (CV) of multispecies catch per unit effort (CPUE) estimates and on (b) the percent change in multispecies CPUE detectable with 80% power and significance level α = 0.05.

Cost-Effectiveness of Locally Based Methods

In terms of time investment, assuming continuous data collection, the professional method (hunter follows) required around 6 person-hours to collect data on a single hunt, whereas over the same time period camp diaries were used to collect data on 153 hunts and weekly interviews on 240 hunts. A similar pattern was seen in the monetary cost of data collection: a single hunt cost US$9.36 to monitor professionally, whereas for the same cost information was recorded on 50 hunts with camp diaries or 94 hunts with weekly interviews. Of the two locally based methods, camp diaries gave less spatial coverage than weekly interviews and did not incorporate information on hunting activity around the village.

The three methods can be compared in terms of the cost and effort required to achieve the minimum number of 1,000 hunts necessary to detect useful levels of change in multispecies CPUE, with either a maximum or random strategy of hunter sampling. With the professional method, 6,000 person-hours was required to sample 1,000 hunts, at an annual cost of US$9360. Locally based methods were hugely more cost and time efficient. Use of camp diaries for data collection, required 39 h at a cost of US$200, and 25 h of weekly hunter interviews cost US$100 (Table 2).

Consideration must also be given to the additional costs of equipment, technical expertise, and fixed costs of setting up and running a monitoring program (e.g., project leader's salary). The fixed costs of project setup can be split equally across methods; therefore, the professional method is likely to be the most costly and to require additional financial investment in equipment and considerably more time investment in the training and supervision of research assistants.

Discussion

We evaluated effectiveness of locally based methods for conservation practitioners to collect multispecies catch–effort data for monitoring bushmeat hunting. Although additional work is required to determine whether the same results emerge for single species or particular taxonomic groups, we found that these methods can be sufficiently accurate, precise for trend detection, and cost-effective. As such they may offer a currently underutilized tool for sustainable management of hunting. These findings also have wider relevance for management of other harvesting systems where resources for monitoring are limited and the involvement of resource users is essential.

Accuracy of Catch–Effort Reporting and the Cost-Effectiveness of Monitoring

Catch was accurately reported with locally based methods, whereas effort was overestimated on average but closely correlated with the professionally derived baseline. This indicates that consistently applied, locally based methods can give reliable catch–effort information, assuming the bias in effort remains constant over time. These results give further support to the findings of Jones et al. (2008) that rapid assessment interviews can supply reliable information on harvesting patterns.

The overestimation of effort, but not catch, may have occurred because catch is important and hence more accurately recalled; catch equates directly to food and income. With effort, there may be a rounding-up effect or a peer-group effect in which hunters slightly overestimate effort, but are less able to inflate catch because animals are sold openly in the village to bushmeat traders.

A certain amount of inaccuracy in locally based reporting is to be expected, even if participants are not deliberately misreporting. More problematic are situations in which there is deliberate misreporting, which may arise if hunters perceive conflicts of interest with the monitoring program (Danielsen et al. 2005) or if they wish to conceal information from other members of the community. If there is a perception that the interviewer might use the information to promote restrictions, then catch and effort are likely to be underreported or denied altogether. Such misreporting may render any information collected useless—the use of locally based methods should therefore be accompanied by consideration of the wider context and possible motivations of resource users (Jones et al. 2008).

The percentage of hunting zones correctly reported was low, which suggests that boundaries between neighboring zones were generally not easily identifiable by hunters. However, error in reported distance was low, and the distances of recorded and reported hunting locations were strongly correlated. This suggests that although the hunting zones defined in this study were too small to be monitored accurately by self-reporting, hunters can be sufficiently accurate at a slightly larger scale. This result is encouraging because it is extremely difficult to assess sustainability of a harvest without reliable information on the area from which animals are taken (Ling & Milner-Gulland 2008), particularly if management involves some form of spatial control or zoning. Few studies have yet investigated the feasibility of obtaining accurate spatial information on biodiversity or resource through locally based techniques (but see Jones et al. 2008).

Reporting of resource use appears to be more accurate in our site than has been found in other studies (Gavin & Anderson 2005; Jones et al. 2008). However, these previous studies compare the results of rapid-interview methods or monthly recall against more detailed self-reporting or daily recall of resource use by informants. In contrast, we compare reported values to recorded information on exact levels of resource use. Similarly, Lunn and Dearden (2006) compared fisher reporting with information on Q2

Table 2. Cost effectiveness of professional (hunter follows) and locally based (camp diaries and interviews) hunting catch–effort monitoring techniques.

Attribute of method	*Hunter follows*	*Camp diaries*	*Weekly interviews*
Data compiler	researchers and trained full-time research assistants (RAs)	hunters from the community (part-time research assistant)	hunters from the community (auxiliary research assistant)
Extent of technical or expert input required for data collection	extensive training, and continual input for electronic data retrieval	minimal training and input required only for establishment	minimal training and input required only for establishment
Total time to train in data collection	2–3 h, number of supervised follows	<1 h, followed up with several short supervisions	<1 h, followed up with several short supervisions
Recall period	none—immediate	in camp at end of day	in village at end of week
Extent of area monitored (km^2) per bout of data collection	area used by a hunter on a single hunt <5 km^2	catchment areas of hunting camps only, approx. 30 km^2 per camp; requires an enumerator in each location monitored (hunting camps in this study); hunts conducted from locations without an enumerator due to cost or logistics excluded from data collection (village-based hunts in this study)	hunting catchment of whole community, approx. 300 km^2
Interval between bouts of data collection	daily	daily	weekly
Number of hunters surveyed per data collection bout	1 hunter	all hunters in a camp, mean 6.4 (SE 1.5) (hunters hunt approx. 4 d per week)	all hunters in community, approx. 80 hunters (hunters hunt approx. 4 d per week)
Time investment per data collection bout (person h)	1 observer per follow, average duration 5.9 (0.2, SE 1) h	1 hunter per camp, approx. 15 min per d per data collector	2 hunters for the community, approx. 4 hours per week per data collector
Effort to sample one hunt (person h)	6 h/hunt	2.4 min/hunt	1.5 min/hunt
Payment to individuals giving data[a]	1000 CFA[c] (US$2.10) per hunter followed	none/occasional small gifts	none/occasional small gifts
Payment to individuals collecting data[a]	salary approx. 17,500 CFA (36.40 US$) per 5-d working week	salary approx. 2,500 CFA (5.2 US$) per week	salary approx. 7,500 CFA (15.6 US$) per week
Total cost to sample one hunt	9.36 US$	0.20 US$	0.10 US$
Cost for yearly data collection (detect 20% change)	9,360 US$	200 US$	100 US$
Time for yearly data collection (detect 20% decline)[b]	6,000 h or 750 d	39 h, or 4.9 d	25 h, or 3.1 d
Equipment required	PDA[d] (60 US$) with GPS (100 US$), computer, electricity supply, replacement batteries	pen and paper	pen and paper

[a]*August 2007.*
[b]*Assume 8-h working day.*
[c]*Central African Franc.*
[d]*Personal Data Assistant.*

exact fishing catch and effort. Lunn found overreporting of catch and effort. However, in bushmeat hunting catch events typically consist of very few animals, making accurate reporting more likely than in fisheries, where catch is usually measured in the tens or hundreds. The characteristics of a harvesting system may therefore predispose it toward or away from accurate reporting. The heterogeneity of the surrounding landscape may influence the spatial accuracy of reporting, as might education levels and the conservation history of a community (e.g., previous work of other researchers).

Although accuracy and precision are often assessed in the selection of monitoring methods, little attention is generally paid to cost-effectiveness—a crucial criterion (Balmford et al. 2003). Our results show that locally based methods are slightly less accurate than the professional benchmark, but that they have vastly lower financial and time costs and are therefore much more cost-effective overall. In contrast, the costs of the professional methods we used are not likely to be cost-effective for long-term and large-scale monitoring.

Power to Detect Changes in Multispecies CPUE

Low precision and poor repeatability of estimates extend the time required to correctly identify declines, with the result that management action may not be initiated until populations have become severely depleted (Wade 1998). Effective monitoring methods must maximize their power to detect change for a given sampling effort, but statistical power is often the first casualty in the face of financial constraints (Field et al. 2005). Our results show that this need not always be the case. In our system, the locally based method detected declines in multispecies CPUE of a reasonably small size with realistic levels of survey effort,

The best strategy was sampling as many different hunters as possible to maximize the repeatability of CPUE estimates. The need for a wider sampling effort likely reflects the considerable variation between hunters in their levels of skill (Hilborn 1992). One consequence of this is that if participation rates by hunters in community monitoring programs are low (Noss et al. 2005), only very large changes in CPUE will be reliably detected. This finding has general implications for any harvesting system that involves many harvesters operating with different efficiencies. Without good participation, the power of the monitoring program will be low and declines may go undetected.

Realities of Locally Based Monitoring

Biological monitoring of resource status alone will not be sufficient to achieve conservation; it must be integrated with the monitoring of use and the underlying socioeconomic factors driving use (Bawa & Menon 1997) and must lead to decision making and action. Catch–effort data are particularly useful because it provides information on trends in the abundance of exploited species and on hunting returns. Thus, CPUE data provides a means of estimating the value of the harvest to people and therefore the cost of imposing restrictions (Godoy et al. 2000).

In our study, community members were paid to act as data collectors. But for any monitoring scheme that applies these methods to be sustainable in the longer term, the incentives for participation must be based on more than short-term financial motivation. For a locally based monitoring scheme to work in practice, the benefits of monitoring (e.g., improved future harvests), must be greater than the costs for the individuals and communities concerned, both of monitoring and implementing management interventions (Hockley et al. 2005).

In comparison with other monitoring techniques (mammals surveys with line transects), CPUE methods are beneficial because they interfere far less with the other activities of local people and are also relatively easy for community members to collect. Furthermore, unlike line transects, CPUE data are relatively easy to analyze and so could potentially be analyzed by local people. Management decisions could also be made locally on the basis of simple decision rules. For example, a decrease in CPUE might suggest a decrease in population size due to overuse, in which case initiating a management action, such as a reduced hunting, would be needed. A pilot monitoring scheme is needed to assess how data could be managed locally to generate management decisions.

Implementation of a Locally Based Monitoring Scheme in Equatorial Guinea

Given the dependence of many rural Ecuato-Guineans on bushmeat for food and income (Allebone-Webb 2008), to achieve more sustainable hunting behavior, the lack of alternative food and livelihood options will need to be addressed simultaneously. Rural communities in Equatorial Guinea do not have stable land tenure, and hunting rights can be sold without the knowledge or consent of the community (J.R., personal observation). Without a long-term interest in the preservation of bushmeat resources for future use, and when outsiders have free access, these communities currently have few incentives to participate in the monitoring or management of wildlife offtake.

In our study, researcher presence and the employment of community members helped facilitate enthusiasm, participation, and accurate data collection. The degree to which such a professional presence is needed for successful and continued implementation of locally based monitoring is still unclear. Monitoring is about more than data collection; the work needs to be organized, data analyzed, and findings presented to decision makers. We evaluated only the accuracy and precision of the data collection. Other potential constraints associated with data management and analysis, such as the use of inconsistent methods across time, would need consideration for the entire process of monitoring to be undertaken by a local community.

A classification system of participatory monitoring approaches has been published recently (Danielsen et al. 2009), and it distinguishes five categories on the basis of relative involvement of local stakeholders and professional scientists. Within this scheme, our locally based methods would be classified as "externally-driven monitoring with local data collectors."

Equatorial Guinea's current lack of capacity for natural resource management means the chances of "collaborative monitoring with local data interpretation" or "autonomous local monitoring" systems becoming established in the near future are very low, unless in the context of an externally driven project. However, given sufficient national will and resource input, together with sufficient international technical assistance, there is potential for the development of such a monitoring system at a national scale. Equatorial Guinea in comparison with its neighbors has an extremely high per capita income (CIA 2008), which in combination with its small size, high forest cover, and relatively healthy wildlife populations, makes national-level monitoring desirable and feasible. Capacity building for monitoring and management at community, as well as national levels, will be essential for the future sustainable management of bushmeat resources.

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