DISCUSSION PAPER SERIES

Managing Forest Wildlife for Human Livelihoods in the Korup-Oban Hills region, West-Central Africa

Challenges in Estimating Sustainable Wildlife Harvest Rates

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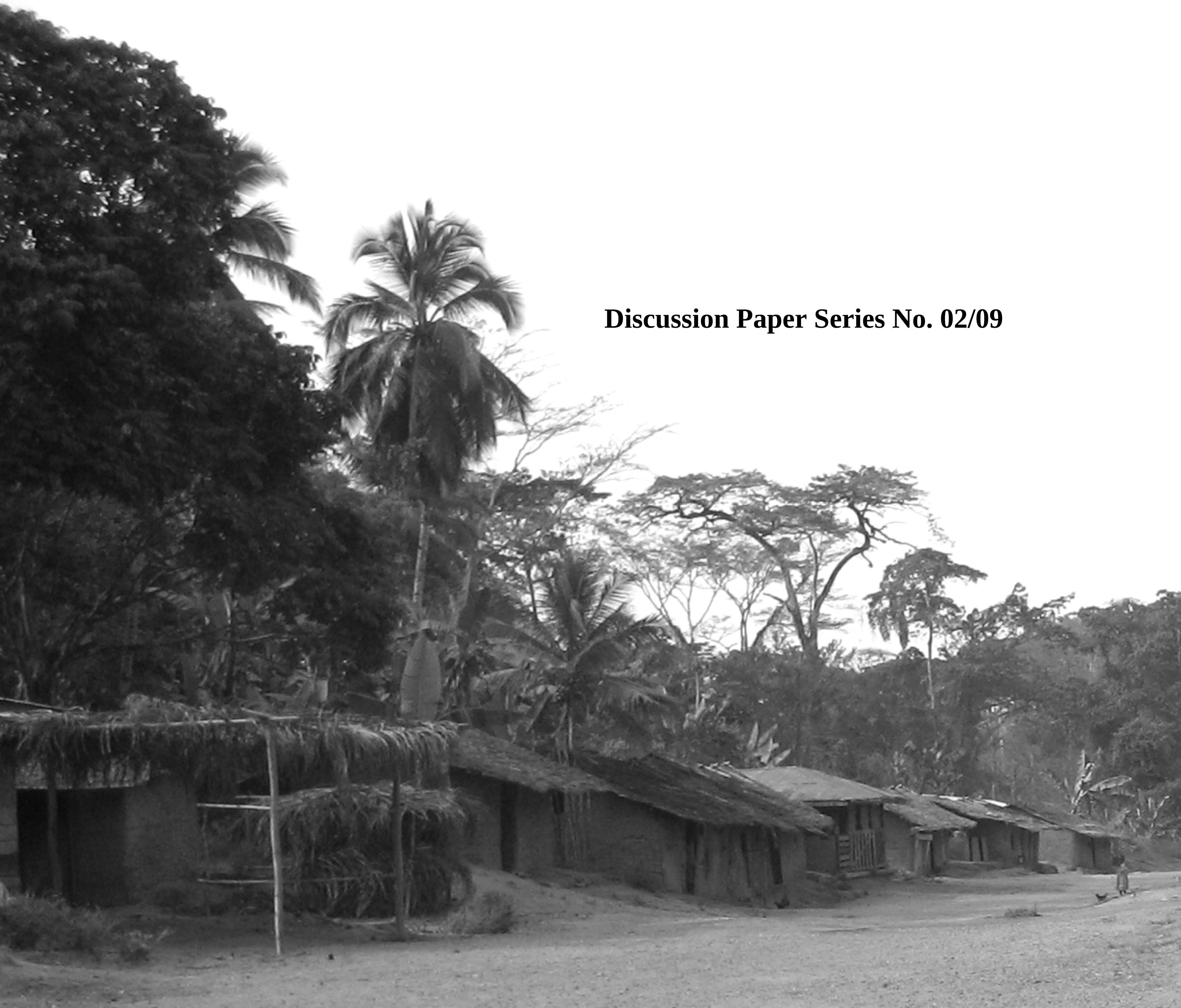

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Challenges in Estimating Sustainable Wildlife Harvest Rates

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Abstract: This paper focuses on the advantages and disadvantages of four commonly used methods for estimating bushmeat extraction rates, and presents as an example the calculations from a real-life application of such an algorithm for estimating maximum sustainable harvest rates of four common bushmeat species (*Cephalophus monticola, Atherurus africanus, Cercopithecus mona* and *Cercopithecus nictitans*) near Korup National Park in Cameroon.

Keywords: bushmeat off-take, sustainable harvest estimates, assessing hunting sustainability

1. Introduction

Unsustainable hunting of animals for "bushmeat" is a serious problem in tropical Africa (Milner-Gulland and Akcakaya, 2001) and considerable resources are currently directed into understanding the social, economic and ecological impacts of current exploitation rates and identifying ways to alleviate them.

A necessary first step in the management of the "bushmeat crisis", as it is often referred to, is evaluating the sustainability of current harvest rates of wildlife. This involves a) measuring the off-take (harvest rate) of bushmeat from an area and b) determining the effect that this extraction has on the hunted wildlife species (Milner-Gulland and Akcakaya, 2001). Over the years, several algorithms have been proposed as quick and simple ways of estimating the sustainability of hunting. Table 1 presents some of the most widely used approaches (adapted from Milner-Gulland and Akcakaya, 2001). Major obstacles have been the lack of available data and the inherent difficulty and high cost of obtaining them in tropical forests. Recognizing the limitations of current harvest-estimation approaches is important for establishing levels of confidence in the produced results. Failure to do so, could lead to confidently making wrong decisions.

This paper focuses on the advantages and disadvantages of four commonly used methods for estimating bushmeat extraction rates, and presents as an example the calculations from a real-life application of such an algorithm for estimating maximum sustainable harvest rates of four common bushmeat species (*Cephalophus monticola, Atherurus africanus, Cercopithecus mona* and *Cercopithecus nictitans*) near Korup National Park in Cameroon.

Table 1: Algorithms used to assess the sustainability of bushmeat hunting and for cetacean bycatch. (adapted from Milner-Gulland and Akcakaya, 2001).

Name of algorithm	Algorithm[a]	Notes
Robinson and Redford	$P = 0.6\,K\,(R_{max} - 1)\,F$	$F = 0.2$ for long-lived species, $F = 0.6$ for short-lived species
Bodmer A	$P = 0.5\,N\,\phi\,s$	$0.5\,N$ is an estimate of the density of the female component of the population. $s = 0.2$ for long-lived species, $s = 0.6$ for short-lived species
Bodmer B (altered version of Bodmer A)	$P = 0.5\,N\,\phi\,s$	s is the actual percentage of individuals surviving to the average age at reproduction
NMFS	$P = 0.5\,N\,(R_{max} - 1)\,F$	N is a minimum estimate. F varies between 0.1 and 1.0, depending on level of bias and uncertainty in the data. Here, $N = 0.9$ of the estimated value, $F = 0.5$
Deterministic discrete logistic	$P = 0.6K \left(\frac{R_{max}}{1 + 0.6(R_{max} - 1)} - 1 \right)$	Assumes that the target population size is $0.6K$

Parameters: P = sustainable level of production; R_{max} = maximum annual per capita rate of increase; K =

population density at carrying capacity;N = current population size; F = mortality or recovery factor; S (Bodmer) = female survival to the average reproductive age; Φ= female fecundity

2. Review of bushmeat sustainable harvest estimates

Recognizing that available data will likely always be imperfect, Milner-Gulland and Akcakaya (2001) suggested that regardless of the algorithm used, management decisions should be cautious and err on the side of safety by assuming that off-take rates of wildlife are on the high end of the estimated range of values while wildlife populations are on the low end of the range. In addition, estimates should be based on proven tools for estimating the sustainability of hunting, and ideally use more than one algorithms.

In general, evaluating an estimation "tool" requires taking into consideration the following issues:

a) Is the collection of the data required by the algorithm feasible given the available resources of management?
b) What is the anticipated level of confidence (or uncertainty) of the data collected for the required parameters taken into consideration?
c) What are the circumstances under which the selected estimation algorithm is likely to fail to detect over-exploitation of wildlife?

It quickly becomes clear that selection of an algorithm requires careful planning and consideration given the specific needs and limitations of a management site.

2.1 Robinson and Redford's production model

Calculation and advantages

Probably the most widely used algorithm for assessing bushmeat hunting sustainability is Robinson and Redford's (1991) production model. It is simple, uses easily-attainable parameters and gives a threshold value against which sustainability can be judged. It uses data on a) population densities (standing population number) and b) the intrinsic rates of growth of that population to estimate the maximum level of production. Production (P) is defined as the number of animals that are added to a population annually. To assess sustainability, P is then compared to the number of individuals harvested from the area. If the current off-take levels are found to be approaching the value calculated for P, there is reason to be concerned. Of course, the challenge is to estimate what proportion of P can be sustainably harvested.

The formula used to calculate the maximum sustainable production is:

$$\mathbf{P= 0.6\ K\ (R_{max} - 1)\ F}$$

The parameters are:

K = Density at carrying capacity. This data can be obtained from lightly exploited or unexploited areas, or from empirical relationships between density, diet and body size (see Fenchel, 1974).

R_{max} = intrinsic rate of population increase. Difficult to estimate. For its calculation see Box 2 in Milner-Gulland and Akcakaya (2001).

Standard value 0.6 = it is the density at which maximum production occurs (maximum sustainable yield level).

P = maximum production (no. of animals/km^2). It describes the production that might be generated by a natural population under the best of all possible environmental conditions (Robinson and Redford, 1991). The point at which maximum production occurs depends on the life-history strategy of the species. Robinson and Redford's assumption of 60% of carrying capacity is suitable for forest ungulates.

F = a factor accounting for natural mortality and varies with longevity ((0.6 = < 5 years (short-lived species), 0.4 = ≥ 5 years but < 10 years, 0.2 = ≥10 years (long lived species). If natural mortality is high, hunters can afford to take a higher proportion.

Robinson and Redford proposed as a rule of thumb that for very short-lived species up to 0.6 of P can be annually harvested sustainably, while the proportion drops to 0.4 and 0.2 for short-lived and long-lived species (Robinson, 1991). An example of how the Robinson and Redford production model is calculated is provided at the end of this paper (data and analysis from Tchigio, 2007).

Drawbacks

The Robinson and Redford production model has been criticized for not taking into consideration the survival rates of species and that Rmax (intrinsic population growth rate) is used in the formula instead of the actual growth rate of a given population (Slade et al., 1998). In reality, the actual population growth rates will be significantly lower than $R_{max,}$ due to density dependent factors. Furthermore, the Robinson and Redford model generally assumes population densities under non-hunted conditions (which affect the K value) (Refisch and Koné, 2005). But if the population to be managed is already depleted due to hunting, an apparently sustainable harvest rate could be in practice unrealistic and result in overharvesting (Millner-Gulland, 2000). Furthermore, Slade et al. (1998) pointed out that the multiplicative factors of F generally tend to overestimate growth rates and maximal production. Moreover, they criticized the models assumption that there is no mortality of juveniles and adults up to the age of last parturition.

These assumptions lead to an overestimation of P and risks, and it could lead to the situation where the model erroneously identifies as harvest rate as sustainable when it is not. This runs contrary to the proposed precautionary principle of Milner-Gulland and Akcakaya (2001), which states that an algorithm that consistently overestimates the maximum sustainable off-take is less satisfactory than one that consistently underestimates it. As a result, the main limitation of the Robinson and Redford algorithm is that it is insufficiently precautionary in situations of uncertainty, such as when wildlife populations are already affected by hunting.

Another important drawback of the algorithm is that it permits wildlife managers only to evaluate whether an actual harvest rate is not sustainable, but can not necessarily identify a sustainable harvest. Slade et al. (1998) noted that the algorithm shows when a population is clearly overharvested, however overexploitation can occur at levels below the maximal production rate. It would thus be wrong to conclude that if harvest rates do not exceed maximal production rates, these situations truly represent ‘sustainable’ harvests (Slade et al. 1998).

2.2 Bodmer model

The Bodmer algorithm calculates population production directly from fecundity rates, rather than using R_{max} (Robinson and Bodmer, 1999). Where rates of birth for a specific population are known, direct harvest models can be used to evaluate the sustainability of hunting. Estimates of production can be derived directly from the average number of young produced per female per year (= reproductive condition of harvested females multiplied by the average no. of gestations per year) and the population’s density (Bodmer 1994 in Robinson and Bodmer, 1999).

The formula used to calculate the maximum sustainable production is:

$$\mathbf{P = (0.5D) \times (Y*g)}$$

The parameters are:

D = population density
Y = litter size
g = mean number of gestations/year

[The same formula is also experessed as P= 0.5NΦs – see Table 1 from Milner-Gulland and Akcakaya, 2001 for details]

The main concern of the performance of Bodmer's algorithm is that the proxy for survival rates is, according to Milner-Gulland and Akcakaya (2001), set too high, which is likely to affect the algorithms ability to realistically detect unsustainable harvest rates.

2.3 National Marine Fisheries Service (NMFS) algorithm

The National Marine Fisheries Service in USA has developed an algorithm used in its harvest management plan for fisheries. Although clearly developed specifically for estimating harvest rates of aquatic resources, it seems a promising approach that can be adapted to other ecosystems and with wildlife species with varying life history strategies. In fact, the ability of an algorithm to adapt to diverse settings is a strong advantage.

The formula used to calculate the maximum sustainable production is:

$$\mathbf{P = 0.5N(R_{max} - 1)F}$$

The algorithm apparently is efficient in reducing the risk of extinction to low levels, but there are expressed concerns by some managers that it may lean too much on the precautionary side, considering that bushmeat in tropical Africa constitutes a primary dietary source of protein, as opposed to an economic activity in developed nations.

2.4 Barne's simulation model

Barnes (2002) introduced a model for measuring the effects on forest mammal populations of increasing harvest rates (adapted from Caughley et al., 1990). The model was tested on the greater putty-nosed monkey (*Cercopithecus nictitans)*, the medium-sized Bay duiker (*Cephalophus dorsalis*) and the small-sized blue duiker (*Cephalophus monticola*). The model was also adapted to incorporate stochastic events in its calculations, which is important given the known inter-annual variation in birth and death rates (r_m) due to the variable impact of weather, food availability patterns, disease and parasite stress and mortality from non-human predators. Barnes simulation model also raised concerns that an unsustainably harvested population may not necessarily show warning signs of a gradually declining population growth, which could inform managers of serious population depletion. Instead, for some species it is possible that a seemingly healthy population may suddenly collapse. Although simulation models are simplifications of reality, they can nevertheless be used to examine the sensitivity of various algorithms in detecting changes in wildlife population trends.

3. Selecting and algorithm

When comparing simulated algorithm performance under a range of scenarios for two contrasting life histories, the Robinson and Redford, Bodmer A, and Logistic Algorithms (see Table 1) perform poorly under realistic conditions of uncertainty (Milner-Gulland and Akcakaya, 2001). The Bodmer B and NMFS algorithms perform respectively better or worse in different scenarios. This realization highlights the need to use multiple algorithms when assessing the levels of hunting in a locality and the potential impact sit may have in the long-run. Failing to do so increases the risk that simple, less complex algorithms will overestimate sustainable levels of wildlife harvest, while on the contrary more-complex algorithms may underestimate acceptable harvest rates.

Ultimately, the dynamic nature of the bushmeat crisis, which is constantly changing due to variables such as human population growth, deforestation and land-conversion of wildlife habitat, road construction and increased accessibility of areas to hunters, logging activities, increasing life aspiration of rural communities, and urban prosperity (which results in increase of bushmeat as a delicacy), may constitute finding a "perfect" algorithm for estimating sustainable wildlife harvest rates an utopic endeavour. As Barnes (2002) put it, "Biologists seek the Holy Grail of sustainability but sustainable harvests may well be a mirage."

4. An example of how to calculate maximum sustainable harvests

Tchigio (2007) used Robinson and Redford's model (1991) to calculate the sustainability of bushmeat harvests around the Korup National Park in Southwest Province of Cameroon. The observed density of common bushmeat species (D) was multiplied by the maximum finite rate of increase of the population (I_{max}) to determine the maximum annual production $P_{max(D)}$.

$$\mathbf{P_{max(D)} = (D \times I_{max}) - D}$$
$$\mathbf{= (I_{max} - 1)\, D}$$

The maximum production also occurs when density is at 60% of the carrying capacity (K).

$$\mathbf{P_{max} = (0{,}6K \times I_{max}) - 0{,}6K}$$

To calculate the effective rate of population growth I_{RR}, the factor f_{RR} of 0.6, 0.4 or 0.2 have to be considered.

$$\mathbf{I_{RR} = 1 + (I_{max} - 1)\, f_{RR}}$$

Thus, the maximum production P_{RR} (= maximum possible sustainable harvest) is:

$$\mathbf{P_{RR} = (I_{RR} - 1)D}$$

where D is either the site-specific estimate or equal to 0.6K (Robinson, 2000 in Tchigio, 2007).

To calculate the potential biomass harvest $P_{RR(biomass)}$, the maximum possible production must be multiplied by the biomass of the species (M):

$$\mathbf{P_{RR(biomass)}. = M \times P_{RR}}$$

An example of a calculation to determine the maximum possible sustainable harvest of the Blue duiker *Cephalophus monticola* for a theoretical community hunting zone of 50 km² (currently the recommended hunting zone size):

$$\begin{aligned} \mathbf{P_{max(D)}} &\mathbf{= (D \times I_{max}) - D} \\ &= (I_{max} - 1)\ D \\ &= (1{,}63 - 1) \times 7{,}8 \\ &= 4{,}\ 914 \end{aligned}$$

$$\begin{aligned} \mathbf{I_{RR}} &\mathbf{= 1 + (I_{max} - 1)\ f_{RR}} \\ &= 1 + (1{,}63 - 1) \times 0{,}4 \\ &= 1{,}252 \end{aligned}$$

Note: Longevity of *C. monticola* is 7 years, thus $f_{RR}.= 0{,}4$

$$\begin{aligned} \mathbf{P_{RR}} &\mathbf{= (I_{RR} - 1)D} \\ &= (1{,}252 - 1) \times 7{,}8 \\ &= 1{,}9656 \end{aligned}$$

$$\begin{aligned} \mathbf{P_{RR(biomass)}.} &\mathbf{= M \times P_{RR}} \\ &= 6{,}3 \times 1{,}9656 \\ &= 12{,}38 \\ &= 12{,}38 \times 50 \\ &= 619 \end{aligned}$$

Thus for *C. monticola* the maximum possible sustainable harvest in biomass is 619 kg/50km²/yr. However, the maximum possible offtake for the other three species is considerably less (see Table 2). It is therefore questionable whether such amounts could sustain the needs of a community, with access to the hunting zone.

What about sustainable livelihoods?

Each individual should daily consume approximately 50 g of protein, which assuming a 20% protein content in meat, equals to a daily dietary need of: 0.25 kg/meat/person. In a year, a properly nourished (in terms of protein) human would then require ~91.25 kg of meat. Dividing the annual sustainable harvest estimated for the blue duiker by Tchigio (2007), then this hunted species could only satisfy the protein demands of 6.78 people annually (within the 50 km^2). The total biomass that can be sustainably harvested from all four species slightly increased the human carrying capacity of the hunting area to 11-12 people. Clearly, a local population could harvest more than these four species, but it is clear that large human populations can not rely exclusively on protein obtained from wild animals, under the current human population densities.

Table 2: Body mass, longevity, reproductive characteristics, and maximum possible sustainable harvest of four key bushmeat species (adapted from Tchigio, 2007)

Species	Common name	Body mass (kg)	Longevity (yrs)	Intrinsic rate of increase (r_{max})	Maximum finate rate of increase (l_{max})	Effective rate of pop. growth (l_{RR})	Observed density (no/km²)	Maximum production: P_{max} (no/km²/yr)	Maximum production: $P_{max(biomass)}$ (kg/km²/yr)	Maximum production: $P_{max(biomass)}$ (kg/50km²/yr)	Maximum possible sustainable harvest: P_{RR} (no/km²/yr)	Maximum possible sustainable harvest: $P_{RR(biomass)}$ (kg/km²/yr)	Maximum possible sustainable harvest: $P_{RR(biomass)}$ (kg/50km²/y
Cephalophus monticola	Blue duiker	6,30	7,00	0,49	1,63	1,252	7,80	4,91	31,00	1550,00	1,97	12,38	619,00
Atherurus africanus	Brush-tailed porcupine	2,80	22,90	0,60	1,82	1,164	10,90	8,94	25,00	1250,00	1,79	5,00	250,00
Cercopithecus mona mona	Mona monkey	4,50	30,80	0,11	1,12	1,024	24,60	2,95	13,30	665,00	0,59	2,70	135,00
C. nictitans nictitans	Putty-nosed monkey	5,40	30,80	0,11	1,11	1,022	6,50	0,72	3,90	195,00	0,14	0,80	40,00

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