Bushmeat hunting in the Congo Basin: an assessment of impacts and options for mitigation

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Abstract

Hunting of wild animals is an important component of household economies in the Congo Basin. Results from the growing corpus of quantitative studies show that: a) bushmeat remains the primary source of animal protein for the majority of Congo Basin families; b) bushmeat hunting can constitute a significant source of revenue for forest families; c) bushmeat consumption by low density populations living in the forest may be sustainable at present; d) demand for bushmeat by growing numbers of urban consumers has created a substantial market for bushmeat that is resulting in a halo of defaunation around population centres, and may be driving unsustainable levels of hunting, even in relatively isolated regions; and e) large-bodied animals with low reproductive rates are most susceptible to over-exploitation compared with more r-selected species that apparently can tolerate relatively intensive hunting (Mangel et al. 1996). As urban populations continue to grow and economies revitalise, unless action is taken to alter the demand for and supply of bushmeat, the forests of the Congo Basin will be progressively stripped of certain wildlife species, risking their extirpation or extinction, and the loss of values they confer to local economies. Consequently, it is essential that: a) logging companies are encouraged or coerced not to facilitate bushmeat hunting and transportation in their concessions, b) we develop a better understanding of the elasticity of bushmeat demand, c) pilot bushmeat substitution projects are supported and their impact on demand evaluated, and d) social marketing activities are put in place to attempt to direct consumer preferences for animal protein away from bushmeat species that are particularly susceptible to over-exploitation.

Bushmeat hunting to provide meat for the family, and as a source of income is a common component of household economies in the Congo Basin and more generally throughout subSaharan Africa (Asibey, 1977; ma Mbalele, 1978; Martin, 1983; Anadu et al. 1988; Geist, 1988; King, 1994; Juste et al. 1995). Some ethnic groups such as the Mvae, Yassa and Kola of Cameroon eat more meat—73 kg/capita/year (primarily bushmeat) than the average person in France (Chardonnet et al. 1995), or the industrialized world—30 kg/capita/year. Previous studies have shown that market and subsistence hunting can result in the unsustainable exploitation of game (Caldecott, 1987; Geist, 1988; Alvard, 1993; Ludwig et al. 1993; Lahm, 1993a; Alvard, 1994; Joanen et al. 1994; Fitzgibbon et al. 1995; Noss, 1995; Chardonnet et al. 1995; Bowen-Jones, 1997). Even when human population densities are low, hunters can extirpate large, slow reproducing species (Alvard, 1993; Redford, 1993; Lahm, 1994; Fitzgibbon et al. 1995). Human population across the region is likely to have at least doubled since the 1920s (Hochschild, 1998), and given average growth rates of 2.7% (range 1.5-3.3%) are expected to double again in 25-30 years. Given this, demand for wild game will increase and may exceed production rates, thus resulting in the progressive depletion of primates and ungulates throughout the forests of the Congo Basin.

This paper synthesises the quantitative literature and further analyses data on bushmeat hunting in the region to: 1) evaluate our confidence in current estimates of the impact of bushmeat hunting on wildlife populations and ocal economies across the Basin; 2) identify gaps in our knowledge; and 3) propose future directions for research and intervention.

Impact of Bushmeat Hunting on Wildlife Populations

What do we need to know to assess the impact of bushmeat hunting on wildlife populations within forested regions of the Congo Basin? The answer is relatively simple to state but difficult to achieve. We need to know whether the ratio of production of individual species per unit area of forest (kg/ha/yr) to present and projected harvest rates for domestic and market consumption (kg/ha/yr) is such that the biomass of harvested species is, or will remain, stable over time.[2] Thus we need information on:

1. harvest rates of bushmeat species (i.e., quantity of bushmeat hunted in a given area over time) for sites across the Basin;
2. maximum possible production per unit area of forest for all primary bushmeat species; and
3. density of primary bushmeat species in areas of known offtake and production over time.

Literature on Bushmeat Harvesting

In the last decade a growing number of studies have voiced concerns about the scale of bushmeat exploitation in the Congo Basin. These studies can be divided into either largely anecdotal accounts that focus world attention on the issue (ma Mbalele, 1978; Klemens and Thorbjarnarson, 1995; Pearce and Ammann, 1995; Pearce, 1996; McRae, 1997), or more quantitative assessments of bushmeat consumption at national and household levels (Heymans and Maurice, 1973; Asibey, 1974b; Pierret, 1975; Mares and Ojeda, 1984; Colyn et al. 1987; Wilson and Wilson, 1989; Hladik et al.

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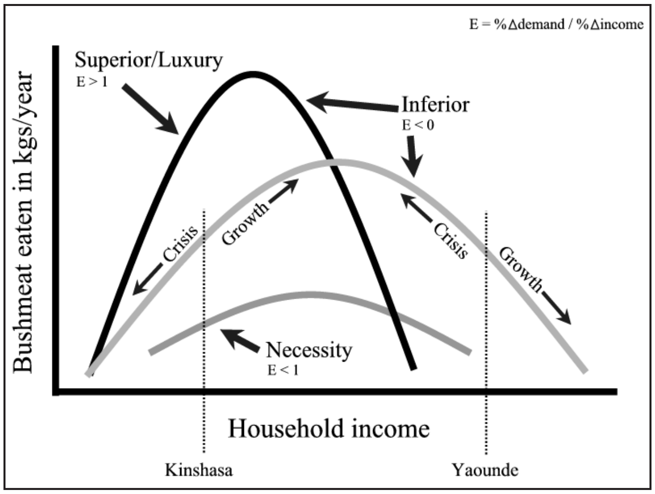

1990; Hladik and Hladik, 1990; Anstey, 1991; Wilson and Wilson, 1991; Laurent, 1992; de Garine, 1993; Takeda and Sato, 1993; Steel, 1994; Bennett Hennessey, 1995; Eves, 1995; Chardonnet, 1995; Njiforti, 1996; Auzel, 1996a).

These studies document the species diversity and quantity of bushmeat being sold in city markets or consumed by families, but tend not to report the catchment area from which these animals were taken. Thus, though we can infer the scale of bushmeat consumption from these studies, we are unable to address issues of sustainability because we do not know if the bushmeat sold in, say the Libreville market, came from 1,000 ha or 1,000 km^2 of forest. Nevertheless, these bushmeat consumption studies have been an essential first step in developing our understanding of the importance of bushmeat to the diets and economies of Africans in the Congo Basin.

Household Consumption of Bushmeat

Bushmeat consumption in forest-dwelling populations within the Congo Basin has been measured in a number of studies. However, comparison across studies is problematic as it is often unclear if consumption estimates are based on whole carcass, dressed, or boned-out weights. Bailey and Peacock (1988) estimated meat consumption for foragers in the Ituri forest of northeastern Democratic Republic of Congo (DRC, formerly Zaire) to be 0.16 kg/person/day. Aunger (1992) used informant diaries and calculated meat consumption for Ituri farmers to be 0.12 kg/ person/day. These values are similar to those reported by Chardonnet et al. (1995). He conducted a survey of wild meat consumption in subSaharan Africa and estimated that foragers ate about 0.104 kg/person/day and farmers 0.043 kg/person/day. Lahm (1993a) estimated that bushmeat consumption in Ogooué-Ivindo, Gabon was between 0.10-0.17 kg/person/day. Noss (1995) reports that Babenjele net-hunters in Mossapoula, Central African Republic (CAR) consume only 0.05 kg/person/day. Meat consumption in villages surrounding the Dja reserve in Cameroon, Odzala national park in the Republic of Congo (Congo), and the Ngotto forest in the CAR range from 0.08-0.16 kg/person/day (Delvingt, 1997). Farmers resident in the Campo Reserve in southwestern Cameroon consume on average 0.19kg of meat/person/day (Dounias et al. 1995 reported in Dethier, 1995). The Yassa, Mvae, and BaKola from coastal southern Cameroon consume between 0.02-0.20 kg/person/day of bushmeat (Koppert et al. 1996). Higher bushmeat consumption rates have been reported by Auzel (1996a) for families living in northern Congo (0.16-0.29 kg/person/day); Koppert et al. (1990) for forest hunter-gatherers (0.29 kg/person/day), and Anstay (1991) for rural Liberians (0.28 kg/person/day).

Chardonnet et al. (1995) report that urban populations in Gabon, DRC and the CAR consumed on average 0.013 kg/person/day—which is less than 10% of the bushmeat eaten by hunter-gatherers living in the forest. However, total meat consumption was higher in urban compared with rural areas (Chardonnet et al. 1995), given their higher population density.

Using these data we can generate gross estimates of the quantity of bushmeat consumed in forest and urban areas across the Congo Basin.

Table 1 suggests that bushmeat consumption across the Congo Basin may exceed 1 million metric tons, and harvest rates may range from 50-897 kg/km^2/year. Unfortunately, the level of gener-

Table 1
Urban and Rural Bushmeat Consumption in the Congo Basin

Country	Forest Area km^2	Population[c] Forest	Population[c] Urban[a]	Bushmeat Eaten[b] kg/year	Bushmeat Eaten[b] kg/km^2/yr
Cameroon	155,330	1,424,000	2,214,620	78,077,172	503
CAR	52,236	219,500	539,775	12,976,507	248
DRC	1,190,737	22,127,000	3,782,369	1,067,873,491	897
Equatorial Guinea	17,004	183,000	227,500	9,762,838	574
Gabon	227,500	181,700	581,440	11,380,598	50
Congo	213,400	219,500	1,245,528	16,325,305	77
Total	**1,856,207**	**24,354,700**	**8,591,232**	**1,196,395,911**	**645**

[a] *Only major urban areas proximal to dense forest are included—Douala, Yaounde, Bangui, Berberati, Nola, Brazzaville, Pointe-noire, Ouesso, Kinshasa, Kisangani, Bukavu, Mbandaka, Libreville, Port Gentil*

[b] *Bushmeat consumption estimated at 0.13 kg/person/day for rural areas, and 0.013 kg/person/day for urban areas*

[c] *Population data from (Bahuchet and de Maret, 1995), (Deichmann, 1997), and the CARPE GIS (http://carpe.gecp.virginia.edu)*

Table 2
Composition of Bushmeat Captured in the Congo Basin

Location	Ungulates[a]	Primates	Rodents	Other
Ituri forest, DRC[1]	60–95%	5–40%	1%	1%
Makokou, Gabon[2]	58%	19%	14%	9%
Diba, Congo[3]	70%	17%	9%	4%
Ekom, Cameroon[4]	85%	4%	6%	5%
Brazzaville, Congo[13]	76%	8%	6%	10%
Ouesso, Congo[5]	57%	34%	5%	4%
Ndoki and Ngatongo, Congo[6]	81–87%	11–16%	2–3%	
Dzanga-Sangha, CAR[7]	77–86%	0%	11–12%	2–12%
Libreville, Port Gentil, Oyem, and Makokou, Gabon[8]	34–61%	20–45%	5–27%	3–12%
Bioko and Rio Muni, Equatorial Guinea[9]	36–43%	23–25%	31–37%	2–4%
Dja, Cameroon[12]	88%	3%	5%	4%
Ekom, Cameroon[10]	87%	1%	6%	6%
Oleme, Congo[11]	62%	38%		

Sources
[1](Hart, 1978; Ichikawa, 1983; Wilkie, 1989; Wilkie and Curran, 1991); [2](Lahm, 1994); [3,4](Delvingt, 1997); [5](Bennett Hennessey, 1995); [6](Auzel and Wilkie, 1998); [7](Noss, 1995); [8](Steel, 1994); [9](Fa et al. 1995); [10](Ngnegueu and Fotso, 1996); [11](Gally and Jeanmart 1996) duikers and other species only; [12](Dethier, 1995); [13](Malonga, 1996)
[a]primarily the duikers (Cephalophinae) and bushpigs (Potamochoerus porcus)

alisation and likely errors in all of the parameters included in these estimates provide us with little confidence in their accuracy.

Bushmeat Species Exploited

Table 2 shows the relative contribution of each species group to animals typically captured by hunters from a sample of studies drawn from across the Congo Basin.

Duikers (*Cephalophinae*), pigs, primates and rodents are the most commonly hunted groups of animals in the forest, with duikers both numerically and in terms of biomass being the most important bushmeat species group. Rodents gain in importance in urban markets, presumably because duikers have been depleted in nearby forests (Steel, 1994; Fa et al. 1995). Interestingly, the ratio of duikers to rodents found in urban markets may provide a very rough index of bushmeat over-exploitation or diminishing hunter access to dense forests (e.g., from table 2—the ratio in rural Ekom, Cameroon, is 14:1, whereas in urban Libreville, Gabon the ratio is as low as 1:1.25).

Studies on bushmeat consumption indicate which species are being exploited and allow for generalisations regarding the likely impact of hunting on wildlife populations. However, without a detailed understanding of the quantity of bushmeat extracted and produced over a given time period from a known area of forest, these studies provide only anecdotal assertions about the sustainability of bushmeat hunting in any given area.

Duiker Harvest Rates

Given the relative and absolute importance of duikers to bushmeat hunters, most of the following sections on harvest rates and production focus on these forest antelope. Several recent studies have taken the critical next step of measuring, not only how much bushmeat is harvested, but estimating the catchment area utilised by hunters. With these data we are able to characterise the range of harvest rates that exist across the region. Table 3 summarises harvest rates in several sites across the Congo Basin for the Cephalophinae (duikers), the most commonly hunted forest wildlife.

Harvest rates estimated from field survey data (Table 3) are all 5-10 times lower than Basin-wide estimates drawn from average consumption data and human population size (Table 1), assuming that the latter estimate includes only the duiker fraction. This suggests that population figures are inflated or that per capita consumption of bushmeat is, on average, substantially lower for most households living in forest or urban communities.

Robinson and Redford (1991) suggest that relatively short-lived animals such as duikers (7-12 years longevity) should not be harvested at a rate that exceeds 40% of annual production. Given this and the range of present harvest rates, we can extrapolate that duiker production must exceed 80-400 kg/km^2/yr, depending on the location, for duiker hunting at its present levels to be sustainable. The following section explores whether, in fact, the data on the productivity of important bushmeat species exist to assess whether harvest rates are, or are not, likely to be sustainable.

Literature on Bushmeat Production Rates

To estimate the maximum biomass of a given bushmeat species that can be harvested each year without causing the population to crash, we need to know at least two things: a) the maximum finite rate of increase of the species–$\underline{r}$ (i.e. the rate that a population increases from year to year) and b) present population density relative to carrying capacity–$\underline{K}$.

Knowing $\underline{r}$ allows us to estimate what the productivity of a population of a given bushmeat species would be at a density from 0 to $\underline{K}$. If the species growth curve follows the logistic model, then maximum productivity would occur at 0.5$\underline{K}$. However, species that

Table 3
Duiker Harvest Rates Across the Congo Basin

Site	Range km^2	Blue Duikers[a] kg/km^2/yr	Red Duikers[b] kg/km^2/yr	All[c] kg/km^2/yr
Cameroon–village zone[1]	37	16	62	81
Cameroon–forest zone[1]	270	4	68	74
Cameroon–Dja[6]	600	8	100	114
Cameroon–Lobéké[7]	3,113	18	56	74
Cameroon–Korup[8]	–	–	–	217
Congo–Diba[2]	55	14	141	162
Congo–Oleme[2]	81	15	39	56
CAR–Dzanga-Sangha[3a]	1,000	22	93	115
CAR–Dzanga-Sangha[3b]	110	67	32	99
DRC–Ituri[4]	12,899	–	–	75
Equatorial Guinea–Bioko[5]	–	2	30	32
Gabon–northeast[9]	–	–	–	75–1390

Source
[1](Dethier, 1995); [2](Gally and Jeanmart, 1996); [3](Noss, 1995) [a]Snares and guns, [b]nets; [4](Wilkie et al. 1998b); [5](Fa et al. 1995) Catchment area was not reported. Primates provided the highest % of hunter captures; [6](Ngnegueu and Fotso, 1996) Extrapolated from 11 of 30 hunters monitored over 5 of 12 months.; [7](WCS, 1996); [8](Infield, 1988); [9](Feer, 1993)

[a]Blue duikers = Cephalophus monticola
[b]Red duikers = Cephalophus callipygus, C. dorsalis, C. leucogaster and C. nigrifrons
[c]Includes C. sylvicultur

do not breed until late in life (e.g. primates) tend not to exhibit a logistic growth curve, and maximum productivity is more likely to occur at higher densities—0.6-0.9K (Robinson and Redford, 1991).

The best way to estimate r is using life and fecundity tables based on the population being studied, where age-specific mortality, survivorship, and numbers of live births per female are determined for individuals present within ranked cohorts of known age.

Fecundity and Mortality Data

Information on duiker, rodent, and primate life history characteristics are reported by Haltenorth and Diller (1980), Kingdon (1997), East (1995), and Estes (1991). However, the primary sources for these estimates are few, and often based on a very small sample of captive animals. As a result, the value of the data is uncertain, and there are gaps in our knowledge. For example, age specific mortality and fecundity are never reported, nor is age at last parturition. Thus, for duikers, we must assume that all females are fecund and reproduce at a constant rate (i.e. continuously pregnant) from sexual maturity at 0.75-1 years old to the end of their average life span of 10-12 years. Paucity of life history data makes estimation of production problematic.

Duiker Density Data

Knowing the observed density of a given bushmeat population relative to its theoretical carrying capacity (i.e. an un-hunted population) in a given area, allows us to determine if densities are a) below that required for maximum production, and thus would need to recover before harvesting, or b) could sustain higher than maximum harvest rates until the density was reduced to 0.5-0.6K.

Though we would like to know the present density, carrying capacity and r for all common bushmeat species in a stratified random sample of forest blocks within the Congo Basin, even measuring the density of the most common species is difficult and the results often uncertain. Small size of most common bushmeat species, discrete behaviour, and dense vegetation make systematic and reliable visual censuses extremely difficult (White, 1994) within a single forest area. Differences in plant species composition and understory density from one site to the next make cross-site bushmeat density estimates difficult even when the same researchers use the same methods. In the Congo Basin, not only have researchers used very different methods to conduct censuses in different areas, the reliability of index measures of density (i.e. dung or track counts) is poorly understood.

The scale of the problem is demonstrated by two studies of forest duiker density conducted in the Ituri forest of northeastern Congo (Koster and Hart, 1988; Wilkie and Finn, 1990). Wilkie and Finn's estimates of duiker density in the northeastern Ituri using pellet counts were 5-10 times greater than Koster and Hart's estimates using drive counts in the southern Ituri. Without further study, we will not be able to discern whether the difference in duiker estimates was a result of the methods used, differences in hunting pressure in the two sites, or reflected true differences in duiker carrying capacity.

Table 4 shows how duiker biomass estimates vary across sites and with census method.

Duiker biomass estimates from one site to another across the Congo Basin vary from 101 to 1,497 kg/km^2 depending on the methods used. Visual counts using either encounter transects or drive counts generate more comparable numbers ranging from 101 to 201 kg/km^2, although even these still differ by almost 100%.

Table 4
Duiker Biomass Across the Congo Basin

Site	Method	Blue Duikers[a] kg/km^2	Red Duikers[b] kg/km^2	Total
Gabon, Lopé[1]	Visual and pellet counts	5	97	101
Gabon, N.E.[2]	Visual daytime counts	20	180	201
Gabon, N.E.[2]	Visual nighttime counts	115	152	267
DRC, N.E.[3]	Visual counts	48	126	174
DRC, N.E.[4]	Pellet counts	226	1,272	1,497
Gabon, N.E.[5]	Capture-recapture	248	685	933
Gabon[6]	Capture-recapture, habitat	257	317	574
Cameroon, S.E.[7]	Visual counts	22	150	171
Cameroon, S.E.[7]	Visual counts and called in	164	1,009	1,173
Cameroon, S.E.[8]	Pellet counts	14	156	170
Cameroon, S.W.[9]	Pellet counts	72	515	587
Cameroon, S.W.[9]	Visual daytime counts	31	221	252
Cameroon, S.W.[9]	Visual nighttime counts	73	50	123

Source
[1](White, 1994); [2](Lahm, 1993b); [3](Koster and Hart, 1988); [4](Wilkie and Finn, 1990); [5](Dubost, 1980); [6](Feer, 1993); [7](Dethier, 1995); [8](WCS, 1996); [9](Payne, 1992)

[a]Blue duikers = Cephalophus monticola
[b]Red duikers = Cephalophus callipygus, C. dorsalis, C. leucogaster and C. nigrifrons

Table 5
Duiker Production Estimates

Site	Blue Duikers kg/km^2/year	Red Duikers kg/km^2/year
Cameroon, Lobéké[1]	5	18
Cameroon, Korup[5]	28–47	24–48
DRC, Ituri[2a]	43	77
DRC, Ituri[2b]	9	133
DRC, Ituri[3]	108	408
Equatorial Guinea[4]	43	28
Gabon[6]	54	218

Sources
[1](WCS, 1996); [2a](Hart, 1985); [2b]Hart in press; [3](Wilkie and Finn, 1990); [4](Fa et al. 1995); [5](Payne, 1992); [6](Feer, 1993)

Duiker Production Estimates

Table 5 is drawn from sources that incorporate the best available information on duiker life-history characteristics and density to present the range of duiker production estimates available for sites located across the Congo Basin.

Given the variability in duiker density estimates and the fact that most studies applied the same production estimation formula and life-history data, it is not surprising that the variance in production estimates mirrors the range in density estimates.

All these production estimates used the same basic equation from Robinson and Redford (1994), which assumes no mortality of juveniles and adults up to the age of last parturition. A recent paper by Slade et al. (1998) suggests that this results in overestimates of production, which risks concluding that bushmeat species are sustainably exploited when they may not be.

Regardless of which method was used to assess duiker productivity, comparison of average harvest rates (97 kg/km^2/yr–Table 3) with average production rates (170 kg/km^2/y–Table 5) suggests that duikers are being overharvested across much of the Congo Basin—assuming that, as Robinson and Redford suggest (1994), relatively short-lived animals should not be harvested at a rate that exceeds 40% of annual production (i.e. 68 kg/km^2/yr).

Estimates of the Sustainability of Bushmeat Hunting

If our confidence in the accuracy of duiker densities across the basin is low, our knowledge of changes in duiker density over time and under different hunting pressure is even worse. Few studies have measured duiker density, and even fewer have done so over time or in ecologically comparable areas that are hunted and not hunted. Similarly, our knowledge of duiker mortality and fecundity rates under unhunted and hunted conditions is exceedingly poor (Hart, 1998).

Direct Measures of Hunting Impact

Lahm (1994) censused game densities in hunted and nonhunted patches of forest near Makokou, Gabon (Table 6).

Assuming that habitat, vegetation density, and visibility are comparable in the hunted and unhunted sites, these data suggest that hunting resulted in a decline in game densities of 43-100% in hunt-

Table 6
Bushmeat Species Densities in Hunted and Unhunted Forest

Species	Hunted Individuals /km^2	Unhunted Individuals /km^2	Impact
Cephalophus sylvicultur	0	0.03	-100%
Gorilla gorilla	0	0.24	-100%
Cercocebus albigena	2.5	51.2	-95%
Pan troglodytes	0.03	0.36	-92%
Cephalophus callipygus	0.6	6.7	-91%
Colobus abyssinicus	0.8	6.8	-88%
Tragelaphus spekei	0.005	0.03	-83%
Potamochoerus porcus	0.36	1.7	-79%
Hyemoschus aquaticus	0.02	0.09	-78%
Cercopithecus nictitans	21.9	80.2	-73%
Cephalophus dorsalis	2.5	5.8	-57%
Cercopithecus pogonias	11.1	19.8	-44%
Cercopithecus cephus	12.5	22	-43%
Cephalophus monticola	30.4	53	-43%

Source: *(Lahm, 1994)*

ed areas. Primates and large-bodied species were most severely affected by hunters, and six of 14 species of wildlife were effectively extirpated from hunted areas. Grey-cheeked mangabey (*Cercocebus albigena*) densities were reduced from over 51 individuals per km^2 to under 3 ind/km^2, a reduction in species biomass of over 280 kg/km^2.

Ngnegueu and Fotso monitored the location, number and yields of snares set by 11 of 30 hunters resident in three villages along the northern edge of the Dja reserve between July and November 1995 (Ngnegueu and Fotso, 1996). To assess the impact of hunting, snare locations were assigned to three zones depending on their distance from the hunter's village (Zone 1 <= 5km; Zone 2 >5 and <=10 km; Zone 3 >10km). Hunters set an average of 117 traps at a density of about 30 traps/km. A total of 105,359 trap nights produced a yield of 789 animals of which 84% were duikers. Comparison of hunter captures in each zone after controlling for trapping effort shows a positive relationship between yield and distance from settlements.

Hunter captures close to villages are seven times fewer than those obtained in forest more than 10km from settlements. These data suggest that snare trapping by hunters in settlements located along the northern edge of the Dja Reserve is having a severe impact on forest animals, assuming that habitats are comparable across zones.

Noss (Noss, 1995) evaluated the sustainability of snare and net hunting in the Dzanga-Sangha special reserve in the CAR. His data suggest that hunters using traditional net-hunting techniques harvest more animals per unit area than hunters using illegal "modern" snares. Net hunts that can be conducted from hunters' permanent villages overexploit all duiker species. This is perhaps not surprising as a relatively small area is repeatedly exploited by a relatively large number of hunters. Though net-hunting from more transient forest camps is less intensive (i.e. a larger area is exploited less frequently by fewer hunters) red duikers (*Cepalophus dorsalis, C. callipygus*) are still likely to be overexploited (Table 3 and 7). Only the brush-tailed porcupine (*Atherurus africanus*) appears to be harvested at sustainable levels by net-hunters. Snare hunting is more wasteful than net-hunting in that 25% or more of species trapped rot or are lost to scavengers. Delvingt (1997) reports that losses account for 4-36% of all animals trapped. Yet, snare hunters in the Bayanga region of CAR may only be overexploiting Peters' and Bay duikers (*C. callipygus and C. dorsalis*). Blue duikers (*C. monticola*) and the brush-tailed porcupine (*A. africanus*) appear to be harvested at sustainable levels (Table 7).

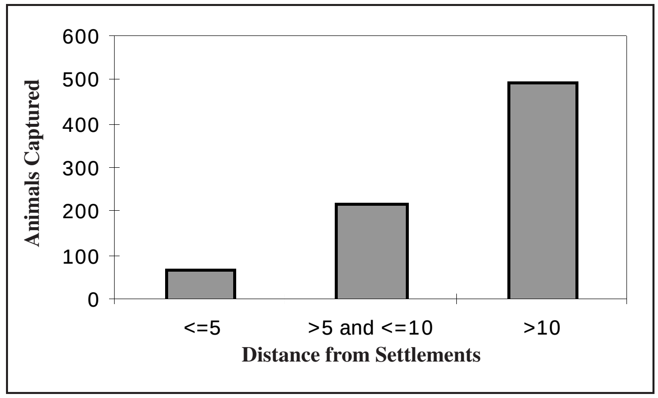

Figure 1. Trapping yields at increasing distance from settlements.

Table 7
Actual and Sustainable Harvest Rates in Dzanga-Sangha
(individuals/km^2)

Species	Snares	Nets	Total	Sustainable Harvest
C. monticola	3.3	14.6	17.9	0.24-23.01
C. callipygus	3.1	0.8	3.9	0.01-0.81
C. dorsalis	0.6	1.2	1.8	0.01-1.13
A. africanus	1.0	2.3	3.3	0.27-11.88

Source: *(Noss, 1995)*

Noss warns, however, that the combined impacts of net and snare hunting are likely to overexploit all duiker species, and that total offtake rates are in reality even higher because the impact of shotgun hunting was not included in the study.

Fimbel and Curran (WCS, 1996) monitored hunter yields of blue and red duikers within four zones of increasing distance from settlements (Zone A 0-10km; Zone B 10-20km; Zone C 20-30km; and Reserve 30+km). Their data show that harvest rates decrease with increasing distance from settlements, which is not surprising as we would expect that hunting intensity is highest in areas most accessible to villages. Their data also show that blue duikers and non-duikers comprise 83% of captures proximal to villages, whereas red duikers comprise 80% of captures at the most distance site. This alone suggests that red duiker populations are overexploited close to villages, and that as Redford contends (1993) hunters prefer larger bodied species. The researchers also compared production versus offtake rates and showed that both blue and red duikers were being overexploited (harvest exceeding production by 338-2,707%) in all zones outside the reserve. Given the intensity of hunting and the continued success of hunting even within 10km of villages it appears that the Lobéké reserve area is serving, as its name implies, as a duiker production and dispersion reservoir.

Dethier (Dethier, 1995) gathered information on hunter captures and duiker densities in forest close to (i.e. <5km) and between 10-18km (3.5-8 hours walk) from settlements located on the northern edge of the Dja Reserve in Cameroon. As in the results of Fimbel and Curran, red duikers comprised a smaller proportion of all duiker captures within 5km of settlements, compared with captures in more isolated forest locations (51% and 82% respectively). Results show that in distant forest trap-lines 26-39% of all trapped animals were left to rot in the traps, and that some hunters left traps set and unchecked for as long as 29-77 days. Village traps were checked much more frequently and wastage was only 11%.

Combining data gathered by Infield (1988) and Payne (1992) shows that offtake of blue duikers and Ogilby's duiker around Korup was 1.3 to 13.2 times greater than could be sustainably harvested.

Proxy Measures

Tracking the relationship between yield and effort in different locations or over time has been used by researchers, primarily anthropologists, to assess the impact of hunting on wildlife in the tropics (Hames and Vickers, 1982; Saffirio and Scaglion, 1982; Stearman, 1990; Vickers, 1991). More recently, two researchers have attempted to use this relatively simple to measure proxy (i.e, the capture to effort ratio) for assessing harvesting impact (Blake, 1994; Blake, 1995; Auzel, 1996b) in northern Congo.

Assuming that all hunters use comparable technologies and modes of travel, and are of equal competence, then differences in the estimated rate of return to hunting measured in kg of game captured per man hour from different areas of the forest should represent differences in animal abundance, and should help to quantify the impact of hunting on forest fauna.

Blake (1994) showed that the estimated rate of return (ERR) to a daytime shotgun hunt conducted on foot was higher in forest that lay outside the SNBS logging concession in northern Congo (1.9 kg/man-hr versus 1.3 kg/man-hr). This suggests that animals are more abundant outside the concession. The ERR for hunters using concession roads and motorized vehicles to travel deep into the forest was higher than for hunts conducted on foot from settlements within the concession (daytime hunts—1.9 kg/man-hr versus 1.3 kg/man-hr; nighttime Jack-lighting—3.7 kg/man-hr versus 2.0 kg/man-hr). These data demonstrate that animal densities increased with distance from settlements, and that hunting at night with a flashlight was more efficient and thus more intensive than simple daytime shotgun hunting. Higher ERR outside concession areas and with increasing distance from concession settlements indicates strongly that hunting within concessions reduced game densities.

Shotgun hunting appears to result in progressively declining rates of return in areas of forest that were hunted regularly. ERR for hunters declined by more than 25% over a three week period, when hunters were forced to return to exploited areas as they waited for a logging bridge to be built and new areas of the forest to be opened up for hunting (Figure 1). This should not be surprising, as rates of return to shotgun hunting are 7 to 25 times higher (1,530) than for hunts using traditional weapons such as bows (0.12 kg/man-hr) and nets (0.18 kg/man-hr).

Role of Logging Concessions

Logging concessions facilitate bushmeat hunting in two primary ways: 1) they dramatically increase hunters' access to the deepest reaches of the forest by building roads and transporting hunters and their bushmeat on logging vehicles; and 2) spur demand through the relatively large number of employees (increased population density) who typically earn 2-3 times the national wage (Auzel and Wilkie, 1998; Wilkie et al. 1998a; Wilkie et al. 1998b).

Impact of Bushmeat Hunting on Household Economies

To assess the importance of bushmeat on local economies we need to know:

- cash income generated by hunting per capita relative to alternative sources of cash income (also how this has changed with changes in national economies)
- relative contribution of bushmeat to animal protein component of an average individual's diet
- availability of affordable substitutes for bushmeat

The literature assessing the relative and absolute contribution of bushmeat to household economies is as sparse as that evaluating the ecological impacts of hunting. See Hladik et al., (1993). This makes it difficult to design mitigation approaches if the role of bushmeat in diet and household income is not well understood.

Dietary Value of Bushmeat

Hunting typically contributes between 30 to 80% of protein consumed by forest-dwelling families in the Congo Basin (Koppert et al. 1996), and almost all animal-based protein. Agricultural crops provide most of the calories. Though cultivated cassava and wild-harvested *Gnetum* leaves are relatively high in protein (by dry weight), they do not provide a complete complement of amino acids, and are thus not absolute substitutes for bushmeat, which has a higher nutritional value (Pagezy, 1993). Thus, unless Congo Basin families have access to true substitutes for bushmeat, any attempt to curtail bushmeat production may result in children suffering the consequences of protein deficiency—i.e. slowed growth and learning delays. At present fish and domestic animals are the only plausible substitutes for bushmeat as a source of protein.

Why people eat bushmeat is controversial. Some argue that bushmeat is a cultural preference and cite consumers' willingness to pay a price premium over domestic meat for the privilege of eating bushmeat (ma Mbalele, 1978; Chardonnet et al. 1995). Steel (1994) found in Libreville, Gabon that the average price for the most popular bushmeat species was $3.7/kg—more than 1.6 times the price of the most popular cut of beef. More recent evidence suggests simply that bushmeat is often the only source of animal protein available and tends to be cheaper than domestic substitutes. Gally and Jeanmart (1996) found that the price of bushmeat per kilo was 0.10-0.25 times the price of available substitutes in three markets in Cameroon, Congo and the CAR. In Bayanga CAR, beef prices are 2-3 times the price of bushmeat (Noss, 1998). Similarly, a kilogram of bushmeat in various towns near the Ngotto forest in CAR ranged from $0.32-0.75, whereas goat was $1.75/kg, chickens were $3.52/kg and caterpillars were a relatively expensive $3.65/kg (Delvingt, 1997).

Bushmeat for the majority of consumers is consumed probably because it has few less expensive substitutes and is an open-access resource available to anyone willing to go hunting. Urban elites may however view bushmeat as a cultural heritage luxury item and thus may be willing to pay a price premium to obtain it. If population growth rates continue at their present levels, per capita demand remain constant and effective substitutes remain unavailable, it is highly likely that bushmeat species will be extirpated from all areas of forest proximal to population centres (i.e., sources of demand) if bushmeat continues to be an open-access resource. Even when bushmeat scarcity causes prices to rise and substitutes to be more competitive, hunting will continue in areas where bushmeat capture and transport costs remain comparable to the costs of livestock rearing.

Economic Value of Bushmeat Trade

Though numerous studies exist documenting bushmeat entering markets, few have documented the economic value of bushmeat to the hunter and trader (Ambrose-Oji, 1997). Noss (1998) reports that snare hunters trapping within the Dzanga-Sangha special forest reserve in southwestern CAR earn between $400-700 per year. Hunters earn more than CAR's official minimum wage, and an amount comparable to guards employed by the park ($450-$625 per year).

In the CIB logging concession in northern Congo, the logging camp village and a village on the Sangha river that had access to markets for bushmeat, on average sold between 36-52% of all bushmeat captured, and generated income of approximately $300 per household/year (Wilkie et al. 1998b). As logging concession employees earn about $4-12/day, bushmeat sales contribute between 6-40% of all households' daily income (Wilkie et al. 1998b).

Gally and Jeanmart (1996) demonstrate the benefits that are received by hunters, traders, and restaurant owners who sell bushmeat, by tracing the sale of 3 monkeys killed with a shotgun. In this case the hunter netted $6.3 (30% profit) from the sale of the monkeys, the trader made $10.2 (19% profit), and the restaurateur made $20.6 (21% profit). These authors also reported that the economic returns to six hunters in Cameroon generated an annual income from hunting that ranged from $330-1,058, an amount well above the national average. In Congo, Dethier (1995) showed that hunters generated between $250-1,050 per year from selling bushmeat. Near the Dja reserve in Cameroon, Ngnegueu and Fotso (1996) showed that individual hunters could generate as much as $650 per year from selling bushmeat. In the six months of their study 30 hunters generated over $9,500 in income from bushmeat sales.

Approaches to Managing Bushmeat Hunting

Results from the growing number of studies on the impact of bushmeat hunting on forest wildlife populations all converge on one conclusion: hunting at present levels is affecting the distribution and density of bushmeat species, is likely to be unsustainable for most large-bodied animals, and may only be sustainable, in the short-term, for blue duikers and rodents. The impact of bushmeat hunting is likely to get worse in the future as road construction by logging companies provides ever more access to the forest and to expanding urban markets.

Given the importance of hunting to local household economies, and the fact that the market for meat is primarily urban centres, strategies to reduce incentives for, and the impact of, market hunting will have to address both economic and law enforcement issues. The importance of bushmeat to local economies is likely to be the single most important barrier to mitigating over-exploitation—because producers and consumers will resist attempts to change their behaviour, and governments have very little incentive to impose restrictions on bushmeat use, and consequently further lowering the welfare of their already poor citizens.

To move towards sustainable use of bushmeat in the Congo Basin the supply of, and demand for, bushmeat need to be brought into balance. This requires reducing consumer demand for bushmeat, or increasing the supply of bushmeat available to hunters.

Supply Side Mitigation Options: Increasing Production of Bushmeat

Theoretically the production of bushmeat could be increased by: a) increasing the production of species that constitute a food source for bushmeat species; and b) controlling bushmeat predators and other competitors. Even if we understood enough about the biology of bushmeat species, their food sources, and their competitors to develop appropriate interventions, the open-access nature of the bushmeat trade and the problem of free-riders makes investment in bushmeat production by hunters unlikely. Moreover, the costs of increasing bushmeat production in the forest would probably match or exceed the costs of livestock rearing, making this an unlikely option even if the forest was privatised.

Demand Side Mitigation Options: Price, Substitutes, and Preference

Consumer demand for bushmeat can be altered by changing: a) the availability and relative price of substitutes; b) the price of bushmeat relative to substitutes; and c) consumer tastes or preferences. The first two options rest on the assumption that bushmeat is a normal good and that demand is elastic—i.e., an increase in the price of bushmeat relative to substitutes will result in a reduction in demand. Given that bushmeat is the primary source of animal protein for most Congo Basin families, unless substitutes are available, bushmeat demand may be inelastic and thus will not decline with increasing price.

Changing Consumer Preferences: The Role of Environmental Education

Consumers, in response to social marketing and education efforts, may be willing to change their preferences for luxury goods such as ivory (O'Connell and Sutton, 1990) or for goods that contribute little to individual diets or household income (e.g. gorillas and chimpanzee). However, changing consumer preference is unlikely to be effective when the good being consumed satisfies some basic human need, for which substitutes are not available (Freese, 1997). Given the importance of bushmeat to local diets and the absence of alternative sources of protein, changing consumer preferences through environmental education and social marketing is only likely to be effective for bushmeat consumed as a luxury item. In this case, capital city elites and restaurants should be targeted, as should expatriate consumers living abroad. The dangers of consuming wild primates, given their assumed role in the spread of Ebola-like haemorrhagic diseases, may also be an effective focus for social marketing efforts to alter consumer tastes for certain types of bushmeat.

Increasing the Availability of Substitutes: Livestock Production

As no data exist to demonstrate that bushmeat demand is elastic, it would be prudent to assume that it is in fact inelastic and that any attempts to increase the scarcity and price of bushmeat would not result in a reduction in demand. In fact, without available substitutes, increasing the price of bushmeat, given that it is an open-access resource, will provide economic incentives for hunters to intensify their harvest of wildlife, and will encourage more individuals to enter the bushmeat trade in search of profits. Thus, seeking ways to strengthen markets for nonwild sources of animal protein are critical to address the unsustainability of bushmeat hunting in the Congo Basin.

Domestic animals in Central Africa are primarily viewed as "savings and insuranc"e rather than as sources of protein. Furthermore, tsetse flies and trypanosomiasis severely limit cattle raising in the region. Considerable attention has been paid, therefore, to non-traditional livestock rearing and the potential for raising bushmeat species that would provide direct substitutes for wild-harvested individuals.

Cane rat and giant rat production is possible using domestic food scraps and agricultural waste (Asibey, 1974a; Tewe and Ajaji, 1982; Jori et al. 1995; Jori and Noel, 1996). Promoting mini livestock production (Branckaert, 1995; Hardouin, 1995) such as rabbit raising has proven effective in Cameroon in areas were bushmeat is already scarce (HPI, 1996). Several pilot projects are underway in Gabon to raise cane rat (Jori and Noel, 1996), brush-tailed porcupine, and bush pig/domestic pig hybrids to reduce demand for bushmeat in cities (Steel, 1994). Small-game raising activities are also part of a UNDP/GEF project in Gabon that focuses on commercial use of forest flora and fauna (Steel, 1994). Raising small domesticated animals such as rabbits is attractive in that methods of husbandry and veterinary care are well-known. Feer (1993) argues that in terms of meat productivity, pigs > zebu cattle > cane rat > duikers. Consequently, it makes more sense to promote pig or cane rat production, both of which are relatively well understood, than to attempt to raise duikers for meat.

Rabbit, porcupine, or cane rat rearing as an alternative to bushmeat hunting is only likely to be successful, however, when the labour and capital costs of production are less than the costs of bushmeat hunting and marketing (i.e. when game becomes too scarce to be worth searching for and transportation costs are prohibitive). Of course, if domestic production of meat only becomes economically viable after wild game have become so scarce as to be unprofitable to hunt, the strategy is clearly ineffective as a conservation measure. In addition, the use of domesticated wildlife species as livestock risks the infiltration of markets with wild-caught individuals sold as "raised" meat, and may promote wildlife habitat loss as forests are converted to produce fodder or pasture for livestock.

Small-animal raising has been shown to be viable in peri-urban areas that are close to sources of demand, and where proximal bushmeat species populations have already been depleted (Lamarque, 1995). Promotion of small-livestock raising in peri-urban areas will of course disrupt the flow of economic benefits from urban consumers to poor rural producers of bushmeat, and may, perversely, encourage intensification of bushmeat hunting to maximise profits before prices drop as domestic substitutes enter the market in increasing quantities.

Changing the Price of Bushmeat: Constraining the Supply

If we instead assume that demand is elastic, then increasing the price of bushmeat will reduce consumption. We can increase the price by increasing the effective scarcity of bushmeat (i.e., constraining the supply) and/or by adding a surcharge to the price of bushmeat consumed. Artificially increasing the scarcity of bushmeat requires enforcing bans or restrictions (e.g., quotas) on hunting.

- *Controlling domestic supply*. Controlling hunting for domestic consumption is likely to be untenable given the size of the area to be policed, and the importance of bushmeat to the nutrition of forest-dwelling families throughout the Congo Basin. Any attempt at *de jure* control of household bushmeat consumption will likely fail for two reasons: 1) households depend on bushmeat as a nutritional staple and are unlikely to relinquish this without considerable pressure or access to substitutes; and 2) sufficient repression would require large numbers of trustworthy law enforcers (i.e. 1 guard per village of 50 people, paid at least $1 per day with an additional $1 per day for equipment and supplies would cost over $46,720,000/year for the Basin—assuming that 30% of the population is rural and 20% of the rural population lives in the forest), which no national agency can afford nor international donor likely to finance. Thus, banning or substantially curbing bushmeat hunting for domestic consumption without providing an acceptable substitute is unrealistic from a cultural, practical, and financial viewpoint. Furthermore, stopping domestic bushmeat hunting will confirm rural communities' fears of national infringement on traditional resource use rights, which may fuel resentment towards the government and may result in retaliatory hunting of rare and endemic species, and increased elephant poaching.

  Some areas of the Congo Basin are sufficiently isolated from human settlements that they are likely to experience minimal human impacts at present; that is, they are already implicitly "protected." If demand for bushmeat were not to increase and roads were not being built into these isolated blocks of forest, thus increasing hunters access and reducing transportation costs, this *de facto* protection is, for the short- to mid-term, likely to be as effective as *de jure* protection.

- *Controlling market supply: confiscation or taxation?* Unlike hunting for domestic consumption, market hunting is more amenable to command-and-control measures, because as bushmeat is transferred from individual hunters to individual consumers, it is concentrated temporarily by traders who transport the meat from the forest and trade it in central sales locations. Control of market hunting can therefore ignore the numerous hunters and consumers and focus only on the far fewer bushmeat traders. Guards need only set up road-blocks or raid market places on random occasions to enforce bushmeat market regulations. Guards could confiscate the bushmeat and fine the bushmeat traders. These interventions still require substantial finances to support a large, incorruptible (i.e. well paid) corps of law enforcers, and assume that alternative distribution and marketing systems will not emerge.

  Alternately, bushmeat does not need to be confiscated at road-blocks; guards could merely charge a market tax. Taxation will raise the effective price of bushmeat and, if demand is elastic, will drive down demand. Not confiscating bushmeat avoids the need to dispose of the game in a way thatdoes not encourage corruption (assuming that guards are not going to purloin the taxes), and prevents the sale of confiscated game at reduced prices (thus fueling demand). As traders' costs increase with taxation (even if guards steal the tax moneys) profits will fall as they attempt to keep rising prices from driving down demand. As demand and profits fall, the price that traders are willing to pay hunters will decline and the income-generating incentive for hunting will decline. Setting the bushmeat tax per kilo sufficiently high attempts to mitigate any cultural preferences for bushmeat and consumer willingness to pay a price premium for bushmeat (Steel, 1994). Market prices of bushmeat and domesticated alternatives should be monitored regularly so that the level of taxation can be maintained high enough to curb consumer demand for bushmeat.

This all said, though taxation of bushmeat would appear to be an option, in the short-term the importance of bushmeat to the diet and income of forest dwelling families, the huge areas of forest involved, the shortage of well-paid (i.e. less corruptible) and trained forestry officers, and little government interest in regulating the bushmeat trade, are likely to preclude the use of command-and-control measures to limit market hunting outside more circumscribed areas such as logging concessions and protected areas.

- *The special case of logging concessions.* Command-and-control measures may work within the confines of logging concessions, because logging companies could be required to pay for sufficient numbers of incorruptible law enforcers and provide them the transportation and equipment necessary for monitoring hunting.

√ *Use of conservation bonds.* Wildlife law enforcers should not be paid directly by the logging concessions; instead the companies should be required to post a bond, paid to the appropriate government ministry, for an amount indexed to the area of forest to be exploited that year. These moneys would be earmarked for natural resource conservation within logging concessions, and thus could only be used to support forestry and wildlife law enforcers and plant and animal surveyors stationed in logging concessions. Repayment of the bond to the logging concession could be indexed to the ratio of pre- and post-logging game survey figures, with the highest rebates occurring at parity. If the bond was set high enough, logging companies might comply with recommendations that wildlife and firearms laws of the country be respected by personnel of logging companies, and that vehicles, roads, facilities, and company time should not be utilized in support of illegal bushmeat hunting. Using a logging company bond-financed fund, earmarked for natural resource conservation within logging concessions, would allow the development of wildlife management plans and a regulated harvest of forest protein. A conservation bond would also help strengthen national and institutions' capacity to enforce wildlife protection, as Verschuren (1989) urges. This approach will, of course, only work if the price of the conservation bond does not make logging uneconomic, if the logging companies do not attempt to bribe forestry and wildlife officers, and if the forestry ministry establishes and enforces wildlife conservation bond legislation, and uses the earmarked fund appropriately.

√ *Curbing the transportation of bushmeat.* An alternative or additional approach is to control the shipment of bushmeat from the concessions to the point of sale. This directly impacts the profitability of market hunting, which is largely determined by access to, and cost of, transportation. When CIB started transporting logs to Douala from the Sangha river port at Sucambo (near Ouesso), bushmeat from Cameroon soon comprised over 13% of the game sold in Ouesso markets (Bennett Hennessey, 1995). Yet, during August 1995, a dispute between the trucking company and the concession halted traffic from Congo through Cameroon, resulting in the temporary collapse of the bushmeat market and the closure of hunting camps that border the roads (Pearce and Ammann, 1995). Bushmeat marketing is a risky business. If the truck does not arrive to ship meat to the market the hunters' produce may rot and become worthless. The key to reducing market hunting is curbing transportation of bushmeat on logging vehicles owned by concessions and by transport companies. This could be accomplished using road-blocks for bushmeat, assuming willingness and the capacity on the part of the national governments to enforce wildlife laws.

- *Controlling access: ownership and zonation.* Another option for constraining the supply of bushmeat is to change the open-access nature of the bushmeat trade by restricting who has the right to hunt and limiting where hunting can occur.

√ *Management of bushmeat exploitation through community ownership.* An often-discussed approach to game conservation in developing countries is community resource management (Kiss, 1990; Hannah, 1992; Wells et al. 1992; Bissonette and Krausman, 1995). Though all forest resources within the Ituri are under *de jure* control by the government, local households have *de facto* management authority. Direct local ownership of game is a fact throughout much of the Congo Basin. However, for this form of management to result in wildlife conservation, communities have to be relatively small and stable, be able to defend their resource from free-riders, and must not discount the future at a high rate (Becker and Ostrom, 1995). Unless communities exhibit these characteristics, externalities will continue to exist, lowering the true value of forest resources and resulting in their irrational over-exploitation. Poverty's "have-to-eat-today" principle (Bodmer, 1994) and the absence of effective political or cooperative institutions above the household or clan level in most Congo Basin forest communities make it highly unlikely that these prerequisites for community-based resource conservation could be met in the near future.

Few governments in the Congo Basin appear ready to devolve ownership and management rights of forest resources to local communities. Furthermore, the prerequisites for common-property resource management may not evolve within forest-dwelling communities before bushmeat consumption seriously impacts forest animal populations. As local communities presently have *de facto* control over forest resources in most of the region, it is exceedingly important that they are involved in development and implementation of all policies associated with sustainable management of wild game populations. Unless local communities are advocates for bushmeat management a command-and-control measure is unlikely to work, and demand-side approaches may be unacceptable or not considered worth adopting. Ignoring the human factor in the sustainable management of bushmeat is a clear recipe for failure (Stephensen and Newby, 1997).

√ *Privatization of bushmeat harvesting.* Privately-owned wildlife ranches, reserves, and conservancies have been able to expand biodiversity conservation outside protected areas in southern Africa. However, they are not economically viable from the sale of meat, but through the sale of live animals to restock more recently established conservancies (Kreuter and Workman, 1994; Bojo, 1996; Crowe et al. 1997), and through revenue generated from trophy hunting (Leader-Williams et al. 1996). Even the Hopcraft game ranch in Athi, 40km from Nairobi, Kenya and with a well equipped slaughterhouse could not make a profit selling bushmeat to local consumers at prices that were competitive with beef and chicken (Stelfox et al. 1983).

Bushmeat ranching was only economically viable when the meat was sold to tourist hotels and restaurants at a considerable price premium. Given transportation costs, the present price structure of the bushmeat trade, and production rates of commonly exploited forest bushmeat species, it is questionable whether private bushmeat "ranchers" could afford to pay the management costs of running a ranch (i.e., excluding "poachers" or paying rent to local communities to cover the opportunity costs of not-hunting) and yet keep harvest levels sufficiently low to be sustainable.

√ *Spatial control of harvest levels.* Dale McCullough (1996) proposes using a changing mosaic of hunted and unhunted areas as an alternative to harvest quotas to control hunting intensity and offtake rate within a given wildlife management area. The approach argues that using quotas to control hunting requires baseline data on species numbers and productivity to set quotas at sustainable levels, and monitoring and law enforcement to ensure that hunters do not exceed their assigned quotas, both of which are likely to be prohibitively expensive in the Congo Basin context. As an alternative he suggests that rather than trying to set and monitor harvest quotas it would be easier, from a management cost effectiveness perspective, to allow hunters to take as many animals as they want, but to constrain where they hunt. If hunters are only allowed to hunt within certain zones, dispersal of surplus animals produced in adjacent unhunted zones could compensate for the individuals harvested by hunters. By increasing or decreasing the relative proportion of hunted to unhunted areas in reponse to time-series data on harvest levels the manager can establish the maximum area that can be hunted without resulting in declining harvest levels.

Spatial control of hunting certainly requires fewer data to maintain harvests at sustainable levels. However, in the Congo Basin context, where travel is the primary cost associated with hunting, convincing hunters to bypass reserve areas to hunt in more distant harvest zones is unlikely unless law enforcement is ubiquitous, strict, and penalties a sufficient deterrent. Most hunters are central-place foragers and hunting intensity declines with distance from their home base (Wilkie, 1989; Wilkie and Curran, 1991). Establishing buffer zones around settlements that approximate the average distance that hunters travel may be a viable alternative to spatially-distributed hunting zones if protected areas bordering the hunting zones are sufficiently large to serve as dispersal reservoirs. The width of the buffer zone could be increased or decreased in response to harvest returns monitored over time. Buffer zones may be more practical in terms of enforcement; however, few areas in the Congo Basin are likely to be large enough to leave core (un-hunted) areas of sufficient size to restock hunted areas that meet even current demand for bushmeat. In the Ituri forest of northeastern DRC even the 1.3 million hectare Okapi Wildlife Reserve appears too small to provide a sustainable supply of bushmeat to meet domestic demand from the area's 30,000 inhabitants (Wilkie et al. 1998a; Wilkie et al. 1998b). Simply stated, in most forests of the Congo Basin zoning is only likely to result in sustainable hunting if offtake is lower than the present level of demand. Lowering demand for bushmeat is therefore the key to wildlife conservation in the region.

Opportunities for Future Research and Interventions

Review of bushmeat studies provides two messages: 1) uncertainty still exists in our ability to quantify bushmeat consumption, offtake rates, and production; and 2) the overwhelming evidence is that bushmeat hunting at present is unsustainable for most primates and large-bodied forest duikers and may only be sustainable for highly productive animals such as rodents.

The first message suggests that further study is needed. Yet much of the uncertainty that exists in the data is less a result of inadequate effort and more a statement of the difficulties associated with studying tropical forest animals. Low visibility, cryptic coloration, and often solitary and shy behaviour make it difficult to obtain accurate and repeatable observations. Though "scientists" are wont to delay taking action until they have enough information or reliable figures, the effects of environmental uncertainties and measurement errors ensure that correct or exact numbers are rarely ever obtainable (Freese, 1997). Consequently, the substantial increase in effort necessary to enhance our confidence in the data is probably not worth the investment, particularly as it is unlikely to alter the second message—bushmeat hunting is probably unsustainable if present trends in population growth and forest access continue.

Given that most studies indicate that bushmeat hunting for direct consumption and for sale is overexploiting most forest mammals other than rodents, it makes most sense to spend scarce resources on mitigation rather than on further study to assess the impacts of hunting. Options for mitigation have been discussed above and fall into three categories: 1) interdiction; 2) bushmeat price manipulation through fines and taxation; and 3) development of substitutes. No single solution is likely to be effective in all contexts; rather, the relative importance of each approach is likely to change with land-use and population density. For example, whereas interdiction may predominate in sources of supply such as protected areas and logging concessions, taxation and provision of substitutes may be more effective near sources of demand such as urban areas.

The importance of bushmeat in the diet and economies of Congo Basin families, the high demand for bushmeat, the lack of effective substitutes, and political resistance to controlling bushmeat hunting make command-and-control measures such as interdiction, fines, and taxation unlikely to be implemented effectively. Consequently, if we are concerned about conservation of a globally scarce resource that is at present still relatively abundant locally, it is essential that: we develop a better understanding of the elasticity of bushmeat demand; that pilot bushmeat substitution projects are supported and their impact on demand evaluated; and social marketing activities are put in place to attempt to direct consumer preferences for animal protein away from bushmeat species that are particularly susceptible to over-exploitation.

The few options available to mitigate bushmeat hunting reemphasise the importance of protected areas where, unlike the majority of forested areas, biodiversity conservation is the primary land use objective. Thus strategic and sufficient financing of protected areas is going to be critical in ensuring that a representative sample of forest wildlife continues to inhabit the Congo Basin in the future.

Given the role that timber exploitation plays in facilitating intensive market hunting in the farthest reaches of the Congo Basin, donors and international NGOs must seek ways to work with concessions to minimise the wildlife impacts of logging. Lobbying, green-labelling, and consumer preference may be effective in encouraging logging companies, particularly those with European home-offices, to manage wildlife populations sustainably within their concessions.

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1 *Though not in the region it is interesting to note that between 1900 and 1990 the population of Zimbabwe grew from fewer than 500,000 to 10 million (Cumming, 1991), and the Kenyan population tripled between 1948 and 1979, and is expected to reach 30 million by the year 2,000 (Byrne, Staubo, et al., 1996).*

2 *If we stated that the "biomass of harvested species remains at 50% of carrying capacity over time" harvest rates would be maximized for populations that exhibit logistic growth.*

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