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Review Article

Eating and conserving bushmeat in Africa

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Abstract

In Africa, overhunting of tropical wildlife for food remains an intractable issue. Donors and governments remain committed to invest in efforts to both conserve and allow the sustainable use of wildlife. Four principal barriers need to be overcome: (i) communities are not motivated to conserve wildlife long-term because they have no formal rights to benefit from wildlife, or to exclude others from taking it on their land; (ii) multispecies harvests, typical of bushmeat hunting scenarios, place large-bodied species at risk of extinction; (iii) wildlife production cannot expand, in the same way that livestock farming can, to meet the expected growth in consumer demand; and (iv) wildlife habitat is lost through conversion to agriculture, housing, transportation networks and extractive industries. In this review, we examine the actors involved in the use of wildlife as food and discuss the possible solutions required to address urban and rural bushmeat consumption. Interventions must tackle use and conservation of wildlife through the application of context-relevant interventions in a variety of geographies across Africa. That said, for any bushmeat solution to work, there needs to be concurrent and comparable investment in strengthening the effectiveness of protected area management and enforcement of wildlife conservation laws.

Key words: bushmeat, conservation, consumption, income, price, wildlife

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Résumé

En Afrique, la chasse excessive de la faune tropicale pour la consommation reste un problème difficile. Les bailleurs et les gouvernements continuent à s'engager à investir dans la conservation et l'utilisation durable de la nature. Mais il faut vaincre quatre obstacles majeurs: (i) les communautés ne sont pas très motivées par la conservation de la nature à long terme parce qu'elles ne jouissent d'aucun droit d'en tirer profit ou d'empêcher d'autres personnes d'en tirer de leurs terres; (ii) les collectes de plusieurs espèces, typiques des scénarios de la chasse de viande de brousse, mettent les plus grosses espèces en danger d'extinction; (iii) la production de viande de brousse ne peut pas, comme le fait la production de bétail domestique, répondre à la demande croissante attendue des consommateurs et; (iv) les habitats de la faune sauvage sont perdus parce qu'ils sont convertis en terres agricoles, en lieux de résidence, en réseaux de transports et en industries extractives. Dans cet article, nous examinons les acteurs impliqués dans la consommation de produits de la nature et nous discutons les solutions possibles nécessaires pour répondre à la consommation urbaine et rurale de viande de brousse. Les interventions doivent s'attaquer à l'usage et à la conservation de la nature grâce à des mesures pertinentes adaptées à toute la variété géographique africaine. Ceci dit, pour qu'une mesure concernant la viande de brousse marche, il faut qu'il existe parallèlement un investissement comparable dans le renforcement de l'efficacité de gestion des aires protégées et de l'application des lois sur la conservation de la nature.

Introduction

In Africa, humans have eaten wildlife since before our lineage separated from other apes, over 6 million years ago (Stanford & Bunn, 2001). Nowadays, wildlife is still hunted in forest and savannah regions as a source of meat (bushmeat), and income to control agricultural crop pests, reduce threats to livestock and human safety, and as trophies (Bennett *et al.*, 2007; Nasi *et al.*, 2008; Wilkie *et al.*, 2011; Lindsey *et al.*, 2013a; Rentsch & Damon, 2013). However, unsustainable bushmeat hunting across sub-Saharan Africa will lead to the following: (i) the loss of an important source of dietary protein, micro-nutrients and income for numerous rural poor (Bennett *et al.*, 2007; Nasi, Taber & Vliet, 2011), (ii) the imperilment of the cultural identities of many indigenous and traditional people for which hunting is part of their heritage and sense of cultural identity (van Vliet & Mbazza, 2011) and (iii) the emptying of Africa's forests and savannahs of large-bodied species, eliminating the important ecological roles these play in the functioning of such ecosystems (Nunez-Iturri & Howe, 2007; Lindsey *et al.*, 2011; Abernethy *et al.*, 2013; Effiom *et al.*, 2013).

Drivers of and solutions to unsustainable bushmeat hunting are well understood (Wilkie & Carpenter, 1999; Wilkie *et al.*, 2005; Laurance *et al.*, 2006; Forget & Jansen, 2007; Wright *et al.*, 2007; Foerster *et al.*, 2012; Lindsey *et al.*, 2013a; van Vliet *et al.*, 2016). They vary according to biome, market access and availability of alternatives, human population density and urbanization and wildlife use rights and governance. In this review, we explore what is currently known about the challenges to conserving and eating wildlife in Africa, and offer a number of policy and practice recommendations to address these issues in both rural and urban contexts.

First, we review who are currently hunting and consuming wildlife in Africa. We then explore the economic drivers of wildlife hunting, trade and consumption and the barriers to balancing bushmeat use and wildlife conservation. Lastly, we look at three key contexts where wildlife are consumed (i.e. rural villages surrounded with wildlife; rapidly growing provincial towns close to sources of wildlife; and established urban areas where wildlife have been depleted from nearby areas) and review opportunities for overcoming barriers to conserving and eating wildlife.

Current hunters and consumers

Traditional hunter-gatherers

Small, isolated bands of nomadic hunter-gatherers in Central (e.g. Baka, Mbuti, Efe), East (e.g. Hadza) and southern Africa (e.g. !Kung) still meet their dietary protein needs almost exclusively from wildlife (Bogin, 2011; Kelly, 2013; Hewlett, 2014). Camps move when hunting declines and only return when wildlife populations are expected to have recovered (Kelly, 2013).

When hunter-gatherer groups are few and range across large landscapes that they defend as 'their' exclusive territory, hunting of all wildlife species can be sustainable (Bennett *et al.*, 2007). However, hunting can rapidly become unsustainable, as has happened in some groups in Central Africa (e.g. Riddell, 2011), if they switch from being bushmeat consumers to traders supplying local or distant markets (Van Vliet *et al.*, 2007; Inogwabini, 2014). Tropical moist forests in Central and West Africa are typically an order of magnitude less productive in terms of wildlife stocks and flows, compared to open woodlands and savannahs typical of East and southern Africa (Robinson & Bennett, 2000). The latter can therefore support higher offtake of wildlife per unit area and time and thus higher densities of predators including hunter-gatherers.

Village farmers

Across Africa, many sedentary rural communities eat wildlife as a primary or supplementary source of animal protein (Abernethy & Ndong Obiang, 2010; Foerster *et al.*, 2012; Rentsch & Damon, 2013; Schulte-Herbruggen *et al.*, 2013; Alexander *et al.*, 2014). Dependence on wildlife for food is greater in moist forests compared to savannah regions of Africa as the meat of livestock is more available in the latter (Lindsey *et al.*, 2013a). Typically, repeated hunting close to settlements depletes large-bodied wildlife meaning that only small-bodied species, that reproduce relatively rapidly and are more resilient to hunting pressure, are available in or near farmers' fields to be hunted for food (Muchaal & Ngandjui, 1995; Ngnegueu & Fotso, 1998; Coad, 2007; van Vliet & Nasi, 2008). Large-bodied species may still exist but further from hunters' homes (Ngnegueu & Fotso, 1998; Kumpel *et al.*, 2010; Lindsey *et al.*, 2012).

For many rural households, bushmeat can constitute as much as half of their annual protein requirements

(Wilkie *et al.*, 2005) but is typically much less than this in landscapes where wildlife have already been severely depleted or where livestock production is more common (East *et al.*, 2005; Foerster *et al.*, 2012; Schulte-Herbruggen *et al.*, 2013). Hunters may consume most of what they hunt, but can sell their surplus within the community or to traders who take it to urban centres (Wilkie & Carpenter, 1999; Barnett, 2000). Some village hunters specialize in commercial, typically illegal, hunting to supply consumers in forestry concessions, mining camps and urban areas (Auzel & Wilkie, 2000; Barnett, 2000). Some hunters also engage in poaching of wildlife with high-value body parts (i.e. tusks and horns) that are traded internationally.

Urban families

In urban areas distant to sources of wildlife, where alternative animal protein is available, bushmeat is no longer a dietary necessity; rather, it is a seldom consumed 'treat' (Wilkie & Carpenter, 1999; Barnett, 2000; Wilkie *et al.*, 2005; van Vliet & Mbazza, 2011; Lindsey *et al.*, 2012; Bachand, Arsenault & Ravel, 2015). Despite this, given the large numbers of urban dwellers consuming bushmeat, their impact on wildlife can be nonetheless substantial (Nasi, Taber & Vliet, 2011; van Vliet *et al.*, 2012). However, in some provincial towns (e.g. Kisangani, Ouesso and NiaNia) that have grown rapidly during periods of social conflict, but are market-isolated and still close to forest areas with relatively abundant wildlife, bushmeat and wild-caught fish remain the principal animal protein sources and their overexploitation is greatly impacting surrounding wildlife populations and fish stocks (Van Vliet, Nasi & Taber, 2011; van Vliet *et al.*, 2012; van Vliet, Nebesse & Nasi, 2015).

Economic drivers

Bushmeat markets and household income

The sale of bushmeat is an attractive economic activity for many hunters, particularly those isolated from market centres (Fa, Currie & Meeuwig, 2003; Fa *et al.*, 2006; van Vliet & Nasi, 2008; Kumpel *et al.*, 2010; Wilfred & Maccoll, 2010; Nasi, Taber & Vliet, 2011). In localities with high transportation times, costs or constraints (i.e. when hunters have to head-carry produce to market), the sale of agricultural commodities becomes uncompetitive or impossible (Brown & Williams, 2003). In these situations, trading bushmeat is more cost-effective (Willcox & Nambu, 2007), because its value-to-weight ratio is superior to agricultural crops, and smoked bushmeat is relatively durable without refrigeration (Bennett *et al.*, 2007; Wilkie *et al.*, 2011). At short distances to markets, the sale of agricultural commodities is more economically rational because farm production can be easily increased to match demand, and farmers unlike hunters own their crops and can legally exclude others from harvesting them (Brown & Williams, 2003).

Participation in an unregulated bushmeat trade is initially lucrative when wildlife is abundant and can involve relatively large numbers of families. As wildlife stocks decline, the overall trade value drops (although unit prices may increase) as does the number of families the market can support (Barnes, 2002; Bassett, 2005; Cowlishaw, Mendelson & Rowcliffe, 2005; Fa *et al.*, 2015; McNamara *et al.*, 2016).

Price matters

Consumers are price-sensitive, and bushmeat has a negative price elasticity of demand (Wilkie & Godoy, 2001; Apaza *et al.*, 2002; Fa *et al.*, 2009; Godoy *et al.*, 2010; Wilfred & Maccoll, 2010). This means that bushmeat consumption tends to decrease with increasing price, and explains why it is chosen by rural consumers when it is the cheapest meat in the marketplace (Fargeot, 2013; Rentsch & Damon, 2013). Price elasticity also explains why urban consumers eat bushmeat as an occasional treat, as it is typically more expensive than substitutes (Wilkie *et al.*, 2005). We also know that consumers treat both freshwater and marine fish as dietary substitutes for bushmeat (Brashares *et al.*, 2004; Demerode, Homewood & Cowlishaw, 2004), and when fish prices increase, so too does bushmeat consumption (i.e. there is a positive cross-price elasticity of demand). Lastly, there is evidence that bushmeat consumption follows an inverted U (i.e. Kuznets curve) with household income (Wilkie & Godoy, 2001). As price-conscious poor households become wealthier, they can afford to eat more meat, so bushmeat consumption rises initially with income. But when households reach a certain income threshold, consumers switch to the typically more preferred and expensive domesticated livestock meats, and bushmeat consumption falls.

Barriers to balancing bushmeat use and conservation of wildlife

There are three principal barriers to conserving wildlife in situations where bushmeat is a source of food and income.

Bushmeat is a state-owned, poorly governed, open-access resource

Across Africa, wildlife is typically a state-owned resource (i.e. a public good) and governing access to and uses of wildlife is largely vested in the state (Kabiri & Child, 2014). Typically, most communities living with wildlife have no rights to this resource on lands they have traditional claims over, and no authority to exclude outsiders from taking wildlife on 'their' lands. Most hunting for food or sale is thus illegal from a law enforcement perspective, and therefore, hunters can be considered poachers (Gibson, 1999). Many, if not all meat 'poachers', consider themselves as possessing legitimate rights according to customary law (Child, 1996; Wilkie, Redford & McShane, 2010). However, most states are too weak or disinterested to enforce national wildlife laws.

In the face of such legal and enforcement inconsistencies, hunters who break national laws – which in theory control access (who can hunt) and meter use (the what, where, when and how much) – do not fear arrest, let alone prosecution or punishment (Wilkie, Redford & McShane, 2010). Ironically, this engenders a scofflaw culture where people break laws with impunity because they sense that these are mostly illegitimate and unlikely to be enforced. As both community and commercial hunters do not have rights to exclude others from hunting, they are perversely motivated to take as many animals as they can, as quickly as they can, because if they do not, someone else will. This situation results in unsustainable hunting for bushmeat and the depletion of an economically and ecologically valuable natural resource (Maisels *et al.*, 2001; Abernethy *et al.*, 2013).

Even where the state has devolved rights to local communities so they can reap legitimate economic benefits from wildlife (i.e. CAMPFIRE districts in Zimbabwe, the ADMADE village areas in Zambia, the conservancies of Namibia and Kenya, and the Wildlife Management Areas of Tanzania), the state still retains ownership rights (Jones, Diggle & Thouless, 2015). Evidence from community conservancies shows that when people benefit tangibly from wildlife on their land, they feel that poaching is stealing from them. Communities are hence highly motivated to regulate their own members, so they conform with established conservation regulations, and provide actionable intelligence to national arresting agencies on outsiders who steal their wildlife (Silva & Mosimane, 2015; Wilkie, Painter & Jacob, 2015).

Multispecies hunts risk driving large-bodied, vulnerable species to local extinction

Bushmeat hunting is unlike trophy or sport hunting where hunters target a single or at most a few selected species or individuals and cease hunting if target species populations become scarce (Robinson & Bennett, 2000; Bennett *et al.*, 2007). Bushmeat hunters target any wildlife species that provides meat (Fa, Peres & Meewig, 2002; Robinson & Bennett, 2004). This has two adverse consequences. Firstly, hunters can afford to use indiscriminate methods, such as leg-hold snares, because almost anything they catch can be eaten or sold. Secondly, unregulated multispecies hunting to meet market demand will eventually drive large-bodied wildlife species to local extinction (Wilkie & Godoy, 1996).

Bushmeat hunters pursue a large range of mammals, birds and reptiles, although they prefer large-bodied species because they generate a larger return on investment (i.e. more meat for the time and ammunition spent hunting). Biologically speaking, populations of large-bodied species are at greater risk of declines from higher hunting pressure because most are *K*-selected – they take longer to reach sexual maturity, have longer gestation periods and interbirth intervals and have relatively fewer offspring over their lifespan compared to smaller bodied *r*-selected species. But, more importantly, the multispecies nature of bushmeat hunting, combined with hunters' economic rationale to target large-bodied wildlife, puts these species at greatest risk.

In multispecies hunts, like those for bushmeat, optimal foraging theory shows (Alvard, 1995; Wilkie & Lee, 2004; Levi *et al.*, 2011) that hunters will always pursue and attempt to kill large-bodied species when encountered (Stephens & Krebs, 1986), regardless of how infrequently that may be the case (e.g. a hunter may only see a Cross River gorilla once every three years, but will attempt to kill it every time he sees one). Thus, in places where there are still sufficient numbers of small-bodied species to motivate hunters to continue hunting, when encountering large-

bodied wildlife, regardless of how infrequently, they will pursue and kill them, hence making them increasingly scarce. This inexorably will result in the local extinction of preferred, large-bodied species (Alvard, 1993; Maisels *et al.*, 2001; Van Vliet *et al.*, 2007; Waite, 2007).

Sustainable wild meat production cannot meet dietary protein requirements

There have been calls for wild-harvested or ranched wildlife to become a source of food for people (Stelfox *et al.*, 1983; Chardonnet, 1991; NRC, 1991; Feer, 1993; Cooper, 1995; Ntiamoa-Baidu, 1998; Hoffman & Cawthorn, 2012; Cawthorn & Hoffman, 2014).

In a context of shrinking habitat and increasing human populations, wildlife will provide an increasingly small proportion of the diets for even rural families living in close proximity to wildlife. Moreover, wildlife ranching, without intensive selective breeding, will unlikely ever be cost-effective relative to raising domesticated livestock where water is not a constraint. That said, wildlife ranches have been shown in South Africa to contribute to the local economy (Taylor *et al.*, 2016). However, to increase the annual production of wild-roaming animals would require expanding their habitat, removing livestock competitors, removing predators or even providing supplementary feedstuff, none of which is practical in most locations.

Mockrin, Bennett & Labruna (2005)reviewed available evidence and concluded that inefficient feed-conversion ratios and long time frames to reach market weight made wildlife farming uncompetitive compared to domesticated livestock. Despite this, there is still much support for wildlife farming. For example, a recent appeal (Nogueira & Nogueira-Filho, 2011) suggests that collard peccary farming should be considered as an alternative to unsustainable hunting in neotropical forests. The study, however, fails to explain why raising collared peccaries would be more efficient and produce a more valued meat product, than simply expanding production of domesticated pigs that are raised and consumed in huge numbers throughout South America.

The most important reason that harvesting or ranching wildlife is never likely to compete with raising domesticated livestock is that the latter have been selectively bred for millennia for increased docility, tolerance of crowding and most importantly to maximize their feed-conversion efficiency (FCR, i.e. the ratio of feed consumed to meat produced) and to minimize time to reach market weight (Feer, 1993). Feed-conversion ratios (e.g. kg feed dry matter intake per kg live mass gain) for domesticated livestock range from a low of 1.6 : 1 for tilapia to a high of 8 : 1 for cattle (3 : 1 = pigs, 2.5 : 1 = rabbits, 2 : 1 = poultry) and time to slaughter weight ranges from a few weeks (12–16 = poultry) to months (6 months = pigs, 12–18 = cattle). In contrast, cane rats (*Thryonomys swinderianus*) take 6–13 months to reach a marketable (adult) weight of 4–5 kg (Houben, 1999) and the green iguana (*Iguana iguana*) takes 3 years to reach a slaughter weight of 3 kg (Werner, 1991). Similarly, captive rearing of pacas (*Agouti paca*), although feasible, is economically irrational because the meat would have to be sold for over $20 per kilogram to cover production costs (Smythe, 1991).

Where water is severely limited or where livestock diseases like sleeping sickness are endemic, free-roaming or ranched wildlife may offer an alternative source of animal protein. Evidence from the Hopcraft Ranch on the Athi Plains in Kenya suggests that when water can be provided using boreholes, a mix of domesticated livestock and wildlife within a fenced area may generate the best returns and smooth production during droughts (Stelfox *et al.*, 1983).

The way forward

Today, and in future, managing hunting and consumption of wildlife as food should focus differently on (i) rural families living with wildlife, (ii) families in rapidly growing towns close to the source of wildlife and (iii) families in urban centres where wildlife has been depleted from nearby areas.

Rural families living with wildlife

Throughout sub-Saharan Africa, families living in rural areas that are poor, isolated from markets, and with little access to protein from domesticated animals still rely heavily on wildlife as food. For these families, eating wildlife and wild-caught fish is not just nutritionally important; it is also a valuable source of income where few jobs exist. In some communities, hunting and eating wildlife is part of their cultural identity. Although population density in rural areas is lower than in urban areas, because of higher per capita consumption, rural consumers in aggregate eat as much bushmeat as is currently

consumed in cities (Barnett, 2000; Wilkie *et al.*, 2005; Foerster *et al.*, 2012; van Vliet *et al.*, 2016). Rapid urbanization and rural outmigration may change this soon.

Devolve rights and authority over wildlife. Historically, rural communities in sub-Saharan Africa had little vested interest in managing wildlife sustainably because they have no rights to benefit from wildlife nor authority to exclude outsiders or regulate access to and meter use of wildlife they live with (Child, 2013). As a result, these communities were often in a race with themselves and others to extract what wildlife and fish they could when it still existed. For rural communities to have a vested interest in protecting wildlife and managing their sustainable use, it is important, where feasible and appropriate, to help them secure formal legitimate and exclusive rights to benefit from wildlife and fish within lands and waters over which they have traditional claims (Murphree, 2009; Agrawal & Ribot, 2012; Child, 2013; Ribot & Larson, 2013). Southern and East Africa have made considerable headway in devolving rights and authority over wildlife to local communities by legally establishing and supporting community conservancies (Pye-Smith, 2013; NACSO, 2014). Central Africa has only recently begun the process of devolution.

Benefits to devolution include, in some but not all contexts, food, income from the sale of resilient species, and fees and salaries from trophy hunting and tourism enterprises. Where appropriate devolution could be modelled on Southern and East African community conservancies where rural families not only have the rights to benefit from wildlife, they also have the authority to co-manage wildlife. In Central Africa, this would require substantial reforms of land rights policies particularly where ex-colonial laws vest all lands and natural resources in the state. It would also require, based on experience with the USAID-funded LIFE programme in Namibia (App *et al.*, 2008), considerable long-term investment in governance capacity training and mentoring and would require the timely and competent support of national agencies with the authority to arrest suspected lawbreakers (Wilkie, Painter & Jacob, 2015). Lastly, given the risk that multispecies hunts pose to large-bodied wildlife species, communities with devolved rights would need to establish norms that restrict the use of indiscriminate methods of hunting and place restrictions on harvest levels of at-risk species.

Smoothing consumption during shocks. Rural families have long used wildlife and fish as insurance to smooth consumption and pay for unplanned events during and after ecological, economic, political and health shocks, thus reducing the risk that they will spiral down into poverty (Paumgarten, 2005; Nielsen, Pouliot & Bakkegaard, 2012; Enuoh & Bisong, 2014; FAO, 2015). Loss of crops and livestock from drought and other climatic shocks risks impoverishing millions of families is a huge drag on economic growth and often forces families to mine rather than steward natural resources (FAO, 2016).

Schemes for compensating landowners for the loss of their animals and crops to wildlife whose presence on the land is valued, at least, by the conservation community has a long and largely successful history (Woodroffe, Thirgood & Rabinowitz, 2005; Treves *et al.*, 2006; Dickman, Macdonald & Macdonald, 2011; Karanth *et al.*, 2012). Judicious use of compensation schemes can not only ensure that poor rural families do not unjustly shoulder the costs of living with wildlife, but also help build a constituency for conservation and encourage rural communities to steward rather than mine wildlife resources. In fact, the success of insurance schemes to indemnify rural families from crop and livestock losses from wildlife could be extended to cover additional loss factors such as severe weather and disease. Index-based livestock insurance has proven highly cost-effective in Ethiopia, Kenya and Mongolia (Linnerooth-Bayer, Mechler & Hochrainer-Stigler, 2011; Jensen, Barrett & Mude, 2015) and could be more widely tested as a conditional incentive (Ferraro, 2011; Clements *et al.*, 2013; Ingram *et al.*, 2014) for rural families to comply with hunting, fishing and trade regulations. More broadly, the efficacy of health and life insurance as a mechanism to smooth consumption during shocks and as a conditional incentive not to mine wildlife resources should also be piloted and evaluated.

Livestock and farmed-fish extension services as conditional incentives. Provision of small livestock production and where appropriate fish-farming extension services primarily to communities with at least local market access should be evaluated as an incentive for rural communities to steward not mine wildlife resources including wild-caught fish. Linking this activity with wildmeat traders may provide viable revenue replacement for reduced bushmeat trafficking. That said, a recent review emphasizes how difficult it has proven to implement

effective 'alternative' livelihood projects in the past (Wicander & Coad, 2015).

Families in rapidly growing towns close to the wildlife source

Second, rural to urban migration is happening throughout sub-Saharan Africa and provincial towns relatively close to sources of wildlife are growing. As these towns are populated with ex-rural families accustomed to eating wildlife, they may increase important sources of demand for wildlife as food. Consumption surveys are needed to evaluate this question.

In Central Africa particularly, relatively market-isolated towns have seen rapid increases in population numbers as people in-migrate to secure employment in extractive industries (e.g. logging and mining) or in search of greater safety during periods of war and civil unrest. This has seen towns like Ouesso and the Pokola logging camp in northern Congo grow to 35,000 and 20,000, respectively. In Democratic Republic of Congo, the civil unrest and its insecure aftermath saw the sleepy rural towns of NiaNia and Mambasa grow to huge regional centres. Kisangani located on the Congo River was once an economic powerhouse connected by road to the coffee, cotton and oil palm plantations of the north-east, and by river to the capital Kinshasa. A decade of civil strife and collapse of industrial agriculture has left Kisangani an enclaved city of over a million residents with few options other than eating wildlife and what remains of a heavily depleted riverine fishery.

All these regional towns share a common problem: their large and growing populations often have limited access to locally produced or imported sources of livestock or farmed fish. As a result, many are almost wholly dependent on meeting their dietary protein needs by importing bushmeat from rural sources. In Central Africa, these trade networks can extend hundreds of kilometres and are extending further each year as more proximal sources of wildlife get depleted.

Livestock production and farmed-fish as a substitute for bushmeat. Livestock and fish-farming are two of the fastest-growing sectors in agriculture, presenting opportunities for economic growth and poverty reduction in rural areas (Thornton, 2010; Robinson *et al.*, 2011; Beveridge *et al.*, 2013; Herrero *et al.*, 2014; Waite *et al.*, 2014), as well providing alternatives to the unsustainable use of wildlife as food.

In towns like Ouesso, NiaNia and Kisangani, the scale of demand for wildlife as a source of protein is exceeding local supply, depleting nearby wildlife populations and forcing traders to extend their networks. This unsustainable consumption of wildlife will continue unless domestic livestock production including fish-farming, or, if feasible, importation of fresh, frozen or canned meat or fish can be substantially increased so that the supply of affordable nonwild animal protein balances consumer demand.

To meet growing demand, it is vital to increase consumer access to reliable, affordable, safe alternative sources of animal protein. Chickens have the most favourable feed-conversion ratios of common domesticated livestock, and they reach market weight quickly. They are prone to the highly contagious Newcastle disease (paramyxovirus), but use of a thermostable vaccine has been demonstrated to protect flocks from the disease (Spradbrow, 2013).

For chicken to substitute for bushmeat such that offtake of wildlife is sustainable, production has to meet a substantial portion of annual consumption of bushmeat and be priced competitively. Too few birds sold at too high a price will do nothing to change demand for and consumption of bushmeat by urban dwellers. That said, consumer access to competitively priced and readily available alternative sources of animal protein, such as chickens, has huge potential to reduce demand for bushmeat, particularly in towns that are close to sources of wildlife.

An alternative to factory farming would be to encourage increased family-level production of livestock but at scale sufficient to generate enough protein to meet demand. The latter, although logistically more complicated, has the advantage that it provides a new income stream for families and most particularly women and does not require centralized feed production and management. Tropical tolerant breeds with low input requirements could be introduced from India where they have proven to substantially increase productivity of village-raised chickens (pers. com. Donald Nkrumah, Bill and Melinda Gates Foundation).

Possibly, the most promising solution to provide protein to families in rapidly growing towns close to sources of wildlife is a mixed production system that combines crops (e.g. rice, millet, maize, legumes) with small livestock (e.g. chickens or rabbits) and fish-farming, where the tilapia or catfish are raised on crop residues and algae fertilized with chicken and rabbit manure (Ogello *et al.*, 2013; Milder

et al., 2014; Oben, Molua & Oben, 2015). This, however, may increase forest clearing in peri-urban areas.

Wildlife ranching and mixed livestock–wildlife production systems. Fenced and unfenced community conservancies in Namibia and Kenya and private game ranches in South Africa have been successful in mixing wildlife and livestock production. In Namibia, income from wildlife comes predominantly from fees paid by trophy hunters and fees and salaries associated with visual tourism (NACSO, 2014). In 2013, there were 79 registered community conservancies covering 19.4% of the nation, generating $5 million in income and 542,280 kg of game meat for the conservancies 175,000 residents. In northern Kenya, visual tourism, reduced cattle rustling and improved access to urban beef markets are providing more secure income to communities (Pye-Smith, 2013). A similar approach was developed at the Savé Valley Conservancy in Zimbabwe, where in 2010 wildlife cropping produced 75,500 kg of meat for 10,000 community members (http://www.rp-pcp.org/projects/completed/eu-parsel).

Mixed wildlife–livestock production can increase income for poor rural families in open woodlands and savannahs of Africa particularly when wildlife are sold to hunters as trophies or as meat to high-value tourist lodges and export markets (Lindsey, Roulet & Romanach, 2007; Lindsey *et al.*, 2013b). However, given that even successful conservancies in Namibia (NACSO, 2014) and Zimbabwe (Perrotton *et al.*, 2011) only provided communities with 3 and 0.5 kg/household/year of wildlife meat, respectively, it appears doubtful that wildlife meat generated from trophy hunting and game cropping can provide a significant portion of the protein requirements of local communities (c.f., Lindsey *et al.*, 2013b). This mixed system is unlikely to be appropriate for low-productivity tropical forests in Africa with lower potential for trophy hunting and visual tourism.

Urban families where wildlife have been depleted from nearby areas

We have long known that large metropolitan areas are markets for bushmeat (Wilkie *et al.*, 2005, 2011; Nasi *et al.*, 2008) and that urban consumers rely on bushmeat, typically, for <2% of their annual dietary protein requirements (Wilkie *et al.*, 2005). Bushmeat is eaten here not as a dietary necessity but as a prestige treat or to reconnect them to their rural heritage.

Where urban consumers are eating wildlife on occasion as a luxury item primarily for cultural reasons, access to affordable substitutes alone is unlikely to curb demand for bushmeat. To prevent urban luxury demand from driving rare wildlife species to local extinction, it is important to regulate what is currently, in most locations, an illegal but unenforced black market trade.

Selective bans on wildlife sold as food. An outright ban on all bushmeat sales in urban markets may result in a consumer backlash that political leaders may want to avoid, and might simply drive this black market trade further into the shadows. Rather, it is better to deploy policies designed to tilt sellers and buyers towards resilient *r*-selected wildlife (e.g. small antelope and most importantly rodents) and away from at-risk *K*-selected species (e.g. primates and large-bodied ungulates). This can be done at least in the short to medium term without explicitly legalizing bushmeat markets and incurring the substantial transaction costs of bringing bushmeat traders into the formal economy (Wilkie *et al.*, 2006). It can also be done without arresting and fining market sellers.

One policy option is for police in partnership with public health staff (there are zoonotic disease risks associated with hunting, butchering and eating wildlife) to frequently visit public markets and transportation hubs, on a random schedule, and confiscate all endangered and at-risk species on display for sale. This approach may be less open to corruption than imposing fines on market sellers, as long as the confiscated meat is not resold. Most importantly, confiscation is a financial disincentive to market sellers to purchase protected species from traders because it amounts to a *de facto* tax or fine on selling protected species. This approach is likely politically easier than arresting and prosecuting bushmeat sellers and is unlikely to result in a significant public backlash, as it does not depend on the actions of a corrupt judicial system and does not prohibit all bushmeat sales. This approach should be seen as an incremental step to halting all demand for and consumption of unsustainably hunted bushmeat in urban areas.

Conclusions

Although the available evidence guides us towards likely effective interventions, none have been rigorously tested

and evaluated under a range of conditions. Prior to deploying any set of interventions to conserve and eat wildlife in Africa, a clear theory of change needs to be elaborated for each test in each geographical area. This will make explicit the underlying assumptions as to how integrated interventions are expected to result in desired outcomes. Clear theories of change also provide a framework for monitoring that allows rigorous evaluation of the effectiveness of interventions over time and a clearer understanding of what works in what combination under which conditions. Sufficient funding and effort needs, therefore, to be allocated to assess rigorously the effectiveness of the different mixes of bushmeat interventions in different urban and rural settings (Ingram *et al.*, 2015).

Given the scale differences between sustainable supply of wildlife as food and the demand for bushmeat, policymakers' intent on both conserving and eating wildlife must focus on providing solutions for rural and urban consumers.

The human population of the planet is predicted to increase from 7 to over 9 billion by 2038 and much of that growth will be in sub-Saharan Africa. With ecological constraints on wildlife production and continuing conversion of wildlife habitat to crop lands, supply of wildlife as a source of food will only decrease per capita in future. Wildlife can only, realistically, be considered an interim source of dietary protein for rural people until production of livestock or nonanimal alternatives increase to meet basic needs.

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