Wild meat: the bigger picture

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Massive overhunting of wildlife for meat across the humid tropics is now causing local extinctions of numerous species. Rural people often rely heavily on wild meat, but, in many areas, this important source of food and income is either already lost or is being rapidly depleted. The problem can only be tackled by looking at the wider economic and institutional context within which such hunting occurs, from household economics to global terms of trade. Conservation efforts must be placed within a landscape context; a mosaic of hunted and no-take areas might balance conservation with continued subsistence use. Successful conservation of hunted wildlife requires collaboration at all scales, involving local people, resource extraction companies, governments and scientists.

Extinctions caused by overhunting of wildlife for meat are nothing new [1,2]. To some extent, each generation of conservationists falls prey to the 'shifting baseline syndrome' [3], by which we measure biodiversity losses against the status quo when we first started our professional lives, rather than recognizing that the crises that we observe now are merely the end-game of a long interaction between humans and nature [1]. Nonetheless, we must set our conservation priorities in the present, and do our utmost to conserve the rich biodiversity and ecological systems and processes that we have inherited.

Here, we argue that the overhunting of wild animals for meat is currently a major threat to biodiversity in the humid tropics, as well as to the people of those ecosystems who depend on wild meat for food and income. We highlight the extent to which overexploitation of wild meat is linked to the wider economy. This means that solutions to the wild meat crisis cannot often be found by concentrating on hunting alone. Instead, a better understanding needs to be developed of the cross-sectoral linkages that drive wild meat hunting and consumption. Researchers and practitioners working to find solutions to the wild meat problem are increasingly placing their findings into this wider context and using tools from other disciplines. Here, we review the current scale and ramifications of wild meat hunting in the humid tropics, highlight recent interdisciplinary advances, and suggest priority areas for future research.

The scale of the problem

Across the humid tropics, wild meat is being consumed on a massive scale. Humans have been hunting wildlife in tropical forests for 100 000 years or more, but consumption has greatly increased over the past few decades. Recent estimates of the annual wild meat harvest are 23 500 tonnes in Sarawak [4], 67 000– 164 000 tonnes in the Brazilian Amazon [5,6], and 1 million–3.4 million tonnes in Central Africa [7,8]. Productivity of tropical forests for wild meat is at least an order of magnitude less than that in more open habitats, such as savannahs. If people depend solely on wild meat for their protein, human population densities $>$ one person km^{-2} are unsustainable in tropical forests [9]. Hunting rates are already unsustainably high across large swathes of the tropics, averaging six times the maximum sustainable rate in Central Africa, for example [4]. Consumption is both by rural communities and by urban consumers, who are often at the end of supply chains that are hundreds of kilometers long [10,11].

The consequences of overhunting are numerous. Many species are facing local or even global extinction. Large species, such as tapirs or primates, disappear first and, as they vanish, people turn to hunting smaller ones, such as squirrels or cane rats [12,13]. Species loss has consequences for both forest dynamics [14] and rural people. Wild meat is a major source of protein and cash for people across the tropics [15], but those who depend most on this resource are often the most remote and marginalized groups who have few easily available alternatives [16].

The rapid recent acceleration in losses of tropical forest species owing to unsustainable hunting occurred in Asian forests first; for example, within the past 40 years, 12 large vertebrate species have been extirpated in Vietnam largely because of hunting [2]. Africa is now experiencing species losses over wide areas [17] and, in the next 10–20 years, losses are likely to be recorded in even the remotest parts of Latin America [18]. This pattern follows the major impacts of development and forest loss on the three continents linked to dramatic human population growth: there are 522 people km^{-2} of remaining forest in South

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and south-east Asia, 99 in West/Central Africa, and 46 in Latin America [19,20].

Hunting has increased dramatically in recent years for several reasons, including loss of forest and increases in human populations (e.g. Africa's population increased eightfold between 1900 and 2000); increased access for hunters and traders to remaining forests as a result of road building and forest fragmentation; the use of efficient modern hunting technologies, especially firearms and wire snares; loss of traditional hunting controls; greatly increased commercialization of hunting; and the exacerbation of all these by extractive industries, such as logging [15].

Bushmeat and wild meat

The word 'bushmeat' is widely used across West/Central Africa and, because the situation is currently reaching crisis levels in Africa, the term 'bushmeat crisis' tends to be used to describe overhunting of wildlife for human consumption in tropical areas. However, the implication that the problem is mainly a West/Central African one can be misleading. The 25 tonnes of turtles exported every week from Sumatra, Indonesia [21], 1500 forest rats sold per week in a Sulawesi market [22], and 28 000 primates hunted annually in Loreto, Peru [23] would not be considered bushmeat in the narrow sense of the word. Yet they are part of the same problem of overhunting of wildlife for human consumption. For this reason, Resolution 2.64, passed unanimously at the IUCN–World Conservation Union General Assembly in Amman, Jordan in October 2000, referred to wild meat rather than bushmeat to reflect the global nature of the issue. Here, we do likewise.

Wild meat and development

Loss of wildlife through overhunting affects many types of people. Townspeople can be major wildlife consumers. The 80 000 townspeople of Bioko Island, Equatorial Guinea, consume >100 000 kg of wild meat every year [10], and up to 90 000 mammals are sold annually in a single urban market in north Sulawesi, Indonesia [22]. One of the tragedies, however, is that the direct cost of wildlife loss falls most heavily on the rural poor, directly reducing the amount of animal protein available to them, and eroding one of the few commodities that they can sell. Rural households can consume large amounts of wild meat. For example, in the Congo Basin, daily per capita wild meat consumption by some rural dwellers is ten times greater than that of urban dwellers [7]. In a rural community in Ghana, wild meat made a significant contribution to both household food supply and cash income, especially in the lean agricultural season [24]. Moreover, this contribution was greatest for extremely poor households. Similar patterns are seen in Latin America, where people from ten indigenous groups derive at least 60 g of protein d^{-1} from wild meat [25] and in Sarawak, where wild meat is found in 67% of all meals of highland people [26].

Traditionally, international development assistance has not addressed the needs of the rural people who live at the margins of the cash economy at the ecological frontier. They frequently lack the skills, education and cultural context to take advantage of cash-earning jobs that are made available through typical development assistance programs [16]. In the short term, they continue to depend, at least in part, on natural resource extraction. Development priorities for these people must therefore focus on making harvests of wildlife and other natural resources sustainable through multifaceted programs, which control access to the resource and develop viable alternatives. Programs that encourage good governance, more favourable terms of trade, and vest tenure and use rights with rural people rather than with outsiders, can both address the root causes of poverty and promote the conservation of natural resources [27]. Conservation and development agencies can therefore find common cause in these issues.

Wild meat and economics

A true understanding of the importance of wild meat can be gained only by putting it in the context of other sources of household income and subsistence, other opportunities in the local economy and local cultural beliefs. Only then can the processes of supply and demand be understood. One factor affecting the consumption of wild meat is the price and availability of substitutes. How these patterns of consumption change as consumers' economic circumstances change depends largely on how people's preferences vary with income (Box 1).

The relationship between improved economic livelihoods and the demand for wild meat is not simple. It cannot be assumed that economic development in itself will reduce demand for wild meat; it could easily increase it in the short term, as exemplified by the burgeoning urban wildlife markets across East Asia. The long term is not relevant for the species that are most endangered by hunting, for which extinction in the next decade is a real possibility [28]. Hence, it is imperative that development assistance to rural communities includes improving the sustainability of natural resource use, from both the food security and conservation perspectives.

The decision to hunt or trade wildlife depends not only on nutritional and economic status, but also on the other opportunities available for food and income generation. Ultimately, the current scale of hunting can only be lowered whilst still maintaining wildlife populations if ample, affordable nonwild fresh protein is available to large sectors of the population (Box 2).

Collaborating to solve the wild meat crisis

Collaborative multifaceted efforts are essential to solve the wild meat crisis, given that hunting is an integral part of rural economies, interacting as it does with other rural livelihood activities, such as logging, agriculture and fishing. An example of how this can work is the development of a Master Plan for Wildlife in Sarawak [29], which is based on long-term research and resulted in the passing and strict enforcement of a new law banning all trade in wild animals and their parts, strict control of shotgun cartridge availability and hunting in logging concessions, broad education programs and involvement of local communities in management of protected areas. One

Box 1. The roles of income and substitute goods in demand for wild meat

Economic theory suggests that providing consumers with access to acceptable and affordable substitutes could help to reduce unsustainable hunting and enhance wildlife conservation. Others believe that eating wild meat is an immutable cultural tradition that is little influenced by income and prices. In Gabon, consumption of wild meat declines as its price increases in absolute terms and relative to the price of substitutes, such as beef and chicken [37]. Here, as you travel further from the capital city and deeper into the forest, transportation costs mean that the price of domestic meat rises and the price of wild meat falls (Fig. Ia). Whether because of availability or consumer choice, the result is that wild meat contributes to 6% of meals containing meat consumed by households in Libreville (the capital) and 88% in isolated forest villages (Fig. Ib). In rural communities in Honduras and Bolivia, when the price of wild meat rises or the price of beef falls, consumers switch from eating wild meat. In Bolivia, a 10% reduction in the price of beef was associated with a 74% decrease in consumption of wild meat [41]. The construction of a road in the Brazilian Amazon dramatically increased beef consumption as it became more available [42].

Economic theory also suggests that, as household income increases, consumption of a commodity will rise if it is a necessity (i.e. has no substitutes), or is considered superior relative to substitutes. Consumption of an inferior good falls with rising income. Kuznets [43] argued that consumption of many goods should exhibit an inverted U pattern with rising income. Consumption initially increases until income reaches a certain level, at which point consumers switch to now affordable substitutes. Depending on a family's initial income, economic development could either drive their consumption of wild meat up or down. The shape of the Kuznets curve determines the rate of change in consumption as incomes rise with economic development. The shape of the curve for a rural forest community in Bolivia is relatively flat. Here, wild meat is a necessity for families with average incomes $<$ US\$1041 y^{-1} but is an inferior good for families with incomes above an average of US\$4646 y^{-1} [41].

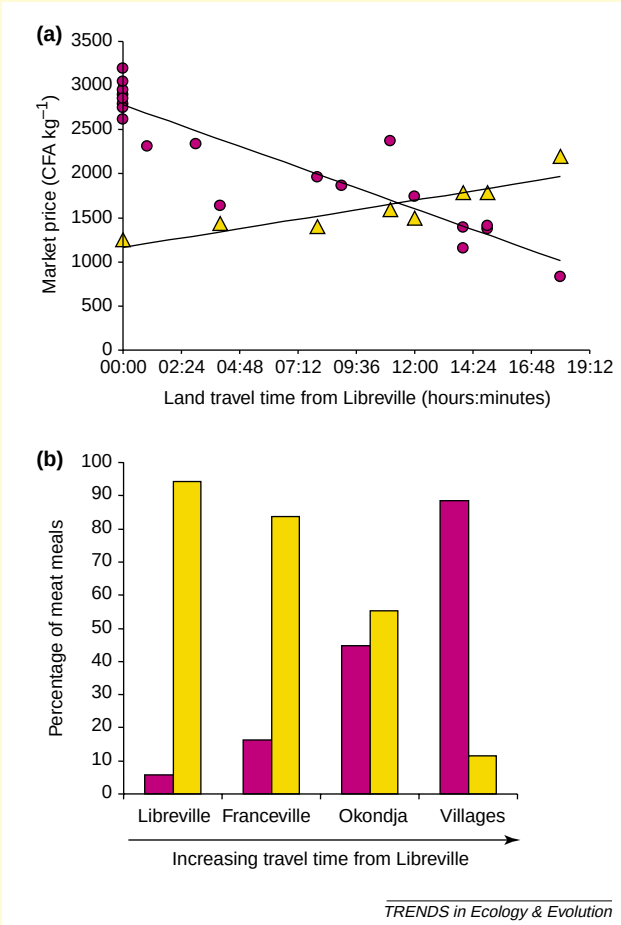

Fig. I. Variation in price and consumption of poultry and porcupine in Gabon. (a) The effect of availability on price. A comparison of the market price per kg of poultry (triangles) and a preferred wild meat species, brush-tailed porcupine *Atherurus africanus* (circles), as travel time from Libreville (the Gabonese capital) increases. Libreville is a major city, in which domestic meats are easily available. Moving into the rural areas of Gabon, the availability of domestic meat decreases, and that of wild meat increases. Linear regressions are also shown: Poultry: $r^2 = 0.792$, $P < 0.001$; Porcupine: $r^2 = 0.833$, $P < 0.001$. US\$1 = CFA 700 (CFA: Communauté Financière Africaine Francs, the common currency of several Central African countries). (b) The effect of availability on consumption. The percentage of meals that contain meat that is either wild meat (pink bars) or meat from livestock (yellow bars). Data from [37].

reason for the success of the Master Plan is that there is strong support from rural community leaders [30].

A different type of collaboration is happening in the People's Republic of Congo. Here, the Congolese Government, a German timber company Congolaise Industrielle des Bois and the Wildlife Conservation Society are working together to control hunting and bushmeat trade within a large logging concession adjoining Nouabalé Ndoki National Park. This programme is also multifaceted and research based, relying on strict enforcement by trained ecoguards who prevent hunters from using wire snares and high-calibre firearms, hunting in no-hunting zones, and killing protected species. Transportation of wildlife is restricted through the concession and forbidden out of the concession. Education programs are given to logging company staff and local communities, and economically feasible alternative protein sources for company workers and their families are being explored [31]. The ease with which species such as gorillas and chimpanzees can be seen in the concession strongly suggests that the program is succeeding.

These examples demonstrate that finding solutions to the wild meat crisis requires an understanding of both the local situation and the institutional context. A major problem facing governments is the cross-sectoral nature of the wild meat crisis; promoting interdepartmental and interagency cooperation is key to effective action. Raising awareness of the issue among the public and policy makers is also vital (Box 3).

The role of research

Given the urgency of the crisis, and the rates at which wildlife populations are declining, we need immediate

Box 2. Alternatives to wild meat

Demand for meat in Africa is likely to have grown at least as fast as the human population, which today is eight times larger than that in 1900. In many areas, livestock rearing has been frustrated by trypanosomiasis and, although domestic animals (mainly chickens and goats) are kept in most forest villages, these are perceived as savings or insurance against illness or disasters. Even in grassland areas, where cattle raising is commonplace, cows are valued as a source of milk, blood and prestige, rather than of meat. The availability of abundant and accessible wildlife as a source of protein has led to a large proportion of the rural population using wild meat [7]. In the absence of regulatory mechanisms, commercial hunting of forest wildlife is unlikely to be ecologically sustainable and will only generate short-term windfalls [44]. Because productivity of wildlife in tropical forests is low, if hunting is reduced to sustainable levels, it is generally unlikely to provide an offtake that is large enough to meet hunters' economic wishes, or consumers' dietary needs [45].

Consumption of livestock must increase relative to wild meat if demand is to be fulfilled without depleting the forests of wildlife. Increasing consumer access to domestic meat and reducing livestock meat prices will diminish demand for wild meat and, consequently, reduce the amount of wildlife hunted for food (Box 1). It is important also to consider other protein sources; in Ghana, there is an inverse correlation between marine fish landings and declines in mammalian biomass inside reserves, with the effect being significantly greater nearer the coast†.

To lower livestock meat prices, governments in developing nations and development agencies must make greater public investments in primary and applied research. Extension services must encourage adoption of new technologies that enable livestock to fulfill multiple roles (e.g. savings, insurance, food and income). These new technologies must increase livestock production and lower prices of domestic meat, while limiting the habitat loss and degradation that are often associated with increased livestock production.

If agricultural research and extension are to help solve the wild meat crisis, donors and developing nation governments must reverse the downward trend in agricultural R&D spending. For most developing nations, total spending on arable and livestock R&D has declined significantly in the past 30 years [46], whereas agricultural research spending (relative to the size of the agricultural sector) has doubled in the USA and almost quadrupled in Australia [47].

action. But we also need research and monitoring, to ensure that actions are having their desired effects. This is especially crucial given the complex ramifications of the issues involved. Minimum data requirements for assessing the sustainability of hunting are the population densities and productivities of hunted species and offtake rates by hunters. However, the difficult conditions and low visibility in tropical forests mean that methods currently available to measure biological parameters are rarely precise. For example, current census methods for elephants based on dung counts can detect only a 15% change in forest elephant populations and might underestimate declines by as much as 50% [32–34]. Spatial modeling and capture–recapture methods might be more accurate [34–36], but are costly. For some species, even poor data are unavailable. No density estimates have been published in the past decade for some of the most commercialized species in Central Africa, such as the blue duiker *Cephalophus monticola* and the brush-tailed porcupine *Atherurus africanus*. The bearded pig *Sus barbatus* is important in the diets of people across Borneo, but its migratory nature means that densities cannot be estimated reliably. These problems severely weaken our ability to predict population trends in the face of hunting, and thus reduce our capacity to introduce effective management.

Studies of consumption tend to focus either on subsistence communities or markets. Market surveys can severely underestimate offtakes because of wastage in the forest, local consumption and informal sales or exchange. The species most threatened by hunting are rarely seen in markets, because they are already at very low population densities. In Gabon, species diversity in the market was only fully documented after 10 000 sales, representing 6–24 months of trade [37]. And even long-term market data might not tell us anything about the status of a species if confounding factors are at work (e.g. if hunters are changing the technology that they use,

Box 3. Policy and public awareness: two key components to resolving the wild meat crisis

Studies showing that most exploitation is unsustainable have had little influence on government policies towards wild meat, and public awareness in tropical forest nations of threats to wildlife is limited. However, since the commercial wild meat trade came to international attention in the mid-1990s, range states and their international partners have started to build public awareness and political will.

Discussions about wild meat have occurred at all recent major international conservation gatherings, including the Convention on International Trade in Endangered Species (CITES, April 2000), the World Conservation Union (IUCN, October 2000) and the World Summit on Sustainable Development (WSSD, September 2002). The passage of Resolution 2.64 at the IUCN Congress in Amman, Jordan, the creation of an official CITES Bushmeat Working Group (BWG), the formation of a CBD Bushmeat Liaison Group, and a global partnership for the Congo Basin Forests announced at the WSSD all attest to a global commitment to curb the unsustainable exploitation of wildlife. These developments are encouraging not only in the potential that they provide for coordinated action, but also in providing guidance about specific actions to resolve the wild meat crisis.

Building political support at the international level has been a crucial accomplishment by groups such as the Bushmeat Crisis Task Force (BCTF), the Ape Alliance and UK Bushmeat Campaign. BCTF provides a forum for constructive dialogue between international NGOs and governments. Through the efforts of BCTF, a subcommittee of the US House of Representatives recently held an official Oversight Hearing on bushmeat, which resulted in several recommendations, including establishment of a Congressional 'Bushmeat Caucus'.

Building public awareness provides the impetus for short-term behaviour changes. Campaigns in the West raise resources and influence policies, but civil society also needs mobilizing in countries where hunting for wild meat is unsustainable. For example, in Ghana, local NGOs (led by Conservation International) and traditional authorities have joined forces to curtail commercial hunting and reverse loss of wildlife. The awareness campaign builds upon links between wildlife and traditional Ghanaian culture, focusing on the need to preserve cultural heritage. In addition to sensitizing the public about existing conservation laws, the campaign promotes open discourse among various sectors of society regarding livelihood issues associated with hunting and consumption of wild meat. Other efforts include a WWF bushmeat video contest in Central Africa and a Bushmeat Awareness Campaign run by the CITES BWG.

Box 4. No-take areas in fisheries and wild meat hunting

Small-scale fisheries and wild meat hunting have much in common. They use a variety of relatively unselective capture methods, targeting a wide range of species that have different levels of resilience to exploitation. They are also difficult to manage. Species are difficult to census in the wild and few, if any, are valuable enough to warrant the investment needed to generate accurate data. Data collection for harvesting effort and species caught is hampered by the dispersed nature of resource extraction, the range of markets and the fact that much of the catch is not traded but is consumed by hunters or fishers and their families. These characteristics make it almost impossible to determine and implement target levels of harvesting effort for each species [48].

Faced with these circumstances, fisheries scientists are increasingly recommending the use of no-take marine reserves, areas permanently closed to all fishing, as a means of sustaining or enhancing fish yields. Protection from fishing enables animals to increase in abundance, live longer and produce more offspring. In the sea, eggs and larvae exported from reserves on ocean currents can replenish fishing grounds. Furthermore, as stocks build up, juveniles and adults spill over from reserves to fisheries. There is widespread evidence for spillover. Concentration of fishing effort around reserve boundaries has been reported in many countries and diverse fisheries [49]. In East Africa, fishing sites adjacent to the Mombassa Marine National Park have become so lucrative that they are reserved by informal agreement for the most senior fishers (L.D. Rodwell, PhD thesis, University of York, 2001). A network of small reserves on coral reefs off St Lucia has increased catches in adjacent fishing grounds by 46–90% in five years [50]. In the Philippines, catch-per-unit-effort adjacent to a marine reserve has increased tenfold over 20 years of reserve protection [51].

Because terrestrial animals lack planktonic larval dispersal, wild meat hunters would need to rely entirely on spillover from no-take areas. Key questions thus include the magnitude of the spillover that is likely in terrestrial systems, how large no-take areas must be to maintain accessible hunted areas and what landscape configuration of no-take and hunted areas would work best [52]. In terrestrial systems, there has been much theoretical work looking at source–sink dynamics [53], which can lead to spillover effects. However, there is no hard empirical evidence that hunted species in tropical forests display such dynamics. A theoretical analysis of tapir hunting in lowland Amazonia showed that a source area of 9300 km^2 would sustain hunting in a 1700 km^2 sink, if tapir dispersal was directed towards that sink [54].

In spite of the uncertainties, no-take areas are a promising way to achieve landscape-wide sustainable hunting that can be enforced more easily than can restrictions on offtake. Although effective source:sink area ratios would be more feasible to implement in sparsely populated areas of Latin America, high hunter densities in Africa and Asia do not necessarily preclude them, provided that the appropriate incentives and controls are in place. In particular, it is important to ensure that the establishment of a no-take area does not exacerbate biodiversity loss in surrounding areas, owing, for example, to immigrants taking advantage of conservation-linked benefits [55]. Even within a protected area, edge effects and movement into neighboring hunted areas can cause animal populations to decline [56,57]. Hence, it is necessary to ensure that no-take areas are large enough to maintain viable populations in the face of hunting and habitat loss in surrounding areas [52].

One of the main advantages of no-take areas is the link to community-based wildlife conservation. Many fully protected areas conflict with the interests of local people, leading to local resentment. Local people are more likely to support full protection of source areas if they perceive direct benefits from them. Fully protected areas can maintain a full complement of biological diversity. Thus, no-take areas can both improve the sustainability of hunting and help resolve conflicts between local people and protected areas. No-take areas can be enforced partly by the community, which makes them cheaper than entirely state-run protected areas. Hence, in the long run, no-take areas managed, at least in part, by local communities offer a more sustainable conservation strategy than does relying solely on traditional protected areas.

dealers are traveling further afield, or market dynamics are changing [11]). Combining long-term surveys of markets, households and wildlife populations is necessary to capture the whole picture, enabling us to predict how offtakes can be made sustainable. Bio-economic modeling can also predict the effects of policy interventions in a way that might be impossible from field studies alone [38].

It is crucially important to conserve ecosystem processes at a landscape level. This enables us to buffer against uncertainty, work with the dynamics of the ecosystem and protect particularly sensitive areas. A landscape approach also integrates conservation planning more fully into the overall land-use policies of a country. There has been a corresponding move towards area-based management in fisheries, focused particularly on the use of marine reserves both for conservation and to provide improved yields for fishers (Box 4). Bridging the divide between fisheries and wild meat is especially important given that there is, in some cases, a direct interaction between the two sectors; consumption of wild meat is directly and inversely related to the ready availability of fish[†].

An emerging consensus

Individual conservation organizations and interest groups can have widely divergent views about the appropriate methods for tackling the wild meat crisis. But a consensus about the scale and potential repercussions of the crisis is emerging (Box 5), the key points of which are:

- The need for effective protected areas is paramount if biodiversity is to be maintained in the face of unsustainable hunting.
- Effectively enforced bans on the hunting of some particularly vulnerable species, such as the great apes and large carnivores, are crucial. These species form only a tiny proportion of offtake and are not livelihood staples, yet they are extremely vulnerable to even low levels of hunting.
- Public awareness of the wild meat crisis must be raised where wild meat is sold and eaten, to educate hunters, traders and consumers about the implications of the lack of sustainability for biodiversity and rural livelihoods.
- Capacity building is essential, so that the countries concerned can implement solutions.
- The hunting issue must be addressed in conjunction with development efforts to increase national security and stability; long-term solutions will only be feasible with strong local capacity and good governance. However, building short-term local support is often vital in countries where long-term stability is a long way off.

† Brashares, J. (2002) The big picture on bushmeat: large mammal conservation and food security in West Africa. Presentation to the Society for Conservation Biology, Canterbury, UK. July 2002, http://www.ukc.ac.uk/anthropology/dice/scb2002/abstracts/Monday/cmone.html

Box 5. Urgent research and action required

The research that is urgently required includes:

- Obtaining fundamental ecological data (distribution, density and rates of change) for hunted species
- Assessing the level of dependence on wild meat by different sectors of society, as distinct from current use of the resource (which might reflect preferences rather than dependence)
- Determining the local, national and international mechanisms and drivers of the wild meat trade, and the interactions between them
- Developing a robust framework for assessing the scale of the wild meat problem. Which data are needed? Are there simple methods for assessing the sustainability of hunting in an area?
- Determining where interventions are best targeted, how and by whom (e.g. governments, logging companies and local communities).

The actions needed are numerous, but priority ones include:

- Promoting greatly increased awareness of the issue of wildlife hunting and its ramifications
- Law enforcement, especially to protect those species at imminent risk of extirpation
- Ensuring that hunting does not accompany resource extraction (i.e. timber, minerals or oil)
- Increasing spending on domestic livestock research and extension
- Ensuring the establishment and effective management of viable protected areas, as these are the only lands that are designated specifically for biodiversity conservation
- Greatly increasing capacity at all levels in tropical countries to manage protected areas and trade

The wild meat crisis is a challenge for conservationists. It is urgent, widespread and complex. However, many of the lessons learnt about successful approaches to the conservation of hunted wildlife are the same as those we are learning for conservation more generally [39,40]. Successful solutions to the wild meat crisis involve multi-disciplinary approaches, and the full integration of the conservation of natural resources into development agendas at the local, national and international levels. Hence, efforts to solve the wild meat problem will be the testing ground for many potentially valuable general approaches to conservation.

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References

1 Diamond, J. (1991) *The Rise and Fall of the Third Chimpanzee*, Vintage
2 Bennett, E.L. and Rao, M. (2002) Wild meat consumption in Asian tropical forest countries: is this a glimpse of the future for Africa? In *Links between Biodiversity, Conservation, Livelihoods and Food Security: The Sustainable Use of Wild Species for Meat* (Mainka, S. and Trivedi, M., eds) pp. 39–44, IUCN
3 Pauly, D. (1995) Anecdotes and the shifting baseline syndrome of fisheries. *Trends Ecol. Evol.* 10, 430
4 Bennett, E.L. (2002) Is there a link between wild meat and food security? *Conserv. Biol.* 16, 590–592
5 Robinson, J.G. and Redford, K.H. (1991) *Neo-Tropical Wildlife Use and Conservation*, Chicago University Press
6 Peres, C.A. (2000) Effects of subsistence hunting on vertebrate community structure in Amazonian forests. *Conserv. Biol.* 14, 240–253
7 Wilkie, D.S. and Carpenter, J.F. (1999) Bushmeat hunting in the Congo Basin: an assessment of impacts and options for mitigation. *Biodiv. Conserv.* 8, 927–955
8 Fa, J.E. *et al.* (2001) Bushmeat exploitation in tropical forests: an intercontinental comparison. *Conserv. Biol.* 16, 232–237
9 Robinson, J.G., Bennett, E.L. eds (2000) *Hunting for Sustainability in Tropical Forests* Columbia University Press
10 Fa, J.E. (2000) Hunted animals in Bioko Island, West Africa: sustainability and future. In *Hunting for Sustainability in Tropical Forests* (Robinson, J.G. and Bennett, E.L., eds) pp. 168–198, Columbia University Press
11 Milner-Gulland, E.J. and Clayton, L.M. (2002) The trade in wild pigs in North Sulawesi, Indonesia. *Ecol. Econ.* 42, 165–183
12 Bennett, E.L. *et al.* (2002) Why is eating bushmeat a biodiversity crisis? *Conserv. Pract.* 3, 28–29
13 Jerozolimski, A. and Peres, C.A. (2003) Bringing home the biggest bacon: a cross-site analysis of the structure of hunter-kill profiles in Neotropical forests. *Biol. Conserv.* 111, 415–425
14 Redford, K.H. (1992) The empty forest. *Bioscience* 42, 412–422
15 Bennett, E.L. and Robinson, J.G. (2000) *Hunting of Wildlife in Tropical Forests: Implications for Biodiversity and Forest Peoples*, The World Bank
16 Robinson, J.G. and Bennett, E.L. (2000) Will alleviating poverty solve the bushmeat crisis? *Oryx* 36, 332
17 Brashares, J.S. Behavioral, ecological, and life-history correlates of mammal extinctions in West Africa. *Conserv. Biol.* (in press)
18 Peres, C.A. (2001) Paving the way to the future of Amazonia. *Trends Ecol. Evol.* 16, 217–219
19 Anonymous, (1998) *World Bank Atlas*, World Bank
20 Naughton-Treves, L. and Weber, W. (2001) Human dimensions of the African rain forest. In *African Rain Forest Ecology and Conservation* (Weber, W. *et al.*, eds), pp. 30–43, Yale University Press
21 Shepherd, C.R. (2000) Export of live freshwater turtles and tortoises from North Sumatra and Riau, Indonesia: a case study. In *Asian Turtle Trade: Proceedings of a Workshop on Conservation and Trade of Freshwater Turtles and Tortoises in Asia, Phnom Penh, Cambodia* (van Dijk, P.P. *et al.*, eds), pp. 112–119, Chelonian Research Foundation
22 Clayton, L.M. and Milner-Gulland, E.J. (2000) The trade in wildlife in North Sulawesi, Indonesia. In *Hunting for Sustainability in Tropical Forests* (Robinson, J.G. and Bennett, E.L., eds) pp. 473–498, Columbia University Press
23 Bodmer, R.E. (2001) Pezo Lozano. *E., Rural development and sustainable wildlife use in the tropics. Conserv. Biol.* 15, 1163–1170
24 Dei, G.J.S. (1989) Hunting and gathering in a Ghanian rain forest community. *Ecol. Food Nutr.* 22, 225–243
25 Townsend, W.R. (2000) The sustainability of hunting by the Sirionó Indians of Bolivia. In *Hunting for Sustainability in Tropical Forests* (Robinson, J.G. and Bennett, E.L., eds) pp. 267–281, Columbia University Press
26 Bennett, E.L. *et al.* (2000) Saving Borneo's bacon: the sustainability of hunting in Sarawak and Sabah. *Hunting for Sustainability in Tropical Forests* (Robinson, J.G., Bennett, E.L., *et al.* eds), pp. 305–324, Columbia University Press
27 Davies, G. (2002) Bushmeat and international development. *Conserv. Biol.* 16, 587–589
28 Nelleman, C. and Newton, A. (2002) *The Great Apes: The Road Ahead*, UNEP
29 Wildlife Conservation Society and Sarawak Forest Department, (1996) *A Master Plan for Wildlife in Sarawak*, Wildlife Conservation Society and Sarawak Forest Department
30 Bennett, E.L. and Tisen, O.B. (2001) A master plan for wildlife conservation. *Sarawak Gazette* 128, 4–10
31 Elkan, P. (2000) Managing hunting in a forest concession in northern Congo. In *Hunting of Wildlife in Tropical Forests: Implications for Biodiversity and Forest Peoples* (Bennett, E.L. and Robinson, J.G., eds) pp. 28–29, The World Bank
32 Walsh, P.D. and White, L.J.T. (1999) What will it take to monitor forest elephant populations? *Conserv. Biol.* 13, 1194–1202
33 Buckland, S. *et al.* (2001) *A Sampling Design for the MIKE (Monitoring*

The Illegal Killing of Elephants) Program in Central Africa, IUCN African Elephant Specialist Group
34 Walsh, P.D. (2002). *Biodiversity Indicators for Gabon's Protected Areas: Evaluating Management Effectiveness*, Program Sectoriel Forêts et Environnement, Ministere de l'Economie Forestière, des Eaux, de la Peche, Chargé de l'Environnement et de la Protection de la Nature, Republique Gabonaise
35 Hart, J.A. (1994) Impact and sustainability of indigenous hunting in the Ituri Forest, Congo-Zaire: a comparison of unhunted and hunted duiker populations. In *Hunting for Sustainability in Tropical Forests* (Robinson, J.G. and Bennett, E.L., eds) pp. 106–153, Columbia University Press
36 Karanth, K.U. and Nichols, J.D. (2002) *Monitoring Tigers and their Prey*, Bangalore Centre for Wildlife Studies
37 Abernethy, K. and Ntsame Effa, E. (2002) *Gestion de la Filiere Viande de Brousse Report to the Direction de la Faune et Chasse, Gabon*
38 Rowcliffe, M. *et al.*, A model of human hunting impacts in multi-prey communities. *J. Appl. Ecol*. (in press)
39 Ling, S. *et al.* (2002) No new recipes for bushmeat. *Oryx* 36, 330
40 Swanson, T. (1994) *The International Regulation of Extinction*, Macmillan
41 Wilkie, D.S. and Godoy, R.A. (2001) Income and price elasticities of bushmeat demand in lowland Amerindian societies. *Conserv. Biol.* 15, 1–9
42 Ayres, J.M. *et al.* (1991) On the track of the road: changes in subsistence hunting in a Brazilian Amazonian village. *Neo-Tropical Wildlife Use and Conservation* (Robinson, J.G., Redford, K.H., *et al.* eds), Chicago University Press
43 Kuznets, S. (1955) Economic growth and income inequality. *Am. Econ. Rev.* 445, 1–28
44 Freese, C.H. (1998) *Wild Species as Commodities: Managing Markets and Ecosystems for Sustainability*, WWF/Island Press
45 Fa, J.E. *et al.*, Bushmeat and food security in the Congo Basin: linkages between wildlife and peoples' future. *Environ. Conserv.* (in press)
46 Anderson, J.R. *et al.* (1994) Sustaining growth in agriculture: a quantitative review of agricultural research investments. *Agric. Econ.* 10, 107–123
47 Pardey, P.G. and Alston, J.A. (1995) *Revamping Agricultural R&D. Report No. Vision 2020 Brief 14*, International Food Policy Research Institute
48 Polunin, N.V.C., Roberts, C.M. eds (1996) *Reef Fisheries. Series in Fish Biology and Fisheries No. 20* Chapman & Hall
49 Gell, F.R. and Roberts, C.M. The fishery effects of marine reserves and fishery closures. *WWF-US* (in press)
50 Roberts, C.M. *et al.* (2001) Effects of marine reserves on adjacent fisheries. *Science* 294, 1920–1923
51 Maypa, A.P. *et al.* (2002) Long-term trends in yield and catch rates of the coral reef fishery at Apo Island, Central Philippines. *Mar. Freshw. Res.* 53, 207–213
52 Peres, C.A. (2001) Synergistic effects of subsistence hunting and habitat fragmentation on Amazonian forest vertebrates. *Conserv. Biol.* 15, 1490–1505
53 Dias, P.C. (1996) Sources and sinks in population biology. *Trends Ecol. Evol.* 11, 326–330
54 Bodmer, R. (2000) Integrating hunting and protected areas in the Amazon. In *Future Priorities for the Conservation of Mammals: Has the Panda had its Day?* (Dunstone, N. and Entwistle, A., eds) pp. 277–290, Cambridge University Press
55 Oates, J.F. (1999) *Myth and Reality in the Rain Forest: How Conservation Strategies are Failing in West Africa, California University*, California University Press
56 Woodroffe, R. and Ginsberg, J.R. (1998) Edge effects and the extinction of populations inside protected areas. *Science* 280, 2126–2128
57 Laurance, W.F. (2000) Do edge effects occur over large spatial scales? *Trends Ecol. Evol.* 15, 134–135