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Wild Meat Is Still on the Menu: Progress in Wild Meat Research, Policy, and Practice from 2002 to 2020

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Abstract

Several hundred species are hunted for wild meat in the tropics, supporting the diets, customs, and livelihoods of millions of people. However, unsustainable hunting is one of the most urgent threats to wildlife and ecosystems worldwide and has serious ramifications for people whose subsistence and income are tied to wild meat. Over the past 18 years, although research efforts have increased, scientific knowledge has largely not translated into action. One major barrier to progress has been insufficient monitoring and evaluation, meaning that the effectiveness of interventions cannot be ascertained. Emerging issues include the difficulty of designing regulatory frameworks that disentangle the different purposes of hunting, the large scale of urban consumption, and the implications of wild meat consumption for human health. To address these intractable challenges, we

propose eight new recommendations for research and action for sustainable wild meat use, which would support the achievement of the United Nations Sustainable Development Goals.

Contents

1. INTRODUCTION

Wildlife has been a source of food for people worldwide since prehistory (1) and continues to support the diets, customs, and livelihoods of millions of people (2). Centuries of agricultural development have greatly diminished reliance on the consumption of terrestrial wild animals in most temperate regions (3, 4); however, in the tropics [defined as all tropical mesic ecoregions (5)], home to three-quarters of all animal species (6), several hundred species are still hunted for their meat [referred to as wild meat, or bushmeat in Africa (7)]. Here, we focus on the hunting, consumption, and trade of wild animals (excluding fish) for meat in tropical countries. In these countries, wild meat can be important for supporting health and nutrition through the provision of protein, fat, and micronutrients (8–10) and is a source of income when traded (7); it can also underpin cultural identity and practices (11). However, as human populations and economies have continued to grow, unsustainable hunting has become one of the most pervasive and urgent threats to wildlife worldwide. It has been estimated to affect a fifth of Red List Threatened species (12) and, coupled with habitat degradation, has led to widespread defaunation and extinctions (13, 14). These processes have cascading consequences for ecosystem functioning and dynamics (13, 14). For people whose subsistence and livelihoods are tied to wild meat, depletion of wildlife additionally risks reducing food security and income (9, 15, 16) and can cause social conflict (2).

Overharvesting of wildlife for meat has been identified as an issue since at least the 1960s (17–20), but the scale of overharvesting and its effects on biodiversity was first brought to global attention in the 1990s (**Figure 1**) (21, 22). In response, numerous nongovernmental institutions were established to promote conservation and sustainable use of hunted species, such as the Comunidad de Manejo de Fauna Silvestre en América Latina (23), which was established in 1992 and continues to the present day. The Bushmeat Crisis Task Force, which focused on wild meat in Africa, was established in 1999 and considered key to raising awareness of the plight of hunted species and their importance to poor rural families (24). In 2002, wild meat specialists convened to discuss the scale of wild meat use across the tropics and the likely ecological and sociocultural repercussions of overexploitation. The meeting culminated in a set of 11 urgent recommendations for research and action needed to balance conservation and development concerns, avert wildlife declines, and tackle rural food insecurity [published as Milner-Gulland et al. 2003 (15)].

Regional cooperation to work toward sustainable use has been evident since the publication of this paper through the discussion of wild meat issues in numerous multinational environmental agreements. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) set up a Central Africa Bushmeat Working Group (now disbanded) and adopted a resolution on bushmeat in the early 2000s; at the eighteenth Conference of the Parties to CITES in 2019, a revised resolution on wild meat was adopted. A United Nations (UN) Convention on Biological Diversity (CBD) Liaison Group on Bushmeat was established in 2009, and in 2012, Parties to the CBD were invited to work toward a suite of recommendations made by the Liaison Group relating specifically to wild meat and sustainable wildlife management (Decision XI/25) that would contribute toward the CBD Strategic Plan for Biodiversity 2011–2020. Furthermore, the UN Sustainable Development Goals (SDGs) were developed in 2015 and, although not explicitly targeting management of hunted wildlife, outline 17 interlinked

Wild meat: the meat and other body parts of wild terrestrial and aquatic animals (excluding fish) used for food

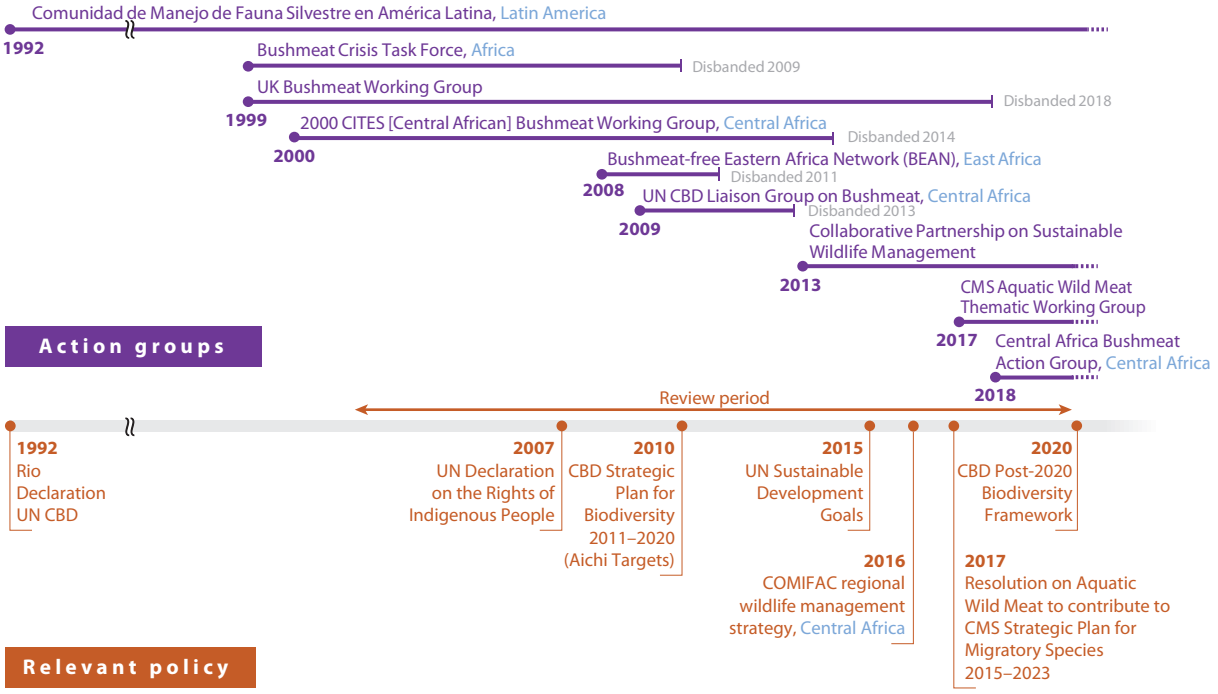


Figure 1

Timeline of policy progress and action groups on wild meat. Blue indicates regions to which policies and action groups are specific, if any. The review period of this article (2002–2020) is also plotted along the timeline. Abbreviations: CBD, Convention on Biological Diversity; CITES, Convention on International Trade in Endangered Species of Wild Fauna and Flora; CMS, Convention on Migratory Species; COMIFAC, Commission des Forêts d'Afrique Centrale; UN, United Nations.

goals as a global "blueprint to achieve a better and more sustainable future for all by 2030" (see **https://www.un.org/sustainabledevelopment/sustainable-development-goals/**).

Despite more than two decades of political statements about the importance of wildlife conservation and improved food security in intergovernmental forums, as well as considerable scientific endeavor to bring the wildlife exploitation crisis to the world's attention, the problem of wildlife overharvesting remains an intractable challenge, accelerating a biodiversity crisis in many tropical regions. The paper published by Milner-Gulland and colleagues in 2003 (15) has been cited several hundred times and reached beyond academia to policy audiences. In view of the evidence that overharvesting is still driving biodiversity loss and impoverishing dependent communities, and given current planning for the CBD's post-2020 Global Biodiversity Framework and need to achieve the SDGs, it is timely to reflect on whether the issues raised almost two decades ago have been addressed, and if so, how successfully. Reflection on successes and failures regarding understanding the issue, making appropriate policy, and taking effective action should guide us to well-informed future strategies that will ensure socially just and ecologically sustainable management.

Here, we critically review the successes and failures of the research and actions pertaining to wild meat management between 2002 and 2020. In Section 2, we discuss progress toward achieving the 11 recommendations proposed by Milner-Gulland et al. (15) through an in-depth review of the literature, together with expert assessments of progress on the ground. We quantified expert opinion because progress in awareness, policy, and practice is not reported in the literature

in the same way as research progress. In Section 3, we highlight four emerging topics relevant to wild meat management, and in Section 4, we present three areas of improvement for future wild meat research and action to work toward the enabling environment needed for successful management. Finally, in Section 5, we propose eight new recommendations for research and action, mapped onto a new theory of change informed by our own experiences. These would support the achievement of wild meat sustainability by 2030, in line with the timetable of the UN SDGs. All the original authors of the 2002 assessment still active in wild meat–related research were invited to assess progress against the recommendations made then, for the regions they are familiar with. The remaining authors are active wild meat researchers (mostly) based in the tropics, who have published new data and interpretations since 2002. Their inclusion importantly increases the number, geographical representation, and diversity of perspectives informing our assessment.

2. ASSESSING PROGRESS TOWARD THE 2002 RECOMMENDATIONS

2.1. Recommendation 1: 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?

In this section, we separate the assessment of progress into two main themes. First, we present progress toward frameworks to assess the scale and impact of wild meat use. Second, we review the variety of methods that have been developed to assess the sustainability of hunting in a given area. Overall progress for this recommendation was perceived to be good in Latin America but limited in sub-Saharan Africa and Asia-Pacific (**Figure 2**).

2.1.1. Frameworks to assess the scale and impact of wild meat use. The following sections document frameworks to assess the scale and magnitude of wild meat extraction. They then summarize what is known about the direct impacts of hunting, as well as its wider impacts, such as those on ecosystem services and functioning.

2.1.1.1. Patterns of offtake. Use of wild meat occurs in nearly every country in the tropics (see references throughout our article as well as those in Reference 4), yet accurate estimates of the scale and prevalence of wild meat use in many of these countries remain lacking. Research into wild meat harvest and use before 2002 was mainly site-based, providing detailed data on individual social-ecological systems. Used individually, site-based surveys cannot be simply extrapolated to provide estimates of hunting offtakes at scale, given site-level differences that influence offtake patterns; estimates of offtake across large regions were therefore either impossible or subject to large error margins. Since 2002, however, the collation of locally generated datasets and the use of spatial modeling techniques (which take account of differences between sites) have enabled better regional estimates of the prevalence of wild meat use and annual offtake at regional levels to be produced; these techniques have also allowed for broader-scale investigation of correlates of wild meat use (25, 26). For example, one recent study of 7,978 households in 24 countries across Latin America, Asia, and Africa showed that 39% of the sampled households harvested wild meat. The authors estimated that this extrapolates to 150 million households who consume wild meat in these regions (26). However, regional estimates of annual offtake still vary widely between models [e.g., from 1.6 to 4.6 million tons year^{-1} in Central Africa (27)], due to differences in site selection, sample size, and the methods used. New initiatives such as the WILDMEAT database (**https://www.wildmeat.org/homepage/**), which aims to collate all existing site-level data on wild meat offtake, consumption, and sales, may help to increase the stability of these modeled estimates by providing researchers with a greater range of available, comparable data.

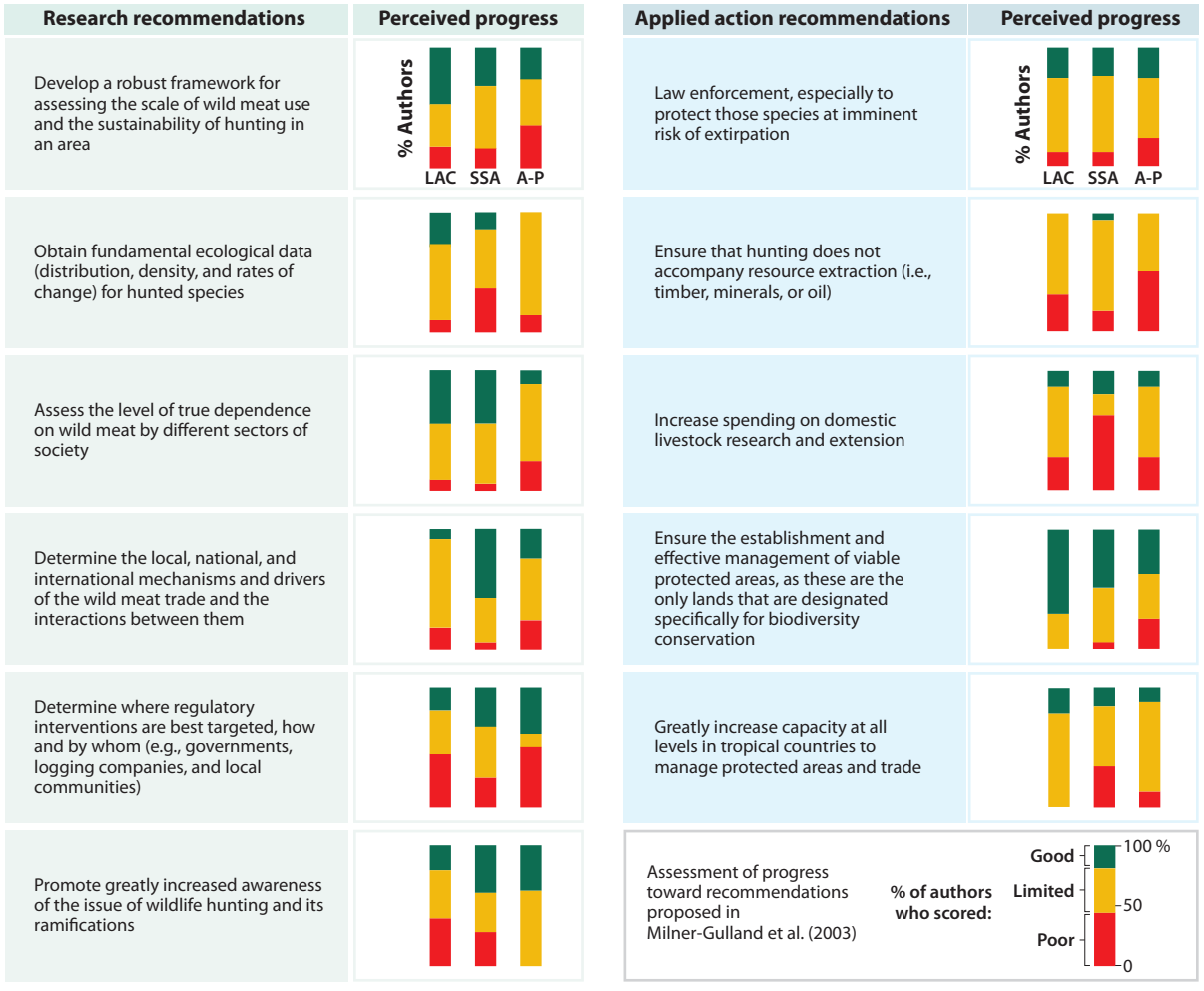


Figure 2

Our assessment of progress toward Milner-Gulland et al.'s (15) recommended urgent research needs and actions. Author-perceived progress was scored as good (*green*), limited (*orange*), or poor (*red*) based on aggregation of rankings given by each participant for the geographical areas that they know well. Stacked bars show the scores (as a proportion of total author scores) separated by region: Latin America and the Caribbean (LAC), sub-Saharan Africa (SSA), and Asia-Pacific (A-P).

2.1.1.2. Impacts of hunting. It was already understood in 2002 that many factors can influence the sustainability of hunting in a given area. Hunting may be sustainable for some species but not others (28), with long-lived, slow-reproducing species generally thought to be the most vulnerable to overexploitation. When hunting is conducted in remote areas using traditional hunting methods, and when good source areas are located nearby, species can persist even if they are sensitive to hunting (29). Indiscriminate hunting methods such as wire snares capture animals not intended for consumption or use, further exacerbating the impacts of targeted hunting, particularly in Africa and Asia (30). The impacts of hunting are generally greater where commercial hunting takes place (31). Although there are still few examples in the literature, management of formerly unsustainably harvested wild species can increase the sustainability of harvests of some species, e.g., Amazon river turtles (32), resulting in positive conservation outcomes that are also beneficial to people.

The impacts of hunting on wildlife populations are highly context-specific, but synthesizing evidence across local hunting studies can show broad trends. Since 2002, there have been more such syntheses published. For example, a meta-analysis of 176 studies found that the relative abundance of tropical mammals and birds is reduced by 83% and 58%, respectively, in hunted areas compared with unhunted areas (31); however, paired comparisons such as this do not take account of gradients of hunting pressure (33) and other factors such as habitat productivity that are likely to influence local population declines (34).

In addition, it was already clear in 2002 that vulnerability and responses to hunting pressure are not consistent across species. Large-bodied species with low reproductive rates are especially vulnerable to overhunting, which can result in size-differential defaunation (14, 35, 36). For example, large mammals (>10 kg) in the tropics experience the greatest reductions in their distributions (29% on average) due to hunting compared with other size classes (37). In the Amazon, terrestrial wildlife species seem to be more resilient to hunting than aquatic species due to access to large portions of continuous forests that are virtually inaccessible to hunters, which act as refuges for these species thereby enabling source-sink dynamics to play a role in the recolonization of hunted areas and sustaining viable populations (38, 39).

2.1.1.3. Wider impacts. Since 2002, there have been studies on both the interactions between hunting and other threats to wildlife (37, 40) and the wider impacts of hunting on ecosystems. Hunting-induced depletion of wildlife can impact community composition, species interactions, seed dispersal and food networks, with concomitant impacts on ecosystem services and functioning, including reduced nutrient cycling and carbon sequestration (13, 35, 41, 42). However, these impacts remain under-researched.

2.1.2. Methods for assessing sustainability. The challenges of estimating the sustainability of local hunting offtakes remain similar to those faced in 2002 (see Section 2.2). Theoretical testing of simple sustainability indicators, such as the Robinson and Redford model, has shown that these do not perform well under realistic conditions of uncertainty, such as natural fluctuations in mortality rates for prey species and imprecise population density and life history estimates (43–46). Complex socio-ecological spatial and dynamic models have been created that might give a better representation of the system in theory (47–52), but these are not yet practicable for local management purposes and most still rely on imprecise life-history data.

An alternative approach to assessing sustainability may be the identification of a robust proxy of sustainable offtake in a given area. Studies searching for indicators of unsustainable harvesting have considered the species composition of wild meat on offer at markets (53)—although this assumes the catchment remains constant—the stability of hunter catch per unit effort (54), the mean maximum rate of increase (r_{max}) of hunted species (55), the content of hunting bags (56), trends in pregnancy rates and age structure of hunted specimens (57), and landscape-scale depletion using local ecological knowledge (58). However, there is little information about how changes in these proxies correspond to actual changes in underlying species populations (but see 59, 60). In data-poor situations, population viability analysis is useful for simulating wildlife densities under different hunting scenarios (61). Given the increasing focus on community management of tropical wildlife, reliable methods and sustainability indicators that are practical to measure and analyze with minimal outside support are still urgently needed.

2.2. Recommendation 2: Obtain Fundamental Ecological Data (Distribution, Density, and Rates of Change) for Hunted Species

In 2002, a lack of fundamental ecological data on tropical species hampered the implementation of harvest management plans that had been successful for ungulate species in temperate areas

(e.g., 62). Calculation of sustainable yields requires knowledge of population distributions and densities as well as life history parameters (e.g., age at first reproduction) (45). Wildlife census methods available at the time, such as dung counts and visual encounters along line transects, were inadequate in tropical forests, especially for smaller and more elusive species (63, 64), leaving managers without information to model populations.

Capacity: the skills and knowledge to know what to do, the financial resources to put that knowledge into action, and the motivation and ability to take action

Encouragingly, methods to estimate occupancy, abundance, and densities of hunted species have improved rapidly through advancement in camera trap technologies and analytical methods, making it possible to report absolute rather than relative abundance of species (65, 66). However, monitoring remains challenging for many hunted forest species, especially cryptic, nocturnal, arboreal, solitary, or rare species. For species that remain difficult to census, methods such as eDNA sampling (67), uncrewed aerial vehicle–mounted thermal sensors, aerial video transects (68), arboreal camera traps (69), and/or passive acoustic monitoring may provide some solutions.

Distribution data for mammals (>1 kg) have improved across the tropics and subtropics (e.g., 70), and more life history data have become available particularly in the Neotropics, where birth rates and the r_{max} have been calculated for the 10 most hunted mammals (71). In the Afrotropics, vital rates are now available for some species (72), including heavily hunted species such as blue duiker (73). Understanding of source-sink dynamics has also improved, through new data on dispersal (74), which has been used to estimate sustainability and the size of source and sink areas necessary for local sustainability (48, 75). Nevertheless, density, dispersal, and life-history trait data for many hunted mammals, and importantly for most hunted invertebrates, reptiles, amphibians, and birds, remain scarce (76). This is symptomatic of the general lack of funding for natural history studies. Progress on achieving this recommendation since 2002 is perceived to be limited across the tropics (**Figure 2**).

2.3. Recommendation 3: Assess the Level of Nutritional and Economic Dependence on Wild Meat by Different Sectors of Society, as Distinct from Use of the Resource

The role of wild meat within food systems and the dynamics between wild meat and other food sources in the tropics remain little understood (4, 77, 78). However, food system sustainability is lowest in tropical regions (79), and people in these regions are often supported by wild-sourced foods (4). Consumption rates alone cannot determine whether people actually depend on wild meat or whether they have the capacity to adapt to its loss (80). The wild meat literature has generally not progressed in evaluation of the role of hunting in wellbeing outcomes and has simply continued to ascribe dependence where dietary or monetary substitutes are not clearly available.

Progress has been made in applying research methods from health sciences to investigate links between wild meat and food and nutritional security. For example, an empirical model based on a prospective longitudinal cohort study in rural Madagascar estimated that the number of children suffering from anemia would increase by 29% if access to wild meat consumption was removed—an increase exacerbated for poorer households (9). In rural Nigeria, consumption of wild meat was correlated with greater household food security (81). Economic reliance has also been shown in parts of Amazonia and Madagascar, where replacing wild meat with the same volume of domestic meats could cost households 50–90% of their annual cash income (16, 82). In Lao People's Democratic Republic, this was true for poorer households leaving them with a protein deficit (83). Although not directly assessing dependence per se, several studies also highlight the current important role of wild meat for families moving from rural to urban areas, showing a nutritional transition toward generally consuming less natural food and more processed food (84–86). Importantly, families may not have the funds or capacity to access alternative healthy food. In a study of

urban and peri-urban households on the Brazil/Colombia border, those who consumed wild meat had an elevated nutritional status in comparison to households that did not, regardless of wealth status (87).

Dependence on wild meat: the extent to which a person's nutritional, economic, or sociocultural wellbeing would be diminished if access to wild meat declined when a substitute is not available

Studies such as those mentioned above have provided a valuable starting point to begin to better understand nutritional and economic dependence on wild meat. However, a key area where progress has remained limited is research measuring dependence directly, ideally using longitudinal cohort studies (88). Given that dependence on wild meat is often viewed through different lenses, progress has been assessed as both good and limited in sub-Saharan Africa and Latin America and limited in Asia-Pacific (**Figure 2**).

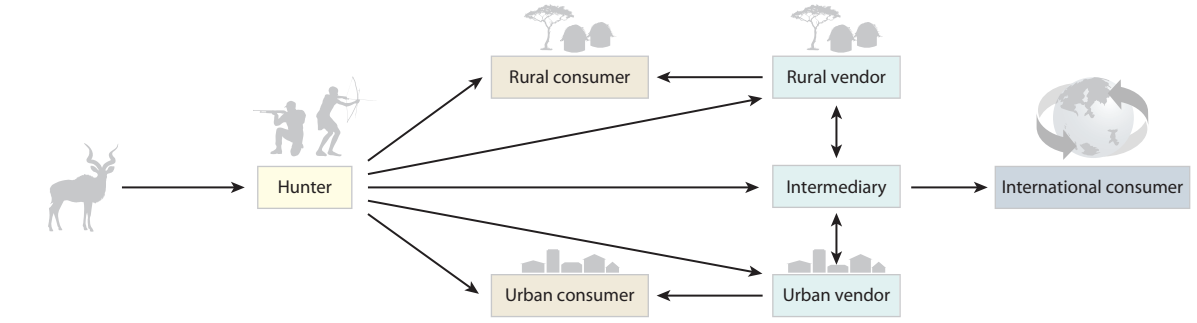
2.4. Recommendation 4: Determine the Local, National, and International Mechanisms and Drivers of the Wild Meat Trade and the Interactions Between Them

The value of wild meat as a source of income (as opposed to food) was known in 2002, but significant progress has been made in establishing that income generation is a key driver of wild meat exploitation, even in remote communities previously thought to be outside market influence (7, 89–95). Hunters' need for income drives trade, and, in turn, consumer demand drives income potential (78, 96–98). Research since 2002 has found that a range of factors influence consumer demand for wild meat (**Figure 3**), including availability and price of alternative foods (96, 99), law enforcement levels (98), market access (100, 101), availability and price of wild meat (102), cultural preferences (103, 104), social norms and taboos (105), and religion (106). Hunting for the market is now a part-time profession for many rural families across the tropics, with hunting for trade increasing when more lucrative wage labor opportunities are scarce (99, 107–109). Often, a small proportion of specialist market hunters regularly capture and trade the majority of the wild meat caught in an area (107, 108, 110). Commercial opportunity, increased ease of movement between rural and urban areas, widespread availability of inexpensive hunting tools, and low barriers to entering the trade in wildlife for food may increase local hunting pressure. In the absence of hunting regulations and enforcement, this may result in a short-term boom in income for participants in the trade. However, the consequent rapid depletion of hunted species then threatens the food security of community members reliant on wild meat for food (108, 111) and may also result in an income bust for hunters and traders (112).

Limited progress has been made on understanding the interactions between drivers at local, national, and international levels (but see Amazonian examples of short-distance wild meat trade (113) and long-distance caiman trade networks (114). Although transport of wild meat has been identified in Europe (115), and the United States (116), long-distance intercontinental trade in wild meat from the tropics is poorly understood, and, to our knowledge, no study has yet followed the entire chain from hunter to international wild meat consumer. Overall, progress on this recommendation is perceived to be good in sub-Saharan Africa but limited elsewhere (**Figure 2**).

2.5. Recommendation 5: Determining Where Interventions Are Best Targeted, How and by Whom

2.5.1. Where to target interventions, and by whom? There are multiple actors (e.g., hunters, traders, rural or urban consumers) and scales (e.g., local, national, international) at which to intervene in regulating wild meat use, but progress in quantifying effective interventions to improve sustainability is generally limited across the tropics (**Figure 2**). Most interventions have targeted the local subsistence hunter level and have aimed to shift hunters away from hunting by providing alternative sources of protein or livelihoods (117), or through enforcement of



Drivers	Mediators			
Sustenance	• Availability of animals • Ethnic tradition or religion • Socioeconomic status	• Rural or urban residence • Relative availability and price of wild meat and alternatives • Legal risk • Social networks mediate access • Ethnic tradition or religion	*Not applicable as sale of meat is not for sustenance purposes*	*Not applicable as international consumers do not need wildmeat for sustenance*
Livelihood	• Opportunity cost • Consumer demand • Legal risk	*Not applicable as consumption is not for livelihood purposes*	• Consumer demand • Availability of animals • Legal risk	*Not applicable as consumption is not for livelihood purposes*
Sociocultural factors	• Ethnic tradition or religion • Socioeconomic status • Legal risk	• Ethnic tradition or religion • Socioeconomic status • Legal risk	• Ethnic tradition or religion • Socioeconomic status • Legal risk	• Ethnic tradition or religion • Socioeconomic status • Legal risk

Figure 3

Illustrative example of a generalized wild meat supply chain, describing the drivers of engagement in the wild meat sector by different actors and the factors that mediate engagement.

hunting restrictions around protected areas (PAs) (118). Research has shown that actors are not homogeneous, and progress has been made in subdividing communities into groups sharing similar profiles (119, 120), which can be used to better target interventions. Research into the identity and motivations of traders is still very limited, but research in Côte d'Ivoire found that traders were introduced into the wild meat trade through other actors in the trade and remained in the trade to support their families (99).

Since 2002, it has become more clear that approaches to manage wild meat use need to be context-specific (120). At the subsistence hunter level, focus has shifted toward developing participatory approaches to regulating offtakes, including comanagement with local communities (121), devolution to local authorities (122), and engaging hunters to monitor their own harvests using catch-per-unit effort (54). Community acceptance of the fairness of rules is a vital component of successful enforcement and management (123, 124). Community-based approaches are more likely to work when unsustainable hunting is largely a consequence of hunting by noncommunity members, and community members are motivated to exclude them. Approaches to addressing wild meat overhunting that involve communities in design, implementation, monitoring, and evaluation are much more likely to have long-term success, but examples of such inclusion are sparse (but see 125). For enforced legal exclusion, efforts may be more appropriate in places where dietary dependence is low (126) and for species that are threatened and totally protected by national law.

Urban consumption of wild meat is now considered to be a key intervention point (see Section 3.2). Past strategies to reduce urban trade have focused on enforcing regulations and market closures [e.g., in Sarawak (127)] but their impact has not been evaluated. More recent research has focused on identifying interventions that could be targeted at urban wild meat consumers to reduce demand, via understanding their choices (96, 104, 128–130). Some of this work may provide insights into potential consumption trajectories of the next generation of consumers. For example, younger generations in some cities in the Sahel region of West Africa consume less wild meat than the older generations (131).

2.5.2. Do interventions work? Despite many different recommendations for intervention types and targets, one of the main barriers to progress has been the lack of systematic monitoring of intervention effectiveness. An evaluation of alternative livelihoods projects to reduce wild meat harvesting found that most projects did not assess the effectiveness of their interventions, so it is not possible to ascertain their success (117). Where interventions have been evaluated, few have been tested experimentally (e.g., before-after-control-intervention or randomized control trial designs). Similarly, the link back to changes in wildlife abundance is rarely made (but see 132). In urban areas, some efforts to reduce urban demand using social marketing and economic incentives have been experimentally tested (129, 130), with the social marketing experiment demonstrating a ~62% reduction in the consumption of mammals and birds (129). For the urban trade in Gabon, an evaluation of a hypothetical taxation scenario to regulate legal trade at sustainable levels found that tax revenue would not be sufficient to fully fund the enforcement needed for compliance with hunting regulations (133).

Participatory monitoring and management of hunting has proved effective in some areas (125, 134), including to reduce hunting (124, and theoretically in 135), and there is evidence that educational campaigns reduced wild meat consumption in a rural area of Côte d'Ivoire (136) and in Madagascar (137, 138). Community outreach and education programs have been shown to reduce illegal hunting activities in an area of Thailand (132). Furthermore, PAs and community reserves are useful tools for hunting management when supported by local people (139–141); however, efforts to enforce exclusion of hunters from PAs has had mixed results (142–144). If the evidence base on the effectiveness of interventions under a variety of contexts builds, managers of wild meat resources at all levels will be able to make more informed decisions about what is likely to work in their particular circumstances.

2.6. Recommendation 6: Promoting Greatly Increased Awareness of the Issue of Wildlife Hunting and Its Ramifications

Prior to 2002, the ramifications of wildlife overexploitation were already well understood in the scientific literature (19, 21), but this knowledge was not necessarily mainstream in the policy arena. Since 2002, the scale of wildlife hunting at unsustainable levels has become increasingly recognized within the scientific literature and is now acknowledged as one of the greatest threats to biodiversity (12, 145). A simple search on Google Scholar (October 2020) using the term "bushmeat" shows an increase from 1,640 results in the 18 years prior to 2002 to 16,600 in the 18 years after. The environmental and social ramifications of unsustainable hunting have become better recognized within the international research and policy communities, as evidenced by the inclusion of sustainable wildlife management targets in international conventions (**Figure 1**); hunters themselves also frequently perceive declines in their local availability of wildlife and understand that this is a result of overhunting (e.g., 146–148).

Increased knowledge of the environmental implications of wild meat hunting and use is not, however, universal; where it has been investigated, knowledge of its impacts was variable in both

urban Vietnam (149) and rural Tanzania (150). Public knowledge of hunting laws and regulations at the local level (where management challenges are most acute) were also found to have been low (107, 137), although this is not helped by the presence of often complex and contradictory laws (151). Although numerous research outputs exist about the issue in Latin America and Africa, authors with expertise in these regions perceive lower general awareness of the issue than those working in the Asia-Pacific region (**Figure 2**).

2.7. Recommendation 7: Law Enforcement, Especially to Protect Those Species at Imminent Risk of Extirpation

Progress on law enforcement is limited across the tropics as a whole with the least progress occurring in Asia (**Figure 2**). This lack of progress largely pertains to the enforcement of laws that regulate or prohibit wild meat consumption or trade, where they exist. Unfit legislation is increasingly recognized as an obstacle to management and may render laws unenforceable (see Section 4.2).

Wildlife law enforcement in the tropics now attracts significant international investment. Between 2010 and 2016, 24 international donors committed more than US$ 1.3 billion to efforts to tackle the illegal wildlife trade across Africa and Asia (152), although this was mostly not targeted at the wild meat trade (rather, at the international trade in high-value products like ivory and rhino horn). Of that funding, 46% supported PA management to prevent illegal hunting (including investments to support rangers and equipment), 19% supported law enforcement efforts to halt trafficking, 15% was allocated for sustainable use and alternative livelihoods, and 8% was allocated for policy and legislation. Wildlife hunted for meat has benefited from strong enforcement programs in some reserves, even if these species were not the intended beneficiaries [e.g., much funding was primarily directed toward elephant conservation (143)]. Little evidence is available to suggest that funding or effort has been allocated to enforcing laws at markets where illegal wild meat is sold or to supporting local communities to regulate hunting and access rights. The relatively small allocation of funding for policy and legislation may need to be reconsidered in order to ensure that laws are well-targeted and seen as legitimate: Without an enabling environment, law enforcement will remain ineffective.

2.8. Recommendation 8: Ensure that Hunting Does Not Accompany Resource Extraction (i.e., Timber, Minerals, or Oil)

Extraction of nonanimal natural resources is widespread across the tropics (153–156). The scale of hunting, consumption, and trade of wild meat by extractive industry workers was not well understood in 2002, and the evidence available was mostly from within logging concessions. Since then, it has become clear that most extractive industries are still associated with hunting for wildlife to feed large numbers of workers and their families (157). Demand for wild meat has been linked to workers from industries extracting oil (158), minerals (159), and timber (160), with increased levels of hunting also associated with road-building in remote areas (161, 162).

Progress toward decoupling commercial hunting from extractive activities has been limited across the tropics (**Figure 2**). Hunting control efforts are most developed for timber companies (e.g., 163) and include bans on hunting by employees, regulating the use of company vehicles to transport hunters and their catch (127), monitor road access (164), issue penalties for workers caught hunting (165), impose hunting regulations (166), and provide domestic animal protein to company employees and villagers (167). Many such provisions are now included in global certification schemes such as the Forest Stewardship Council (168). The few evaluations of these control measures provide some evidence of success (137, 169). For private sector projects financed by the International Finance Corporation, including agribusiness and extractive

industries, recipients are required to identify and address impacts on biodiversity along their supply chains under Guidance Note 6 (170). When workers on large-scale industrial projects are not eating wild meat, it is likely that they will eat other sources of animal protein and stimulate new investments to provide protein sources (127, 171). For example, one study showed that a protein substitution program that partly relied on imported beef also increased support for local fishing and domestic animal rearing (167). Future work should therefore investigate the possible options for replacing wild meat to feed workers of extractive industries, as well as potential unintended consequences, particularly where consumption may shift to wild fish or domesticated ruminants.

2.9. Recommendation 9: Increase Spending on Domestic Livestock Research and Extension

In 2002, there was concern that investment into agricultural research and development (R&D) had lost momentum across the tropics. Progress since then has been limited across the tropics (**Figure 2**). However, it is difficult to assess progress in spending specifically on domestic livestock R&D and extension because (*a*) available reporting (i.e., FAOSTAT) mixes R&D government expenditure for livestock with other forms of agriculture as well as forestry and fishing, (*b*) data are not available for many countries, and (*c*) spending records either aggregate or exclude extension services. Nevertheless, between 2000 and 2008, public and private spending on agricultural R&D in tropical regions increased, mostly in middle-income countries such as China, India, and Brazil (172). However, this is not necessarily good for wildlife if it eventually results is increased conversion of natural habitats for agriculture.

With regard to the provision of alternative sources of protein, progress has been made via research exploring the industrial-scale production of insects as human and livestock food (e.g., funded by the Rockefeller Foundation), and through investments at scale into backyard improved-breed poultry production in several African countries (e.g., funded by the Bill and Melinda Gates Foundation). Current challenges to increasing backyard poultry production include the prevalence of lethal infections such as Newcastle disease, inadequate access to affordable vaccination, lack of a cold chain to preserve vaccines, and limited government extension services meaning chicken mortality remains high, particularly in remote areas (173). In Asia and Latin America, aquaculture now makes up an increasing proportion of fish supply through development of new techniques and extension projects, which may also be appropriate for parts of Africa (174). Despite this progress, the agricultural development and biodiversity conservation sectors remain siloed, despite growing calls for multisectoral programs to address food security, public health, and nature conservation simultaneously (175).

2.10. Recommendation 10: Ensure the Establishment and Effective Management of Viable Protected Areas

Increasing the coverage of PAs (all categories recognized by the International Union for Conservation of Nature) across the tropics was considered important in 2002 as a way to maintain wildlife habitat in perpetuity. PA coverage is changing, as they are established, downgraded, downsized, and degazetted (176). Overall, the total global extent of PAs increased between 2004 and 2016, although nearly all this growth occurred in the marine realm (177). The effectiveness of PA management has generally increased over time, primarily as a result of better strategic planning, formal recognition of the territorial rights of Indigenous Peoples and local communities, as well as law enforcement (178). However, in 2018 only 25.4% of the total area of the PAs that were assessed globally reported having adequate staffing and budgets (140). Recent pantropical

analyses show that for hunted species, mammals are more abundant inside PAs but that there is no protective effect for birds (31). For many globally threatened mammals, PAs and indigenous lands remain critical for ensuring long-term protection (31, 179). Progress in PA establishment and management has been greatest in Latin America and the Caribbean, followed by sub-Saharan Africa then Asia-Pacific (**Figure 2**).

2.11. Recommendation 11: Greatly Increasing Capacity at All Levels in Tropical Countries to Manage Protected Areas and Wildlife Trade

At the turn of the century, capacity to manage PAs (see Section 2.10) and the wild meat trade was deemed inadequate (15). Public sector ability to address biodiversity loss has been recently evaluated, revealing that across the tropics, government agency technical and financial capacity remained similar between 2000 and 2016, and the percentage of GDP allocated to R&D was static between 2000 and 2015 (6). For management of the international wild meat trade through CITES, there has been an increase in the number of Parties over time, although as of November 2019 only 57% of Parties met the legislative requirements to fully implement the Convention (180). Capacity on the ground, among rangers, is still low or nonexistent in many places, and investment in improving basic conditions is still inadequate (181). Overall, progress in capacity-building has been limited; the least progress was considered to have been made in sub-Saharan Africa followed by Asia-Pacific (**Figure 2**).

2.12. Observations on Perceived Progress

Our assessment of research progress showed substantial intercontinental differences. Latin America and the Caribbean made greatest progress on sustainability assessments (Recommendation 1) and limited progress on understanding drivers of the wild meat trade (Recommendation 4), whereas in sub-Saharan Africa most progress has been made on understanding of drivers of trade but the least on obtaining ecological data on hunted species (Recommendation 2). In the Asia-Pacific region, the least progress had also been made in ecological research, but most progress had been made on increasing public awareness (Recommendation 6). These results suggest that establishing cross-continental research networks might catalyze progress across a wider range of the recommendations.

For the applied actions, across all three regions, experts perceived progress to be greatest for improved management of PAs (Recommendation 10), and least on ensuring that hunting does not accompany extractive industries (Recommendation 8). The cross-continental nature of these trends may be indicative of global-scale influences on actions. A valuable line of future enquiry would be to determine the drivers of global progress on protecting habitat, asking whether we can conclude that international targets for PAs have been effective in catalyzing progress. Conversely, the assessment that extractive industries continue to drive hunting and trade worldwide indicates that global efforts to promote good environmental governance in this sector are not yet effective.

3. EMERGING TOPICS SINCE 2002

Our review process highlighted that progress has been limited for many of the expert recommendations made in 2002, but it also revealed a better understanding of the complexity and diversity of the drivers of hunting, consumption, and trade of wildlife. We identified four escalating or emerging topics that contribute to this complexity and pose significant challenges for sustainable management.

3.1. Blurred Lines Between Motivations for Hunting

Our review in Sections 2.3 and 2.4 brought to light a new recognition of the important, complex, and blurred boundary between subsistence and commercial harvesting, and the resulting challenges for designing regulatory frameworks for management. Rural families may depend heavily on wild meat for income as well as for nutrition. People may hunt to feed their family, or to generate income through local trade (to feed others), or to supply an international market for meat or body parts. Individuals may do all three, depending on their needs and circumstances, and wildlife in a single area may be targeted by hunters responding to all three drivers. For example, African pangolins are (legally and illegally) consumed and traded as wild meat across parts of Africa (182), although pangolin meat and scales are also illegally trafficked internationally (183). Local hunting and trade can also be driven in new and unexpected directions by the influx of nonlocal or overseas workers with new demands (184), and teasing apart local dependence on wildlife as a dietary necessity from luxury demand (e.g., pangolin scales in this example) is extremely challenging. The protagonists and drivers in these supply chains are different but interacting. Management is also further complicated by social change and the changing role of cultural taboos (105, 185) and traditional medicine (186), expansion of the market economy to include subsistence communities (187), presence of commercial hunters living in urban areas (188), changing hunting technology (189), and the intergenerational differences in actions and perceptions of people (131), all of which affect which species are hunted and consumed, and why.

Local authorities and governments often recognize that enforcing hunting restrictions on subsistence communities would impose hardship, but when an illegal and detrimental commercial harvest is entangled with a legal subsistence harvest upon which people may depend for their food security, management decisions are exceptionally difficult. The species hunted or consumed, and the motivation for this choice, differ among different groups of people and over time, reinforcing the need for tailored wild meat management strategies (120). The commercial trade in wild meat has escalated since 2002 in many areas across the tropics, heralding the need for far more nuanced legal and regulatory frameworks to support just and sustainable management than was the case 18 years ago (175). Crucially, research is greatly needed to provide guidance on how to intervene effectively and ethically (185).

3.2. Urban Consumption of Wild Meat

Before the realization that there was a bushmeat crisis in the late 1990s, there was limited acknowledgment that the consumption of wildlife in urban areas may be a conservation issue (but see 20). However, a string of literature since that time has shown clearly that, although per capita consumption of wild meat in urban areas is generally low, the aggregate biomass of wild animals consumed can be high in many parts of the tropics (96, 100, 190). Large urban populations can support very long-distance wild meat trade (e.g., of caiman in Amazonia) (114). Tropical forests are estimated to sustainably support a maximum of one person per km^2 if they depend solely on wild meat for protein (22), which is highly likely to be exceeded if an area is also supplying urban markets. In many urban areas, by contrast, alternatives such as fish and domestic meat are often both available and cheaper, and trade in wild meat is driven by demand from consumers who can afford to choose the more expensive option (191). City dwellers may consume wildlife for many reasons, including a desire for traditional cuisines and to maintain a cultural connection to a rural heritage (192), or a perception of wild meat as fresh, healthy, tasty, exotic, and/or as a marker of status (104). Therefore, reducing demand in metropolitan areas is rarely a question of providing affordable and accessible substitutes, as these already exist. Instead, it is about changing consumer attitudes and

practices. Limiting the demand for, and supply of, wild meat to cities will need political will and the engagement of social psychologists, consumer choice analysts, and experts in behavior change.

Although most urban consumption of wild meat is facultative, some key examples of urban dependence on wild meat pose an even more striking challenge for long-term management. Conflict, economic crises, and natural disasters in the tropics can isolate urban communities, which have grown faster than their food production or importation systems. In such cases, wild meat remains or becomes a necessity for populations deprived of adequate alternative proteins (193). In Kisangani (Democratic Republic of the Congo), for example, more than 1.5 million people get a large proportion of their protein from wild meat, which has led to terrestrial and aquatic wildlife populations becoming severely depleted within several hundred kilometers of the city (194). This effect has also been shown around smaller provincial towns in Brazil (58). High levels of wild meat consumption in these rapidly growing towns (195) in previously remote wildlife habitats is a challenge that was not envisioned in 2002. Solutions are likely to require a mixture of strictly regulated trade in wild species and investment in peri-urban and household-level sustainable production of livestock with high feed to biomass conversion ratios, such as chickens, rabbits, aquaculture, and possibly insects (175). However, any reduction in the volume of urban trade will affect the livelihoods of vendors and intermediaries (who are often women who may have dependents reliant on their income) and rural hunters. Therefore, regulatory interventions must be accompanied by improved employment opportunities and social safeguards along the value chain, if they are to get support at a regional or national level (196). The recognition of the need for holistic reforms of the food system is far greater in 2020 than it was in 2002, when most wild meat projects were implemented at a single site, with little grasp of the importance of landscape contexts and the broader supply chain (113).

3.3. Interactions Between Hunting and Other Stressors

Evidence of the complex interactions between hunting and other stressors of wildlife populations has been increasingly brought to light over the past two decades. For example, studies have shown that climate shocks can disrupt the availability or productivity of other foods, such as crops (197), generating knock-on effects that can temporarily intensify hunting and fishing by local communities (198). Deforestation and extractive industries compound the threat to heavily hunted species worldwide (199), and the roads produced for these industries increase access to remote areas for hunters (161). Habitat degradation can reduce habitat suitability and carrying capacity of some hunted species (200), and eventual conversion to agriculture reduces overall habitat availability. Rapid structural changes in habitat, such as forest clearing or fragmentation, may make hunted species more detectable and less able to escape increasing hunter effort. Land-use change also brings farmers closer to wildlife areas, where they often hunt wildlife for food and to supplement their income, particularly during agricultural lean seasons, and may capitalize on their crop protection efforts by selling pest species (201). The hunting activities of most farmers are not monitored, although some farmers working under certification schemes may be subject to evidence checks of hunting controls for protected species [e.g., Roundtable on Sustainable Palm Oil (202)].

Overexploitation may also exacerbate the effects of other stressors, for example reducing populations of important seed dispersers has implications for future carbon storage capabilities and resilience to climate change (35, 203). It is far clearer than it was in 2002 that multiple stressors and the often-intensifying effect of their interactions must be taken into account when designing management strategies for hunted wildlife (204). This lengthens the list of data required for adequate harvest modeling, to include spatiotemporal predictions for other threats and changes in the social-ecological system over the timeframe that sustainable hunting is envisaged.

3.4. Diverse Implications of Wild Meat Use on Human Health

The hunting and consumption of wild meat have both positive (e.g., can provide essential nutrients) and negative (e.g., zoonotic disease risk, bioaccumulation of hydrocarbons and heavy metals) implications for human health (10). To better understand the role of wild meat in human health, conservation researchers need to partner with health and nutrition experts in governmental, nongovernmental, and academic sectors (particularly from within the countries concerned). Planetary health approaches to research and policy require holistic efforts to include both environmental conservation and public health as joint objectives (205). For example, this field has demonstrated the important role of maintaining forest cover to reduce diarrheal disease and improve nutrition (206) and the important role of PAs in benefitting human health (207). However, this approach has entered wild meat research only to a limited extent [e.g., zoonotic disease risk (208)], potentially limiting progress on this important issue.

Given that most emerging infectious diseases are zoonoses (209), the health implications of selling and consuming wild meat will need to be considered, particularly in large tropical urban areas. Animals are removed from their natural habitats and offered for sale in urban markets in densely populated towns and cities with species from other biomes and settings (210); such markets are often located far from wild areas and have poor sanitation and hygiene, and the risks may be higher in markets where the animals are alive rather than smoked. Overharvesting, paired with environmental degradation, thus amplifies the risk of zoonotic disease emergence and transmission (211, 212).

Developments in wild meat policy and management are also likely to progress quickly in response to the outbreak of the coronavirus disease 2019 (COVID-19), which could have profound implications for wildlife dependent peoples, as well as wild meat hunting, consumption, and trade (185). The issue is still evolving, but several calls for change are already evident, e.g., calls for bans on all commercial trade by international NGOs and temporary closing of wild meat markets. Although the impacts of the COVID-19 pandemic on the wild meat system are largely speculative, impacts could include economic shockwaves resulting in systems change, potential urban-rural migration, and increasing hunting intensity (213), changes to the captive-bred wildlife industry, increased enforcement of regulation for species considered high disease risk, and potentially a shift away from wild meat consumption in urban areas. It is therefore not yet clear whether impacts will be positive or negative for wildlife and the people who rely on wildlife.

4. 2021 VISION FOR IMPROVED WILD MEAT MANAGEMENT

In this section, we outline three key focal areas through which to direct efforts to inform and improve future wild meat management. These were chosen based on the need to expand our awareness of wild meat use for a broader range of regions and species, improve the governance and regulation of wild meat use, and build partnerships to improve wild meat management.

4.1. Balanced and Integrated Research Effort

Wild meat research has been biased toward forests in the Neotropics and Afrotropics (214), buffer-zone settlements near PAs, and indigenous hunters (28). Quantitative estimates of hunting offtakes and wild meat consumption remain rare in Asia, Oceania, and some savannah and grassland biomes. Going forward, research is needed to support hunting management outside strict PAs, such as in Indigenous and private lands. Furthermore, research effort on threatened hunted species is positively correlated with species body mass (199), but in many areas depleted of large-bodied animals, consumption is underpinned by smaller species whose life history traits are not known. Abundance and life-history trait data are further biased toward mammals and birds (76), and assessments of the impacts on hunted species populations are also largely limited

to comparisons of mammal and bird abundances in hunted and unhunted areas (31). Amphibians, reptiles, and invertebrates are also widely harvested across the tropics [e.g., (215–217)], yet few studies quantify harvests or related population impacts. Balancing these disparities in research effort is greatly needed to understand the full scale of wild meat use, conduct sustainability assessments and, most critically, identify effective management approaches. That there has been limited investment in supporting researchers who are based within the tropics further threatens the sustainability and relevance of research on this topic.

4.2. More Effective Regulation

Although most nations with hunted and traded wildlife have legal frameworks defining which species can be hunted within a given place, time, and circumstance, these laws are frequently not clearly written, evidence-based, or well enforced (151). Governance of the wild meat trade could be made more effective by (*a*) ensuring that law enforcement agencies have the skills, legitimate authority, and financial resources needed to enforce national laws, (*b*) tackling corruption, (*c*) revising unsuitable legislation that is often derived from sport hunting regulations in temperate countries but applied to hunting for food and income in tropical countries, and (*e*) ensuring that wildlife laws respect the rights of Indigenous Peoples and traditional communities and support their self-determined management regimes (134, 151, 218, 219). Moving forward, if nations are to preserve hunted species from depletion and maintain the nutritional, economic, and cultural values they provide to wildlife-dependent communities, issues with hunting laws will need to be addressed and innovative and inclusive management options must be explored; otherwise, further funds poured into law enforcement are likely to be ineffective.

4.3. Cross-Sectoral Linkages and Inclusive Management

As demand for wild meat continues in the context of growing human populations, heightened investment in existing management tools such as wildlife management and the establishment of PAs will be necessary in the future but will be increasingly insufficient. Cross-sectoral collaboration with governments, business, and food industries will be needed to ensure employment opportunities in rural and urban areas and to ensure access to safe, nutritious, and sustainable food. Collaboration with the agricultural sector could include investigation into the appeal and relevance of alternative protein sources for wild meat consumers (see 129), the feasibility of green labeling for sustainably sourced wild meat (133, 220), and the scalability of individually owned backyard production to meet urban consumer demand (175). Critically, industrial-scale domestic meat production does little to address the rural poverty and unemployment that can drive the wild meat trade (175) and comes with heavy environmental costs of its own (82, 221). National regulation of infrastructure, mining, and logging companies needs to be strengthened to ensure that wild meat harvests do not negatively impact wild meat–dependent communities nor the wildlife populations themselves (222). Community-led partnerships need to be encouraged, incorporating social safeguards that can guarantee free, prior and informed consent, gender equity, and fair and transparent grievance resolutions for wildlife management. Ensuring the sustainability of wild meat for local people, therefore, needs to be set within the broader requirements for economic development to generate no net loss or net gain of biodiversity (223).

5. LOOKING FORWARD

From our assessment, there is clearly no one-size-fits-all solution to address the challenges of managing the wild meat system. A multisectoral and multipronged approach is needed, one that is

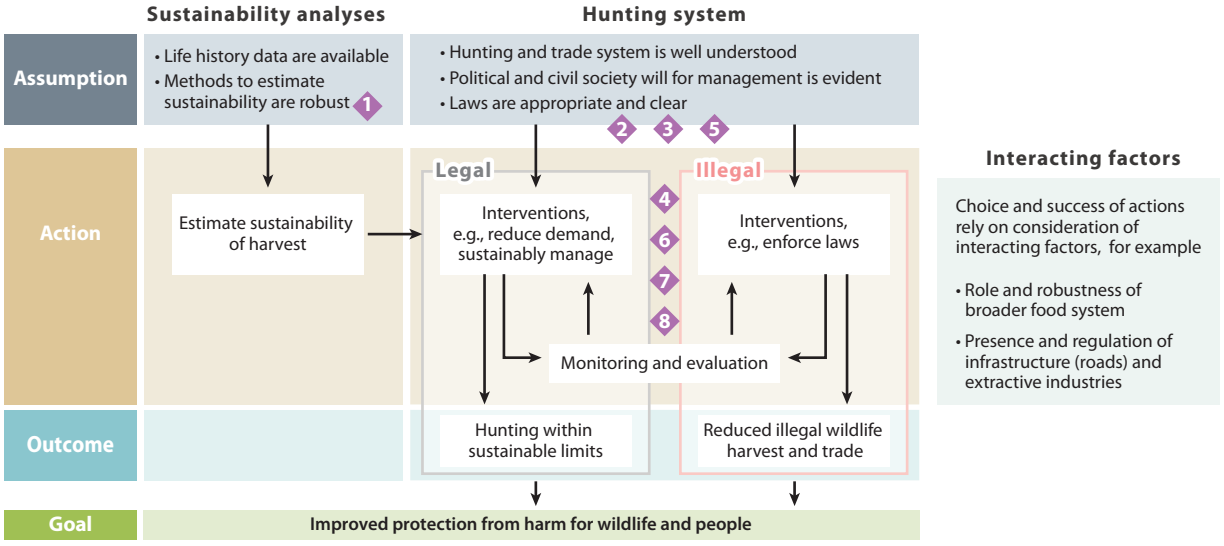


Figure 4

Theory of change for how the wild meat sector could move toward improved sustainability, highlighting the position of our recommended urgent research needs and actions for sustainable wildlife management, as per the numbers in the Future Issues list at the end of our article. The figure illustrates assumptions, actions, and outcomes necessary to achieve the overall goal of improved protection from harm for wildlife and people, in relation to wild meat. Actions depend on the legality of hunting and whether the main outcome is managing hunting sustainably or reducing illegal hunting, consumption, and trade. The role of monitoring and evaluation of actions is central to outcome success.

underpinned by research and is adaptively managed in response to both wildlife status monitoring and socio-economic assessment. All parts of the system, from the point of offtake to the point of consumption, will need assessment and, if necessary, action. In the Future Issues section of this article, we have identified the eight main areas of research and highest priority actions that could fill crucial knowledge gaps and play the greatest role in informing sustainable future management; these have been mapped onto a broad theory of change (**Figure 4**) to highlight how the sector could move toward improved sustainability.

5.1. Recommendations for Further Research

Our recommendations for research and action focus on the neglected and emerging areas that we identified in our review. Since the 2002 wild meat assessment, fundamental ecological and life history data, as well as intrinsic growth rates in field settings, are still required for most hunted species and for the robust assessment of the potential for sustainable harvesting (Future Issue 1). The dearth of funding specifically allocated for studies on the natural history of wildlife is leaving

conservationists without the necessary building blocks for sustainability analyses. This must change if under-researched tropical wildlife is to be successfully conserved in landscapes shared with expanding human populations. Although it is known that the broader food and economic systems can influence wild meat use, the role and dynamics of wild meat within these systems is not yet understood (Future Issue 2). Dependence on wild meat has often been inferred from frequent consumption, but few studies have rigorously investigated the viability of alternatives or the contribution of wild meat consumption to health (in terms of both benefits and risks; Future Issue 3). We prioritize the need to better identify the people most dependent on wild meat or culturally tied to the hunting activity, to whom regulatory interventions may be detrimental, and to explore solutions to safeguard the food and income security of these groups.

Evidence accrued since 2002 shows the current large scale of commercial harvests and trade for urban consumption in many developing countries. With an increased focus on understanding urban consumption, we encourage innovation of methods to induce behavioral changes in consumers, by developing conservation psychology and learning from those with expertise in delivering public health campaigns. We emphasize the importance of understanding how interventions can be designed to target unsustainable wildlife trade in an area while not disrupting (or enforcing against) sustainable local use where permitted (Future Issue 4). Without clarity on this issue, socially just resource access and use are unlikely to be achieved, and management policies will not gain popular support.

5.2. Recommendations for Urgent Actions

Our recommendations for urgent actions focus on wild meat demand reduction; sustainable management; reduction of opportunities and need to be involved in hunting or trade; and ensuring the legal frameworks around wildlife are clear, fair, and enforceable. Functioning judicial systems knowledgeable of wildlife laws, issues, and threats are therefore needed in conjunction with equitable and clear hunting regulations (Future Issue 5). Urgent actions are particularly important for two main groups of people: (*a*) residents of metropolitan areas, where actions are needed to reduce or halt consumption of wild meat on which they are not dependent (Future Issue 6), and (*b*) communities dependent on wild meat, for which it will be important to support sustainable management (e.g., in rural areas) and to develop alternative sources of nutrition and livelihood to meet needs not fulfilled by sustainable offtakes (e.g., in remote provincial towns) (Future Issue 7). To achieve these recommendations, multistakeholder partnerships (e.g., between government, wild meat user groups, and the environmental, health, and development sectors) will be needed to reduce participation in the wild meat trade by improving education and access to sustainable alternative employment opportunities to those working along the wild meat supply chain. Crucially, long-term monitoring and evaluation is desperately needed to understand which interventions may lead to change and how they may be coupled with interventions targeting other parts of the supply chain (Future Issue 8).

5.3. Requirements for Success

Our recommendations are only likely to be successful within an enabling environment in which there is clear and appropriate governance, clearly defined usufruct rights, political and public will for change, donor support, stakeholder consensus, and consistent and appropriate training for staff in tropical countries. Assessments of national-scale governance, however, show that the effectiveness of current government is low in many tropical countries with limited improvements between 2000 and 2016 (6). Our recommendations are also most likely to be successful when there is continued support from governments and funding agencies for managing national parks and

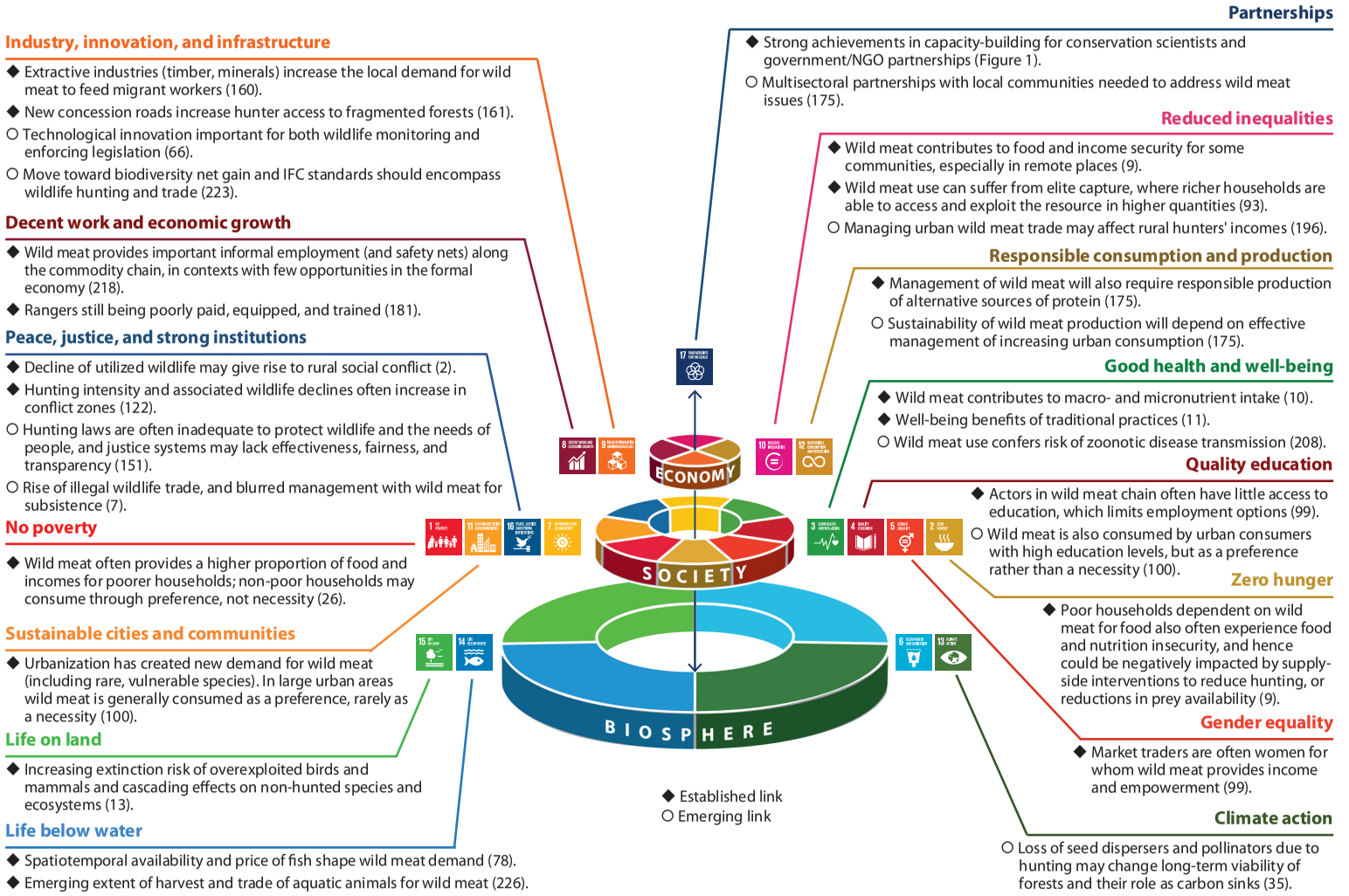


Figure 5

Established (*black diamonds*) and emerging (*white bullets*) links between wild meat and the SDGs to consider for managing wild meat harvest and trade, mapped onto the tiers of the SDGs separating those that focus on economy, society, and the biosphere. Interactions between tiers are bidirectional and illustrate how the economy and society must operate within sustainable levels of the biosphere. One example reference is given per link. Tier diagram adapted with permission from Rockström & Sukhdev (225), and design by Azote for Stockholm Resilience Centre. Abbreviations: IFC, International Finance Corporation; NGO, non-governmental organization; SDGs, Sustainable Development Goals.

community reserves. For example, there is ample evidence to show that terrestrial community reserves work well when (*a*) authority to manage wildlife access and use is legally devolved to Indigenous Peoples and traditional communities with legitimate territorial claims, (*b*) rights-holding communities receive the technical support they need to put in place locally appropriate governance and revenue generation systems, and (*c*) the rights of communities are respected and protected by the timely and competent support of government agencies with the authority to arrest suspected law breakers (116). The informal nature of wildlife trade means that there is often no monitoring of the money or potential tax revenues generated by actors along the supply chain, and thus it is impossible to capture wildlife trade in national accounting. As such, local natural resources can be stolen from rural communities without penalty, rendering these resources particularly vulnerable to overexploitation and potentially amplifying food insecurity in deprived rural communities.

5.4. Policy Outlook and Conclusions

As the current implementation period for the CBD 2020 strategic plan has come to an end, a Post-2020 Global Biodiversity Framework will be developed to work toward a vision of "*Living in Harmony with Nature*" by 2050 (224). Working toward the sustainable management of wildlife will be paramount to achieving this vision.

The important role that biodiversity plays in ensuring a sustainable future for the planet is also reflected in the SDGs. Although management of hunted wildlife is not explicitly dealt with by the SDGs, there are many inextricable synergies evident through this review (**Figure 5**). Given the roles that the environment, development, and health sectors will need to play in tackling the issues surrounding wild meat in the tropics, achieving sustainable hunting, trading, and consumption practices will clearly contribute to overall success across the portfolio. These solutions are complex, and the road to success is mostly uncharted; however, to make progress with this challenging issue, and to achieve the SDGs, researchers, practitioners, and policymakers must learn from past successes and failures, or be doomed to repeat them. Our belief, however, is that the issue is not insurmountable—and with the right research attention and focus on solutions that are equitable as well as effective, a better outlook for wildlife and people is within reach.

SUMMARY POINTS

1. Soon after the formation of the Convention on Biological Diversity (CBD), hunting and wildlife trade were identified as major threats to biodiversity, particularly for slow-reproducing species.
2. Ensuring the sustainability of the wild meat sector is an intractable challenge because of the need to balance the protection of species living in dwindling ecosystems with the needs and desires of a growing human population.
3. Nearly 30 years since the formation of the CBD, and 20 years after a seminal review of the impacts of wild meat hunting, we find limited progress toward sustainability in most areas of wild meat research and management.
4. Major progress has been made in understanding the complexity of the drivers of both hunting and demand for wild meat.
5. The major obstacles to progress over the past two decades have been related to (*a*) practical difficulties of implementing solutions where local capacity, good governance, and

political will are limited, (*b*) a lack of understanding the role of wild meat in the broader food system, and (*c*) a lack of cross-sectoral collaboration in providing long-term solutions and resources.

6. The trade of wild meat to urban consumers is emerging as an important intervention point, where a decrease in consumption is urgently needed to enable greater potential for sustainability in rural areas where people may rely on the resource for survival.
7. Although the types of interventions suggested to manage legal and illegal wild meat use have diversified, evaluation of the efficacy of interventions remains scarce and hinders efficient management choices in the underfunded environmental conservation sector.
8. The rapid development and implementation of robust, equitable, and sustainable wild meat management strategies will be necessary to achieve many of the SDGs in tropical nations but will depend on greatly increased training and support for wild meat researchers, practitioners, and local communities in consumer countries.

FUTURE ISSUES

1. Fundamental ecological data on hunted species are still needed to feed into sustainability analyses, and further work is needed to develop simple but robust monitoring methods that are accessible to a broad range of wildlife managers. This research should be led by in-country researchers/institutions.
2. Research is needed to evaluate the role and dynamics of wild meat in the broader food and economic systems.
3. A greater understanding of the positive and negative contributions of wild meat to the multiple dimensions of human health (nutrition, disease, mental health) is needed, as well as how to harness/minimize them.
4. Research is needed to understand how interventions can be designed to target unsustainable wildlife trade in an area while not disrupting (or enforcing against) sustainable local use where permitted.
5. Reassessment of hunting laws, regulations, and policies (including the species listed as protected and land rights) is needed to increase equitability, enforceability, and therefore success of management options.
6. Actions will be needed to reduce consumer demand for those who are not dependent on wild meat, e.g., those who consume it as a luxury in large urban areas.
7. Support will be needed to enable wild meat–dependent communities to manage hunting sustainably and to explore and codesign appropriate protein and livelihood alternatives.
8. Better engagement is needed with other sectors (e.g., agriculture, public health) to codesign and co-implement multistakeholder interventions that take a systems approach at multiple scales, crucially accompanied by long-term monitoring and evaluation of suggested interventions.

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