Follow the meat: the economics of small-scale wild meat systems in low and middle income countries

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ABSTRACT

In low and middle income countries (LMICs), wild meat – often called bushmeat – is an important source of food and income, but its production threatens species and biodiversity conservation. The conservation literature uses empirical work to identify drivers, and levels, of wild meat consumption and production, while the economics literature provides insight into various actors' decisions about wild meat harvest, sale, and consumption. We describe these literatures by following the path of wild meat from hunting decisions through intermediaries to markets and consumers, which emphasizes that decisions in any part of the wild meat system ultimately trace back to conservation outcomes. The opportunity cost of land for habitat differentiates wild meat production from fisheries and necessitates a landscape perspective. Heterogeneity within and across settings in terms of demand characteristics, costs, and species attributes complicates the implementation of policies without site-specific information.

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1. INTRODUCTION

The production and consumption of wild meat - or bushmeat - contributes to a loss in biodiversity and ecosystem services around the world, but also provides a valuable income and food source to many households in low and middle income countries (LMICs) (Ingram et al., 2021). The loss of biodiversity caused by hunting for wild meat causes economic losses through reductions in ecosystem services and other use and non-use values of species (Carlier & Treich, 2020). The wild meat system also poses a risk to public health as a potential source of a zoonotic disease outbreak due to wildlife-human contact (Daszak et al., 2000). Yet, forming general policy guidelines for wild meat systems faces challenges due to the disparate related literatures, the setting-specificity of such systems, and the ambiguity of policy impacts due to multiple partially offsetting policy responses across the wild meat systems. In order to spur more interdisciplinary and economic research on wild meat systems, we organize and integrate the most relevant economics and conservation science literature according to the path of wild meat – starting from hunting decisions and working through the supply chain to endpoint consumption decisions. This structure helps identify information gaps, prioritize efforts by economists, and explore the drivers of ambiguity in policy responses. Most important, this structure and discussion emphasizes that policy in any portion of the wild meat system traces back to conservation outcomes through many interactions across this path.

Given the potential for negative impacts on conservation outcomes through wild meat production, the conservation literature includes many assessments of wild meat production. Ingram et al. (2021) identify challenges in wild meat policy design including a lack of knowledge about the ecology of hunted species, the sustainable hunting levels in a location, and household dependence on wild meat for protein and income. The conservation and ecology literatures provide empirical analysis of the socio-economic drivers of hunting, trading, and consumption of wildlife; quantify the trade; and analyze potential policies in various markets (see Ingram et al. 2021). They point to a limited understanding of the drivers of the actors in the supply chain of wild meat from hunters to consumers and how these actors' incentives interact. Oyanedel et al. (2021) also emphasizes market actor interactions and creates a framework for assessing these interactions and demand and supply characteristics. Still, the economics literature on wild meat systems provides few frameworks to link decisions around wild meat production and sale to conservation outcomes.

The economics literatures concerning fisheries, the wild-caught pet trade, trophy hunting, the international wildlife product trade, and hunting in developed countries consider similar questions and policies to those in wild meat production and consumption in LMICs. Yet, the specific attributes of the production processes, supply chains, and actors in wild meat production and markets differ from these other wildlife-related markets and raise questions about the relevance of insights from those markets to inform species conservation through wild meat policies. Here, we draw on the small-scale fisheries economics literature to understand actors in wild meat systems due to their similarities, but also discuss how economic frameworks of wild meat production should differ from those of fisheries.

The economics literature addressing wild meat tends to focus on portions of the path from production to consumption rather than the path or interactions along that path. For example, models of wildlife hunters predict how hunters behave in response to changes in the relative price of wild meat by altering production decisions such as land allocation (Bulte & Horan, 2003) or hunting technique (Robinson, 2008b). Similarly, economic analyses of urban consumers of wild meat estimate elasticities of substitution and income (Godoy et al., 2010; Wilkie & Godoy, 2001). Yet, less economic analysis considers how interactions of hunters, producers, and intermediaries determine conservation outcomes.

With complex, context-specific drivers and interactions of the actors in the production process of wild meat, we call for integrating and expanding the economic and conservation science literatures to provide insights for conservation strategies that address wild meat production in order to protect valuable ecosystem services and global biodiversity. By structuring this literature critique according to the wild meat pathway, we identify key decisions and actions along the supply chain to inform conservation policy across policy levers, points in the system, and geographic location. In sections 2, 3, and 4, through assessment of the conservation and economics literature concerning wild meat, we investigate the economic features of each step of wild meat systems, from the production of wild meat via hunting, through accessing urban markets, to urban demand for meat, thereby tracing the path of wild meat from source to consumer. In section 5, we consider how conservation policies – protected areas, hunting and trading rules, and consumer preferences – and non-conservation policies – alternative livelihood projects, taxes and subsidies, live market regulations, and roads – operate through this path of wild meat to influence conservation outcomes. We identify gaps in the literature with particular attention to general economic features across settings and the context-specific aspects of wild meat production and consumption.

2. PRODUCTION OF WILD MEAT: HUNTING

Wild meat is supplied to markets by households who hunt and trap wildlife. The decisions of where to hunt, which species to hunt, how much time to spend hunting, what hunting techniques to use and whether to sell wild meat constitute the production decisions that ultimately supply wild meat to markets. The economics literature on the production of wild meat consists of models investigating hunting decisions made by households (*e.g.,* Skonhoft 1999; Bulte and Horan 2003; Robinson 2008b) and the conservation science literature includes empirical estimates of the drivers of hunting (see Ingram et al. 2021). The models of households making hunting decisions can show the underlying processes at work behind potential causal relationships identified by the empirical literature. The general modeling literature can also help interpret how variation across sites in terms of initial habitat condition and market setting lead to the empirical literature's findings of site-specific drivers of species choice and outcomes. Combining these two types of research provides a more complete understanding of the tradeoffs households face when making hunting decisions. Because these hunting decisions directly affect the populations of individual species and overall biodiversity, this fuller understanding could inform conservation policy analysis.

Given the focus of this paper on wild meat systems in low-income countries, the discussion and critique of the literature builds on development and agricultural economics literatures' characterization of such settings. For example, agricultural household models depict the labor and land use decisions by households with various degrees of links between production and consumption that reflect the degree of market involvement of the household (Singh et al., 1986; Taylor & Adelman, 2003). The degree of market engagement may be a function of the market access transaction or distance costs or endogenously determined by the individual household's opportunity cost of labor (Robinson et al., 2002). The result of conservation and development policies depends on which markets – such as labor, land, or resources – a household accesses (Muller & Albers, 2004). For example, an alternative livelihood project induces no conservation benefits in a complete market setting, increases conservation in a missing labor market situation, and decreases conservation in a missing resource market setting. In addition, household labor and land constraints also contribute to the response to policy. As in the agricultural household modeling literature, the interactions of the market access setting with land and labor constraints leads to situations in which the response to policy is ambiguous because some forces induce one direction of change while others induce potentially offsetting changes; the net direction of the response reflects which force dominates. In the hunting literature discussed here, empirical work identifies site-specific responses but generalizing from those specific studies proves difficult without understanding the characteristics of the setting – both ecological and socioeconomic – that drive the outcome. Yet, the economic modeling work identifies a range of potential outcomes including many cases of "ambiguity" because only site-specific information can determine which force dominates. Below, we describe the modeling assumptions that drive an article's results, including those that are ambiguous results, in an effort to identify areas of needed research both in terms of data collection and framework analysis. While not entirely inclusive of the economic factors we emphasize as driving ambiguity along the supply chain, Ingram et al., (2021) Figure 3 provides characteristics at each level of the supply chain that can be heterogeneous across settings and could drive ambiguous outcomes.

In this section, we examine the production process of wild meat; specifically focusing on general hunter extraction decisions and how they compare to those in the fisheries and non-timber forest product (NTFP) literatures, as well as the characteristics of those involved in extraction, the interaction of landscape and hunting decisions, and hunter decisions to sell the wild meat or to consume it. We conclude the section by drawing connections between hunting decisions and conservation outcomes.

2.1 Hunting Decisions

The economic literature characterizing the production of wild meat has both commonalities with, and distinctions from, economic literatures on fishery harvest and on NTFP extraction. Hunters independently make hunting decisions including labor allocation, gear, and species choices. Households or agencies also make land use allocation decisions between habitat for wildlife and other valuable land uses that influence hunting. For some species, households and wildlife agencies consider the nuisance costs of wildlife on agriculture. Considering these factors and

characteristics of the supply chain that influence prices, hunters determine how much, and possibly which types, of wild meat to produce.

For a particular amount of land or habitat that supports wildlife, economic models of fishery extraction provide the basis for wild meat extraction decisions. Typically, a bioeconomic framework connects a resource growth equation to harvest decisions, often with a logistic growth function and a Schaefer production function. In such frameworks, open access to the wildlife leads to overexploitation of the resource from a social perspective, while community management or government regulation moves hunting toward a socially preferred level of harvest that considers dynamic and static stock effects. Also akin to the fishery economics literature, hunters may make choices about gear – guns, arrows, spears, traps, *etc.* – and which species of wildlife they pursue. Individual hunters or the aggregate of hunters make a decision about how much effort to employ in hunting, which leads to a steady state level of hunting and wildlife population size.

NTFP extraction has considerable similarities to hunting choices, including the hunting literature's choice of effort often reflecting a labor allocation choice between hunting labor and other labor opportunities, such as agricultural production (see Bulte and Horan 2003; Bulte and Rondeau 2007; Albers and Robinson 2013). For example, improvements in agricultural prices induce a conservation response by inducing households to allocate less labor to NTFP extraction, with similarity to the hunting response (Gunatileke & Chakravorty, 2003). These labor allocation tradeoffs and hunting technology decisions lead to situations in which it is difficult to determine the impact of wild meat price changes on hunting for wild meat and on the resulting wildlife stocks. Damania et al. (2005) model the decisions of a household allocating their labor between gun hunting, snare hunting, and agriculture, with different possible species being hunted. They show that when agricultural prices increase so does the rural demand for wild meat, which can cause households to use the more efficient and expensive hunting techniques. The ability of hunters to switch techniques while reducing hunting labor hours can result in ambiguity in the effect of a reduction of hunting labor hours on the wildlife stock. Furthermore, hunting techniques may be discriminatory or non-discriminatory across species, which results in different species being harvested, potentially at the detriment of more endangered species (Robinson, 2008b). As with dynamite fishing's impact on carrying capacity, hunting gear choices may also influence wildlife populations and their behavior.

2.2 Who Hunts?

Whether a household allocates labor to hunting is a function of the relative values of their labor activities and their wealth level. The empirical NTFP literature considers the relationship between household poverty and reliance on NTFPs, which can include wild meat, with differences between the share of income versus the absolute value of income from natural resources or "environmental income" (Angelsen et al., 2014; Narain et al., 2008). Households with higher levels of wealth tend to earn more income from NTFPs, but those with lower wealth tend to earn a higher percentage of their income from NTFPs, meaning poorer households are more reliant on these goods (Mahapatra et al., 2005). These poorer households also generally have smaller landholdings and less education than wealthier households and face the largest

losses from conservation policies that limit or ban NTFP collection (Mulenga et al., 2014). Increases in the efficiency of agriculture can reduce NTFP extraction reliance (Illukpitiya & Yanagida, 2010), though NTFP extraction can be used by households to mitigate risks associated with agriculture and climate (Dash et al., 2016). The relationships identified in the empirical wild meat literature show that the likelihood of being a hunter is negatively associated with area of land owned in Cote d'Ivoire (Bachmann et al., 2019) and, in the central Amazon in Brazil, farmers consume more wild meat than people in other professions (Chaves et al., 2017).

Empirical explorations differentiate between income motives for hunting – which implies market participation – and food motives for hunting; these motives can drive the choice of species hunted (Bachmann et al., 2020). Bachmann et al. (2020) found in Cote d'Ivoire that hunters reliant on the income from hunting hunted primates and duikers, but hunters reliant on hunting for protein hunted rodents. The potentially different drivers and conservation outcomes of commercial versus subsistence hunting are rarely distinguished in the literature, though the motives for hunting may be identified in surveys. In Serengeti National Park, Loibooki et al. (2002) found a majority of hunters arrested reported they hunted primarily for cash income, while only a quarter reported hunting primarily for food. However, interviews with households around Serengeti National Park found that most households depend on wild meat as a source of protein and only about a quarter reported hunting wild meat for income (Mfunda & Røskaft, 2010). Coad et al. (2010) determine the reliance of households on their wild meat income for food security in Gabon. They found that household food purchases decreased with increased wild meat offtake but increases in cash income from wild meat were largely spent on cigarettes and alcohol by males in the household - indicating that while wild meat consumption is important for household food security, the income from wild meat was not.

The distinction between what drives the quantity of wild meat offtake and what drives hunters to enter the market is made to determine what increases or decreases the number of wild meat hunters. Hunters may enter the market because of unemployment and would therefore leave the market if comparable wage labor was available (Van Vliet et al., 2019). When hunters and intermediaries in the wild meat system earn wages above the local wage rates, it prevents them from leaving the market (Bachmann et al., 2019). Choice experiments across Tanzania identify characteristics that could reduce hunting, including increases in the number of cattle owned and increases in the local wage rate (Moro et al., 2013; Nielsen et al., 2014). Arrested hunters in Serengeti National Park were found to be mostly young men with no income and few livestock, reinforcing the importance of household livestock ownership for reducing hunting (Loibooki et al., 2002). Other characteristics that could reduce hunting trips include access to microcredit, access to markets, and increases in the likelihood of being arrested (Moro et al., 2013).

2.3 The Hunting Landscape: Habitat, Protected Areas, and Wildlife Movement

Fishery economics typically takes the area of fishing as a given location or pre-determined set of "patches" in a metapopulation, with reefs or patches providing habitat resources to fish that may move beyond those particular sites (*e.g.* Speers et al. 2016). In fishing settings, the opportunity cost of creating marine reserves to provide habitat largely depends on the net loss (or gain) of fish harvest to the region rather than an alternative productive use of that site. Unlike fishery

settings, hunting occurs in and near areas that provide habitat for wildlife but also have significant opportunity costs in terms of other land uses, such as agriculture or urbanization (Bulte & Horan, 2003; Skonhoft, 1999). The amount of habitat can be incorporated into wildlife biomass functions, where the growth is a function of the wildlife stock and the size of the area in habitat. With a logistic growth function, the carrying capacity can be a function of the habitat area (Skonhoft, 1999; Swallow, 1990). This land opportunity cost of habitat creates a distinction between choices and policies around fish harvesting and wildlife hunting. That distinction implies that analysis of hunting requires addressing the habitat size, who makes decisions about that habitat size, and tradeoffs across valuable land uses rather than relying on fishery frameworks alone. In addition, as in fishery metapopulation models, wildlife moves across landscapes rather than remaining in designated habitat areas, often imposing nuisance costs. Last, the addition of the land allocation decision to extraction frameworks poses questions about the role of protected areas within the landscape and enforcement of habitat as a land use.

2.3.1 Incorporating land allocation into extraction models

In contrast to typical fishery settings with low opportunity cost of the fishing area, Skonhoft (1999) finds the socially optimal allocation of scarce land between habitat and agriculture and of limited labor between hunting and farming; the habitat that permits hunting has an opportunity cost in terms of its value in agriculture. That framework includes non-hunting and non-consumptive values of species, such as existence values or tourism, which reflects the public good nature of wildlife as wildlife as opposed to the private value of wildlife for wild meat. Wildlife can also create nuisance costs, such as destroying agricultural crops. As above, more habitat shifts the growth function for the stock of wildlife and reduces the amount of land for agriculture. Although the opportunity cost of habitat and the non-use value operate in expected ways on the allocation of land to habitat or agriculture in Skonhoft's socially optimal decision, the impact of changes in prices for wild meat are ambiguous. All else equal, a higher wild meat price leads to more harvesting and a lower stock while a higher wild meat price makes habitat more valuable and increases habitat size. Taken together, however, the increase in habitat size influences both stocks and harvest costs, which generates an ambiguous response of stock size to wild meat prices. In contrast, when the habitat land has no opportunity cost, the impact of policy and parameters mimics those of the standard fishery economics case (Skonhoft, 1999).

Bulte and Horan (2003) also extend the classic Gordon-Schaefer fishery extraction model by incorporating several aspects of terrestrial species hunting, including that the opportunity cost of land in habitat stems from land's value in agriculture. Unlike Skonhoft (1999), instead of exploring the socially optimal land and labor allocations, they explore a framework in which a set of individuals make labor allocation decisions between hunting and farming, and land use allocation decisions between habitat and agriculture, under open access for both land and wildlife, without a labor market. As in Skonhoft (1999), each activity's opportunity cost of time is based on the returns from allocating labor to the other activity and converting habitat to cropland which reduces the growth and stock of the landscape's wildlife. This analysis results in multiple steady states, each with different levels of habitat and hunting. Comparative static analysis finds many analytically ambiguous situations in which policies changing key parameters

can increase or decrease welfare and wildlife conservation; for example, whether reducing the effective price of wild meat leads to less hunting and more wildlife depends on the steady state considered. The ambiguity stems from direct and indirect effects that alter the relative values of both the labor allocation decision and the land allocation decision.

Bulte and Horan (2003) also explore this framework for a case in which perfect cooperation among individuals occurs through common property management. In this article, in contrast to resource management, without both a labor and a land allocation decision, many situations arise in which cooperation under common property management leads to less habitat and lower wildlife stocks than the open access scenario, albeit with higher aggregate income. Whether people cooperate or operate under open access, the link between land allocation decisions and labor allocation decisions introduces situations in which the impact of policy on wildlife conservation and hunting levels is unclear. In a modeling framework, the addition of the tradeoff in time spent between agriculture and hunting implies that the decline in long run stocks predicted by a transition of habitat land to agriculture land is partially mitigated by less time being spent hunting because more time is spent on agriculture (Bulte & Horan, 2003). In addition, the literature does not contain exploration of the impact on habitat and wild meat production of the privatization of common property resources, with such privatization being difficult to prevent or reverse (Robinson, 2008a).

Bulte and Horan (2003) discuss their assumption that conversion of habitat to agriculture is instantly reversible and provide examples of abandoned agriculture providing species habitat benefits immediately but do not explore the case of conversion to habitat requiring costly restoration activities or long recovery times. Incorporating such time or input costs to land allocation decisions would require models of land allocation decisions by forward-looking agents that include transition periods surrounding land use change and account for time preferences, which could produce quantitatively and qualitatively different landscape management outcomes (Albers, 1996; Albers & Robinson, 2007). In addition, converting some habitats to other land uses can prove economically or technically irreversible (Albers, 1996). For example, species that depend on mature habitat may be driven to local extinction following land use conversion and not re-colonize the area once the habitat is restored. Similarly, conversion of primary tropical forests causes permanent losses in habitat for species whose habitat requirements are not met by secondary forests. Analysis of the impact of costly reversibility or complete irreversibility of habitat conversions could produce different dynamic pathways for both land and labor allocations that influence hunting dynamics and long-term conservation outcomes.

Throughout this literature, the inclusion of land allocation decisions between habitat and alternative uses in species extraction frameworks proves critical in defining conservation outcomes and differentiates the cases of wild meat and fishery production. Even without an explicit land allocation choice, in practice, how much land is in land uses such as habitat and agriculture creates the initial condition in which hunting decisions and responses to policy occur. Similarly, the attributes of the habitat in terms of quality for different ecosystem services including species conservation contribute to hunting decisions. Land allocation changes could also influence the types of species being hunted, where conversion to crop land could provide

habitat for different species for wildmeat, such as rodents. Outcomes will also differ with land ownership types, where an individual has less influence over land owned by the communities or by government.

2.3.2 Wildlife nuisance costs and wildlife movement

In many settings, proximity to habitat leads to costs imposed on farmers by nuisance species that damage crops. Agencies, communities and individuals making land allocation decisions may consider these predation costs in determining the socially optimal level of habitat land (Skonhoft, 1999). In land use patterns with protected areas bordering agriculture, the issue of nuisance species is particularly acute (Johannesen & Skonhoft, 2004). Wildlife agencies may compensate farmers for lost crops or lost life, although such processes can be slow (Gross et al., 2022). Individuals may also make labor allocation decisions based on hunting's value in reducing nuisance species or undertake defensive actions to prevent wildlife predation (Bulte & Rondeau, 2005). Using variation in the catchability parameter, Bulte and Rondeau (2007) find that compensation for wildlife damages to crops causes an increase in the amount of agricultural land because of increased returns to farming when households allocate their time between farming, hunting, and crop defense. Yet, with the introduction of the time tradeoff in Bulte and Horan (2003), the additional agricultural land can cause wildlife stock depletion by a reduction in habitat land, which can be offset by a reduction in time spent hunting (Bulte & Rondeau, 2007). The effect of habitat reduction on the wildlife stock is most likely to be greater than the effect of reduced hunting pressure when agricultural land is a poor substitute for natural habitat and for species that have a lower catchability parameter (Bulte & Rondeau, 2007). In the empirical literature, Duonamou et al. (2021) found that since 2001 there has been an increase in the sale of species that consume crops in Guinea, indicating a species' nuisance behavior could be a significant factor in its hunting and therefore conservation outcomes, although the relative availability of these species may also drive hunting.

2.3.3 Protected areas

While the fisheries and terrestrial extraction literatures differ in the opportunity cost of habitat area, they both include the reactions of extractors to protected areas, which informs both the conservation and welfare outcomes from such tools. The fishery economics literature tends to focus on the impact of a marine reserve on seascape fish stocks, often with the perfectly-enforced reserve creating a high density of fish that then disperse to lower density areas that permit fishing (*e.g.* Sanchirico and Wilen 1999). Those analyses find that while the seascape fish stock may increase with marine reserves, the dispersal of fish to non-reserve locations offsets the economic losses from the lack of fishing in the reserve only in particular cases (Sanchirico & Wilen, 2001). Other analyses reflect the differences between open-access and managed settings outside the reserve (Costello & Polasky, 2008), while others determine the optimal size and location of marine reserves when both fish and people move across space explicitly and reserves may not be perfectly enforced (Albers et al., 2020, 2021). In contrast, the terrestrial conservation economics literature, including the NTFP economics literature, rarely emphasizes the dispersal of species beyond a protected area to locations in which they may be hunted. In a unique example, Johannesen (2007) poses the question of how expanding an existing protected area (PA) will

affect wildlife populations at the landscape level. With perfect enforcement against hunting in the PA, the density of the wildlife population in the PA causes wildlife to move throughout the landscape. As in the marine reserve economics literature, when the PA expansion occurs on land with no opportunity cost beyond lost hunting area, the PA expansion promotes wildlife conservation. In the case in which the PA expansion occurs on agricultural land however, the outcome is less clear. The expanded PA decreases the area available to agriculture and modifies the agriculture-hunting labor allocations, yet the impact on landscape wildlife populations is ambiguous. Again, because people make tradeoffs between labor allocation to hunting and to agriculture, in the presence of an opportunity cost to the land included in a PA, the impact of PA expansion does not always increase wildlife populations on the landscape, even with perfect enforcement against hunting in the PA (Johannesen, 2007).

Much of the NTFP extraction literature considers the impact of enforcement against extraction in PAs on locations of extraction and on sizing of PAs and buffer zones. In that work, people make spatial decisions about extraction in response to the probability of detection and penalties (Albers & Robinson, 2013). Similarly, Albers et al. (2020) explore the optimal sizing and enforcement of MPAs when people make fishing location decisions; costly enforcement and budget constraints lead to incomplete enforcement, and fish move across the marinescape. In those models and empirical assessments, enforcement budgets are often far too low to induce perfect compliance with hunting restrictions. Yet, to the best of our knowledge no economic analyses combine the spatial responses of hunters with the spatial response of wildlife to determine optimal PA sizes, zones, and enforcement levels with limited budgets.

The economic literature on hunting enforcement includes (Robinson, 2008b) exploring the case in which a conservation manager must generate their own enforcement budget through fines and permit sales, which connects the probability of detection to the level of the fine, while focusing on a case in which the rarest animal is both of highest value to the PA manager and the most valuable animal for wild meat. Using a Poisson arrival model that has more rare – that are assumed also to be more valuable – animals arriving less frequently than other animals, the model considers the response to enforcement of hunters who can and cannot discriminate between species prior to killing them. A discriminating hunter decides whether to shoot less or more valuable species while a non-discriminating hunter decides whether to take the animal it kills, depending on the species' value, permits, fines, and probability of detection. When the wildlife management agency must generate their enforcement budget, the best options for protecting rare species include permitting hunting of common species and promoting hunting technologies that enable hunters to discriminate between species prior to killing them (Robinson, 2008b). Enforcement becomes more challenging when, as in real world settings, hunters butcher meat on site to disguise illegal species.

The empirical literature on hunting enforcement includes Moro et al. (2013)'s choice experiment in villages adjacent to Serengeti National Park. They found the benefits of wild meat hunting were generally seen to outweigh the risks of arrest, despite the households participating in the experiment not being hunters themselves. Nielsen et al. (2014) found known hunters or intermediaries of wild meat surveyed in the Kilombero Valley in Tanzania had a small reaction

to changes in enforcement and fines. Further, many people in this experiment who had been caught illegally hunting or trading wild meat reported that they were able to provide bribes rather than paying the formal fine, which could partially explain the lack of responsiveness to fine and enforcement changes.

2.4 Home Consumption or Sale?

The production function for wild meat reflects household tradeoffs and those households also determine whether they will consume the wild meat or become suppliers to the market. Most of the hunting economics literature assumes that hunting households are perfectly integrated with markets and make decisions about producing and selling wild meat based on market prices (*e.g.* Skonhoft 1999; Damania et al. 2005; Bulte and Rondeau 2007). Damania et al. (2005) determine the proportion of wild meat that a household consumes versus sells in a market. They find that higher prices for a particular wild meat typically leads to a higher fraction being sold at market while higher prices for agricultural output have an ambiguous impact on the proportion of wild meat consumed at home versus sold in the market. A household's decision to consume or sell their harvest can also change the spatial patterns of hunting. In Ghana, a study of the fruit bat supply chain shows that when urban markets cannot source bats locally because local hunters consume their own harvest, vendors source bats from more distant locations to supply the market (Kamins et al., 2011).

In many LMIC settings, households vary in their market access, as explored in agricultural household models (Singh et al., 1986). For example, subsistence households for wild meat consume exactly what they produce while households with costly access to markets may or may not interact with wild meat markets. Brashares et al. (2011) found in a survey of 2,000 households across Ghana, Tanzania, Cameroon, and Madagascar that in communities furthest from urban markets, a majority of hunted wildlife was consumed by hunters, while in communities closest to the urban markets a majority of hunted wildlife was sold. This transition from hunters primarily hunting for subsistence to primarily hunting for income may occur as prices increase for wild meat closer to the urban market. Although not well developed in the hunting economics literature, the general NTFP extraction literature emphasizes that the relationships between the opportunity cost of extraction labor and the cost of market access determine which NTFP extractors interact with the market to buy or sell NTFPs and which households do not interact with the market and extract for subsistence use only (Robinson et al., 2002). Robinson (2008b) determines how hunting households that differ in their opportunity cost of labor respond to enforcement and permit schemes in terms of their market access and hunting labor allocation. In hunting, due to the range of values across wild meat types, the market participation decision for hunters also relies on the particular species hunted, although that choice hasn't been explicitly explored as a function of opportunity cost and market access costs. In addition, although hunting of different species can require specific gear choices, the probabilistic nature of the type of wild meat produced by less discriminatory methods of hunting implies that the market interaction choice may be a function of the particular species that is actually harvested.

Hunting method is also related to which species are sold at market, with species caught by selective methods being more likely to be sold at market, likely because selective methods allow hunters to choose species most desirable in urban markets (Allebone-Webb et al., 2011). Market access itself also influences the target species hunted. For example, in Equatorial Guinea, the market access of a region appears to determine which species are primarily hunted. In areas with more market access, species that lead to the highest profits for hunters are hunted, but in areas with less market access – where intermediaries are relied on to transport the meat to the market – species that yield the highest profits for the intermediaries are hunted (Allebone-Webb et al., 2011).

2.5 Hunting and Conservation

Species conservation outcomes reflect hunting decisions about the amount of wildmeat produced and about the harvested species – choices that influence population levels of specific species and biodiversity in general. Those decisions include labor allocations to hunting and other activities, which species to target, and gear choices, which reflect the opportunities and opportunity costs in a particular setting. In addition, while both the fishery setting and terrestrial wild meat setting rely on the marinescape or landscape's ability to generate and maintain habitat for species, the land allocation decision becomes critical in most terrestrial settings due to the high opportunity cost of land conserved for habitat (Skonhoft, 1999). Whether individuals, communities, or non-local actors establish habitat areas, land allocation across habitat and other land uses contributes to hunting decisions based on a land constraints' impact on marginal value tradeoffs. In addition, the enforcement of protected areas for habitat and the dispersal of species beyond those areas also influence hunting levels and hunting species choices. Overall, biodiversity conservation relies on hunting choices that are influenced by both individual labor allocation decisions as a function of opportunity costs of time and by land allocation decisions as a function of land opportunity costs, in addition to landscape level characteristics and wildlife movement.

3. TO MARKET

Hunters who do not consume their entire harvest have the option to sell some portion of the remaining harvest. A hunter's decision of where and how to sell their remaining harvest depends on the prices offered in different markets or by different actors, and the costs associated with reaching those markets or interacting with those actors. Generally, the remaining harvest is either traded within hunting communities, sold by hunters at a rural market, sold to an intermediary for transportation to an urban market, or sold by hunters at an urban market. Each of these possible points of sale presents its own costs and benefits for hunters, with context-specific determination of the available options. In this section, we explore the literature on the different types of wild meat markets, how hunters access them, and hunters' market interaction choices. We also discuss the role of intermediaries in wild meat markets by examining the better understood role of intermediaries in small-scale fisheries.

3.1 Rural Markets

In rural settings, hunting households may sell wild meat directly to other rural households at cost or through trades that might include exchanges of labor and farm produce (De Mattos Vieira et

al., 2015). Although such local exchange of wild meat within rural communities and community-level markets where the hunting occurs appears common (Wilkie et al., 2006), little research focuses on this local trade. Yet, this local demand creates local prices for wild meat that influence hunters' decisions about time allocated to hunting, areas in which to hunt, and which species to hunt, which influences rural welfare and species populations. Similarly, the literature rarely distinguishes between the drivers of wild meat demand in rural areas across heterogeneous households, including hunting and non-hunting households (Bachmann et al., 2020; Chaves et al., 2017). In addition, although local preferences and rural markets influence hunter decisions and the resulting species outcomes, species preferences in rural markets are poorly understood and may differ from better-studied urban preferences. While rural demand characteristics influence which species are consumed locally, urban market characteristics also influence which species are consumed locally by determining which species are most valuable to bring to urban markets (Allebone-Webb et al., 2011).

3.2 Accessing Distant Markets

As with production of agricultural outputs and non-timber forest products produced in rural settings, wild meat producers make decisions about local sales as above, transporting the harvest to an urban market themselves, or selling the wild meat to an intermediary for transportation to urban markets. Transportation costs, whether borne by hunters or other actors in the supply chain, introduce a wedge between rural (including farmgate) and urban prices and change the profitability of wild meat production across regions as a function of distance and other market access costs. For example, charcoal prices to producers decline as a function of distance from urban markets due to transportation costs (Hofstad, 1997), which implies different incentives to produce charcoal across locations. Many empirical studies of deforestation rely on von Thunen's simple model of transport costs as a determinant of land use patterns (*e.g.,* Robalino and Pfaff 2013; Fontes and Palmer 2018). The agricultural economics literature examines cropping choices as a function of transportation costs, including through agricultural household models in which households produce low value food crops rather than higher valued cash crops (Omamo, 1998). Both the agricultural and the fishery economics literatures discuss the impact of transportation networks and transportation providers on cropping and harvest decisions (Baraka et al., 2021; Crona et al., 2010). Although the literature on transportation costs and actors, such as intermediaries, is thin for wild meat's path to urban markets, here we discuss the implications for wild meat as observed in these related literatures.

3.2.1 Hunter market access decision: self-transport or sale to intermediary

A hunter's choice to self-transport the meat to the market versus to sell to an intermediary who incurs the transportation costs depends on the costs the hunter faces to reach the market, wild meat prices at the market relative to local prices, and the hunter's other market related needs. These transportation costs depend on transportation availability, infrastructure, distance to the market, the opportunity cost of hunters' time, jointness of other market engagement, and the mass of the load (Cowlishaw et al., 2005). Self-transport may occur through buying truck space, taking a taxi, renting a vehicle, or paying extra baggage fees on public transportation (Cowlishaw et al., 2005). Hunters may choose to sell some or all of their harvest to intermediaries who act as

middlemen between hunters and the urban market vendors. By selling to these intermediaries, hunters reduce or eliminate their transportation costs and accept a price below the urban market price. As in agricultural and fisheries settings, relationships between intermediaries and local producers include one-off agreements, longer-term commitments, and contracts that involve credit-price relationships that potentially influence the wild meat producers' decisions about using intermediaries versus self-transporting to urban markets or selling locally (*e.g.,* Russell 1987; Aggarwal 2008; Crona et al. 2010; Baraka et al. 2021).

Hunters may make the decision to use intermediaries jointly with their target species decisions to reflect opportunities in urban markets. In Equatorial Guinea where the supply chain includes hunters selling to intermediaries who sell to consumers in urban markets, species harvested using selective methods were more likely to be sold in urban markets (Allebone-Webb et al., 2011). Species with the highest urban market price or the highest markup were most likely to enter urban markets. The opportunity to use intermediaries influences hunter's decisions including whether to enter the wild meat market (Latinne et al., 2020), the species being hunted (Allebone-Webb et al., 2011), and the locations relative to the urban market where hunting occurs (Latinne et al., 2020).

3.3 The Roles of Intermediaries

Intermediaries are common in LMIC resource markets when extraction or production of the resource occurs at some distance from the market as documented in small-scale fisheries and farming literatures (*e.g.,* Ngeleza and Robinson 2013; Van Vliet et al. 2019; Latinne et al. 2020). In addition to covering distance costs, these intermediaries provide access to credit, markets, technological expertise, and contracts to mitigate risks (*e.g.,* Russell 1987; Aggarwal 2008; Crona et al. 2010). However, in some situations, intermediaries capture a majority of the surplus and increase risks to local extractors, especially when intermediaries have market power (Aggarwal, 2008). The wild meat literature rarely describes the role of intermediaries outside of transportation, but some intermediaries in the wild meat system behave similarly to those in fisheries by hiring hunters, training them, and transporting them to hunting sites (Latinne et al., 2020), having market power (Allebone-Webb et al., 2011), and earning the highest profits in the system (Morcatty & Valsecchi, 2015). Given the similarities between intermediaries in fisheries and in wild meat markets, we interpret the fisheries intermediary literature for the context of wild meat supply chains, along with the smaller wild meat intermediary literature.

Self-transportation and intermediary transportation can differ in ways that influence both wild meat profitability – and therefore species conservation – and health safety. As examples, hunter and intermediary transportation costs can differ due to distances traveled and the types of transportation services used by the two types of actors (Cowlishaw et al., 2005). Some intermediaries own their own vehicles that allow them to define their routes to make full use of those investments and to avoid rental costs, while extractors may be unable to cover the fixed costs of such large purchases as was found with crab harvesters in Brazil (Nascimento et al. 2017). In addition, Cowlishaw et al. (2005) found that hunters in west Africa transport more of their harvest fresh than intermediaries, with potential implications for public health due to the differences in disease transmission from fresh carcasses (Peeters et al., 2002).

3.3.1 Beyond transportation costs: credit and risk

Intermediaries in LMIC country resource markets frequently provide credit to harvesters as part of the contract, especially to cover capital for resource production or to provide cash for low output seasons as seen with private traders and farmers in India (Aggarwal, 2008), middlemen and fishermen in Kenya (Crona et al., 2010), and middlemen and hunters in Indonesia (Latinne et al., 2020). These pre-harvest contracts create a commitment between the harvester and the intermediary, guaranteeing supply to the intermediary and purchase of output to the harvester. Even when interest free, as some cultural traditions dictate, loans tie the extractor to the intermediary, with loans often repaid through the sale of the resource to the intermediary (Crona et al., 2010). Even without formal contracts, fishermen report being loyal to intermediaries unless the intermediary is unable to purchase the harvest. Intermediaries also use these loans to recruit people to harvest a resource and pay for transportation, housing, and food to bring extractors to an area (Crona et al., 2010; Nascimento et al., 2017). These agreements can also reduce risk to the extractor by enabling production and ensuring sale, which improves hunter well-being.

The contracts between extractors and intermediaries can also pose losses to conservation by increasing hunting through reducing hunter risk, enabling more periods of hunting, and dampening the effect of ecological variation in the harvests. Similarly, intermediaries actively recruit harvesters to enter the market, which increases extraction as seen in both small-scale fisheries (Crona et al., 2010) and wild meat systems (Latinne et al., 2020). Intermediaries and the contract requirements may also induce non-selective harvest or illegal poaching by creating pressure to improve harvesting efficiency and by purchasing below legal size in fisheries (Nascimento et al., 2017; Pedroza, 2013). Given that the incentives to harvest may be driven by a contract or relationship with an intermediary, the structure of these contracts influence extractors' harvesting decisions, such as gear types and species.

3.3.2 Intermediaries and market power

When intermediaries are numerous, intermediaries have limited market power – with competition driving prices to hunters toward a competitive equilibrium where the difference in urban and rural prices reflects market access costs. In such cases, hunters have more control and options in their harvest sale decisions (Cowlishaw et al., 2005). A more common setting, however, consists of barriers to intermediary entry and intermediary-hunter relationships/contracts creating intermediary market power, especially in terms of setting prices to hunters. Brazilian crab harvesters reported feeling exploited by the intermediaries due to the low prices they were paid (Nascimento et al., 2017).

Market power arises from an intermediary's ability to overcome various costs that resource extractors face. Entering the market as an intermediary in small-scale fisheries may require large amounts of cash upfront to purchase from harvesters, buy or rent a vehicle, and to keep the harvest fresh (Nascimento et al., 2017; Pedroza, 2013). In Brazil, 95% of mangrove crab harvesters reported not having the infrastructure necessary to bring their crabs to market (*e.g.*, transportation, fuel, and insulated boxes to hold crabs), leading to reliance on intermediaries

(Nascimento et al., 2017). Intermediary market power is important in driving these systems and distances to markets has been found to correlate with the number of fisheries intermediaries (Liese et al., 2007). Similarly, fisheries systems in which loans and credit are central to operations typically contain many extractors and few intermediaries (Crona et al., 2010; Nascimento et al., 2017). Market power varies over space as a function of distance from markets and as a function of spatial heterogeneity in opportunity costs and culture, which can drive spatial variation in prices to harvesters (Chatterjee, 2019).

The level of intermediary market power informs wild meat producer decisions and, ultimately, species conservation outcomes. In Equatorial Guinea, villages with less market access, more intermediary market power, and fewer intermediary visits sell the species with the highest markup (larger profits for the intermediary) while villages where intermediaries have less market power sell the species with the highest price (larger profits for the hunter) (Allebone-Webb et al., 2011). In some fisheries settings, the intermediary's market power generates low prices that cause harvesters to use more efficient techniques to increase their incomes by increasing harvest levels (Nascimento et al., 2017). The resource economics literature suggests that market power leads to higher levels of resource conservation due to low prices incentivizing less harvesting effort, leading to the idea that monopolists are conservationists' friends (Katayama & Abe, 1998). In the conservation of species literature, that finding extends to fisheries intermediaries with market power having a positive impact on species populations by decreasing harvesting levels through low prices to fishermen (Tháy et al., 2019).

Analysis that considers both hunter decisions to access markets themselves if intermediaries' prices are too low and intermediaries' decisions about with which villages to interact finds a more complex relationship (Rushlow, 2021). First, some villages face low enough market access costs that hunters prefer to take their harvest to the urban market and intermediaries have no impact on harvest levels. Second, in villages where intermediaries profitably provide their services, the prices they offer are low enough to induce lower levels of harvest than in a no-intermediary case, creating a conservation benefit as described in the economics literature. Third, however, in villages with high market access costs, no harvest for sale to urban markets occurs in the absence of intermediaries, which means that intermediaries increase harvest in such villages. In addition, with the lower prices paid to hunters by intermediaries with more market power, greater intermediary market power can result in profitable hunting at lower wildlife stock levels. Where distance costs dominate market access costs, the advent of intermediaries leads to a net conservation outcome that reflects both the intensive margin decrease in harvests and the extensive margin increase in harvests.

3.4 Market Access Costs, Intermediaries, and Species Conservation Outcomes

Overall, market access costs and intermediaries influence hunter decisions about both which species to hunt and how much to hunt, with resulting impacts on specific species and on biodiversity conservation. When market access costs or other factors limit hunters to selling or bartering wildmeat in rural markets, rural demand and prices influence hunter decisions about how much to hunt and which species to hunt to address local preferences. In settings of individuals facing more moderate access costs for urban markets, hunters explore the net price

they receive from selling in urban markets after incurring those market costs to determine both the levels of hunting and the species to hunt. Intermediaries can induce more people to become hunters by incurring transportation costs and addressing other concerns like risk and credit constraints, in addition to encouraging hunters to produce more wild meat and wild meat of species that are desirable in urban markets. Intermediaries in settings in which hunters already access urban markets can also increase hunting levels by making time in hunting more valuable compared to time in bringing wild meat to markets. The advent of intermediaries with market power in such settings, however, can reduce hunting levels by reducing prices to hunters, which provides some positive conservation outcome. Yet, intermediaries with market power in locations with hunters who do not provide wild meat to urban markets can increase the amount of hunting, particularly of species with urban appeal, with those locations experiencing conservation losses.

4. URBAN MARKETS AND DEMAND

As with many outputs produced in rural areas, wild meat is often traded in urban markets. Urban demand and markets are the focus of much of the wild meat literature due to the large quantities of wild meat traded in urban markets, the feasibility of conducting research in these markets, and the availability of other protein sources for consumers in urban areas (Wilkie et al., 2006). These markets vary in their structure and focus, with some wild meat sold in specialty markets and "live" markets, other wild meat sold among a wide range of food items, and still other wild meat sold directly to restaurants. In addition, urban markets vary significantly in terms of the prominence of cash, negotiation, and barter sales. Urban demand and markets determine wild meat prices, which ultimately inform hunter production decisions. Drivers of urban and rural demand for wild meat can be quite different, including in terms of the elasticities of demand and the demand for particular wild meat species.

4.1 Vendors

Wild meat is sold in urban markets by "vendors." These vendors may purchase the wild meat from intermediaries or from hunters that transport the wild meat to the market. Vendors sell the wild meat to consumers, often either at a market or indirectly through sales to restaurants. Some intermediaries are also market vendors who both transport the wild meat and sell it to consumers (Randolph et al., 2022). Although anecdotal evidence suggests that vendors can range from specializing in wild meat sales to selling many items, little research characterizes their decisions and actions. Recent research studies the role of restaurants in the wild meat supply chain, and uses restaurant data to characterize urban consumer preferences (Gluszek et al., 2021; Wright et al., 2022). Gluszek et al. (2021) find that different restaurant tiers (determined by menu prices) have different "hot" products, consistent with wild meat preferences being a function of consumer income.

4.2 Urban Demand

Demand for wild meat encompasses both demand for wild meat on aggregate and demand for wild meat from specific species. Urban wild meat demand characteristics for an individual species may vary across countries and within countries for rural and urban areas, environmental

settings, and ethnic groups (Fa et al., 2009; Sheherazade & Tsang, 2015). The characteristics of urban wild meat demand are determined by the consumer's preferences, income and price elasticities, and substitution and income effects.

Consumer preferences for wild meat in general and for specific species varies across settings, groups, and time. Cultural differences across ethnic groups within the same region lead to different preferences for wild meat consumption, including some groups avoiding consumption of some species (Fa et al., 2009; Sheherazade & Tsang, 2015). Consumer preferences can change and shift demand for wild meat. For example, following the 2014 Ebola outbreak, wild meat sales in Nigeria of most species decreased, and during the COVID-19 pandemic, sales declined again (Funk et al., 2022). Generational differences can also create different preferences for wild meat, with young people in west African cities consuming less wild meat than older generations (Funk et al., 2022).

Although complex, the relationship between household wealth and wild meat demand is generally found to be positive in urban settings (Brashares et al., 2011; East et al., 2005; Fa et al., 2009; Wilkie & Godoy, 2001). In contrast, the effect of income on wild meat consumption is often found to be negligible (Godoy et al., 2010; Wilkie & Godoy, 2001). This lack of relationship may reflect that research does not separate urban and rural demand and that these studies have limited income variation to help understand this relationship (Godoy et al., 2010). In contrast to urban demand, wealthier households are often found to consume less wild meat in rural areas. However, Brashares et al. (2011) note that identifying a causal relationship in this trend is difficult given that wealth measures also correlate with access to wildlife, the opportunity cost of hunting, and the relative price of wild meat. Similarly, the negligible effect of income changes on wild meat consumption may reflect differences between that relationship in rural and urban settings. In rural areas, households that consume wild meat often also sell wild meat, which links income, hunting, and consumption in ways that confound regression analysis (Brashares et al., 2011). In addition, within one market, some species of wild meat may be inferior goods, while other species are normal or luxury goods (Bowen-Jones et al., 2003; McNamara et al., 2019). When some species are an inferior good, increases in income can cause a decline in demand for those species but an increase in demand for other species that are normal goods.

Price elasticity of demand measures responsiveness of consumers to changes in price, which can be influenced by policy and by market power. In Central and South America, Wilkie and Godoy (2001) found that wild meat was much more price elastic for households in the upper half of the income distribution than for households in the bottom half. When consumers are less responsive to changes in price, they could drive species populations toward collapse by continuing to demand high quantities of wild meat even at high prices, whereas consumers who are responsive to changes in price switch away from a species as it becomes expensive due to scarcity.

When consumers are faced with changes in relative prices of the goods that they consume, they substitute between those goods based on the changes in real income and relative prices. For example, if consumers treat wild meat similarly to other fresh food, domestic meat substitutes readily when the relative price of wild meat increases (East et al., 2005). Domestic animals and

fish are commonly available substitutes for wild meat, and are substituted for wild meat by consumers in multiple settings (Wilkie & Godoy, 2001). Variation in protein substitutability depends on the household's surroundings: coastal villages may eat less wild meat because they have easier access to fish as a protein source, whereas forest villages consume the most wild meat (Fa et al., 2009). The substitutions that consumers choose to make as relative prices of goods change affect the prices for wild meat species and therefore the hunting and conservation of that species.

4.3 Urban Market Characteristics Alter Conservation Outcomes

Wildmeat prices in urban markets result from urban consumer preferences for wild meat and its substitutes, and for particular species of wild meat. The absolute level of wild meat prices in urban markets feeds back to hunter decisions through the market access costs or intermediaries to contribute to the levels of hunting undertaken and, thus, the species populations and conservation outcomes. Those prices also influence gear choices, which can alter the particular species harvested. In addition, the relative prices across types of wild meat can contribute to the hunters' choice of targeted species. The prices in these markets and the market access costs operate upstream through the wild meat supply chain to determine both hunting levels and species, which determines the conservation outcomes in hunting settings.

5. POLICY DISCUSSION

Many policies aim to protect species and conserve biodiversity through reductions in wild meat hunting. Other policies influence various actors throughout the wild meat supply chain and markets in ways that contribute to conservation outcomes. Protected areas with enforced restrictions on hunting, alternative livelihood programs that increase opportunity costs of hunting, and local and international regulations that prohibit the hunting of particular species all influence hunter decisions and conservation outcomes. Taxes and subsidies, wild meat market regulations or closures, incentives for domestic animal husbandry, improving agricultural productivity, and improving roads to increase market access also influence conservation outcomes as these policies operate through the wild meat market system. Here, we discuss and call for analysis that starts from the point of a policy intervention and follows the flow of wild meat forward from that point to the urban markets and backward from that point, through intermediaries, to the hunting production decisions to elucidate the impact of a policy on species conservation outcomes. Although this discussion is general, predicting the impact of policy faces two critical issues that create a need for site-specific data to inform policy: heterogeneity across settings and information gaps.

5.1 Protected Areas and Enforcement

Many countries use protected areas (PAs) – including nature reserves, parks, and multiple use areas – as a central component of plans to conserve biodiversity. While PAs provide many ecosystem services, their impact on species conservation stems from the PA's role in providing habitat and in preventing over-exploitation of species. Both roles interact with landscapes and hunter decisions to influence the impact of the PA on reducing the production of wild meat.

The direct impact of a PA on reducing hunting for wild meat operates through changes in hunters' decisions about hunting within the now-PA. Some hunting may be deterred simply because it is illegal. Many hunters, however, consider their expected returns from hunting in the PA. If the PA undertakes management actions that increase wildlife populations within the PA, that additional stock attracts hunters. In contrast, enforcement – including detection and penalties – of hunting restrictions within the PA reduce the expected returns from hunting (Albers & Robinson, 2013). Much of the conservation science and conservation economics literatures recognizes illegal activity within PAs, yet few address the costs of those actions or the responsiveness of hunters to those actions (Albers et al., 2021; Albers & Robinson, 2013). In practice, many PAs do not have effective management plans or sufficient budgets to protect species, with only 20% of PAs considered "well-managed" and many PAs characterized as "paper parks" – meaning parks that are legally designated but not effectively managed to generate conservation (Albers & Ashworth, 2022; UNEP-WCMC; IUCN; and NGS, 2018; Watson et al., 2014). In addition, few data characterize the responsiveness of illegal hunters in PAs to incentives or disincentives, which further constrains the ability of a PA siting or management plan to predict the impact of the PA on wild meat production. Still, both empirical observation and modeling analyses demonstrate that the impact of any PA on reducing wild meat production is a function of the PA management, which includes enforcement or incentives to reduce hunters' allocation of labor to hunting in the PA.

Although some communities or individuals may choose to establish hunting areas, most PAs are designated by governments. Establishing PAs in a landscape removes that land from other productive uses, like agriculture. That land reduction influences decisions about other land uses in the landscape, such as agricultural expansion into remaining hunting areas. Similarly, the reduced land availability and the reduced land for hunting both influence the tradeoffs that define labor allocation decisions between agriculture and hunting. Whether this reduction in land for alternative uses increases or decreases hunting activities outside of the PA is a function of the particular context of opportunity costs of labor and agricultural and wild meat prices, with ambiguous impact on the level of wild meat production from the landscape as a whole.

In addition, the establishment of a PA within a landscape can create negative spillover effects on nearby land, such as wild animals consuming agricultural crops, preying on livestock, or injuring people outside of the PA. In such cases, people living near the PA may increase their hunting/trapping activities to limit wildlife nuisance costs or to generate partially offsetting income from consuming or selling wild meat. Again, whether an increase in such defensive wild meat production in response to a PA generates a net gain or net loss in wildlife at the landscape level is highly context specific.

Establishing a PA, especially with strong management to prevent overexploitation of species within the PA, reduces hunting and wild meat production within the PA, thereby conserving species within the PA. Yet, the PA is but one part of a landscape for both wildlife and people. Overall, the net impact of a PA on wildlife conservation through reductions in wild meat production depends on the PA management, the response of species, the availability of land, and the response of people to changing land and labor values.

5.2 Alternative Livelihoods

The mechanisms through which alternative livelihood projects are expected to generate conservation outcomes include changing incentives and opportunity costs of actions, generating good-will that discourages harmful actions, and "conservation by distraction" that limits the labor time available for non-conservation (Nicholls, 2004; Wright et al., 2016). Alternative livelihood policies aimed at hunters' harvest levels attempt to change hunter behavior by providing an income substitute for the sale of wild meat and by changing the opportunity costs of labor time allocated to hunting. Yet even projects that successfully provide incomes may generate negative impact on conservation when considering the net impact of the project on hunters, intermediaries, and demand for wild meat. Hunting households whose income is increased by these programs may increase their demand for wild meat (Damania et al., 2005). Hunting households may change their hunting technique when faced with less time to hunt, which could alter which species are threatened by hunting (Robinson, 2008b). Alternative livelihood practices do not directly affect other actors in the wild meat supply chain, which means that intermediaries may cause a shift of wild meat hunting to other areas with its own impact on regional conservation. Similarly, if alternative livelihood projects lead to a reduction in wild meat supply, demand in rural and urban markets may drive higher prices that then increase hunting and limit net conservation outcomes.

When a domestic species provides a close substitute for a popular wild meat species, investments in the production of the domestic species can reduce wild meat consumption and offer alternative livelihoods for hunters (McNamara et al., 2019). As with many "integrated conservation-development projects," however, failure to effectively link alternative livelihood projects to conservation actions limits the impact of such programs on conservation outcomes. For example, many of these livelihood programs do not require that participating households not hunt, and therefore could be providing additional income to hunting households without eliminating hunting activity (Ingram et al., 2021). In addition, such projects are rarely evaluated based on their impact on conservation and livelihoods. Reviewing alternative livelihood programs implemented in West and Central Africa, Wicander and Coad (2018) find that few livelihood projects assessed the impact of the programs in a formal manner, and rarely assessed the impact on wildlife populations.

Alternative livelihood projects create changes throughout the wild meat supply chain, including indirect effects such as changes in the price of wild meat, which have ambiguous effects on conservation outcomes. For example, projects aimed at increasing returns to agriculture drive land use change from habitat to agriculture land, which leads to changes in time allocated to hunting and can cause hunters to switch to more time-efficient non-discriminatory hunting techniques. Alternative livelihood projects that affect the opportunity cost of habitat land can result in land conversion and lower wildlife populations in some contexts. Furthermore, when the nuisance costs from a species is part of the wild meat production decision, improved agriculture prices lead to ambiguous outcomes by decreasing the relative value of hunting labor and increasing the value of nuisance species removal.

5.3 Rules on Hunting and Trade of Specific Species

Bans on the hunting and/or sale of specific species aim to protect threatened species, but enforcement remains challenging with respect to targeting action along the supply chain and in identifying illegal species (Lee et al., 2005; Wilkie et al., 2006). If enforcement of species bans occurs at the hunter level, monitoring and penalties create incentives to use discriminatory hunting techniques to avoid accidently harvesting illegal species. However, enforcement at the hunter level implies high costs due to the many individual actors and large areas involved. Targeting enforcement at the intermediaries provides another opportunity to change incentives to hunt at potentially lower policy cost. In Sulawesi Indonesia, the unique geography of the island allowed a single check point on the main road to markets to monitor wild meat being brought to the market (Lee et al., 2005).

Wherever enforcement occurs, it creates incentives for avoidance activities and black markets. For example, the Convention on International Trade in Endangered Species (CITES) ban on trade in some animals and animal parts, such as rhino horns and elephant tusks, led to high prices that increase incentives for hunting (Biggs et al., 2013). In the case of local wildlife bans, enforcement actions can drive up the price of wild meat paid to hunters and the price paid by consumers, which can extend the extensive margin of hunting for non-local markets.

5.4 Taxes and Subsidies

Within the wild meat system, taxes could be implemented to raise the price of wild meat in urban markets, therefore discouraging its consumption and encouraging consumers to substitute toward alternative protein sources. However, the nature of the wild meat system and informal characteristics of markets make taxation infeasible in many settings. In many countries, the hunting, or sale of wildlife is already regulated, but a lack of enforcement, large quantities of public lands, and a perceived lack of legitimacy of regulations results in regulations not being closely followed (Wilkie et al., 2006). Many rural and urban markets do not use set pricing and instead barter, negotiate, and bundle in ways that make a price-based tax challenging to implement. Taxes on the sale of wild meat at a market could also lead to more use of informal markets (Wilkie et al., 2006). Alternatively, subsidizing domesticated meat could encourage households to substitute wild meat for the relatively cheaper domesticated meats. Yet, discount coupons for chicken provided in the Brazilian Amazon led households to consume more chicken but did not reduce consumption of wild meat (Chaves et al., 2018).

Efforts to change prices at urban markets have upstream effects on the rural households that supply the wild meat, the intermediaries transporting the meat, and the vendors selling it. The net policy response to taxes and subsidies includes the substitutions consumers make, but also the substitutions hunters, intermediaries, and vendors make in response. Any impact on the relative price of species paid to hunters could alter hunter incentives and result in different hunting levels, species being hunted, or hunting techniques.

5.5 Change Consumer Preferences

Beyond pure price relationships, urban demand for wild meat relies on urban households' preferences for wild meat in general and for specific species of wild meat. Preferences for wild meat can reflect cultural influences, such as Muslims consuming less wild meat than other

groups (Bachmann et al., 2020) and a Chinese tradition of shark fin soup at weddings and other important events (Jeffreys, 2016). Informational and educational campaigns seek to reduce urban demand for wild meat by changing consumer preferences. For example, NBA great Yao Ming's efforts to inform potential consumers of the connections between wildlife conservation and consumption of wildlife products - including wild meat - appears, anecdotally, to have changed preferences among younger people (Jeffreys, 2016). Still, the research on these strategies has shown some positive and some null results (Chaves et al., 2018; Veríssimo et al., 2018). Like with taxes and subsidies, little analysis explores the upstream impact on hunters and intermediaries from these policies. Such changes in preferences could operate through markets and the supply chain to create unintended hunting responses. Policies that induce species substitutions or nondiscriminatory hunting practices could lead to negative conservation outcomes such as harvesting of endangered species or species that are unwanted for consumption and trade.

5.6 Policies at Live Markets

With COVID-19 and other zoonotic diseases thought to have originated or spread through live markets or wild meat consumption (Pekar et al., 2022), health policies include closing live markets and imposing regulations on the handling and sale of wild meat. Again, such policies operate largely at urban markets but affect species conservation through the responses across the demand and supply chains for wild meat. To the extent that less wild meat is sold in urban areas, that reduction could translate to positive conservation outcomes if hunters reduce their hunting but, as above, hunters may respond with different behavior that has negative consequences for the conservation of species. Although little analysis depicts the impact of such policies, closing and regulating urban markets could induce much of the wild meat trade to occur in more informal markets to meet urban demand. Whether that shift in marketing translates to more or less hunting, or to a shift to other species, depends on the costs of informal markets and their impact on prices both at the informal urban markets and at the rural hunting sites.

5.7 Roads and Conservation Policy

Infrastructure and development policies often include improvements in roads, which influence land use and conservation outcomes in rural areas. In the case of wild meat, improved roads could reduce the costs of accessing urban markets. That reduction could induce near-market hunters to transport their meat to urban markets while inducing distant hunters – and new hunters – to use intermediaries to begin selling in urban markets. Yet, that transport cost reduction would also change the profitability of agriculture, making the impact on incentives to hunt less clear. In addition, the market access costs could change the number of intermediaries and their market power in various locations. Overall, the impact of road improvements, or other modes of transportation, on the level of hunting in different locations operates through the interacting decisions of hunters, intermediaries, vendors and market demand to determine the impact on hunting levels and hunted species across space. Similarly, policies that increase market access costs, such as road tolls or gas taxes, also operate through that supply chain to determine the conservation outcomes from changes in hunting activities (Albers et al., 2021). While rarely intended as conservation policies, infrastructure policies can influence the decisions of various

actors in the wild meat sector that aggregate to conservation outcomes for biodiversity and for particular species across heterogenous regions.

5.8 Challenges and Next Steps for Research to Inform Policy

Although Skonhoft (1999) and other articles emphasize the interaction of land and labor allocation decisions in hunting settings, much of the literature on protected areas and on hunting management contain a narrow focus rather than the landscape perspective required to account for these interactions, and the resulting impact on biodiversity. Changes in agricultural or protected area policies affect hunting household land, time, and gear allocation decisions by changing relative values facing hunters, which determines the hunting response that contributes to species outcomes. An analysis focused only on species within a protected area does not reflect the protected area's influence on land and labor values and the movement of species, which contribute to the hunting response both outside and inside the protected area to generate landscape level species outcomes. Similarly, frameworks that focus on the response to agricultural policy without considering the policy's impact on habitat through land allocations and on hunting labor allocations misrepresent the policy's effect on landscape species conservation. Working in the opposite direction, policies aimed at hunting itself – including enforcement of regulations or subsidizing selective gear – also change household land and labor allocations in ways that influence agricultural and species outcomes. Further efforts to develop and explore landscape level frameworks that incorporate both household land and hunting labor responses to policies will lead to more efficient policies to promote landscape biodiversity conservation.

Because landscape effects are only one component of the wild meat supply chain, research that models the wild meat system as a whole will provide policy insight into how to leverage different parts of the system to promote biodiversity conservation. Models of subsets of the actors in the system miss interactions and characteristics that ultimately drive harvesting decisions and, therefore, may incorrectly predict responses to policy. Models that account for the different interactions and characteristics of all actors in a specific landscape, such as market access, rural and urban demand characteristics, market power of hunters and intermediaries, and substitutability in production and consumption, can identify which of these features drive species outcomes. Policies that appear to have little relationship to conservation, such as road tolls or market sanitation rules, change incentives for non-hunter actors in the supply chain in ways that ripple through the system to influence hunting decisions and conservation outcomes. Policy analysis that takes a full system perspective, including a landscape view nested inside a full market framework, will help define policies that promote biodiversity conservation while demonstrating the impact on other economic outcomes.

Heterogeneity across and within settings complicates the definition of general policy responses. Heterogeneity at the production level includes across-hunter differences in substitution between hunting and agriculture, species hunted, gear choices, and production costs. While settings vary across and within regions, policy outcomes reflect the specific setting at the landscape level because the landscape characteristics influence the available species, agriculture and hunting tradeoffs, nuisance species, and the opportunity cost of land. The characteristics of accessing

wild meat markets contains wide differences across locations with respect to markets and across regions, including in infrastructure and transportation services, in who transports the wild meat to the market, the market power of intermediaries, and the types of hunter-intermediary contracts. Vendors may also be intermediaries and vendors at the market may sell directly to consumers or may sell mostly to restaurants. Consumer heterogeneity in wild meat preferences in general and across species means that different species and different markets have a range of demand characteristics, such as price and income elasticities, that vary according to cultural norms, religion, and region. Economic frameworks can predict policy response as a function of general characteristics of landscapes and actors that depict this heterogeneity, but, because different characteristics lead to different responses, defining policy for a given setting requires information about the attributes of the setting (Oyanedel et al., 2021).

Although research in the past two decades has generated appropriate data in some regions (see Ingram et al. 2021), many knowledge and data gaps remain within individual wild meat systems and across settings of wild meat systems. Data to describe the various actors and actions within the wild meat system exist for relatively few wild meat systems, leaving gaps in understanding of consumer characteristics like price and income elasticities, vendor characteristics like operating costs, intermediary characteristics like entry costs, and hunter characteristics like species choice as a function of price. In addition, few data describe the interconnections between actors in wild meat systems – both direct, such as hunter and intermediaries' contracts, and indirect, such as vendor prices altering hunter decisions. For policies implemented at any point in the wild meat system - tracing back to hunters and forward to consumers through these interactions - these data limitations restrict policy analysis and implementation.

6. CONCLUSION

This article examines the resource economics and conservation science literatures to characterize insights and gaps concerning policy to conserve species and biodiversity by limiting wild meat production. Like fish production, wild meat production or hunting decisions reflect labor allocation choices based on the value of labor in hunting versus other activities. Unlike fish production, landscape features – including protected areas and spillovers of nuisance species – define the opportunity cost of land allocated to habitat for hunted species, which interacts with hunting decisions. The value of hunting reflects both local tradeoffs and broader market characteristics including market access mechanisms through intermediaries and market features through vendors and consumer demand. Actions or policies at any point in the wild meat system – at production, at transport to markets, at markets, at consumer preferences – ripple through the entire system through the interactions of various actors – hunters, intermediaries, vendors, consumers – to define the impact on conservation outcomes for particular species and for biodiversity in general. Economic analysis that includes data collection and modeling of these system interactions could use the path of wild meat to determine likely conservation outcomes from policies implemented anywhere along the supply and market chain for both general policies and site-specific policies.

REFERENCES

Aggarwal, R. M. (2008). Resource-Poor Farmers in South India: On the Margins or Frontiers of Globalization? *Globalization and the Poor in Asia*, 196–220. https://doi.org/10.1057/9780230594005_8

Albers, H. J. (1996). Modeling ecological constraints on tropical forest management: spatial interdependence, irreversibility, and uncertainty. *Journal of Environmental Economics and Management*, *30*(1), 73–94. https://doi.org/10.1006/jeem.1996.0006

Albers, H. J., Ashworth, M., Capitán, T., Madrigal-Ballestero, R., & Preonas, L. (2021). MPAs and Aspatial Policies in Artisanal Fisheries. *Marine Resource Economics*, *36*(4), 341–367. https://doi.org/10.1086/715818

Albers, H. J., & Ashworth, M. F. (2022). Economics of Marine Protected Areas: Assessing the Literature for Marine Protected Area Network Expansions. *Annual Review of Resource Economics*, *14*(1). https://doi.org/10.1146/annurev-resource-111820-024652

Albers, H. J., Preonas, L., Capitán, T., Robinson, E. J. Z., & Madrigal-Ballestero, R. (2020). Optimal Siting, Sizing, and Enforcement of Marine Protected Areas. In *Environmental and Resource Economics* (Vol. 77, Issue 1). Springer Netherlands. https://doi.org/10.1007/s10640-020-00472-7

Albers, H. J., & Robinson, E. J. Z. (2007). Spatial-temporal aspects of cost-benefit analysis for park management: An example from Khao Yai National Park, Thailand. *Journal of Forest Economics*, *13*(2–3), 129–150. https://doi.org/10.1016/j.jfe.2007.02.002

Albers, H. J., & Robinson, E. J. Z. (2013). A review of the spatial economics of non-timber forest product extraction: Implications for policy. *Ecological Economics*, *92*, 87–95. https://doi.org/10.1016/j.ecolecon.2012.01.021

Allebone-Webb, S. M., Kümpel, J Rist, N. F., Cowlishaw, G., Rowcliffe, J. M., & Milner-Gulland, E. (2011). Use of Market Data to Assess Bushmeat Hunting Sustainability in Equatorial Guinea. *Conservation Biology*, *25*(3), 597–606. https://doi.org/10.1111/j.1523-1739.2011.01681.x

Angelsen, A., Jagger, P., Babigumira, R., Belcher, B., Hogarth, N. J., Bauch, S., Börner, J., Smith-Hall, C., & Wunder, S. (2014). Environmental Income and Rural Livelihoods: A Global-Comparative Analysis. *World Development*, *64*(S1), S12–S28. https://doi.org/10.1016/j.worlddev.2014.03.006

Bachmann, M. E., Junker, J., Mundry, R., Nielsen, M. R., Haase, D., Cohen, H., Kouassi, J. A. K., & Kühl, H. S. (2019). Disentangling economic, cultural, and nutritional motives to identify entry points for regulating a wildlife commodity chain. *Biological Conservation*, *238*(June), 108177. https://doi.org/10.1016/j.biocon.2019.07.022

Bachmann, M. E., Nielsen, M. R., Cohen, H., Haase, D., Kouassi, J. A. K., Mundry, R., & Kuehl, H. S. (2020). Saving rodents, losing primates—Why we need tailored bushmeat management strategies. *People and Nature*, *2*(4), 889–902. https://doi.org/10.1002/pan3.10119

Baraka, B., Mburu, J., & Muriithi, B. (2021). Transaction costs magnitudes, market participation, and smallholder profitability in rural-urban vegetable supply chain. *International Journal of Vegetable Science*, *27*(1), 54–64. https://doi.org/10.1080/19315260.2019.1700204

Biggs, D., Courchamp, F., Martin, R., & Possingham, H. P. (2013). Legal trade of Africa's Rhino horns. *Science*, *339*(6123), 1038–1039. https://doi.org/10.1126/science.1229998

Bowen-Jones, E., Brown, D., & Robinson, E. J. Z. (2003). Economic commodity or environmental crisis? An interdisciplinary approach to analysing the bushmeat trade in central and west Africa. *Area*, *35*(4), 390–402. https://doi.org/10.1111/j.0004-0894.2003.00189.x

Brashares, J. S., Golden, C. D., Weinbaum, K. Z., Barrett, C. B., & Okello, G. V. (2011). Economic and geographic drivers of wildlife consumption in rural Africa. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(34), 13931–13936. https://doi.org/10.1073/pnas.1011526108

Bulte, E. H., & Horan, R. D. (2003). Habitat conservation, wildlife extraction and agricultural expansion. *Journal of Environmental Economics and Management*, *45*(1), 109–127. https://doi.org/10.1016/S0095-0696(02)00009-8

Bulte, E. H., & Rondeau, D. (2005). Research And Management Viewpoint: Why Compensating Wildlife Damages May Be Bad For Conservation. *Journal of Wildlife Management*, *69*(1), 14–19. http://www.jstor.org/stable/3803581

Bulte, E. H., & Rondeau, D. (2007). Compensation for wildlife damages: Habitat conversion, species preservation and local welfare. *Journal of Environmental Economics and Management*, *54*(3), 311–322. https://doi.org/10.1016/j.jeem.2007.02.003

Carlier, A., & Treich, N. (2020). Directly valuing animal welfare in (environmental) economics. *International Review of Environmental and Resource Economics*, *14*(1), 113–152. https://doi.org/10.1561/101.00000115

Chatterjee, S. (2019). Market power and spatial competition in rural India. *Cambridge Working Papers in Economics*.

Chaves, W. A., Valle, D. R., Monroe, M. C., Wilkie, D. S., Sieving, K. E., & Sadowsky, B. (2018). Changing Wild Meat Consumption: An Experiment in the Central Amazon, Brazil. *Conservation Letters*, *11*(2), 1–10. https://doi.org/10.1111/conl.12391

Chaves, W. A., Wilkie, D. S., Monroe, M. C., & Sieving, K. E. (2017). Market access and wild meat consumption in the central Amazon, Brazil. *Biological Conservation*, *212*(April), 240–248. https://doi.org/10.1016/j.biocon.2017.06.013

Coad, L., Abernethy, K., Balmford, A., Manica, A., Airey, L., & Milner-Gulland, E. J. (2010). Distribution and Use of Income from Bushmeat in a Rural Village, Central Gabon. *Conservation Biology*, *24*(6), 1510–1518. https://doi.org/10.1111/j.1523-1739.2010.01525.x

Costello, C., & Polasky, S. (2008). Optimal harvesting of stochastic spatial resources. *Journal of Environmental Economics and Management*, *56*(1), 1–18. https://doi.org/10.1016/j.jeem.2008.03.001

Cowlishaw, G., Mendelson, S., & Rowcliffe, M. J. (2005). Structure and Operation of a Bushmeat Commodity Chain in Southwestern Ghana. *Conservation Biology*, *19*(4), 1194–1204. https://doi.org/10.1111/j.1523-1739.2005.00170.x

Crona, B., Nyström, M., Folke, C., & Jiddawi, N. (2010). Middlemen, a critical social-ecological link in coastal communities of Kenya and Zanzibar. *Marine Policy*, *34*(4), 761–771. https://doi.org/10.1016/j.marpol.2010.01.023

Damania, R., Milner-Gulland, E. J., & Crookes, D. J. (2005). A bioeconomic analysis of bushmeat hunting. *Proceedings of the Royal Society B: Biological Sciences*, *272*(1560), 259–266. https://doi.org/10.1098/rspb.2004.2945

Dash, M., Behera, B., & Rahut, D. B. (2016). Determinants of household collection of non-timber forest products (NTFPs) and alternative livelihood activities in Similipal Tiger Reserve, India. *Forest Policy and Economics*, *73*, 215–228. https://doi.org/10.1016/j.forpol.2016.09.012

Daszak, P., Cunningham, A. A., & Hyatt, A. D. (2000). Emerging infectious diseases of wildlife - Threats to biodiversity and human health. *Science*, *287*(5452), 443–449. https://doi.org/10.1126/science.287.5452.443

De Mattos Vieira, M. A. R., Von Muhlen, E. M., & Shepard, G. H. (2015). Participatory monitoring and management of subsistence hunting in the Piagaçu-Purus Reserve, Brazil. *Conservation and Society*, *13*(3), 254–264. https://doi.org/10.4103/0972-4923.170399

Duonamou, L., Konate, A., Xu, J., & Humle, T. (2021). Temporal evolution of bushmeat traded in High Niger National Park, Guinea, West Africa. *Oryx*, *55*(5), 717–724. https://doi.org/10.1017/S0030605319001443

East, T., Kümpel, N. F., Milner-Gulland, E. J., & Rowcliffe, J. M. (2005). Determinants of urban bushmeat consumption in Río Muni, Equatorial Guinea. *Biological Conservation*, *126*(2), 206–215. https://doi.org/10.1016/j.biocon.2005.05.012

Fa, J. E., Albrechtsen, L., Johnson, P. J., & Macdonald, D. W. (2009). Linkages between household wealth, bushmeat and other animal protein consumption are not invariant: Evidence from Rio Muni, Equatorial Guinea. *Animal Conservation*, *12*(6), 599–610. https://doi.org/10.1111/j.1469-1795.2009.00289.x

Fontes, F., & Palmer, C. (2018). "Land sparing" in a von Thünen framework: Theory and evidence from Brazil. *Land Economics*, *94*(4), 556–576. https://doi.org/10.3368/le.94.4.556

Funk, S. M., Fa, J. E., Ajong, S. N., Eniang, E. A., Dendi, D., Nasi, R., Di Vittorio, M., Petrozzi, F., Amadi, N. K., Akani, G. C., & Luiselli, L. (2022). Impact of COVID-19 on wild meat trade in Nigerian markets. *Conservation Science and Practice*, *4*(2), 1–6. https://doi.org/10.1111/csp2.599

Gluszek, S., Viollaz, J., Mwinyihali, R., Wieland, M., & Gore, M. L. (2021). Using conservation criminology to understand the role of restaurants in the urban wild meat trade. *Conservation*

Science and Practice, *3*(5), 1–13. https://doi.org/10.1111/csp2.368

Godoy, R., Undurraga, E. A., Wilkie, D., Reyes-García, V., Huanca, T., Leonard, W. R., McDade, T., Tanner, S., & Vadez, V. (2010). The effect of wealth and real income on wildlife consumption among native Amazonians in Bolivia: Estimates of annual trends with longitudinal household data (2002-2006). *Animal Conservation*, *13*(3), 265–274. https://doi.org/10.1111/j.1469-1795.2009.00330.x

Gross, E. M., Pereira, J. G., Shaba, T., Bilério, S., Kumchedwa, B., & Lienenlüke, S. (2022). Exploring Routes to Coexistence: Developing and Testing a Human–Elephant Conflict-Management Framework for African Elephant-Range Countries. *Diversity*, *14*(7). https://doi.org/10.3390/d14070525

Gunatileke, H., & Chakravorty, U. (2003). Protecting Forests Through Farming. *Environmental and Resource Economics*, *24*(Guppy 1984), 1–26.

Hofstad, O. (1997). Woodland deforestation by charcoal supply to Dar es Salaam. *Journal of Environmental Economics and Management*, *33*(1), 17–32. https://doi.org/10.1006/jeem.1996.0975

Illukpitiya, P., & Yanagida, J. F. (2010). Farming vs forests: Trade-off between agriculture and the extraction of non-timber forest products. *Ecological Economics*, *69*(10), 1952–1963. https://doi.org/10.1016/j.ecolecon.2010.05.007

Ingram, D. J., Coad, L., Milner-Gulland, E. J., Parry, L., Wilkie, D., Bakarr, M. I., Benítez-López, A., Bennett, E. L., Bodmer, R., Cowlishaw, G., El Bizri, H. R., Eves, H. E., Fa, J. E., Golden, C. D., Iponga, D. M., Minh, N. V., Morcatty, T. Q., Mwinyihali, R., Nasi, R., … Abernethy, K. (2021). Wild Meat Is Still on the Menu: Progress in Wild Meat Research, Policy, and Practice from 2002 to 2020. *Annual Review of Environment and Resources*, *46*, 221–254. https://doi.org/10.1146/annurev-environ-041020-063132

Jeffreys, E. (2016). Translocal celebrity activism: shark-protection campaigns in mainland China. *Environmental Communication*, *10*(6), 763–776. https://doi.org/10.1080/17524032.2016.1198822

Johannesen, A. B. (2007). Protected areas, wildlife conservation, and local welfare. *Ecological Economics*, *62*(1), 126–135. https://doi.org/10.1016/j.ecolecon.2006.05.017

Johannesen, A. B., & Skonhoft, A. (2004). Property rights and natural resource conservation. A bio-economic model with numerical illustrations from the Serengeti-Mara ecosystem. *Environmental and Resource Economics*, *28*(4), 469–488. https://doi.org/10.1023/B:EARE.0000036774.15204.49

Kamins, A. O., Restif, O., Ntiamoa-Baidu, Y., Suu-Ire, R., Hayman, D. T. S., Cunningham, A. A., Wood, J. L. N., & Rowcliffe, J. M. (2011). Uncovering the fruit bat bushmeat commodity chain and the true extent of fruit bat hunting in Ghana, West Africa. *Biological Conservation*, *144*(12), 3000–3008. https://doi.org/10.1016/j.biocon.2011.09.003

Katayama, S., & Abe, F. (1998). Is the monopolist the friend of the conservationist? Two remarks on the Hotelling-Solow paradox. *Journal of Economic Behavior and Organization*, *33*(3–4), 493–505. https://doi.org/10.1016/s0167-2681(97)00072-3

Latinne, A., Saputro, S., Kalengkongan, J., Kowel, C. L., Gaghiwu, L., Ransaleleh, T. A., Nangoy, M. J., Wahyuni, I., Kusumaningrum, T., Safari, D., Feferholtz, Y., Li, H., Hagan, E., Miller, M., Francisco, L., Daszak, P., Olival, K. J., & Pamungkas, J. (2020). Characterizing and quantifying the wildlife trade network in Sulawesi, Indonesia. *Global Ecology and Conservation*, *21*, e00887. https://doi.org/10.1016/j.gecco.2019.e00887

Lee, R. J., Gorog, A. J., Dwiyahreni, A., Siwu, S., Riley, J., Alexander, H., Paoli, G. D., & Ramono, W. (2005). Wildlife trade and implications for law enforcement in Indonesia: A case study from North Sulawesi. *Biological Conservation*, *123*(4), 477–488. https://doi.org/10.1016/j.biocon.2005.01.009

Liese, C., Smith, M. D., & Kramer, R. A. (2007). Open access in a spatially delineated artisanal fishery: The case of Minahasa, Indonesia. *Environment and Development Economics*, *12*(1), 123–143. https://doi.org/10.1017/S1355770X06003421

Loibooki, M., Hofer, H., Campbell, K. L. I., & East, M. L. (2002). Bushmeat hunting by communities adjacent to the Serengeti National Park, Tanzania: The importance of livestock ownership and alternative sources of protein and income. *Environmental Conservation*, *29*(3), 391–398. https://doi.org/10.1017/S0376892902000279

Mahapatra, A. K., Albers, H. J., & Robinson, E. J. Z. (2005). The impact of NTFP sales on rural households' cash income in India's dry deciduous forest. *Environmental Management*, *35*(3), 258–265. https://doi.org/10.1007/s00267-003-8203-9

McNamara, J., Fa, J. E., & Ntiamoa-Baidu, Y. (2019). Understanding drivers of urban bushmeat demand in a Ghanaian market. *Biological Conservation*, *239*(November), 108291. https://doi.org/10.1016/j.biocon.2019.108291

Mfunda, I. M., & Røskaft, E. (2010). Bushmeat hunting in Serengeti, Tanzania: An important economic activity to local people. *International Journal of Biodiversity and Conservation*, *2*(May 2014), 263–272.

Morcatty, T. Q., & Valsecchi, J. (2015). Social, biological, and environmental drivers of the hunting and trade of the endangered yellow-footed tortoise in the Amazon. *Ecology and Society*, *20*(3). https://doi.org/10.5751/ES-07701-200303

Moro, M., Fischer, A., Czajkowski, M., Brennan, D., Lowassa, A., Naiman, L. C., & Hanley, N. (2013). An investigation using the choice experiment method into options for reducing illegal bushmeat hunting in western Serengeti. *Conservation Letters*, *6*(1), 37–45. https://doi.org/10.1111/j.1755-263X.2012.00284.x

Mulenga, B. P., Richardson, R. B., Tembo, G., & Mapemba, L. (2014). Rural household participation in markets for non-timber forest products in Zambia. *Environment and Development Economics*, *19*(4), 487–504. https://doi.org/10.1017/S1355770X13000569

Muller, J., & Albers, H. J. (2004). Enforcement, payments, and development projects near protected areas: How the market setting determines what works where. *Resource and Energy Economics*, *26*(2), 185–204. https://doi.org/10.1016/j.reseneeco.2003.11.007

Narain, U., Gupta, S., & van 't Veld, K. (2008). Poverty and resource dependence in rural India. *Ecological Economics*, *66*(1), 161–176. https://doi.org/10.1016/j.ecolecon.2007.08.021

Nascimento, D. M., Alves, R. R. N., Barboza, R. R. D., Schmidt, A. J., Diele, K., & Mourão, J. S. (2017). Commercial relationships between intermediaries and harvesters of the mangrove crab Ucides cordatus (Linnaeus, 1763) in the Mamanguape River estuary, Brazil, and their socio-ecological implications. *Ecological Economics*, *131*, 44–51. https://doi.org/10.1016/j.ecolecon.2016.08.017

Ngeleza, G. K., & Robinson, E. J. Z. (2013). Cartels and rent sharing at the farmer-trader interface: Evidence from ghana's tomato sector. *Journal of Agricultural and Food Industrial Organization*, *11*(1), 15–30. https://doi.org/10.1515/jafio-2012-0011

Nicholls, H. (2004). The conservation business. *PLoS Biology*, *2*(9). https://doi.org/10.1371/journal.pbio.0020310

Nielsen, M. R., Jacobsen, J. B., & Thorsen, B. J. (2014). Factors determining the choice of hunting and trading bushmeat in the Kilombero Valley, Tanzania. *Conservation Biology*, *28*(2), 382–391. https://doi.org/10.1111/cobi.12197

Omamo, S. W. (1998). Transport Costs and Smallholder Cropping Choices: An Application to Siaya District, Kenya. *American Journal of Agricultural Economics*, *80*(1), 116–123. https://doi.org/10.2307/3180274

Oyanedel, R., Gelcich, S., & Milner-Gulland, E. J. (2021). A framework for assessing and intervening in markets driving unsustainable wildlife use. *Science of the Total Environment*, *792*, 148328. https://doi.org/10.1016/j.scitotenv.2021.148328

Pedroza, C. (2013). Middlemen, informal trading and its linkages with IUU fishing activities in the port of Progreso, Mexico. *Marine Policy*, *39*(1), 135–143. https://doi.org/10.1016/j.marpol.2012.10.011

Peeters, M., Courgnaud, V., Abela, B., Auzel, P., Pourrut, X., Bibollet-Ruche, F., Loul, S., Liegeois, F., Butel, C., Koulagna, D., Mpoudi-Ngole, E., Shaw, G. M., Hahn, B. H., & Delaporte, E. (2002). Risk to human health from a plethora of Simian immunodeficiency viruses in primate bushmeat. *Emerging Infectious Diseases*, *8*(5), 451–457. https://doi.org/10.3201/eid0805.010522

Pekar, J. E., Magee, A., Parker, E., Moshiri, N., Izhikevich, K., Havens, J. L., Gangavarapu, K., Malpica Serrano, L. M., Crits-Christoph, A., Matteson, N. L., Zeller, M., Levy, J. I., Wang, J. C., Hughes, S., Lee, J., Park, H., Park, M.-S., Ching Zi Yan, K., Lin, R. T. P., … Wertheim, J. O. (2022). The molecular epidemiology of multiple zoonotic origins of SARS-CoV-2. *Science*, *377*(6609), 960–966. https://doi.org/10.1126/science.abp8337

Randolph, S. G., Ingram, D. J., Curran, L. M., Holland Jones, J., & Durham, W. H. (2022). Urban wild meat markets in Cameroon: Actors and motives. *World Development*, *160*, 106060. https://doi.org/10.1016/j.worlddev.2022.106060

Robalino, J., & Pfaff, A. (2013). Ecopayments and deforestation in Costa Rica: A nationwide analysis of PSA's initial years. *Land Economics*, *89*(3), 432–448. https://doi.org/10.3368/le.89.3.432

Robinson, E. J. Z. (2008a). India's Disappearing Common Lands: Fuzzy Boundaries, Encroachment, and Evolving Property Rights. *Land Economics*, *84*(3), 409–422.

https://doi.org/10.3368/le.84.3.409

Robinson, E. J. Z. (2008b). Wanted dead and alive: to what extent are hunting and protection of an endangered species compatible? *Environment and Development Economics*, *13*(5), 607–620. https://doi.org/10.1017/S1355770X08004403

Robinson, E. J. Z., Williams, J. C., & Albers, H. J. (2002). The influence of markets and policy on spatial patterns of non-timber forest product extraction. *Land Economics*, *78*(2), 260–271. https://doi.org/10.2307/3147272

Rushlow, J. R. (2021). *The spatial economics of transportation middlemen in the wildlife trade*. https://www.proquest.com/openview/f023c7fe2372a3f350a2839fcfc5b53f/1?pq-origsite=gscholar&cbl=18750&diss=y

Russell, S. D. (1987). Middlemen and Moneylending: Relations of Exchange in a Highland Philippine Economy. *Journal of Anthropological Research*, *43*(2), 139–161. https://doi.org/10.1086/jar.43.2.3630222

Sanchirico, J. N., & Wilen, J. E. (1999). Bioeconomics of Spatial Exploitation in a Patchy Environment. *Journal of Environmental Economics and Management*, *37*(2), 129–150. https://doi.org/10.1006/jeem.1998.1060

Sanchirico, J. N., & Wilen, J. E. (2001). A bioeconomic model of marine reserve creation. *Journal of Environmental Economics and Management*, *42*(3), 257–276. https://doi.org/10.1006/jeem.2000.1162

Sheherazade, & Tsang, S. M. (2015). Quantifying the bat bushmeat trade in North Sulawesi, Indonesia, with suggestions for conservation action. *Global Ecology and Conservation*, *3*, 324–330. https://doi.org/10.1016/j.gecco.2015.01.003

Singh, I., Squire, L., & Strauss, J. (1986). A survey of agricultural household models: Recent findings and policy implications. *World Bank Economic Review*, *1*(1), 149–179. https://doi.org/10.1093/wber/1.1.149

Skonhoft, A. (1999). On the optimal exploitation of terrestrial animal species. *Environmental and Resource Economics*, *13*(1), 45–57. https://doi.org/10.1023/A:1008261206811

Speers, A. E., Besedin, E. Y., Palardy, J. E., & Moore, C. (2016). Impacts of climate change and ocean acidification on coral reef fisheries: An integrated ecological-economic model. *Ecological Economics*, *128*, 33–43. https://doi.org/10.1016/j.ecolecon.2016.04.012

Swallow, S. K. (1990). Depletion of the environmental basis for renewable resources: The economics of interdependent renewable and nonrenewable resources. *Journal of Environmental Economics and Management*, *19*(3), 281–296. https://doi.org/10.1016/0095-0696(90)90074-9

Taylor, J. E., & Adelman, I. (2003). Agricultural Household Models: Genesis, Evolution, and Extensions. *Review of Economics of the Household*, *1*, 33–58. https://doi.org/https://doi.org/10.1023/A:1021847430758

Tháy, P. T. T., Flaaten, O., & Skonhoft, A. (2019). Middlemen: Good for resources and fishermen? *Environment and Development Economics*, *24*(5), 437–456.

https://doi.org/10.1017/S1355770X19000196

UNEP-WCMC; IUCN; and NGS. (2018). Protected Planet Report 2018. In *United Nations Environment Programme - World Conservation Monitoring Centre (UNEP-WCMC) International Union for the Conservation of Nature (IUCN) & (NGS)*. https://livereport.protectedplanet.net/pdf/Protected_Planet_Report_2018.pdf

Van Vliet, N., Muhindo, J., Nyumu, J. K., & Nasi, R. (2019). From the forest to the dish: A comprehensive study of the wildmeat value chain in Yangambi, Democratic Republic of Congo. *Frontiers in Ecology and Evolution*, *7*(APR). https://doi.org/10.3389/fevo.2019.00132

Veríssimo, D., Schmid, C., Kimario, F. F., & Eves, H. E. (2018). Measuring the impact of an entertainment-education intervention to reduce demand for bushmeat. *Animal Conservation*, *21*(4), 324–331. https://doi.org/10.1111/acv.12396

Watson, J. E. M., Dudley, N., Segan, D. B., & Hockings, M. (2014). The performance and potential of protected areas. *Nature*, *515*(7525), 67–73. https://doi.org/10.1038/nature13947

Wicander, S., & Coad, L. (2018). Can the Provision of Alternative Livelihoods Reduce the Impact of Wild Meat Hunting in West and Central Africa? *Conservation and Society*, *16*(4), 441–458. https://doi.org/10.4103/cs.cs_17_56

Wilkie, D. S., & Godoy, R. A. (2001). Income and price elasticities of bushmeat demand in lowland Amerindian societies. *Conservation Biology*, *15*(3), 761–769. https://doi.org/10.1046/j.1523-1739.2001.015003761.x

Wilkie, D. S., Starkey, M., Bennett, E. L., Abernethy, K., Fotso, R., Maisels, F., & Elkan, P. (2006). Can taxation contribute to sustainable management of the Bushmeat Trade? Evidence from Gabon and Cameroon. *Journal of International Wildlife Law and Policy*, *9*(4), 335–349. https://doi.org/10.1080/13880290601039287

Wright, J. H., Hill, N. A. O., Roe, D., Rowcliffe, J. M., Kümpel, N. F., Day, M., Booker, F., & Milner-Gulland, E. J. (2016). Reframing the concept of alternative livelihoods. *Conservation Biology*, *30*(1), 7–13. https://doi.org/10.1111/cobi.12607

Wright, J. H., Malekani, D., Funk, S. M., Ntshila, J., Mayet, L., Mwinyihali, R., Fa, J. E., & Wieland, M. (2022). Profiling the types of restaurants that sell wild meat in Central African cities. *African Journal of Ecology*, *60*(2), 197–204. https://doi.org/10.1111/aje.12993