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Research

Who gets to eat wild fish and meat? A socially disaggregated analysis of wild animal consumption across diverse rural environments in five countries of the Global South

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ABSTRACT. Wild fish and meat (WFM) are vital provisioning ecosystem services in tropical regions, supporting food security, livelihoods, and cultural identity. Yet their use increasingly intersects with conservation and nutrition challenges amid rapid social and ecological change. Actors engaged in WFM span a wide spectrum, from rural subsistence consumers to commercial harvesters and urban consumers for whom WFM represents a luxury good. Understanding this social differentiation is essential for developing conservation and nutrition policies that are both equitable and sustainable. Using data from approximately 2000 households across 40 settlements in two regions, the Amazon Rainforest (AR: Colombia, Peru) and East African Savannas (EAS: Malawi, Mozambique, Kenya), we modeled how settlement-level (urban connectivity, proportion of uncultivated area) and household-level (income, livelihood activity) factors influenced the likelihood of consuming wild meat, fish, and domestic meat within a week. WFM consumption varied widely across sites, reflecting distinct ecological and cultural contexts. Fish was consumed more frequently than wild meat, underscoring its central nutritional role. In AR, wild meat was more common in remote settlements, whereas in EAS it played dual roles: a subsistence food in poorer, remote areas and a luxury item among wealthier, more urban-connected households. Consumption patterns further revealed that wild meat in AR, and fish and domestic meat in EAS, were normal goods, with their likelihood of consumption increasing with income. Domestic meat intake rose with urban proximity, consistent with the global "nutrition transition." Yet concurrent consumption of wild and domestic proteins within settlements suggests complementarity rather than substitution. Overall, spatial and economic access to markets and landscapes, rather than culture alone, shaped animal protein use in tropical rural areas. WFM remains a critical yet evolving dietary component. Policies reconciling biodiversity conservation with nutrition security should integrate sustainable fisheries and community-based wildlife management while ensuring equitable access to diverse animal and plant proteins within local food systems.

Key Words: *consumption; fish; multi-country dataset; nutrition transition; wild meat*

INTRODUCTION

Wild fish and meat (WFM) sustained by local land-, water-, and seascapes are important provisioning ecosystem services, providing livelihoods and income as well as animal protein and micronutrients to the diets of hundreds of millions of people, particularly in the developing world (Sarti et al. 2015, Lynch et al. 2017, Nielsen et al. 2018). Simultaneously, wild meat consumption and trade pose a grave threat to many species and ecosystems and are a leading cause of extinctions in many contexts (Abernethy et al. 2013, Lindsey et al. 2013, Ripple et al. 2016, Benítez-López et al. 2017). Similarly, conservation concerns related to overfishing and the targeting of vulnerable species have intensified in recent decades (Pomeroy 2012, McIntyre et al. 2016), and even small-scale fisheries are known to contribute to overexploitation and aquatic ecosystem degradation (Gough et al. 2020). Hunting, trade, and consumption of wild meat also increase the risk of zoonotic disease transmission (Magouras et al. 2020).

At the same time, the nature of WFM use is changing within rapidly evolving economic, ecological, and social contexts. Land use change, resource extraction, infrastructure development and urbanization are reshaping food systems (Antunes et al. 2025), increasing market access and driving the commercialization of food sources (de Bruin et al. 2021, Rahbarinejad et al. 2025). As households become more connected to urban centers, WFM may shift from a primarily subsistence resource to a traded commodity, with implications for consumption patterns and sustainability. Yet the role of WFM within these transforming food systems, and its relationship with household income and access to alternative foods, remains poorly understood (Halpern et al. 2019, Ingram 2020). This highlights the need for a more nuanced understanding of how urban connectivity and socioeconomic change influence WFM consumption.

One way to address unsustainable WFM use is to understand who consumes it, why, and what alternatives are available across different levels of income and market access (Ingram et al. 2021). As with other ecosystem services, the value of WFM to human well-being depends on who benefits, and on the needs and aspirations of those beneficiaries (Daw et al. 2011, Fisher et al. 2014). If WFM is primarily consumed by wealthier households with access to alternative foods, its contribution to food security may be limited. In contrast, for poorer and more marginalized

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households, often excluded from market-based food systems, locally accessible WFM, whether harvested, shared, or affordably purchased, can be nutritionally vital (Roche et al. 2007, van Vliet et al. 2015, Reyes-García et al. 2019).

Literature suggests multiple mechanisms through which changing economic and environmental conditions, and increasing market and urban connectivity, shape WFM consumption. On one hand, communities may experience a "nutrition transition," in which traditional, locally sourced foods, including wild animals, are replaced by imported, domesticated, and often cheaper mass-produced meats as societies globalize (Piperata et al. 2011, van Vliet et al. 2015, Reyes-García et al. 2019, Donders and Barriocanal 2020). This shift, particularly near urban centers, may result from livelihood diversification (Chaves et al. 2017) and increased cash income that enables food purchases or buffers seasonal shortages (Turner et al. 2007, Mugido and Shackleton 2017, Torres-Vitolas et al. 2019). WFM consumption may also decline where ecosystem degradation reduces wild animal availability (Broegaard et al. 2017, Antunes et al. 2025; "uncultivated area" hypothesis, Table 1).

Conversely, improved urban connectivity can increase WFM demand, as growing urban populations and rising incomes drive commercial harvest and trade (Parry et al. 2014). In such cases, WFM may become more accessible through markets and more affordable with cash incomes, despite often being priced higher than substitutes because of transport costs, a pattern we term the "luxury food" hypothesis (Table 1). For example, catches from small-scale fisheries in remote areas frequently enter domestic or international markets as luxury products, such as sea cucumbers (Eriksson and Clarke 2015) and live reef fish (Warren-Rhodes et al. 2003).

At the household level, income, social status, livelihood, ethnicity, and education influence WFM consumption (Morsello et al. 2015, Merson et al. 2019, Walelign et al. 2019). Hunting and fishing livelihoods may increase access to WFM, whereas non-harvesting livelihoods, often associated with higher education, may reduce consumption by reallocating labor or shaping preferences (Bachmann et al. 2020). Depending on their income elasticity of demand, WFM may function as "inferior" or "normal" goods (Brashares et al. 2011; Table 1): consumption may decline with rising income if WFM are replaced by livestock or processed meats, or increase alongside income if demand grows with purchasing power. Because income often correlates with social status, livelihoods, and education, it is included here as a key household-level variable.

Compared to the moist forests of the Amazon and Congo basins, WFM trade in savanna habitats remains relatively understudied. Existing research indicates heavy commercial hunting in African savannas (Nielsen and Meilby 2015) alongside substantial wildlife declines (Lindsey et al. 2013). In the Amazon, urbanization and the expansion of industrial meat production are already reshaping diets and wild meat trade (van Vliet et al. 2015). Using data from the multi-country Nature4SDGs project (Poudyal et al. 2024), this study examines household-level WFM consumption across tropical savanna and rainforest landscapes. We assess how socioeconomic, spatial, and cultural factors shape consumption in contrasting ecological and development contexts, and whether wild-sourced meats are substituted by, or complement, domestic and market-based meats (Table 1). In doing so, we contribute evidence on the role of WFM within rapidly transforming regional food systems.

METHODS

Study sites and sampling

We used data from pre-existing household surveys conducted between 2011 and 2015 that were compiled as part of the research project Nature's Contribution to Poverty Alleviation, Human Well-being and the Sustainable Development Goals (Nature4SDGs; Pouydal et al. 2024). The objective of the project was to investigate the relationships between ecosystem services and multidimensional human well-being across countries in the Global South using datasets that collected comparable information on natural resource use, livelihoods, and human well-being. The settlements included in the present study are a subset of those compiled under the Nature4SDGs project for which data on household consumption of wild meat, fish, and domestic meat were available. Our combined dataset included 2287 household surveys from 40 settlements across eight sites in five countries within two regions, namely the East African savanna (EAS; Kenya, Mozambique, and Malawi) and the Amazon Rainforest (AR; Colombia and Peru; Fig. 1). Settlements had varying degrees of dependence on natural ecosystems (rainforests, woodlands, inland and coastal fisheries; Table 2). In the original studies, settlements were deliberately chosen based on study objectives, so we evaluated their representativeness along remoteness and naturalness gradients, key factors influencing wild resource use (Brashares et al. 2011). Except for one peri-urban area, our settlements were mostly rural, spanning these gradients. This sample enables comparative analysis of wild and domestic meat consumption across diverse tropical social-ecological contexts. Within each settlement, household surveys were conducted randomly or adjusted to correct bias (see Appendix 1 (b)). Details on site selection, sampling, survey dates, and taxa consumed are provided in Table 2.

Household surveys

Consumption

Data on whether wild meat, fish and domestic meat (beef/goat/pork/poultry) were consumed within the past seven days (binary: Yes/No) was extracted from individual project datasets. Surveys in Colombia, Peru, and Malawi asked whether different meat types (including fish) had been consumed in the past seven days. In Kenya, surveys asked when meat and fish were last eaten, from which we determined consumption in the past seven days. In Mozambique, data on frequency of consumption within the past month was converted to frequency per week by dividing by four; if this was > 0.75 then consumption within the past seven days was coded as "Yes," if < 0.75 then coded as "No" (for further details on survey questions see Appendix 1 (c)).

Other household variables

From the household surveys, we extracted data on (a) household income, and (b) WFM harvesting activity (i.e., whether the household engaged in hunting and fishing activities). Household income was measured as gross income from all livelihood and subsistence activities in the past year as reported by households in the surveys. Income was defined as total earnings from:

Table 1. Variables used and hypotheses tested to explain variation in wild fish and meat (WFM) consumption across settlements and households within settlements.

Variable	Hypothesis
Settlement level	
% of natural/ uncultivated area in the landscape (i.e., all non-cultivated lands including water bodies)	*Uncultivated area hypothesis*: Given access, WFM consumption of households increases with increasing availability of uncultivated area around the settlements (habitat for wild animals and fish).
Travel time to nearest urban center (proxy for market access)	*Nutrition transition hypothesis*: Greater market access (= less travel time) leads households to consume less WFM, as these foods are replaced by livestock meats that become more affordable and increasingly favored. *Luxury food hypothesis*: Greater market access (= less travel time) increases consumption of WFM because of greater availability through markets. Income may interact with market access such that poorer households are more likely to consume WFM in remote settlements, while wealthier households consume more WFM in less remote settlements because of commercialization and higher prices.
Household level	
Gross income of household in the past 12 months in purchasing power parity US$ (proxy for wealth)	*Inferior good hypothesis*: Wildlife is a cheap and accessible food source for poorer households; therefore, lower-income households are more likely to consume WFM than higher-income households. Sub-hypotheses: *Income-related substitution*: Higher-income households substitute WFM with higher-value domestic meats, implying a negative association between WFM consumption and income and a positive association between domestic meat consumption and income. *Stacking*: Domestic meats are added to, rather than substitute diets that include WFM, implying no association between WFM consumption and income and a positive association between domestic meat consumption and income. *Normal good hypothesis*: Consumption of WFM increases with household income, implying a positive association between WFM consumption and income.
Consumption of domestic meat by the household in the past seven days (Yes/No)	*Negative association*: Consumption of domestic meat is negatively associated with consumption of WFM after controlling for other settlement and household variables. *Positive association*: Consumption of domestic meat and WFM are positively associated.
Consumption of fish by the household in the past seven days (for the model on wild meat) (Yes/No)	*Negative association*: Consumption of wild meat is negatively associated with consumption of fish. *Positive association*: Consumption of wild meat is positively associated with consumption of fish.
Whether the household derived any income (including subsistence income) from (a) wild meat hunting, and (b) fishing	*Livelihood activity hypothesis*: (a) Harvesters of wild meat are more likely to consume wild meat than non-harvesters because of greater access. (b) Fishers are more likely to consume fish than non-fishers because of greater access.

direct (e.g., fuelwood) or derived (e.g., rope) products from wild harvests used for subsistence or sale + cultivated sources (agriculture, horticulture, aquaculture) + livestock + non-farm and non-wild harvest businesses such as small and medium enterprises, trading + wages from salaried jobs + remittances

Wild harvest included any harvest of food, fodder, fiber, or fuel from uncultivated resource systems around the settlement during the survey period. In case of wild harvested or cultivated products that were sold, we used annual harvest quantities and market price of each product to measure earnings. If prices were missing for a household, we assigned the median price of the product at the settlement level. In case of subsistence harvests or gifts, we imputed the prices from the median at the settlement level, from qualitative information or through consultation with site experts to derive their monetary value.

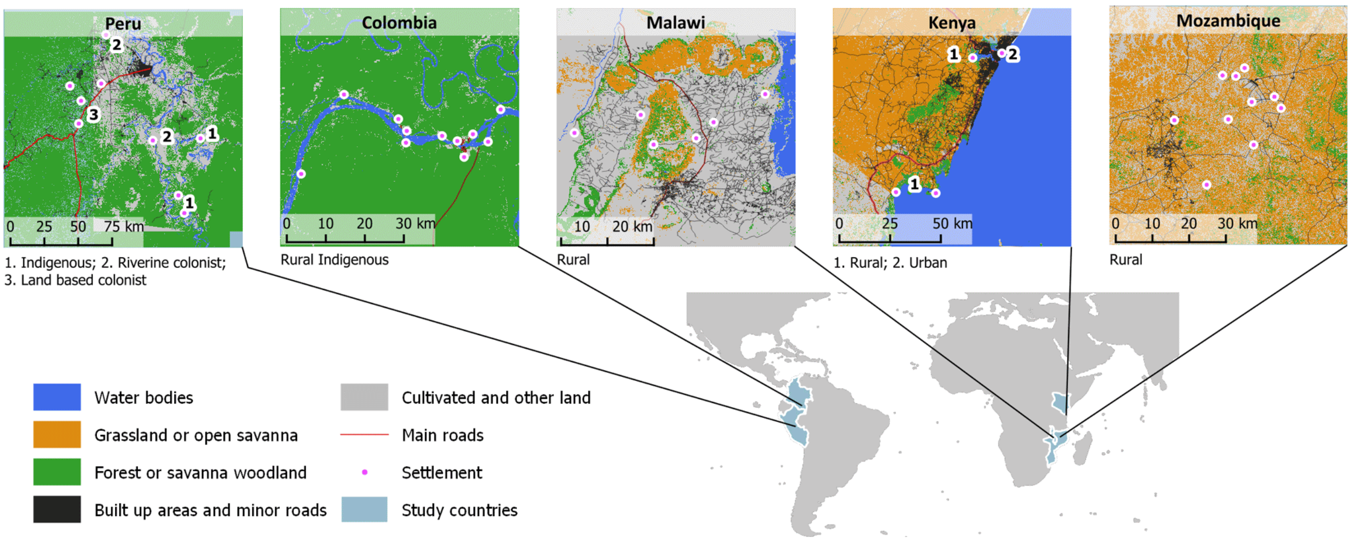
Because of a lack of robust data on labor and other input costs, aggregation of harvest values and other earnings give the total household gross income. To make the income estimates comparable across countries and years of survey, we converted the gross household income into US$ using World Bank indices of purchasing power parity in the year of the survey.

For WFM harvesting, we used data on household livelihood activities to determine whether the household derived any subsistence or sale income by harvesting wild meat (hunter, binary: Yes/No) or fish (fisher, binary: Yes/No) in the past year. Poudyal et al. (2024) provides further details on the methods of identification, processing, validation, and publication of the livelihood sources and income data used in this study.

Settlement-level social-ecological variables

We used global geospatial datasets to characterize the social-ecological context of each of the 40 settlements in the year of the survey. We used log-transformed travel time to the nearest urban center as a proxy for market access (Weiss et al. 2018), and percentage of uncultivated cover as proxy for wild animals and fish abundance. These were obtained within a simple circular buffer around the settlement centroid. The radius of the buffer was defined by the socially accessible land cover based on one typical day's return journey from the settlement, as informed by surveys and site descriptions, and ranging from 2 km to 7.5 km. To obtain the percentage of uncultivated land cover, we mapped land use land cover around each settlement (ESA 2016). We reclassified the land cover into a binary gridded dataset of natural/ uncultivated (forest, shrub, herbaceous, wetland, water bodies, ocean) and all other (non-natural) land classes and measured the percentage of uncultivated land cover within the buffer. Further explanation of the choice of these variables and circular buffer to measure land cover is provided in Appendix 1 (d).

Fig. 1. Map showing location of study sites and settlements within countries.



ANALYSES

Prevalence and means of access of consumption

This descriptive analysis was conducted at the site level (as mentioned in Table 2). From the consumption data in the household surveys, we extracted information on (i) proportion of households within a site that consumed wild meat, fish, and domestic meat in the past seven days, (ii) means of access of the meat types consumed across sites, i.e., whether gifted, harvested (in case of wild meat, fish), produced (in case of domestic meat), or purchased from a seller/at a market. Additionally, we obtained qualitative knowledge from site experts on the nature and extent of WFM harvest and consumption.

Settlement and household-level variation in consumption

We assessed settlement and household-level variation in consumption of WFM and domestic meat guided by our hypotheses (Table 1). For both EAS and AR, we performed three mixed-effects binary logistic regressions to model the probability that households consumed fish, wild meat, and domestic meat during the previous seven days. The regression equation can be written in R as:

glmer (wild fish, wild meat, domestic meat ~ HH level variables + settlement level variable + interaction term (HH income*settlement level variable) + country + (1| country: settlement), family = binomial)

Because the households were nested within settlements located in different countries, we modeled the random differences between settlements as random intercepts. As there were few "country" levels in our data, we deemed it inappropriate to model these as a random effect. Instead, we added "country" as a fixed factor because we expected there to be significant differences between countries. So, our model structure "country + (1|country: settlement)" specifies fixed effect of "country" plus random variation in intercept among settlements within countries. It should be noted that our settlements are not representative of the countries and it would be erroneous to treat them as though they capture "country" contexts. Hence, the "country" variable accounts for all the unobserved group-level variation above the level of settlements.

We observed correlations between the settlement level independent variables (unsurprisingly, extent of uncultivated area and travel time to urban center were correlated; Appendix 1 (e)), preventing us from distinguishing between the "uncultivated-area" and "nutrition-transition" hypotheses. We selected uncultivated area for wild meat and travel time for fish and domestic meat to represent these correlated variables, based on lower Akaike's Information criterion values. We also tested for interaction between household income and the settlement level variable, using likelihood ratio tests to assess the significance of the interaction term and select the final model.

We performed model checks using the DHARMa package in R (Hartig 2022). For the random variation between settlements, we measured the intraclass-correlation coefficient (ICC) using the icc () function in performance package in R (Lüdecke et al. 2021). The ICC is a measure of the proportion of the variance explained by the grouping structure in the population (Nakagawa and Schielzeth 2010) and ranges from 0, if the grouping conveys no information, to 1, if all observations in a group are identical.

RESULTS

Prevalence and means of access of consumption

Proportion of households that consumed wild meat, fish, and domestic meat in the past seven days varied across sites (Fig. 2a), reflecting the various social-ecological settings of the sites such as type of ecosystem (coastal vs. inland), community composition (indigenous vs. non-indigenous), rurality (rural vs. urban), or condition of ecosystem (Table 2). Generally, consumption of fish was much more common (44% at Kenya urban coast, 90% at Mozambique rural) than wild meat (0% at Kenya urban coast, 56% at Colombia indigenous), while domestic meat consumption varied between 10% (Kenya rural coast) to 91% (Peru land-based colonist).

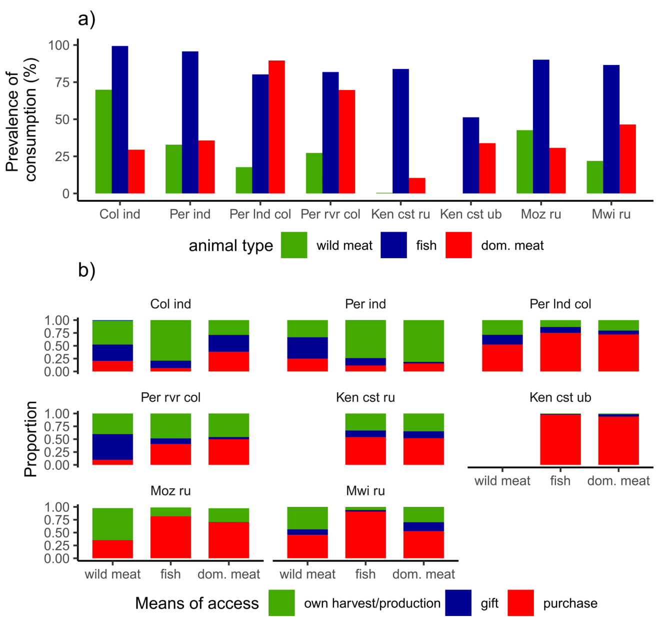
Table 2. Sampling strategy, and a description of the social-ecological context and nature of harvest and consumption of wild fish and meat across study sites.

Country: site	Site selection and social-ecological setting	Nature of harvest and consumption of fish	Nature of harvest and consumption of wild animals	No. of settlements; No. of HH; HH sampling strategy	Date of HH surveys	Species reported to be consumed
Kenya: coastal rural	Purposive selection of coastal communities with access to nearshore fishing grounds and some areas of mangrove and coastal forest, Fisheries and agriculture are primary livelihoods.	Locally caught marine fish (demersal and pelagic) widely consumed.	Very limited and sporadic consumption of terrestrial animals due to low wildlife populations and the local religion and culture (coastal and mostly Islamic). Anecdotal evidence of consumption of wild goats.	3; 459; random sampling	Mar 2012–Jul 2012	An unknown species of wild meat, turtle, more than 100 local names of fish
Kenya: coastal urban	Suburb of a large coastal city. Livelihoods are generally not natural-resource dependent, e.g., informal labor, trade, etc.	Small-scale fishing conducted in coastal waters. Locally caught marine fish consumed alongside marine fish imported from other sites, or from inland aquaculture (tilapia) and fisheries (Nile perch).	No known consumption of wild terrestrial animals.	1; 351; random sampling	Mar 2012–Jul 2012	No wild meat reported, around 30 local names of fish
Mozambique: rural	Villages selected at different intensities of the dominant land use (smallholder production of crops such as soya, pulses, sunflower) in the Gurué District in Zambezia Province. Rural with access to miombo woodlands. Subsistence and commercial smallholder crop production.	Access to almost perennial streams. Access to markets for traded fish. High consumption of fish.	Agriculture expansion frontier so many big to medium sized mammals are rare. Local hunters still hunt regularly for small mammals like rabbits, hare, squirrels, cane rats, elephant shrews, and common duikers. Some hunting of bigger animals, duikers, impala, bushbuck, and Kudus, in the forests in the hills that were relatively less disturbed and had more animals.	10; 638; stratified random sampling based on wealth categories with the aim of oversampling the rich and very poor households	Aug 2015–Dec 2015	Primarily rodents, gazelle, wild rabbit, wild pig, hare, monkey, reedbuck, mongoose, elephant shrew or sengi, wild birds, more than hundred varieties of fish
Malawi: rural	Sites were selected along a gradient of woody vegetation cover and deforestation from Lake Chilwa in the east, through and beyond the Zomba forest reserve in the west in Zomba District, southern Malawi. Rural rain-fed agriculture. Reliance on forests and wetlands (fishing is a central livelihood strategy in the village next to Lake Chilwa). Natural ecosystems have undergone significant degradation.	Commercial (regulated by govt.) and artisanal (limited regulation) fishing in the village next to Lake Chilwa. Local freshwater fish was mostly consumed (tilapia). Fish consumption combined self-consumption and small-commercial extraction depending on availability / season in wetland areas. Fishing stocks are decreasing because of decreasing water levels in Lake Chilwa and associated rivers.	Wildlife is largely depleted in the area from significant deforestation though small game and insects thrive well in agroecosystems. Formally, access is regulated by the government. But unclear how well restrictions are implemented because forest reserves endure encroachment. Opportunistic / sporadic hunting of minor species (e.g., birds, presence of a large Lake Chilwa attracted migratory and resident water birds) mainly for self-consumption.	6; 484; systematic random sampling	May 2014–Jan 2015	Small wild animals such as mice, hare, and duiker, wild birds, around 30 local names of fish, termites, or other insects
Colombia: indigenous	Purposive selection of remote indigenous Amazonian communities located in the Lower Caquetá River Basin, tributary of the Amazon River, in the Department of Amazonas. High forest cover. Slash and burn agriculture, natural resources harvesting.	Major stocks of freshwater fish accessible to community members. Indigenous control and regulation of fishing. Very frequent fishing and consumption by most households.	Significant wildlife still exists. Indigenous control and regulation of hunting. Frequent hunting and consumption.	11; 156; full census	Dec 2013–Mar 2014	Peccary, tapir, agouti, lowland paca, armadillo, giant anteater, capybara, South American coati, brocket deer, parrots, curassow, Undulated Tinamou, Gray-winged Trumpeter, caimen, Arrau turtle, Taricaya turtle, red-footed or morrocoy tortoise, around 50 local names of fish, palm grubs, ants
Peru: indigenous	Purposive selection of rural indigenous communities in the Ucayali region in the Peruvian Amazon with access to seasonally flooded tropical forest. Agricultural production, artisanal fishing, minor hunting, and trading activities.	Major stocks of freshwater fish accessible to community members. No formal restrictions at the time. Fish extracted mostly for small-scale trading, self-consumption, and exchanges / gifts.	Limited stocks of minor game (i.e., small mammals) obtained from local forest areas. No restrictions in place to community members. Sporadic small-scale trading activities. Most extraction was for self-consumption and exchanges / gifts.	3; 70; random sampling	Dec 2014–Apr 2015	Deer, paca, armadillo, monkeys, peccary, agouti, tapir, heron, Spix's guan, wild duck, variety of fish
Peru: land based colonist	Purposive selection of rural roadside communities in the Ucayali region in the Peruvian Amazon with access to tropical forest. Commercial agriculture, logging, hunting, and fishing.	Major stocks of freshwater fish accessible to colonists. No formal restrictions were in place at the time. Fish was extracted mostly for small-scale trading and self-consumption.	Limited stocks of minor game (i.e., small mammals) obtained from colonists' private forest areas and some communal riparian forest areas. No restrictions in place as long as within hunter's private landholdings or communal areas. Hunting activities were sporadic, combining opportunistic and recreational activities. Most extraction was for self-consumption and exchanges / gifts.	4; 96; random sampling	Dec 2014–Apr 2015	armadillo, paca, peccary, agouti, trogon, variety of fish

(con'd)

Peru: riverine colonist	Purposive selection of rural riverside communities in the Ucayali region in the Peruvian Amazon with access to tropical forest. Commercial agriculture, logging, hunting and fishing.	Major stocks of freshwater fish accessible to community members. No formal restrictions at the time. Fish extracted mostly for small-scale trading, self-consumption, and exchanges / gifts.	Limited stocks of minor game (i.e., small mammals) obtained from local forest areas (both private and community areas). No restrictions to community members were in place at the time (aside from not hunting in other people's private forest areas). Hunting involved occasional small-scale trading. However, most extraction was for self-consumption and exchanges / gifts.	2; 33; random sampling	Dec 2014–Apr 2015	Paca, armadillo, monkey, wild duck, some species of fish, grubs

Fig. 2. Site wise prevalence and means of access of wild meat, domestic meat and fish. (a) Prevalence of consumption, i.e., % of households that consumed wild meat, fish, and domestic meat in the past seven days. (b) Means of access of wild meat, fish, and domestic meat consumed by households in the past seven days, i.e., whether harvested (in case of wild meat/fish) or own production (in case of domestic animals) by the household, gifted by someone, or purchased. Barplots show the proportion of consumption events. Key: Col ind = Colombia - indigenous, Per ind = Peru indigenous, Per lnd col = Peru land colonist, Per rvr col = Peru riverine colonist, Ken cst ru = Kenya coastal - rural, Ken cst ub = Kenya coastal - urban, Moz ru = Mozambique rural, Mwi ru = Malawi rural; dom. meat = domestic meat.



We found variation in how wild meat, fish, and domestic meat were obtained by households across sites (Fig. 2b). For domestic meat, purchase (varied between 15.6% of consumption events at Peru indigenous to 94% at Kenya coastal - urban) appeared to be the most important source at most sites, followed by own production (1.4%–81.2%). For fish, markets were the major source in most sites (6.7%–97.8%) followed by own harvest (1%–78.9%). For wild meat, own harvest (28.6%–62.3%) or gifts (0.2%–50%) were as much, or more important sources across sites than markets/purchase (10%–52.4%). There were also regional differences. Purchase appeared more common in EAS whereas own harvest/production or gifts were more common in AR.

Settlement and household-level variation in consumption

We did not detect any misspecification problems in our models (Appendix 1 (f)).

Wild meat

We found similar impacts of drivers on probability of wild meat consumption in EAS and AR. In case of AR, a doubling of income increased the odds of wild meat consumption by 14.1% (95% CI [1%, 29.3%]), while a 1% increase in proportion of uncultivated area in the landscape increased it by 2.5% (95% CI [1%, 3.9%]). In case of EAS, we found a statistically significant negative interaction effect between household income and proportion of uncultivated area on consumption of wild meat (*coefficient* = -0.57, P = 0.01). This implies that the likelihood of wild meat consumption rose with household income in settlements with less uncultivated area in the landscape (i.e., closer to urban centers). However, in settlements with a higher proportion of uncultivated area, the relationship between income and wild meat consumption became more equitable or even reversed (see Fig. 3g). Conversely, the probability of wild meat consumption increased as the proportion of uncultivated area increased, particularly among lower income households. Consumption of domestic meat in the past seven days was associated with an increase in odds of wild meat consumption by 66% in EAS (95% CI [24.6%, 121.1%]), and by 344% or 4.4 times in AR (95% CI [2.3, 8.7]). Fish consumption was not statistically significantly associated with wild meat consumption in both regions. Being a hunter tripled the odds of wild meat consumption in EAS (3.3 times, 95% CI [2.2, 5.2]) and more than doubled it in AR (2.6 times, 95% CI [1.4, 4.7]). Households in Mozambique and Malawi were much more likely to consume wild meat than Kenyan households, which were coastal (see Table 2 and discussion). No statistically significant difference was detected between households in Colombia and Peru (Table 3, Fig. 3).

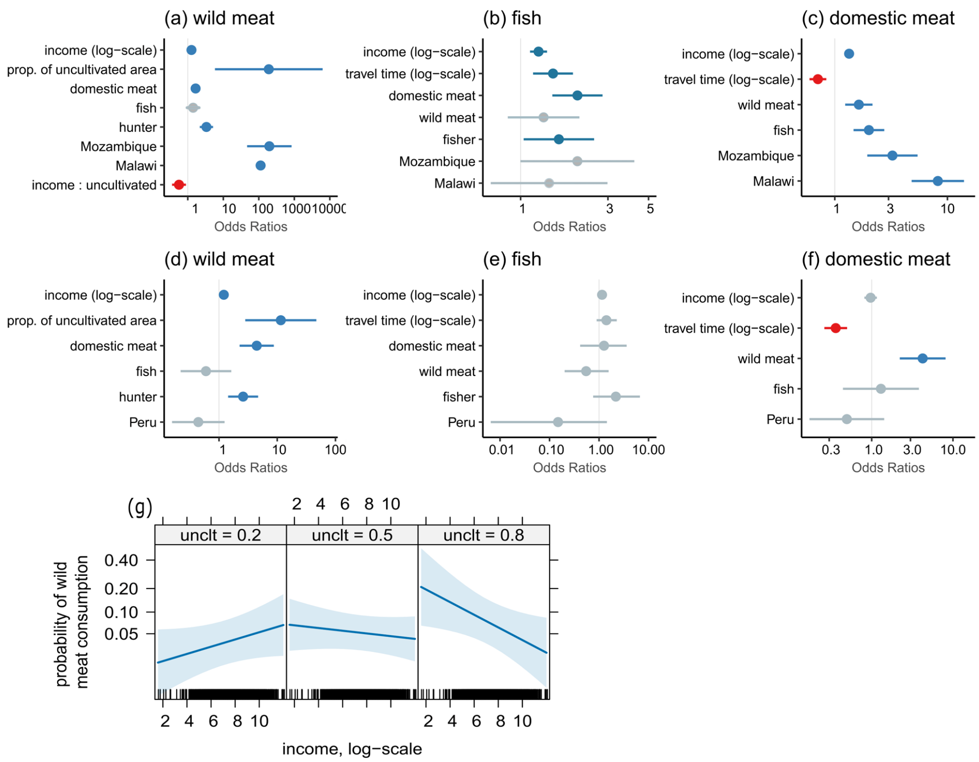
Fish

In EAS, every doubling of income increased the odds of fish consumption by 16.9% (95% CI [8.6%, 25.9%]), while every doubling of travel time to the nearest urban center increased it by 32.6% (95% CI [11.5%, 57.8%]). Consumption of domestic meat doubled the odds of fish consumption in EAS (increased by 104.4%, 95% CI [49%, 180.2%]), and being a fisher increased the odds of fish consumption by 61.8% (95% CI [3.9%, 152%]). We did not detect impact of any drivers on fish consumption in the Amazonian sites. The differences between countries within regions were not statistically significant (Table 3, Fig. 3).

Domestic meat

We found a statistically significant impact of income on domestic meat consumption only in EAS, where doubling of income increased the odds of consumption by 22.5% (95% CI [15.2%, 30.2%]). Every doubling of travel time to the nearest urban center

Fig. 3. Odds ratios from the mixed effects logistic regression models of consumption of wild meat, fish, and domestic meat in the past seven days are shown with respect to household and settlement level independent variables. Red and blue colors refer to negative and positive raw regression coefficients (i.e., log of odds ratios), respectively, and grey indicates non-significance. Plots are shown for east African savanna (a–c) and Amazon rainforest (d–f). Plot (g) shows the interaction effects of income and proportion of uncultivated area on probability of wild meat consumption in east African savanna.



decreased the odds of domestic meat consumption by 21.3% in EAS (95% CI [11.3%, 30.1%]), and by 50.6% in AR (95% CI [38.3%, 60.5%]). Odds of domestic meat consumption increased with consumption of both wild meat (by 63.5%, 95% CI [23.7%, 161.1%]) and fish (by 100%, 95% CI [46.8%, 174.9%]) in EAS, while in AR, a positive and statistically significant association was found only with wild meat (increased by 323.9%, 95% CI [121.6%, 711%]). Households in Mozambique were 3.2 times and in Malawi 8.2 times more likely to consume domestic meat as compared to Kenya (Table 3, Fig. 3).

The unadjusted ICC, which accounts for the variance explained by the fixed effects, was 0.007 (0.7%) and 0.046 (4.6%) for the wild meat and fish consumption models in EAS, and 0.015 (1.5%) for the wild meat model in AR. These low ICC values indicate that only a small proportion of the total variance was attributable to differences among settlements, suggesting little random variation between settlements.

DISCUSSION

Prevalence and means of access of consumption of WFM across sites

WFM consumption varied in prevalence across sites, reflecting different social-ecological contexts (*personal communication* with site experts). High WFM consumption occurred in Neotropical sites (Colombia, Peru), especially in indigenous communities because of their significant reliance on natural resources including wild animals and fish (Porro et al. 2015). Fish consumption was higher than wild meat at almost all sites, underscoring its importance in food systems. For example, Kenya's rural coast showed high fish intake linked to coastal resources and Swahili fishing culture, paired with low wild and domestic meat consumption. In contrast, the peri-urban Mombasa suburb had the lowest fish consumption, possibly because of less fish availability and greater ethnic diversity. Inland rural Malawi and Mozambique also had high fish consumption, highlighting the importance of inland fisheries, aquaculture (O'Meara et al. 2021), and regional fish trade (Mussa et al. 2017). Wild meat was rare in Malawi, where villages lacked natural forests.

We found variation across sites and meat types in how WFM was sourced. Purchase and gifting played key roles, meaning beneficiaries extended beyond hunters, fishers, or livestock keepers. Except for indigenous Amazonian sites, domestic meat and fish were more market-based, while wild meat was often harvested or gifted. This supports findings that wild meat is commonly gifted, possibly helping poorer households access it (de Merode et al. 2004, Carignano Torres et al. 2021). Sharing gifts of fish was also reported as important for social relationships in coastal Kenya. The relational nature of gifting shows that wild meats (and to some extent fish, Chaigneau et al. 2019) support relational well-being as well as nutrition and income, bridging the cultural and provisioning categories of ecosystem services (Delisle et al. 2018, Carignano Torres et al. 2021).

Table 3. Coefficients of mixed effects logistic regression models of consumption of wild meat, fish, and domestic meat in the past seven days with respect to household and settlement level independent variables (as mentioned in Table 1). Country differences are reported relative to Kenya for African savanna and Colombia for Amazon rainforest.

	East African savanna				Amazon rainforest			
	Coefficient	SE	z value	*P*	Coefficient	SE	z value	*P*
Wild meat								
Intercept	-8.64	1.19	-7.26	< 0.001	-3.14	1.09	-2.87	0.004
Income (log-scale)	0.24	0.12	2.07	0.039	0.19	0.09	2.06	0.04
Domestic meat	0.51	0.15	3.46	< 0.001	1.49	0.35	4.32	< 0.001
Fish	0.35	0.24	1.45	0.15	-0.52	0.51	-1.01	0.312
Hunter	1.21	0.22	5.49	< 0.001	0.95	0.3	3.15	0.002
Proportion of uncultivated area	5.25	1.78	2.95	0.003	2.44	0.72	3.41	< 0.001
Mozambique	5.29	0.74	7.19	< 0.001				
Malawi	4.73	0.8	5.9	< 0.001				
Peru					-0.82	0.53	-1.55	0.122
Income: prop. of uncultivated area	-0.57	0.23	-2.48	0.01				
Fish								
Intercept	-1.83	0.61	-3	0.003	0.77	2.18	0.35	0.724
Income (log-scale)	0.22	0.05	4.13	< 0.001	0.14	0.1	1.37	0.17
Domestic meat	0.71	0.16	4.44	< 0.001	0.23	0.54	0.43	0.671
Wild meat	0.29	0.23	1.26	0.209	-0.6	0.52	-1.17	0.244
Fisher	0.48	0.23	2.13	0.033	0.78	0.55	1.42	0.157
Travel time (log-scale)	0.41	0.13	3.18	0.001	0.34	0.24	1.44	0.15
Mozambique	0.71	0.37	1.95	0.051				
Malawi	0.36	0.37	0.96	0.339				
Peru					-1.91	1.26	-1.51	0.131
Domestic meat								
Intercept	-3.74	0.48	-7.83	< 0.001	6.51	1.46	4.46	< 0.001
Income (log-scale)	0.29	0.05	6.5	< 0.001	-0.03	0.09	-0.33	0.739
Fish	0.7	0.16	4.36	< 0.001	0.26	0.55	0.48	0.633
Wild meat	0.49	0.14	3.45	< 0.001	1.44	0.33	4.37	< 0.001
Travel time (log-scale)	-0.35	0.09	-3.94	< 0.001	-1.02	0.16	-6.19	< 0.001
Mozambique	1.18	0.26	4.49	< 0.001				
Malawi	2.11	0.27	7.72	< 0.001				
Peru					-0.7	0.54	-1.3	0.193

Conservation concerns

Across our study sites, pressures on fish and wildlife resources varied widely. In the Amazonian settlements, particularly in indigenous areas, resource use was largely subsistence-based and governed by community management systems, with no reports of poaching or overharvesting at the time of data collection. By contrast, nearshore reef fisheries in the Kenyan coastal sites, especially outside well-enforced protected areas, are widely considered overfished, with inconsistent enforcement of gear regulations (Samoilys et al. 2017). In settlements in Malawi, large wildlife has long been depleted by deforestation and habitat loss, though small game and insects remain common and are harvested opportunistically. In Mozambique, commercial pressure persists on high-value species, whereas smaller species that dominated wild food consumption in our surveys face relatively lower conservation risk. Across both regions, despite limitations in matching local names to specific species, several taxa we could reliably identify were classified as "Vulnerable" on the IUCN Red List, highlighting the need for ongoing monitoring of harvesting pressures across these diverse social-ecological contexts.

Settlement and household-level variation in consumption

Our study reveals strikingly similar patterns in the determinants of animal meat consumption across two ecologically and culturally distinct tropical regions: the Amazon Rainforest (AR) and the East African savannas (EAS). Despite their differences, the dietary choices in both regions appear to be influenced by a shared set of underlying economic and spatial dynamics, most notably proximity to urban centers, household income, and access to natural landscapes. By revealing consistent socioeconomic and spatial drivers in both rainforest and savanna systems, our findings suggest that common processes, rather than purely local factors, shape wild food use across the tropics. Furthermore, by integrating both terrestrial and aquatic sources across diverse tropical contexts, our analysis offers a more holistic understanding of wild food systems, linking their nutritional, cultural, and relational roles.

Nutrition transition and role of landscape and urban access

We observed that fish in EAS and wild meat in AR were more frequently consumed in remote settlements characterized by longer travel times to urban centers and a higher proportion of uncultivated land. This pattern was also evident for wild meat in poorer households in EAS. In contrast, domestic meat consumption was more prevalent closer to urban areas in both regions, consistent with findings from Gabon (Wilkie et al. 2005), Equatorial Guinea (Fa et al. 2009), and the Colombian Amazon (van Vliet et al. 2015). These spatial patterns reflect the global nutrition transition, where diets shift from traditional, wild-harvested foods to market-based and domestic animal meat as households gain better access to infrastructure and markets (Nasi et al. 2011, van Vliet et al. 2015, Kraft et al. 2018). It should be noted that nutritional transition is a temporal process. Our results rely on inter-site comparison at a point in time. Nonetheless, we detected similarities between our rainforest and savanna sites. The consistency of these trends across two disparate regions highlights the significance of economic and spatial factors in shaping rural diets. This has critical implications for conservation, as it suggests that transitions in food systems are not merely cultural or ecological, but also closely tied to infrastructure and land-use change. By explicitly linking dietary transitions to spatial and infrastructural factors, our study fills a gap in understanding how physical accessibility and land-use patterns mediate the nutrition transition in tropical regions, emphasizing how development pathways shape both diet and conservation outcomes.

Income, market integration, and shifting roles of wild meat

In AR, wild meat consumption increased with household income, suggesting that wild meat is a normal good. No significant income association was observed for fish or domestic meat in AR, potentially because of the widespread availability and cultural integration of fish in the Amazonian diet (Isaac et al. 2015), and of domestic meat among non-indigenous communities (Fig. 2a).

In contrast, in EAS, consumption of both fish and domestic meat increased with income, affirming their roles as normal goods. Interestingly, wild meat consumption in EAS followed a more nuanced pattern: it was higher among wealthier households in settlements closer to urban centers, while in more remote areas, poorer households consumed wild meat at similar or even higher levels. This suggests that wild meat may function as an inferior good in remote contexts, while retaining value as a luxury item in more urbanized settings, a dual role consistent with other findings (Fa et al. 2009, van Vliet et al. 2015, McNamara et al. 2019). As market access improves, higher-income households may choose to consume wild meat or fish not out of necessity but because of taste preferences, social status, or perceptions of quality (Chausson et al. 2019).

Previous studies have failed to detect a consistent relationship between income and consumption of wild meat and fish, highlighting the importance of site level variation (Wilkie and Godoy 2001, Apaza et al. 2002, Wilkie et al. 2005, Fa et al. 2009, Godoy et al. 2010, Rentsch and Damon 2013, McNamara et al. 2019). Several factors, including market integration, landscape access, wildlife populations, and cultural preferences (e.g., indigenous vs. non-indigenous) mediate the relationship by influencing prices and desirability. Our study adds new nuance through the explicit modeling of interaction effects while simultaneously assessing two disparate regions, i.e., South America and Africa. Taken together, our findings reinforce the broader consensus that income and urban proximity are key drivers of animal protein consumption, but they also highlight important contextual variation.

Moreover, the type and value of animal protein consumed can vary substantially by income group. Lower-income households may rely more on locally available, low-cost species such as insects, snails, or small fish, while wealthier households are more likely to access high-value species like antelope, aardvark, or large fish such as Nile perch, species that may also be traded in domestic or international markets and function as luxury goods (Drury 2011). Over time, as high-value species become depleted, there is often a shift toward the exploitation and commercialization of lower-value species (Scales et al. 2006), further complicating the income-consumption relationship.

Livelihoods as determinants of consumption

We found that hunting and fishing households in EAS were significantly more likely to consume wild meat and fish, respectively, while in AR, only hunting households showed elevated wild meat consumption. The lack of association between fishing households and fish consumption in AR likely reflects the already high baseline prevalence of fish consumption across households in this region. These results reinforce the importance of subsistence livelihoods in shaping dietary choices and highlight the need to consider hunting and fishing households as key targets for both food security and biodiversity conservation strategies.

Wild and domestic meat sources as dietary complements

Interestingly, we also found that, after accounting for household income and proximity to urban areas, recent consumption of domestic meat was positively associated with the likelihood of consuming wild meat and fish in EAS, and wild meat in AR. This suggests that these meat sources may not function strictly as substitutes, but rather as complementary components of household diets. Some households may have a higher preference or capacity for animal meat in general and thus pursue multiple sources simultaneously. Alternatively, shared social or economic factors, such as food sharing networks, cultural preferences, or festive events, may drive concurrent consumption of both wild and domestic meats (Golden et al. 2011, Coad et al. 2019). This underscores the importance of considering both substitution and complementarity in designing policies to reduce unsustainable wildlife consumption.

A few caveats to our study should be acknowledged. First, our response variable was limited to reported consumption within the seven days preceding the survey, during a specific season. Seasonal and other temporal fluctuations in the availability of wild animals, agricultural products, and labor can influence WFM consumption patterns. Moreover, we did not capture variation in the types or quantities of WFM species consumed. Second, with the exception of one site, all our study locations were rural. As a result, our findings are not fully generalizable to urban populations. Collecting higher-resolution data across multiple seasons, landscapes, and on the quantities and diversity of species consumed would likely strengthen our ability to detect and interpret the relationships between consumption and its drivers. Nonetheless, the consistency of our results across both Amazonian and African savanna contexts suggests that our findings are robust, despite these limitations. Although our datasets are not very recent, we believe our findings are, if anything, increasingly relevant: indigenous Amazonian sites remain relatively isolated, whereas other sites have experienced varying degrees of land-use change, deforestation, aquaculture expansion, and COVID-19-related disruptions in the past decade, factors that have likely intensified the scarcity of wild resources and accelerated nutrition transitions.

CONCLUSION

Our study underscores the multifaceted role of wild fish and meat in tropical rural food systems and their critical implications for both conservation and nutrition security. Across the Amazon Rainforest (AR) and East African savannas (EAS), patterns of WFM and domestic meat consumption were shaped by cultural as well as shared economic and spatial drivers, most notably household income, proximity to urban centers, and access to natural landscapes. Fish emerged as the most consistent source of animal protein, while wild meat played dual roles: serving as a subsistence food for poorer, remote households and as a cultural or luxury item among wealthier, more urban-connected households who also had greater access to domestic meats. We found evidence of the broader "nutrition transition," in which traditional wild-sourced foods are progressively complemented or replaced by market-based foods as households integrate into the cash economy. Yet, the continued consumption of WFM across contexts underscores its enduring nutritional, cultural, and relational significance.

In line with recent scholarship and the call for a "sustainable wild meat sector," our findings emphasize the need to integrate conservation and nutrition agendas through principles of social justice (Coad et al. 2019, Ingram 2020, Zhou et al. 2022). Sustainable WFM management must move beyond restrictive, "one size fits all" enforcement-based models toward participatory, rights-based, and context-specific strategies. Strengthening community tenure, co-developing management plans, and enhancing monitoring and traceability can promote ecological sustainability while safeguarding rural food security. Concurrently, investment in sustainable small-scale fisheries, diversified, including plant-based protein sources, and community-led governance can help reconcile biodiversity conservation with equitable nutrition outcomes. Reducing rural economic dependence on commercial hunting while curbing urban demand for wild meat will be critical to ensuring that WFM continues to sustain both people and nature in changing tropical landscapes.

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Data Availability:

The data used in this paper is published online in the journal Scientific Data and can be found at https://www.nature.com/articles/s41597-024-02967-0. Data is available at UK Data Service's ReShare archive at https://reshare.ukdataservice.ac.uk/856560/.

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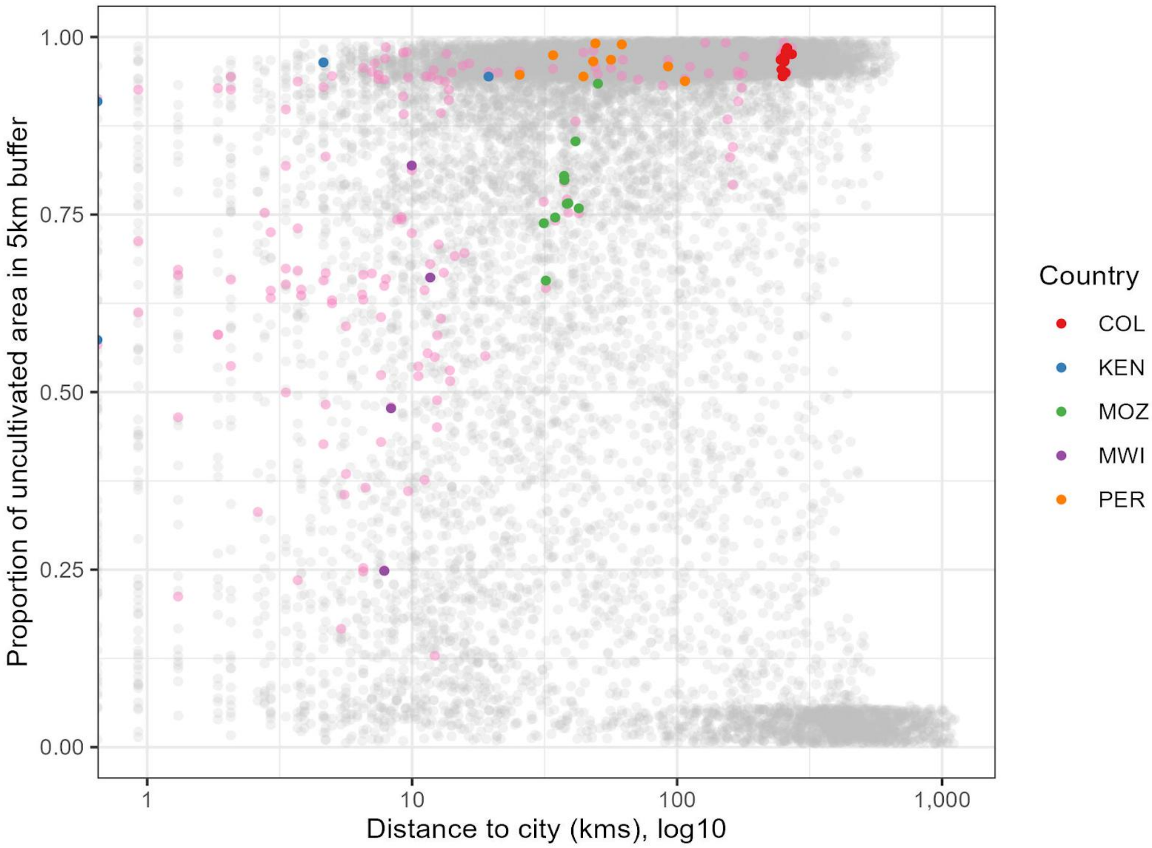
Appendix 1.

a) **Figure.** Settlements selected for the study and a systematic random (~50 km grid) sample of >14,000 points (grey dots) across the study region (tropics and on land, excluding urban and arid areas) are shown along the axes of 'distance to city' (Weiss et al. 2018) and 'proportion of uncultivated area in 5 km buffer' (LULC data: ESA 2016). The settlements included in the current study are a subset of those compiled under the Nature4SDGs project for which data on wild meat, fish, and domestic meat consumption were available. Nature4SDG settlements are shown as pink dots, while the subset used in the present study are shown in the legend. After Wells et al. (2024)*. COL = Colombia, KEN = Kenya, MOZ = Mozambique, MWI = Malawi, PER = Peru.



* Wells G, Ryan C.M, Das A, Attiwilli S, Poudyal M, Lele S, Shreckenberg K, Robinson B, Keane A, Homewood K, Jones J, Torres-Vitolas C, Fisher J, Ahmad S, Mulligan M, Dawson T.P, Adams H, Setty S, Daw T.M. 2024. Hundreds of millions of people in the tropics need both wild harvests and other forms of economic development for their well-being. One Earth, 7 (2): 311-324.

b) Corrections for random sampling

In the Kenyan urban site, there was an oversampling of 77 fisheries households to fulfil the study objectives. We excluded these households from our prevalence measures, as this is a biased sample. However, we included them in our regression where we are comparing fishing households with non-fishing households. In Mozambique, the richest and poorest wealth category households were oversampled. This bias was corrected by randomly removing households from oversampled wealth ranks and duplicating random households from underrepresented wealth ranks in each settlement till the distribution of wealth ranks matched those from the initial wealth rank census done in each settlement.

c) Survey questions used to extract data

The data were extracted from the following pre-existing surveys that were compiled as part of the Nature4SDGs project (https://www.nature4sdgs.org/ ; https://doi.org/10.1038/s41597-024-02967-0):

- For Colombia, Peru and Malawi, we used the 'ASSETS' data (**Attaining Sustainable Services from Ecosystems through Trade-off Scenarios**). This project collected data in two waves, broadly corresponding to seasons. Wave 1 data was used for the current analysis.
- For Mozambique, we used the 'ACES' data (**Abrupt Changes in Ecosystem Services and Wellbeing in Mozambican Woodlands;** https://miomboaces.wordpress.com/).
- For Kenya, we used the 'SPACES' data (**Sustainable Poverty Alleviation from Coastal Ecosystem Services**). This project also collected data from few coastal sites in Mozambique. However, that data could not be used for the current analysis since the income data was incomplete for those sites.

Following survey questions were used to extract consumption data for the current analysis:

- ASSETS Module I (Food): i_2 "Over the past 7 days, did you or others in your HH consume any [FoodID]?" (1) Yes (2) No
- ACES h_source_protein: "How often do members of your household consume this type of protein in the last four weeks? Specify what type it was"
- SPACES 10. Food: 10_2_1 "Did you or other household members eat fish yesterday? (Yes/No)". 10_2_2 "[IF 'no'] When was the last time your household ate fish?" (no. of days back, or choose from > 1 week, > 1 month, > 6 months > 1 year).
  10_3_1 to 10_3_4 "Have you or other household members eaten meat or chicken yesterday?", "What type of meat or chicken did you eat?", "When was the last time your household ate meat or chicken?", "What type of meat or chicken did you eat most recently?"

d) Social-ecological context:

We reasoned that the following drivers would impact consumption of wild meat and fish (a) abundance of wild animal/fish populations (b) human population pressure, and (c) market access. While (a) and (b) determine ecological availability of WFM per capita, (c) would capture trade in WFM. Since we did not have ecological data on abundance of wild animals and fish surrounding the settlements, we used ‘percentage of uncultivated cover’ i.e., proportion of wild or less disturbed area around the settlement as a proxy for wild animal abundance. Human population density was measured using existing global land cover data (CIESIN 2018). Market access was measured using travel time to the nearest urban centre as a proxy variable (Weiss et al. 2018).

The other question was of scale of measurement of these variables. Many of the settlements surveyed in our datasets are highly dependent on local natural resources for subsistence as well as livelihoods. We contextualised the settlement-level resource landscape around the 'service shed(s)' idea (Olander *et al.* 2018). We mapped the land cover within a resource ‘buffer’ around each settlement, where the buffer was defined by a radius that represented the maximum distance up to which natural resource harvest occurred based on qualitative and household survey data. We measured percentage of uncultivated area and human population density within this buffer. Specifically, when it comes to wild meat, most of the studies have focussed on certain well known trade centres and markets. Sites where subsistence harvest or gifting is more common have received less attention in wild meat studies. Our data shows high levels of harvest and gifting as means of access to wild meat. Hence it makes sense to use a local resource buffer to characterize the social-ecological context of the settlements. There may be significant wild meat or fish consumption obtained through trade from outside our circular settlement buffers. We aimed to capture variation in trade through our third variable, i.e., travel time to urban centres, which may be a crude but reasonable proxy for the trade and transportation network around a settlement. These three variables adequately capture different components of the social-ecological context of our settlements.

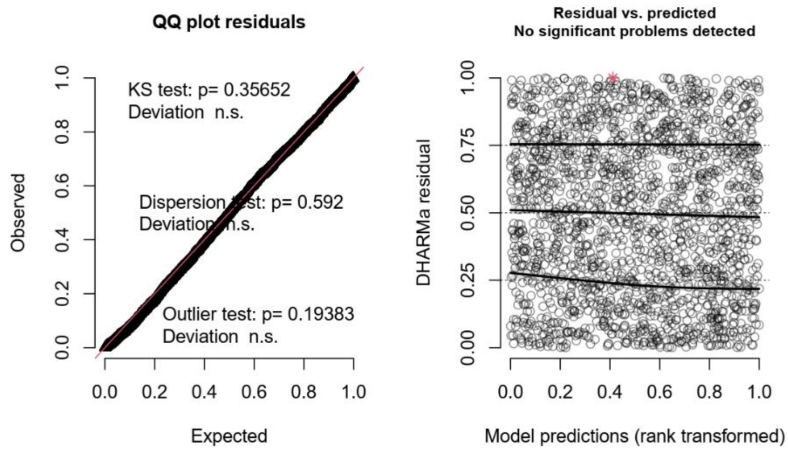
*Olander, L. P. et al. Benefit relevant indicators: Ecosystem services measures that link ecological and social outcomes. Ecol. Indic. 85, 1262–1272 (2018).

e) Table. Generalized vif values of independent variables to check for multicollinearity

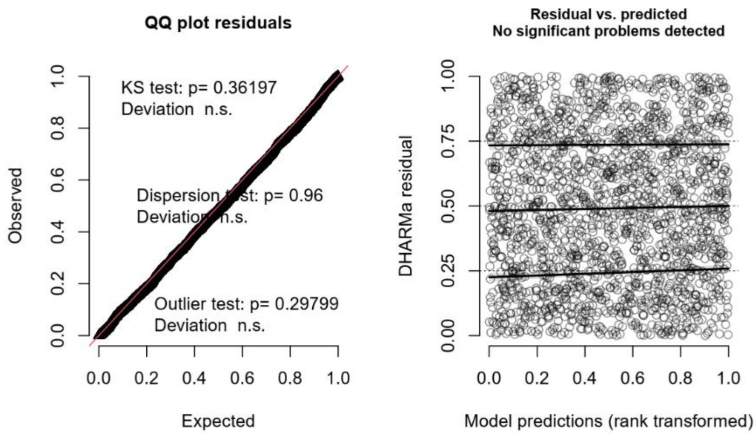
	GVIF	Df	scaled GVIF = GVIF^(1/2Df)	squared scaled GVIF
income (log-scale)	1.14	1	1.07	1.14
domestic meat	1.12	1	1.06	1.12
fish	1.05	1	1.02	1.04
hunter	1.07	1	1.03	1.06
country	73.35	4	1.71	2.92
proportion of uncultivated area	7.55	1	2.75	7.56
travel time (log-scale)	12.65	1	3.56	12.67
population density (log-scale)	16.18	1	4.02	16.16

f) Figure. QQ plots and residual vs. predicted plots to perform model checks for (i) wild meat consumption in East African savanna (EAS) (ii) fish consumption in EAS (iii) wild meat consumption in Amazon Rainforest (AR). For fish consumption in AR, we had to omit the random effects to simplify the model.

(i)



(ii)



(iii)