



From the Forest to the Dish: A Comprehensive Study of the Wildmeat Value Chain in Yangambi, Democratic Republic of Congo

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Given the importance of wildmeat for local and national economies, understanding the structure and operations of the informal wildmeat value chains is necessary to provide recommendations for a sustainable wildmeat sector. However, the limited number of case studies available hinders our capacity to understand general patterns in wildmeat trade chains and provide recommendations that apply in different contexts. This study contributes to our understanding of wildmeat trade chains with another case study from the Yangambi landscape, in the Democratic Republic of Congo. We use a value chain approach to explore the structure and functioning of the trade and identify the main barriers to entry into the business, as well as the main levers that can be used to reverse unsustainable use. Bushmeat remains the most consumed source of meat both in the main urban area and in surrounding villages. Urban consumption generates a trade of about 103–145 tons of bushmeat per year for a human population of 37,997 inhabitants. Yangambi combines all the factors for a depletion scenario: a quasi-open access system and high levels of dependency on the resource at all levels of the chain (from consumers to hunters). Despite this, emblematic species such as the chimpanzee, buffalo, okapi, red colobus and giant pangolin are still present in the area. The trade chain follows a “redundant” structure with few barriers to participation in the sector: (1) many hunters and rights holders; (2) many traders; (3) significant demand. Hunters, on average, obtain a higher profit than traders, who bear the highest costs of transportation, fines and bribes. Reducing unsustainable trade in this context, will necessarily imply reducing the burden on natural ecosystems as the main providers of animal protein. Moreover, supporting processes to re-structure local governance systems in this post-conflict context will also support efforts to reverse unsustainable use. The differences observed in Yangambi as compared to other well-studied wildmeat trade chains illustrates that no two bushmeat market chains are alike. Recommendations to reduce unsustainable trade in urban areas need to be tailored to specific contexts, taking into consideration differences in terms of whether markets are open or underground, the length of the trade chains (from local to international trade chains), the existence and type of barriers to entry, the number and type of stakeholders involved and the factors influencing the demand–supply equilibrium.

Keywords: wildmeat, market, trade chain, structure, Congo basin

INTRODUCTION

Wildmeat is defined as non-domesticated terrestrial mammals, birds, reptiles and amphibians harvested for food. It is part of the diet in contemporary societies, particularly in tropical and sub-tropical areas, where it contributes to food security, nutritional diversity and personal well-being (Alves and van Vliet, 2017). While hunting for wildmeat often occurs primarily to satisfy the needs of the family, surplus meat is traded and the income is used to purchase other food items, invest in medical care, pay school fees and purchase non-necessities (Coad et al., 2010; Luskin et al., 2014; Endamana et al., 2016; Vasco and Sirén, 2016). Where a high demand exists and no other alternatives are available as sources of income, hunters may specialize in commercial hunting and sell most of the prey (van Vliet et al., 2015b; Greengrass, 2016; Mendonça et al., 2016).

The sale of wildmeat often occurs in the informal sector, either because the legal texts do not provide a stipulation to allow commercialization (Ruas et al., 2017), or because the regulatory framework presents contradictions or gaps (van Vliet et al., 2015a), or because legal texts, often inherited from colonial times (e.g., in Central African countries), no longer represent local realities (Sartoretto et al., 2017). Understanding the structure and operations of wildmeat value chains is now recognized as necessary to provide recommendations for a sustainable wildmeat sector, given the importance of wildmeat for local and national economies (CBD, 2012). As for any other marketable forest product, value chain analysis is important to infer recommendations for improving the business environment, the horizontal and vertical linkages between actors and the marketing issues, as well as ensuring ecological, economic and social sustainability (Te Velde et al., 2006).

Information on wildmeat consumption, as well as on the biomass traded in markets is increasingly available for the tropics, in Central Africa, West Africa and the Amazon (Fa, 2007; Parry et al., 2014; van Vliet et al., 2014, 2017a,b). What is drastically limited is our understanding of the main barriers to entry into the wildmeat business and the levers that can be used for a more sustainable sector. Only a limited number of studies have described the structure and operations of wildmeat value chains, the actors involved, the direction of flows and the economic value of wildmeat species traded (Cowlshaw et al., 2005; van Vliet et al., 2015b; Lescuyer and Nasi, 2016; Nielsen et al., 2016). These studies suggest that the sale of wildmeat generates significant revenues for different stakeholders, including the hunters, retailers and traders. However, the differences observed in each context, highlight for the need of more case studies to understand the general patterns in wildmeat trade chains and explain the differences observed in each context.

Our aim is to complement existing literature on wildmeat market chains, with a case study from the Yangambi landscape, in the Democratic Republic of Congo (DRC), a region characterized by a post-conflict situation. Using participant observation, semi-structured interviews of hunters, traders and consumers, participatory mapping and market monitoring, we analyze how wildmeat reaches its point of consumption from the point of extraction, and the implications of this for local economies,

food security and ecological sustainability. Our study provides a comprehensive understanding of the structure and operations of the trade, the nature of the flows, the income generated by the wildmeat trade at the level of hunters and traders, the contribution to food security and the status and trends of the resource as perceived by the users.

MATERIALS AND METHODS

Study Site

Yangambi is a town located in the northeast of the DRC, about 100 km West of Kisangani City in Tshopo Province (**Figure 1**). As is typical in the Congo Basin, the landscape around Yangambi is characterized by a range of land tenures combining the Yangambi Man and Biosphere Reserve (YBR), created in 1979; the Ngazi Forest Reserve, which belongs to the Institut National des Etudes et Recherches Agronomiques (INERA); a logging concession; and customary land. In practice, due to the lack of human and financial resources, both reserves (Yangambi and Ngazi) have no official management plan, their limits are contested and they are not under any specific form of management.

The climate in our study region is marked by two dry seasons (from December to mid-March and from June to July) that alternate with two rainy seasons (from April to May and from August to November). The landscape is covered by old secondary forests, semi-deciduous dense forests, young secondary forests and dense evergreen forests. The rest is covered by a mosaic of agriculture, marshy forests and agroforestry systems. While several botanic surveys carried out since colonial times have provided a good understanding of the vegetation (Jacobsen et al., 2018), the only information on mammals comes from a recent assessment of hunters' perceptions (van Vliet et al., 2018a).

The human population living around the YBR is estimated at 141 643 inhabitants based on data from the Yangambi Registry Office dating from 2016. Yangambi was originally a research campus of INERA and IFA (Institut Facultaire de sciences Agronomiques) during colonial times, where only staff and their families could live, but over the years it became a town, due to the migration of workers and people searching for job opportunities in what became an economic hub for the area. The population around the YBR can be sub-divided into three groups: (1) the urban population (37,997 inhabitants) living in the 10 districts (Bangala, Ekutsu, Likango, Lomboto, Lumumba, Lusambila, Moussa, N'Gazi, Okito, and Yaekema) of the research campus of INERA and IFA (Institut Facultaire de sciences Agronomiques), which have evolved into a town; (2) the Turumbo and Topoke populations living in villages surrounding the reserve to the south, west and north along the unpaved trails/roads (Yambau, Yawenda, Yelongo, and Weko community groups); (3) The Bamanga (Bamanga Bengamisa and Bamanga Yambuya community groups) living toward the northeast of the reserve belonging to the Bamanga and Mba tribes.

Traditional agriculture, including cultivating cassava, banana, maize, rice, cowpeas, beans and groundnuts, is the main activity in all villages around the reserve and provides basic household livelihoods. The Bamanga population is more specialized in

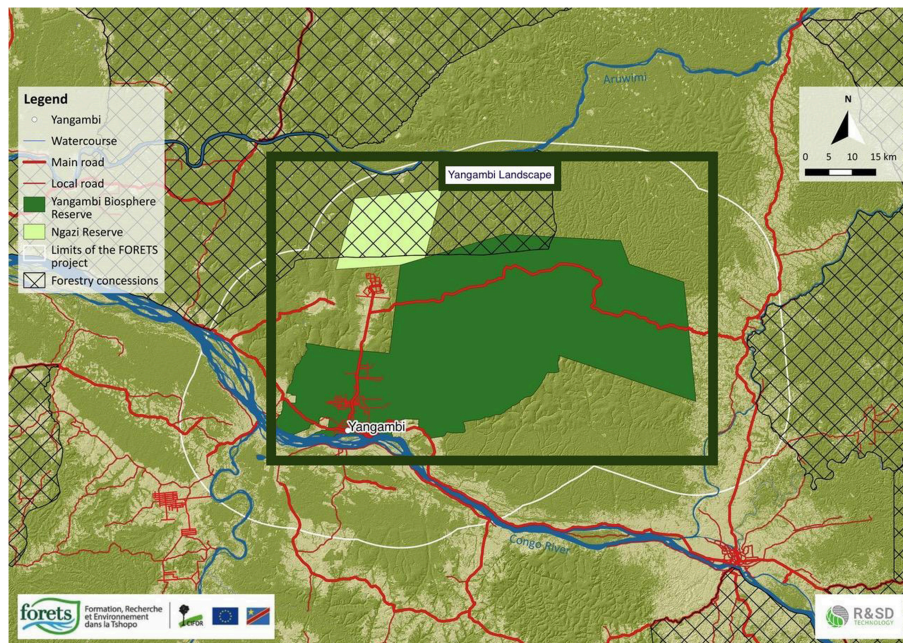


FIGURE 1 | Geographical location of the study site.

agriculture (particularly rice and peanuts) than the Turumbo, who practice hunting as the second most important livelihood activity. Agriculture is a complementary activity for the urban population of Yangambi, where the majority of the residents are state employees (researchers, technical and administrative staff from the INERA and IFA research centers, the Tshopo Province Administration and the YBR that falls under the Ministry of Environment). Besides hunting and fishing, families also use many non-timber forest products for food and medicinal purposes and non-wood plant products for crafts and building materials. In the villages, households keep small livestock in extensive traditional production systems (poultry, pigs, ducks, goats, sheep), used to cover exceptional expenses, donations, dowries or to solve village conflicts.

During the last three decades, basic community infrastructure (roads, housing, educational and health facilities, etc.) has deteriorated significantly. The roads are in poor condition and basic necessities are supplied mainly by canoes on the Congo River. Health establishments are insufficiently equipped, most urban and rural households have no access to drinking water and the town of Yangambi is not electrified.

Data Collection

The methodology applied in the context of this study as approved by CIFOR's Ethics committee is based on a combination of participatory methods including: participant observation, semi-structured interviews and group discussions. The actors involved in this study all participated freely giving informed consent. The objectives of this study were introduced to the competent local authorities (INERA, IFA, UNIKIS (University of Kisangani), MAB (Man and Biosphere), sector chiefs, village chiefs) in order

to obtain the necessary authorizations and the institutional support required to carry out fieldwork. The working team consisted of three people: one main coordinator and two research assistants. Field work was carried out from July 2017 to March 2018.

Participant Observation

The first stage of this study was based on participant observation and informal interviews with different stakeholders. The research team, composed of two local researchers, spent a month staying overnight in villages surrounding the reserve, visiting the various places involved in the bushmeat trade, carrying out informal discussions, and observing the dynamics of the different stakeholders involved in consumption and trade. Information on market days was obtained for the different markets from the study area and visits were organized to observe wildmeat flows, relationships among the different stakeholders involved in wildmeat trade, client choices, means of transportation to and from the market, and number of traders, among others. Participatory mapping was used to locate the different source areas and the flows of wildmeat from rural areas to town. In each of the villages, discussions were held with the chief and key members of the community (as chosen by the chief) to identify the number of active hunters participating in trade, to understand customary rights over the resources and to locate the limits of the hunting grounds. Participant observation was not only used at the beginning of the study, it was embedded in the researcher's attitude and was used as a continuous approach to elucidate issues that were not immediately obvious and gain trust from stakeholders.

TABLE 1 | Total number of traders and sampled number for semi-structured interviews.

Wildmeat market	Wildmeat traders			
	Men		Women	
	Total	Interviewed	Total	Interviewed
Bangala-Sai Sai	3	3	14	10
Market Mipila	47	11	38	10
Market Beach	14	10	23	10
Market Weko	6	6	16	10
Market Lileko	21	10	42	10
Market Yambelo pk52	3	3	8	8
Yaikela	6	6	12	10
TOTAL	100	49	153	68

Semi-structured Interviews

Semi-structured surveys were conducted with a representative sample of different key stakeholder groups (206 hunters, 127 traders and 632 household heads) to better understand their practices and their level of dependency on hunting, wildmeat trade and wildmeat consumption. In addition, hunters were also interviewed on the status and trends of mammal species as explained in more detail below. All interviews were administered using Kobocollect[®], a data collection tool for Android phones.

Semi-structured Interviews With Traders

All traders in each market were identified through informal discussions with market authorities, participant observations, market stalls counts and informal interviews with local informants. In each market, we sampled traders according to the following rules:

- if the total number of traders was > 40, then a sample of 25% was interviewed;
- if the total number of traders was between 10 and 40, then 10 traders were interviewed;
- if the total number of traders was <10, then all of the traders were interviewed.

Sampled traders were chosen according to availability and willingness to participate in the interview. As such, a total of 127 traders (out of the 253 identified) were interviewed (78 women and 49 men), as shown in **Table 1**.

The aim of interviewing traders was to provide qualitative and quantitative information on the socio-economic background of the trader (gender, ethnicity, main income-generating activities), general information on the trade (number of years in the activity, relations with other actors, species marketed, places of sale and supply), motivations for trading, problems encountered, potential solutions, detailed information on biomass, prices, variable costs related to the sale (e.g., transportation costs) and fixed costs (e.g., taxes, depreciation of investments). This information was used to calculate the average net profit per trader according to the following formula:

$$\begin{aligned} \text{Average net profit/week/trader} = & \left(\sum \text{average revenue/week} \right. \\ & - \sum \text{average variable costs/week} \\ & \left. - \sum \text{average fixed costs/week} \right) / N \end{aligned}$$

Profit-related calculations did not include time spent on the activity, since it is often difficult to quantify, particularly when traders spend time transporting the meat from the source area to town, with unpredictable transportation means, or when traders combine different commercial activities at the same time. Thus, the calculated net profits are based on remuneration for the work.

In order to quantify the commercial flows of wildmeat, we chose a sub-sample of traders (23 out of the 127 interviewed) with whom we had established trust and visited them once a month from September to December 2017 (covering the end of the dry season and the start of the rainy season), on market day, to monitor their activity. We know that trade may vary with season and other factors, so we tried to cover different seasons and include the two peak seasons paralleling cash needs (September for the start of the school year and December for the holidays), as well as two regular months (October and November). We focused our questions on the sale of mammal species, which generally make up the bulk of bushmeat traded in urban areas. Questions included species sold, hunting method, status of the meat, provenance, purchase price, and biomass per species. Biomass was measured using two balances: a mechanical balance of 100 kg for whole carcasses and a digital balance of 5 kg for pieces. Due to the difficulty in identifying certain taxa to species level in smoked specimens, some species were combined and recorded as generic groups (e.g., small diurnal monkeys, red duikers). The quantities of biomass sold by the sub-sample of traders were extrapolated to all traders in order to calculate the total biomass sold per month (minimum and maximum) and per year in Yangambi markets, as well as the economic value of the trade in the region.

Semi-structured Interviews With Hunters

The total number of hunters in the area was obtained through discussions with village chiefs and other key stakeholders. The information was corroborated through informal discussions with different stakeholders. Only hunters who actively participated in the trade and for whom hunting represented one of the main activities were considered. A total of 206 hunters were surveyed out of 538 identified. To ensure spatial representativeness, the sample was geographically distributed among the different villages around YBR (see **Table 2**). The sample was chosen based on availability and willingness to participate in the interview.

The semi-structured interviews with hunters included two main sections: one section on hunting activity and one exploring wildlife abundance and trends as perceived by the hunters.

The first section of the interview provided information on the socio-economic background of the hunter (gender, ethnicity, main activities, number of years of hunting experience), hunting practices (hunting tools, hunting grounds), motivations for

TABLE 2 | Number of active hunters per village/neighborhood and number of hunters sampled in this study.

	Village	Number of hunters involved in the market chain (N)	Number of hunters interviewed (n)
Turumbo Sector	Yelongo	25	19
	Yawenda	30	15
	Yakako	20	0
	Bosukulu	30	0
	Yambau	60	15
	Obiloto	10	0
	Botiagulu	10	0
	Weko	100	43
Bamanga Sector	Bahumbi	8	1
	Bakobi	11	10
	Bandeli	8	8
	lokeleli	12	10
	Yaliboto	8	8
Yangambi town	Okito	9	3
	Ekutsu	15	6
	Likango	15	10
	Bangala	10	10
	Lumumba	28	12
	Ngazi	80	22
	Lusambila	50	14
	TOTAL	539	206

hunting, problems encountered, potential solutions, data needed to calculate the net profit (frequency of hunting, average quantities sold per hunting trip, variable costs related to each hunting trip (cartridges, batteries, food), and fixed costs (taxes or other, including depreciation of investments). We used these data to calculate the average net profit per hunter using the following formula:

$$\text{Average Net profit/week/hunter} = \left(\sum \text{average revenue/week} - \sum \text{average variable costs/week} - \sum \text{average fixed costs/week} \right) / N$$

As in the case of traders, profit-related calculations for hunters did not take into account the time spent on this activity, since it is often difficult to quantify. For example, when a hunter spends 4–5 full days in a hunting camp, he may spend his time traveling, resting, cooking, eating or doing other complementary activities (fishing/collecting), besides hunting. Thus, the calculated net profit is remuneration for work.

The second section of the interview used an ethno-zoological approach to analyze the abundance and distribution of hunted species, as well as the main factors that explain the observed trends, according to their perceptions. This section included questions about date and location of last observation of each species, observed population trends for each species in the last

30 years and factors explaining such trends. The geographical location of observations was based on a detailed map of the hunting ground covered by a grid in which each cell was identified by a letter and a number. The map of the hunting ground was produced prior to the interviews through a combination of participatory mapping and the geo-location of each of the landscape features using GPS and visits to the different locations (hunting camps, hunting trails, streams, rivers, etc.) (see van Vliet et al., 2018a, for more detail).

Semi-structured Interviews With Consumers

The purpose of the household interviews was to understand the contribution of wildmeat to food security and the levels of wildmeat consumption in comparison with other sources of protein from the wild (fish, caterpillars, etc.) or of domestic origin (poultry, beef, goat, etc.). The semi-structured interview provided information on the socio-economic background of the household (gender of household head, ethnicity, main activities), perceptions of household food security, recall of meat types consumed in the last 24 h, dietary preferences in terms of animal sources of food, consumption patterns of wildmeat (frequency, form of supply, availability and prices). A sample of 632 households was chosen to represent the total population of Yangambi (town and villages surrounding the reserve). Our household interviews on the consumption of animal products were conducted in September 2017 and are therefore not necessarily representative of consumption throughout the year.

Group Discussions

Discussions were organized with separate groups of traders and hunters to gain more qualitative insights into how the market chain operates, how the sector has changed over time and main factors of change.

One workshop was organized in Yangambi with traders from the main markets (35 participants) and 9 group discussions with hunters (10 participants per group) were organized in the main villages (Bande, Bangala, Bossukulu, Lokeli, Lumumba, Ngazi, Weko, Yaliboto, Yselia) surrounding YBR. Participants were selected based on their availability and willingness to participate; efforts were made to include a range of age groups.

The aim of the group discussion with the traders was to obtain supplementary information on the stakeholders involved in the trade, the geographical location of the flows, the economic importance of the sector (number of actors involved, volumes marketed, income generated globally) and the factors limiting or driving the sector. A historical trend analysis was developed covering the period from 1995 to 2017, highlighting changes that have occurred in the market chain and the main drivers of change (e.g., changes in wildlife habitat, climate-related changes, changes in infrastructure, demographic changes (displacement, emigration, migration), changes in governance, changes in local economies and changes in hunting techniques).

The aim of the group discussion with the hunters was to supplement information on hunting grounds, hunting practices, relationships with other stakeholders in the chain, seasonality, economic importance of hunting for their community (number of hunters involved, volumes hunted, income generated globally),

and the limiting or driving factors influencing hunting. A historical trend analysis was developed covering the period from 1995 to 2017, highlighting changes that have occurred in hunting activity and the main drivers of change. Moreover, participants were invited to add to the information gathered through the interviews on changes in mammal populations across the study site and the main drivers of change.

RESULTS

Structure of the Market Chain

We identified 845 people involved in the bushmeat trade chain as their primary activity: 253 traders and brokers (153 women and 100 men), 539 hunters and 53 women, who participate in hunting trips with their husbands.

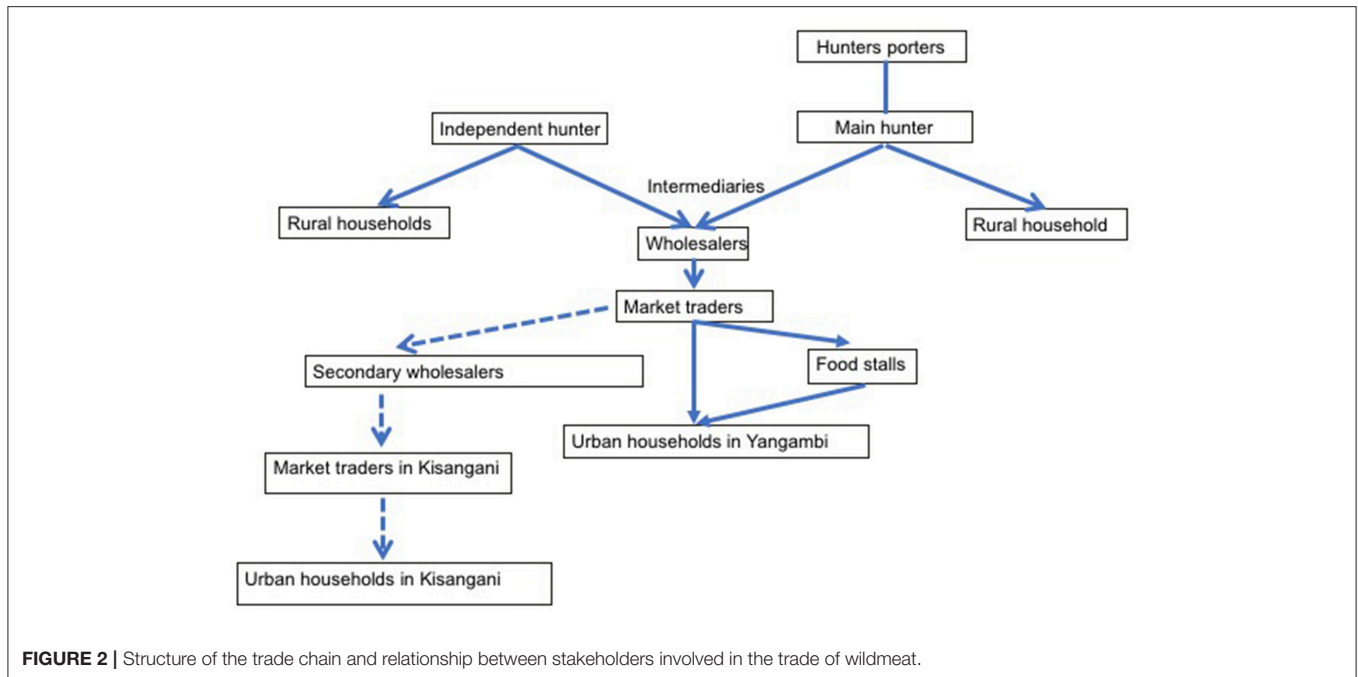
There are three main categories of actors actively involved in the trade (Figure 2):

- Hunters: Hunters actively participating in the trade chain are mostly from the Turumbo ethnic group. Turumbo hunters are known for their hunting skills. They usually hunt once a week on long hunting trips (5–6 days). They hunt on their ancestral land in areas where wildlife is perceived as abundant (about 15 km from their village). They interact with many other hunters and may organize the hunting trips for group of 4–5. The hunting trip is planned to end the day before market day, so the meat can be sold as soon as they are back from the forest. They sell the meat to brokers they trust. The day they return from hunting is celebratory: hunters proudly show what they have caught, tell stories of the forest, purchase traditional drinks and share a spirit of camaraderie. The most commonly used hunting methods are fire arms and snares but hunting with spears and dogs is also practiced. There are three types of hunters. The independent hunter usually hunts alone. The lead hunter leads a group of hunters/porters and provides all inputs necessary for the hunting trips (cartridges, food, batteries, cigarettes, firearms etc.). He pays hunters/porters in kind or in cash and is responsible for selling the meat. The hunter/porters are hunters who work for a lead hunter. The hunter/porters are often younger than the independent hunters, do not own firearms and have no investment capacity to fund their hunting trips. There are few barriers to entering the hunting business, as access to the resource is relatively open: once a hunter from outside is introduced by someone from the village, then there are no rules to regulate his activity and the hunter acquires de facto the same hunting rights as traditional rights holders. Hunters bear very low costs as the supplies are often provided by the brokers or the lead hunters, and Environmental Agency enforcement officers rarely reach them into the forest.
- Brokers: Brokers are often women who travel to villages the day before market day and wait for the hunters to return. They seek to purchase the maximum amount of meat for the cheapest price possible. The brokers incur high transportation costs between the remote informal markets and the official markets in the town of Yangambi and also bear the high costs of paying bribes to Environmental Agency officers when they are encountered on the road to market. Some brokers rely on other women (often with family links to the hunters) to act as intermediaries between hunters and the brokers at the informal market. These intermediaries earn a small profit when they successfully facilitate trading between hunters and brokers. Some brokers establish relationships with the hunters and supply them with ammunition and other necessities. In fact, many brokers are also traders in the markets, as described below.
- Traders: Both women ($N = 153$) and men ($N = 100$) operate as traders in the market. They are mainly from the town of Yangambi and are from the Turumbo and Topoke ethnic groups. They sell bushmeat at the official markets on market days. Some of the traders have more than 30 years' experience in the trade but given the lack of income-generating opportunities many younger women, with little or no experience, also engage in the trade. There is little barrier to entering the business, although being from the Turumbo ethnic group facilitates relationships with hunters, who are mostly Turumbo. Many of the bushmeat traders also sell fish and other non-timber forest products. Most traders operate independently, but a few have organized themselves around micro-credit associations (*tontine*) to fund exceptional expenses. Traders bear high costs related to market fees and bribes for market authorities and the Environmental Agency. During the closed hunting season, there are no major changes in the number of traders and amounts sold, but the level of bribery increases.

There are no restaurants in Yangambi. However, a few women sell food from market stalls and include bushmeat on their menu.

Flows of Bushmeat

The town acts as the main hub for bushmeat demand in Yangambi. The volume of smoked bushmeat varies from 2,150 to 3,036 kg/week. These volumes, if extrapolated to the whole year, range from 103 to 145 tons. Until the last decade, bushmeat from the Yangambi area was taken as far as Kisangani or along the Congo river to Kinshasa and Equateur Province. However, with increased local demand from the town and the decrease in supply, the wildmeat trade chain is now limited to the immediate area. The main supply location for Yangambi brokers is Mipila market (about 25 km north of Yangambi), a spontaneous informal market. It is located in the forest close to Ngazi village, at a crossroads of different hunting trails in Weko Forest. The trails extend 25–50 km from Yangambi. The market has been active since 1978 and serves as a gathering point for hunters. Weko Forest supplies more than 66% of traders. Another supply area is located in Lileko, to the west of Yangambi toward Bassoko (about 30 km from Yangambi) and serves as a meeting point for brokers and hunters from Monganzo Forest. Bushmeat trade occurs throughout the year with peaks in August, September and December, when households need cash to pay school fees and for holidays. Hunters state that about 34 species are hunted. The most traded species are small monkeys (38% of the biomass) and red duikers (*Cephalophus* spp.) (31%), blue duikers (*Philantomba monticola*), bush pigs (*Potamochoerus porcus*), and bush tailed



porcupines (*Atherurus africanus*) (Table 3). Most meat is smoked and sold. The whole carcass of small species (monkeys, rodents and blue duikers) is smoked, while larger species are cut into pieces before being smoked.

Income Generated by the Bushmeat Trade in Yangambi

Traders sell an average of 10 kg of bushmeat per week, with a margin of about USD 0.99 per kilo. Weekly costs were calculated at approximately USD 4.6. Thus, the weekly profit that the traders can make is equivalent to USD 7.3 per week, or USD 29.3 per month, which is about 1.6 times the official minimum wage (USD 17 per month). The main items of expenditure in the sale of game are various taxes and bribes. When the trader is also the broker, then transportation costs exceed all other costs. Income from the sale of game is used for the following expenses (in decreasing order): school, health, clothing and food. The majority of traders operate to provide for the basic needs of their family, given the lack of better job opportunities. Female-headed households often get involved in bushmeat trade due to the relatively low investment required compared to other businesses. However, the sale of game is complemented by other activities in the household, because it does not generate sufficient income for the subsistence of the family.

For hunters, income varies depending on luck and skill, but can range between USD 15 to 20 a week (or a multi-day hunting trip), for a net profit of about USD 40 per month (double the 2017 official minimum income in the DRC). Commercial hunters sell 80% of their meat. The most profitable months are October to December, during the rainy season, and the least profitable are January to March, during the dry season. Hunting income is used by men to cover for their own expenses (alcohol and cigarettes)

and pay for school fees, clothing, health and food for the family. The main variable costs of hunting (in decreasing order) are the price of ammunition, cables (for snare hunters), food needed in the forest and batteries.

Importance of Bushmeat for Food Security

Starchy foods, meat/fish and vegetables form the basis of the diets in the studied location. Households consume few sources of plant protein (lentils, beans, etc.), little or no sugar, no dairy products, and few or no fried foods. A significant proportion of households report not having consumed any animal product the day before the interviews (27%), while 32% of households consumed bushmeat, 18% consumed fish and 10% consumed caterpillars. Pork and chicken were only consumed by 7 and 2% of households, respectively, on the day before the interview. More than 60% of households eat bushmeat more than once a week and about 40% of households eat fish more than once a week. Thus, even if these data correspond only to the month of September, which would lead to a bias in the contribution of caterpillars, the contribution of wildmeat and fish is clearly significant throughout the year. The perception of food security varies between the rural Turumbo sector, where <4% of households consider themselves as having poor food security, and Yangambi, where more than 50% of households consider their food security as bad or very bad. In the rural Turumbo area, most households live on hunting, fishing, farming and small livestock rearing. In these villages, 91% of households obtain bushmeat by hunting themselves and 85% of them obtain fish by fishing themselves. The opposite trend found in the town of Yangambi, where a large majority of households depend on a monthly salary to purchase food, as they have limited access to land and resources.

TABLE 3 | List of species traded as wildmeat in Yangambi.

	Family	Scientific names	Local name in turumbo		
Afrosoricida	Tanricidae	<i>Potamogale velox</i> (Du Chaillu, 1860)	Bowengele		
Arctiodactyla	Bovidae	<i>Tragelaphus scriptus</i> (Pallas, 1766)	Kenge		
		<i>Tragelaphus spekiei</i> (P.L. Scaler, 1863)	Mbulimasuwa		
		<i>Cephalophus nigrifrons</i> (Gray, 1871)	Mbengela		
		<i>Cephalophus callipygus</i> (Peter, 1876)	Koto		
		<i>Cephalophus dorsalis</i> (Gray, 1846)	Koto		
	Giraffidae	<i>Okapia johnstoni</i> (Sclater, 1901)	Okapi		
	Suidae	<i>Potamochoerus porcus</i> (Linnaeus, 1758)	Ngulu		
	Tragulidae	<i>Hyemoschus aquaticus</i> (Ogilby, 1845)	Elebe, Bolafi		
	Carnivora	Felidae	<i>Panthera pardus</i> (Linnaeus, 1758)	Nkoy	
		Herpestidae	<i>Crossarchus alexandri</i> (Thomas & Wroughton, 1907)	Liende	
Mustelidae		<i>Aonyx capensis</i> (Schinz, 1821)	Bohoso		
Viverridae		<i>Genetta servalina</i> (Pucheran, 1855)	Isisimba		
		<i>Genetta victoriae</i> (Thomas, 1901)	Bolende		
		<i>Civettictis civetta</i> (Schreber, 1915)	Libobi (Limbuta)		
		<i>Nandinia binotata</i> (Gray, 1830)	Alela		
Cetarctiodactyla	Bovidae	<i>Syncerus caffer</i> (Sparman, 1779)	Nzayi		
		<i>Philantomba monticola</i> (Thunberg, 1789)	Mboloko		
Hyracoidea	Procaviidae	<i>Dendrohyrax sp</i> (Fraser, 1855)	Eloka		
Macroscelidea	Macroscelididae	<i>Rhynchcyon cirnei</i> (Peters, 1847)	Ifini		
Pholidota	Manidae	<i>Smutsia gigantea</i> (Illiger, 1815)	Liha		
Primates	Cercopithecidae	<i>Ptilocolobus badius</i> (Kerr, 1792)	Ekota		
		<i>Papio anubis</i> (Lesson, 1827)	Abula		
		<i>Cercopithecus Ascianus</i> (Audebert, 1799)	Kidekide		
		<i>Cercopithecus neglectus</i> (Schlegel, 1876)	Funga		
		<i>Cercopithecus wolffi</i> (Meyer, 1891)	Bongande		
		<i>Cercopithecus hamlyni</i> (Pocok, 1907)	Kputuko		
		<i>Pan troglodytes</i> (Blumenbach, 1776)	Mukomboso		
		Lorisidae	<i>Perodicticus potto</i> (Müller, 1766)	Efombé	
		Proboscidea	Elephantidae	<i>Loxodonta africana</i> (Anonym, 1827)	Nzoku
		Rodentia	Hystricidae	<i>Atherurus africanus</i> (Gray, 1842)	Nziko
Nesomyidae	<i>Cricetomys emini</i> (Wroughton, 1910)		Lotomba		
Sciuridae	<i>Protoxerus strangeri</i> (Waterhouse, 1843)		Bokoma		
Thryomyidae	<i>Thryomys swinderianus</i> (Temnick, 1827)		Simbiliki		
Tubulidentata	Orycteropidae	<i>Orycteropus afer</i> (Pallas, 1766)	Tumba, Libongo		

The most consumed fish are ngolo (*Clarias sp.*), sela (*Labeo sp.*), njombo (*Protopterus sp.*), ndakala (*Stolothrissa tanganyicae/Limnothrissa miodon*), and mpoto (*Distichodus sp.*). The most consumed bushmeat species are small monkeys, red duikers, bush tailed porcupine, blue duiker and bush pig. The most favored meats are bushmeat (fresh rather than smoked) and fish. If bushmeat and fish were to disappear or become too expensive, chicken and pork would be the two most suitable substitute proteins. In general, when families do not eat enough of their favored food, it is because it is seasonal or unavailable. Sometimes, selling prices also explain food choices. In Yangambi, fish costs almost twice as much as bushmeat (average price: 8.1 USD/kg for fish and 4.1 USD/kg for smoked bush meat). During the sampled season (end of harvest period), only smoked caterpillars were sold, attaining a very high price (13.6 USD/kg). Bushmeat remains the most affordable source of meat. Domestic

sources of meat (eg. pork, chicken) have limited availability in local shops or markets, due to the lack of electricity for proper preservation, and, when they are available, they are expensive.

State of the Resource

At all levels of the sector, the availability of game seems to be the main barrier to entry into the system. At least 79% of traders find it difficult to obtain the quality of bushmeat they are looking for and 81% of sellers do not find enough. For 75% of traders, the sale of bushmeat has become more difficult in the last 10 years due to the lack of wildlife and 64% of them believe that their income has decreased. For 92% of consumers, access to bushmeat has reduced over the last 10 years. Over 88% of hunters consider hunting to have become more difficult over the last 10 years.

According to hunters, mammal abundance in the study area is characterized by a steady decline for all species. Three species

are thought to have drastically declined: the okapi (*Okapia johnstoni*), red colobus (*Piliocolobus badius*), and chimpanzee (*Pan troglodytes*). Only small species with short gestation periods, such as hyrax (*Dendrohyrax* sp.), cane rat (*Thryonomis swinderianus*) and African giant squirrel (*Protoxerus stangeri*) are believed to be stable. Species that are nocturnal, have cryptic behavior or prefer habitats that are not easily accessible to hunters are more likely to persist in hunting areas. Five of the 34 hunted species (classified in one of the IUCN critical categories: near threatened, vulnerable, endangered, critically endangered) are vulnerable: chimpanzee (*Pan troglodytes*), okapi (*Okapia johnstoni*), giant pangolin (*Smutia gigantea*), otter (*Aonyx congicus*), and red colobus (*Piliocolobus badius*). The elephant (*Loxodonta africana*) is the only mammal species to have disappeared from the entire study landscape over the period from 1995 to 2018, the last sighting (direct and indirect observations combined) dates from 2007. While okapi (*Okapia johnstoni*), forest buffalo (*Syncarus caffer nanus*), and red colobus (*Piliocolobus badius*) are still present in the north of Ngazi, these species have become very rare or locally extinct from within the boundaries of YBR.

Drivers of Change in the Wildmeat Value Chain

Political conflicts related to successive rebellions between 1996 and 2003 are presented as being the source of many cascading effects on the social, economic and ecological systems of the study area, with significant direct and indirect impacts on wildlife. During these periods of rebellion, soldiers of the Armed Forces of the Democratic Republic of Congo (FARDC), and other armed groups (Congolese, Rwandans and Ugandans from eastern DRC) hunted for meat, but were also involved in trafficking ivory, skins and meat. The uncontrolled use of wildlife resources by armed soldiers eroded local customary governance systems. In addition, the already weakened economy of the region was significantly affected by political instability and resulted in limited transportation means, reduced exchange networks and the closure of factories, which were the only source of stable employment in the region. With population growth and the lack of production/supply of meat from domestic animals, more families became dependent on forest resources for food security. As a result, the number of hunters involved in commercial hunting and the volumes traded have increased steadily over the last 20 years. Hunting practices have also changed to maximize harvest with both day and night hunting (due to the introduction of headlamps), multi-day hunting trips, and locally manufactured guns and cartridges. The number of traders has increased from 15 traders in the 1990s to more than 200 traders today. This is principally explained by the reduction in numbers of employees and the reduction of salaries in state-owned research and outreach centers, which previously represented the main source of employment in the region.

DISCUSSION

Our study provides an example of a bushmeat trade chain in a medium-sized catchment area around the town of Yangambi. In

the studied location, the trade contributes significantly to local food security and constitutes the most affordable and available source of animal protein, as also observed in Kisangani in 2002 (van Vliet et al., 2012) or in Bangui (Fargeot et al., 2017). As opposed to what has been observed in large cities, where bushmeat consumption is consumed as a delicacy or for specific cultural reasons rather than as a necessity (Wilkie et al., 2016; Luiselli et al., 2018), in medium sized towns, such as Yangambi, bushmeat seems to remain a key component for the food security of the poor.

The bushmeat trade chain in Yangambi has a “redundant” structure, which, according to the typology described by Phelps et al. (2016), refers to a structure where the number of stakeholders is very high at all levels of the chain. In Yangambi, the number of active hunters ($N = 539$), the number of traders ($N = 252$) are very high and more than 60% of households eat bushmeat more than once a week, keeping demand at the highest level. According to Phelps et al. (2016), redundant market chains often occur in contexts where there are few barriers to participation in the sector. In Yangambi, the bushmeat sector is poorly controlled by the State, as is the case throughout the Congo Basin (Fa, 2007; Lescuyer and Nasi, 2016). At the level of hunters, the resource is quasi-open access. Indeed, the armed conflict eroded local governance structures controlling access to resources. Hunting is not limited by access to firearms, as observed in Tanzania (Nielsen et al., 2016), since hunters rely on locally made firearms and ammunition. At the level of traders, the number of stakeholders involved is not limited by ethnicity as observed in Makokou, Gabon (Okouyi, 2006), as traders belonging to different ethnic groups may engage in trading. In Leticia, Colombia, van Vliet et al. (2018b) observed that the likelihood of any person to engage in trading wildmeat was low because traders required a well-established network in order to navigate the illegality of their activity. This does not seem the case in Yangambi, as the number of traders has been increasing steadily over the decades and many of them are new to the business. The number of consumers is not limited either, since the population is increasing and no other source of meat of domestic origin is competitive with bushmeat. In fact, the only barrier to entry in Yangambi, is the availability of wildlife resources. All stakeholders agree that wildlife is becoming scarce and some vulnerable species have almost been locally depleted. Despite the persistence of some emblematic species such as the chimpanzee, buffalo, okapi, red colobus and giant pangolin, the quasi-open access system observed in Yangambi, with high levels of dependency on the resource at all levels of the chain (from consumers to hunters) is likely to jeopardize the resilience of wildlife populations in the future.

Our study confirms observations by Brown and Williams (2003) in Ghana that hunting generates high profits, while requiring low investment and risks. As such, beyond the camaraderie of hunting trips, hunting is also attractive to young men living in rural areas for financial reasons. As observed by Nielsen et al. (2016) in Tanzania, hunters gain a higher profit than traders. In Yangambi, hunting may generate an income of about USD 400/year, an amount comparable to values provided by Lescuyer and Nasi (2016) for rural areas in Cameroon. In the case of Yangambi, it is actually the trade which is currently

at the limit of profitability. Transportation costs reduce net profits for brokers and traders, given the poor state of the roads, which are only accessible by bicycle or motorbike most of the year. When they move to supply areas, brokers strive to maximize the amount of meat they get for the cheapest price possible, to cover their transportation costs. In contrast to the situation in Ghana (Cowlshaw et al., 2005) and Colombia (van Vliet et al., 2015b), but, in common with Tanzania (Nielsen et al., 2016), transportation costs are not borne by the hunters, but rather by the brokers and traders, as a result of demand outstripping supply.

Wildmeat trade in Yangambi illustrates the functioning of a medium-sized catchment area, involving relatively short market chains. We hypothesize that these short market chains in emerging towns from the Congo Basin are becoming more common, as wildlife harvests no longer generate surplus to supply more distant towns and local demand increases with rising human population in those secondary urban areas. Transportation costs hinder the profitability of wildmeat trade to distant areas. In those distant towns, as wildmeat becomes scarcer, prices of this commodity rise and become less competitive as compared to other sources of meat available, and consumption of wildmeat becomes a luxury rather than a necessity. Particular attention should be given to understanding market dynamics in those emerging consumption hubs where both urban food security and ecological sustainability are at stake.

The differences observed in available market chain studies, call for tailored approaches to each context to reduce unsustainable trade to urban areas. Initiatives targeting the hunters will have little impact in a context where the profits generated by hunting are attractive as compared to other sources of livelihoods. While behavior change campaigns, as suggested by Chaves et al. (2018), might work in some contexts, we believe that patterns

of bushmeat consumption in Yangambi will not change until alternative sources of food and income for a growing population can be established. Where the dependency on the resource is so intrinsically linked to people's basic needs, there are little chances that behavioral change campaigns will have a significant impact. Strict law enforcement, although necessary, will not stop illegal behaviors, but may rather fuel retaliatory killing (Soliku and Schraml, 2018), particularly where local livelihoods have continued to expand over the protected area's territory in the absence of any sort of management for decades. In contrast, if substitutes become more available, as already observed in the neighboring town of Kisangani (van Vliet et al., 2017b), the amounts of bushmeat traded may decrease over time. With sustained peace and a structured economy to guarantee steady incomes, maintain exchange networks and incentivize investment in livestock production systems, consumers may find other alternatives to secure their nutrition. A process that supports the re-structuring of local governance systems in a post-conflict context will also help reverse unsustainable use in the long run.

AUTHOR CONTRIBUTIONS

NV developed the methodology of the research, coordinated field activities, analyzed the data and wrote the initial draft of this manuscript. JN and JM carried out the field work and contributed to data analysis. RN provided guidance all along the process and participated in the writing of the manuscript.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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