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Local-Scale Dynamics and Local Drivers of Bushmeat Trade

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Abstract: *Bushmeat management policies are often developed outside the communities in which they are to be implemented. These policies are also routinely designed to be applied uniformly across communities with little regard for variation in social or ecological conditions. We used fuzzy-logic cognitive mapping, a form of participatory modeling, to compare the assumptions driving externally generated bushmeat management policies with perceptions of bushmeat trade dynamics collected from local community members who admitted to being recently engaged in bushmeat trading (e.g., hunters, sellers, consumers). Data were collected during 9 workshops in 4 Tanzanian villages bordering Serengeti National Park. Specifically, we evaluated 9 community-generated models for the presence of the central factors that comprise and drive the bushmeat trade and whether or not models included the same core concepts, relationships, and logical chains of reasoning on which bushmeat conservation policies are commonly based. Across local communities, there was agreement about the most central factors important to understanding the bushmeat trade (e.g., animal recruitment, low income, and scarcity of food crops). These matched policy assumptions. However, the factors perceived to drive social-ecological bushmeat trade dynamics were more diverse and varied considerably across communities (e.g., presence or absence of collaborative law enforcement, increasing human population, market demand, cultural preference). Sensitive conservation issues, such as the bushmeat trade, that require cooperation between communities and outside conservation organizations can benefit from participatory modeling approaches that make local-scale dynamics and conservation policy assumptions explicit. Further, communities' and conservation organizations' perceptions need to be aligned. This can improve success by allowing context appropriate policies to be developed, monitored, and appropriately adapted as new evidence is generated.*

Keywords: bushmeat, participatory modeling, poaching, protected areas, Serengeti ecosystem, wildebeest, zebra

Dinámicas a Escala Local y Conductores Locales del Mercado de Carne de Caza

Resumen: *Las políticas de manejo de la carne de animales silvestres se desarrollan continuamente fuera de las comunidades en las que se implementarán. Estas políticas también se asignan rutinariamente para ser aplicadas uniformemente a lo largo de comunidades con poca consideración por la variación de las condiciones sociales o ecológicas. Usamos mapeo cognitivo de lógica difusa (FCM, en inglés), una forma de modelado participativo, para comparar las suposiciones que conducen a las políticas de manejo generadas externamente con las percepciones de las dinámicas del mercado de carne de animales silvestres colectadas de miembros de la comunidad local que admitieron estar involucrados recientemente en dicho mercado (p. ej.: cazadores, vendedores, consumidores). Los datos se colectaron durante 9 talleres en 4 aldeas de Tanzania, con límites al Parque Nacional Serengueti. Específicamente, evaluamos 9 modelos generados en la comunidad en la presencia de los factores centrales que comprometen y conducen al mercado de carne de animales silvestres*

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y si o no los modelos incluyen los mismos conceptos centrales, relaciones y cadenas lógicas de razonamiento sobre las cuales las políticas de conservación se basan comúnmente. A través de las comunidades locales, hubo un acuerdo sobre los factores más centrales que importan para entender este mercado (p. ej.: el reclutamiento de animales, bajos ingresos y la escasez de cosechas). Éstos coincidieron con las suposiciones de las políticas. Sin embargo, los factores percibidos como conductores de las dinámicas socio-ecológicas del mercado de carne de animales silvestres fueron más diversos y variaron considerablemente a través de las comunidades (p. ej.: presencia o ausencia de la aplicación colaborativa de la ley, incrementar la población humana, demanda de mercado, preferencia cultural). Temas sensibles de conservación, como el mercado de carne de animales silvestres, que requieren cooperación entre las comunidades y las organizaciones externas de conservación, pueden beneficiarse de acercamientos de modelado participativo que hacen explícitas a las dinámicas a escala local y las suposiciones de las políticas de conservación. Además, las percepciones de las comunidades y las organizaciones de conservación necesitan alinearse. Esto puede aumentar el éxito al permitir políticas apropiadas dentro del contexto que se puedan desarrollar, monitorear y adaptar apropiadamente mientras se genera nueva evidencia.

Palabras clave: Áreas protegidas, carne de animales silvestres, caza furtiva, cebra, ecosistema del Serengueti, modelado participativo, ñu

Introduction

Extreme poverty, advances in hunting techniques, and increasing human populations near protected areas have increased demand for bushmeat and significantly affected wildlife populations in many developing countries (Knapp 2012; Rentsch 2012). Although the term *bushmeat* refers to the hunting and consumption of all wildlife, on-going and extensive illegal hunting has been particularly damaging to the native biota in Africa and has driven many species to be classified as threatened or endangered (Schenk et al. 2006; Ndibalema & Songorwa 2008; Mfunda & Røskaft 2010). Further, the emergence of market-based economies and the commercialization of bushmeat in urban centers have increased demand for bushmeat through commodification and exportation (Brashares et al. 2011). Wildlife managers and conservation agencies are increasingly forced to make decisions that involve trade-offs between the nutritional (Golden et al. 2011) and economic (Brashares et al. 2011) needs of rural communities and the long-term protection of wildlife populations (Fa et al. 2003 ; Rentsch 2012).

In response to these conservation issues, national and local governments in Africa have created wildlife protection areas, many with a "fine and fences" approach to wildlife management (Hilborn et al. 2007). This approach often limits local community access to the wildlife resources that they have historically relied on. In so doing, these measures have essentially transitioned subsistence and culturally driven hunting into an illegal activity (Tadie & Fischer 2013), and the rules in place are often imposed from outside the community. Not surprisingly, the design of these programs has been called into question (e.g., Gibson & Marks 1995; Songorwa et al. 2000; Morton et al. 2010), and many conservation agencies now seek to engage communities in more collaborative wildlife conservation efforts (Songorowa 1999; Songorwa et al. 2000; Brashares et al. 2011).

Although community-based conservation approaches to illegal hunting are expected to be more amenable to local communities, compared with simply restricting use, these policies are often based on defining *community* at larger scales and somewhat homogenously. As a result, there are questions about the conservation outcomes of community-based policies because they are often applied with little consideration of variation in culture, availability of wildlife, access to alternative sources of protein, or distance from protected areas, which all influence human-wildlife interactions (Martin et al. 2012). Further, these community-based conservation policies are founded on different assumptions regarding the drivers and social-ecological dynamics of the bushmeat trade. These assumptions are often based on global or regional trends that tend to define bushmeat value solely in terms of income and protein. The result has been a set of unilateral bushmeat conservation policies applied across Africa (Nasi et al. 2008) that include providing income alternatives to influence bushmeat supply, providing protein alternatives to influence bushmeat demand, and establishing community-based management programs that distribute wildlife use benefits back to community members (CBD SBSTTA 2011). Although these initiatives are all designed to meet conservation and community goals concurrently, there are few data to support whether different community perceptions of the bushmeat problem align with conservation agencies' assumptions. Furthermore, methods that provide this information remain elusive. In fact, recent studies have identified potential problems collecting individual information about illegal behaviors because of differences in understanding between community members and researchers, issues of anonymity and discomfort, and fear of potential retaliation (Bitanyi et al. 2012; Nuno et al. 2013).

Given this challenge, we sought to develop a more community-driven understanding of bushmeat trade dynamics by applying a novel form of participatory modeling and to compare these community-defined dynamics with assumptions about bushmeat trade dynamics that underlie externally generated bushmeat conservation policies. To accomplish these goals, we compared logical chains of reasoning that represented different community assumptions of bushmeat trade dynamics collected from groups of individuals who self-identified as recently engaged in the bushmeat trade (hunters, sellers, and consumers) and represented the assumptions of 3 commonly applied bushmeat management policies. From a conservation policy perspective, our participatory research highlights a new way to collect data that captures the nuances of a sensitive and persistent conservation problem. Additionally, we suggest this novel method can be used to align the assumptions of the socio-ecological dynamics that underlie many conservation practices with a detailed understanding of local community perceptions to identify similarities and differences.

Methods

Study Area

This study was carried out in 4 Tanzanian villages (Bisarara, Bonchugu, Nyamburi, and Robanda) located near the Serengeti National Park (SNP) and 2 game reserves (Ikonongo and Grumeti). These sites were selected based on the communities' knowledge and proximity to protected areas; known engagement in the bushmeat trade; and interaction with governmental and nongovernmental wildlife conservation organizations (Rentsch 2012). The 4 villages were randomly selected from 6 villages currently engaged with microcredit lending bushmeat conservation groups located near the wildlife management area adjoining the western portion of SNP (Fig. 1). Approximately 2 million people live along the western edge of the SNP (Kideghesho 2010), and the populations in these villages are increasing by approximately 3% per year (Loibooki et al. 2002; Kideghesho 2010). In all of the villages, agriculture and keeping livestock are the major economic activities (Loibooki et al. 2002). Because the area serves as critical habitat for several charismatic species, there is a range of international conservation agencies actively engaged in conservation programs in the region (Rentsch 2012). The SNP is a World Heritage Site (http://whc.unesco.org), which ostensibly extends the scale of wildlife stakeholders to the global community.

Although SNP has a strict no take wildlife policy, regulated legal hunting is allowed in the Ikonongo and Grumeti game reserves. However, because legal hunting in these game reserves requires licenses, is limited to specific points of access, and prohibits local hunting techniques such as snares, hunting is restricted, almost exclusively, to foreign hunting-based tourism activities.

Characterizing Community Perceptions about Bushmeat Trade

Using a participatory modeling approach, we collected data from workshops in the 4 villages near SNP. These models represented the social and ecological variables associated with the bushmeat trade and their interrelationships. Our multistep approach to selecting an even distribution of knowledgeable individuals to take part in each of the model-building workshops included the following steps which are described in further detail below. First, we interviewed community leaders in each village to identify the types of knowledgeable actors involved in the bushmeat trade to be included in the model-building workshops. Second, we advertised, through NGO and government partners, the community meetings to individuals in each village who were at the time or were recently involved in the bushmeat trade. Third, we held 9, 2-day, community meetings in the 4 villages that included focus group discussions on day 1 to discuss the bushmeat issue and identify knowledgeable and vocal individuals to take part in the modeling workshops and model building workshops on day 2 with the smaller number of identified expert individuals.

To identify workshop participants with reliable expertise, individuals were drawn from all community members engaged in the bushmeat conservation micro-credit lending program and who had admitted to recently being involved in the bushmeat trade. The number of meetings in each of the villages varied based on the degree of participation in the micro-credit programs. Care was taken to model the complete trade system, from harvest to consumption, during workshops. Therefore, to identify the different types of expertise required to model the bushmeat trade, prior to the meetings, interviews with community leaders in each village identified the 3 types of actors involved at each step of the bushmeat production chain: hunters, sellers, and consumers.

Selection of modeling workshop participants was structured the same way during the 9 community meetings which were advertised by local NGO and government partners. The first day included a focus group discussion about the dynamics of the bushmeat trade, local hunting areas, reasons for hunting, and the roles of different actors involved (hunters, sellers, and consumers). Participation in these first-day focus groups ranged from 20 to 40 individuals (total sample of 270 individuals). At the end of the first day, participants were asked to identify the hunters, sellers, or consumers among them and nominate a list of 12–15 that were the most knowledgeable and vocal individuals to return the next day for the modeling workshop. Participation in the modeling workshops on day 2 ranged from 10 to 26 individuals (a total sample of 157 individuals) and lasted from 6 to 8 h. Two of the 9 workshops were limited to only bushmeat seller and consumer stakeholder groups. All workshops were led by an independent facilitator who was a local

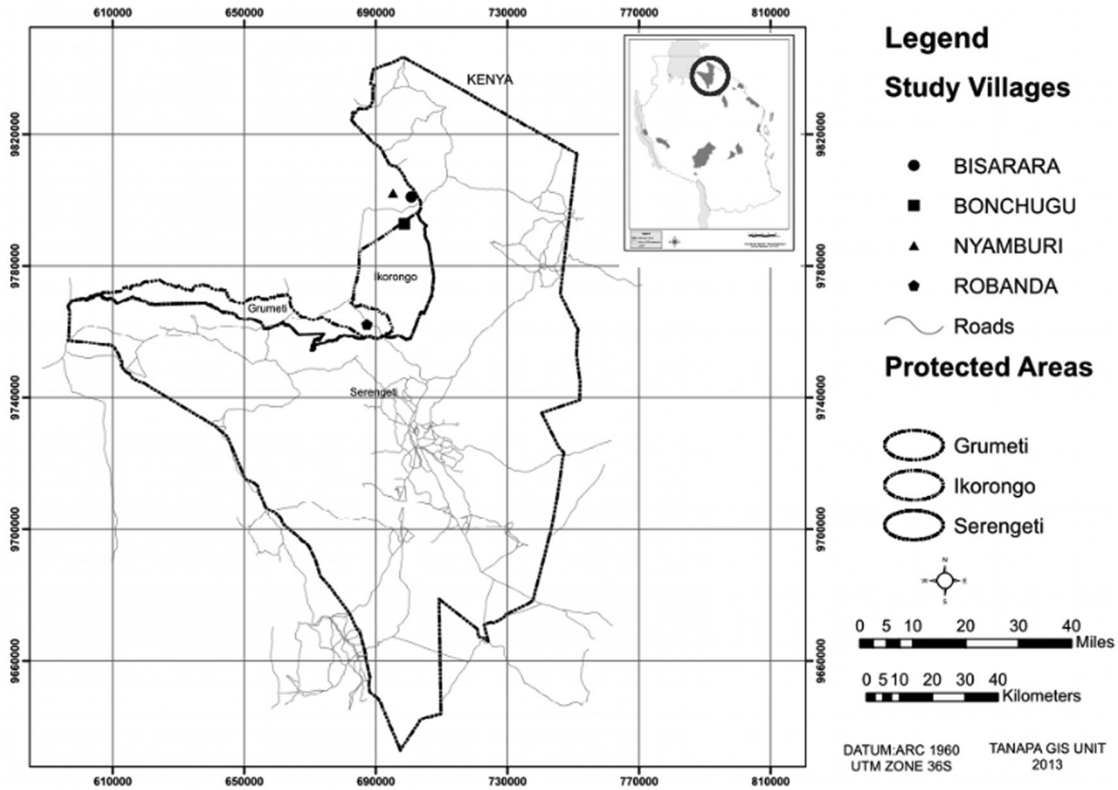

Figure 1. Map of the 4 villages to the west of Serengeti National Park included in workshops in which models of bushmeat trade dynamics were developed.

community member and spoke both of the predominant languages in the region, Swahili and English.

To build models during the workshops, we used a method called fuzzy-logic cognitive mapping (FCM). FCM is a simple and easy form of graphical stock-and-flow modeling that allows groups to share and negotiate knowledge collaboratively and build semi-quantitative conceptual models. FCM facilitates the explicit representation of group assumptions about a system being modeled through parameterized cognitive mapping (Özesmi & Özesmi 2004; Gray et al. 2014). Specifically, FCM allows cognitive maps to be constructed by defining the most relevant variables that comprise a system, the dynamic relationships between these variables, and the degree of influence (either positive or negative) that one variable can have on another. In group settings, FCM models are constructed based on combining group beliefs in a similar format as individuals share their experiences and understanding (Gray et al. 2014).

The strength of using FCM in this context is the ability to extract, combine, and represent group knowledge in a sensitive situation for comparison between or among groups. FCM places less reliance on any one individual because there is more anonymity in a group setting. In terms of collecting information regarding community interaction with bushmeat, this may reduce some of the social desirability biases found in personal interviews and surveys (Nuno et al. 2013). It also allows these representations of a specific issue to be structured for debate and does not ask about individual behavior; rather, it examines the perceived behavior of a dynamic system of which an individual is a part. Collecting FCM from groups is generally easier, simpler, and faster than acquiring detailed knowledge from individuals or household surveys, which is the typical approach used in many bushmeat studies (Kaltenborn et al. 2005; Brashares et al. 2011).

We collected FCM data following methods outlined by Özesmi and Özesmi (2004). During workshops, participants were introduced to the cognitive mapping process and an unrelated example FCM was constructed of an agricultural system. After participants were comfortable with the task, groups discussed the variables and relationships that were important to understanding the bushmeat trade. These variables were recorded on a blackboard in front of the group. In addition, all groups were provided with 2 variables to begin the model building process: bushmeat consumption and zebra and wildebeest population size. After a list of relevant variables were identified through brainstorming and recorded, we then asked participants to collectively identify relationships between components, represented by directed arrows between variables that could be defined as positive (e.g., as rain increases water availability increases), negative (e.g., as drought conditions increases water availability decreases), or no relationship. Last, participants weighted the relationships as strong, medium, or low. These qualitative categories were then translated into quantitative values between +1 and −1. A strong positive relationship was defined as +1, medium positive as +0.5, small positive as +0.25, strong negative relationship as −1, medium negative as −0.5, and small negative as −0.25. This translation (or "fuzzification") of qualitative influence to quantitative influence allows the emergent dynamics of a system to be evaluated (Kosko 1986).

During all workshops, groups of individuals refined and revised their models as they shared information about their experience and their role in the bushmeat trade. All models were constructed on a blackboard in front of the group with the independent local facilitator. After groups were satisfied with their models and had nothing more to add, models were photographed for subsequent transcription and analyses following Özesmi and Özesmi (2004) and digitized in an FCM software, Mental Modeler (see www.mentalmodeler.org; Gray et al. 2013).

Characterizing Bushmeat Management Policy Assumptions

Because of the ecological significance of the Serengeti ecosystem and the increasing human-based pressures on regional wildlife habitat (e.g., agropastoral population growth, livestock impacts, and subsistence cultivation [Homewood et al. 2001]), several wildlife conservation programs have been implemented in the area to specifically reduce the illegal hunting of bushmeat (Alcorn et al. 2002; Rentsch 2012). The majority of these programs are based on commonly assumed solutions to illegal hunting such as providing income alternatives, providing protein alternatives, and establishing community wildlife management (CWM) programs.

To evaluate the assumptions of these programs, we developed 3 different logic models (Wholey 1987) based on a review of 30 case studies. Studies were drawn from a primary (Web of Science; Science Direct) and gray literature (internet) search limited to bushmeat studies conducted in the Serengeti ecosystem. Logic models are often used by program evaluators to explicitly define the inputs, activities, outputs, and outcomes and impacts of planned or implemented programs (McLaughlin & Jordan 1999). Logic models were developed for each policy with FCM, in a manner consistent with the collection of the community-generated models, with FCM so they could be directly compared with models collected from the communities.

Comparing Policy Assumptions with Community Perceptions

Within each of the 9 community models, bushmeat conservation policy variables were identified for each of the 3 management policy assumptions (income alternatives, protein alternatives, CWM). For example, variables for the income-alternatives policy included identifying income generating activities aside from hunting, such as tourism-based employment. Variables related to protein alternatives included identifying components related to protein selection such as availability of fish. Variables related to CWM included identifying components related to receiving benefits of wildlife such as collaborative law enforcement. The relationship of these variables to illegal hunting, bushmeat consumption, and zebra and wildebeest populations was also identified in each community model and their dynamics were compared with the policy models. A comparison of policy assumptions with community-generated models was done to determine if the chains of logical reasoning about the bushmeat trade dynamics were consistent between community assumptions and policy assumptions.

Evaluating Community Model Structure

Community models were also evaluated by identifying individual variable centrality, which is the measure of the relative importance of each variable to the modeled system's dynamics, and driving variables, which are considered to have a substantial impact on bushmeat trade dynamics. For these analyses, community models were converted into a matrix and the degree of influence between variables was converted from qualitative terms into quantitative values between −1 and +1 (Kosko 1986; Özesmi and Özesmi 2004; Gray et al. 2014). These quantitative influence values were then listed in the rows and columns in an adjacency matrix by listing all variables included in the model on 2 axes. After each FCM was converted into a matrix, variable centrality and identification of driving variables were determined by calculating each variable's out-degree and in-degree.

Out-degree (od) is the row sum of absolute values of a variable in the adjacency matrix. It indicates the cumulative strength of relationships that are defined outwardly from a variable, where N is the total number of variables and a_{ik} is cumulative strength of connections exiting a variable :

$$\mathrm{od}(v_i) = \sum_{k=1}^{N} \overline{a}_{ik}. \quad (1)$$

In-degree (id) is the column sum of absolute values of a variable in the adjacency matrix. It indicates the cumulative strength of relationships that are defined inwardly into a variable, where N is the total number of variables and a_{ki} is cumulative strength of connections entering a variable:

$$\mathrm{id}(v_i) = \sum_{k=1}^{N} \overline{a}_{ki}. \quad (2)$$

The centrality of variables and identification of important driving variables were calculated using out-degree and in-degree values. The centrality of a variable (c), also called its total degree (td), is calculated by summing its in-degree (in arrows) and out-degree (out arrows) (Harary et al. 1965; Bougon et al. 1977; Eden et al. 1992), where centrality (c) is equal to total degree [$\mathrm{td}(v_i)$] which is composed of the sum of the out-degree [$\mathrm{od}(v_i)$] and in-degree [$\mathrm{id}(v_i)$]:

$$c_i = \mathrm{td}(v_i) = \mathrm{od}(v_i) + \mathrm{id}(v_i). \tag{3}$$

Driving variables have a positive out-degree, $\mathrm{od}(v_i)$, and zero in-degree, $\mathrm{id}(v_i)$ (Bougon et al. 1977) and indicate that, although they influence other variables in the model, they are not themselves affected by any other variable. Because comparison of all variables included in the model would be overly complex for analysis (Özesmi & Özesmi 2004), the top 6 most central variables (i.e., the highest centrality scores) and the top 6 driving variables (i.e., highest out-degree scores with in-degree scores of zero) were identified within each model and then compared across each of the 9 models. Comparisons were used to look for consistent identification of the most important variables in each model and the variables that were perceived to have the most substantial influence on bushmeat trade dynamics.

Results

Characterizing Bushmeat Management Policy Assumptions

The 3 logic models generated from each of the bushmeat management policies showed structural similarities but differed slightly in their approaches, relationships, and assumptions about bushmeat trade dynamics. These differences were found in either investment into alternative sources of income generation aside from wildlife hunting, investment into providing alternative or subsidized sources of protein, or investment in community-based management programs. The activities and outputs of these investment activities also varied slightly; income alternatives were geared toward influencing mostly hunters and household income, protein alternatives were geared toward influencing household consumption and nutritional needs, and CWM focused on collaborative resource ownership and distributing the benefits and costs of wildlife management. The ultimate assumed impact of the 3 policies, however, was the same and all policies aimed to have positive impacts on wildlife populations (Fig. 2).

Comparing Policy Assumptions with Community Perceptions

On average FCM models included 32.6 (SD 5.5) variables and 89.7 (SD 24.2) connections. When individual model dynamics and variables were compared with the dynamics and variables included in the 3 conservation policy models, most showed structural consistencies indicated by the same relationships and arrows flowing between the central variables (Table 1). However, there were differences by village. For example, all 3 workshops from the village of Bonchugu showed no relationships between protein alternatives and bushmeat consumption, wildlife populations, and illegal hunting. Furthermore, one of the Bonchugu group models showed no relationships between CWM and the bushmeat trade variables. Additionally, 1 of the 3 workshop models from Nyamburi showed the opposite relationship between alternatives sources of income and bushmeat consumption, indicating that as income rises from nonbushmeat-related activities, bushmeat consumption will likely increase, as opposed to the policy assumption that it will decrease. All other models showed consistency for the relationships between variables. For example, one model (Fig. 3) matched all 3 bushmeat policy assumptions because it included variables such as increased income from tourism; bushmeat price lower than beef, chicken, fish; and CWM, which were all linked to bushmeat consumption, illegal hunting, and wildlife populations in a manner similar to assumptions of these conservation policies.

Central Variables and Dynamics of the Bushmeat Trade

All variables in every community model were given a centrality score in order to rank the relative network importance of each variable in each model. The variables of bushmeat consumption and zebra and wildebeest population sizes were omitted in the centrality analysis because they were provided to the workshop participants to begin the modeling process. Illegal hunting was included in all groups as the most central variable, followed by food and water for wildlife, which was included by 7 groups in their top central variables. Recruitment and low income were also included in 6 of the community models, followed by scarcity of food crops (identified in 4 group models) and crop destruction and the existence of a bushmeat market or demand for bushmeat (identified in 4 group models). The remainder of important variables central to model dynamics included drought, collaborative enforcement, alternative income generating activities, increased human populations, proximity to protected areas, and deforestation (Fig. 4).

Driving Variables of the Bushmeat trade

All driving variables included in each model were also ranked to determine their relative effect on bushmeat trade dynamics. The 6 variables with the most effect were tallied for every model and these lists were compared by group. Driving variables had less agreement

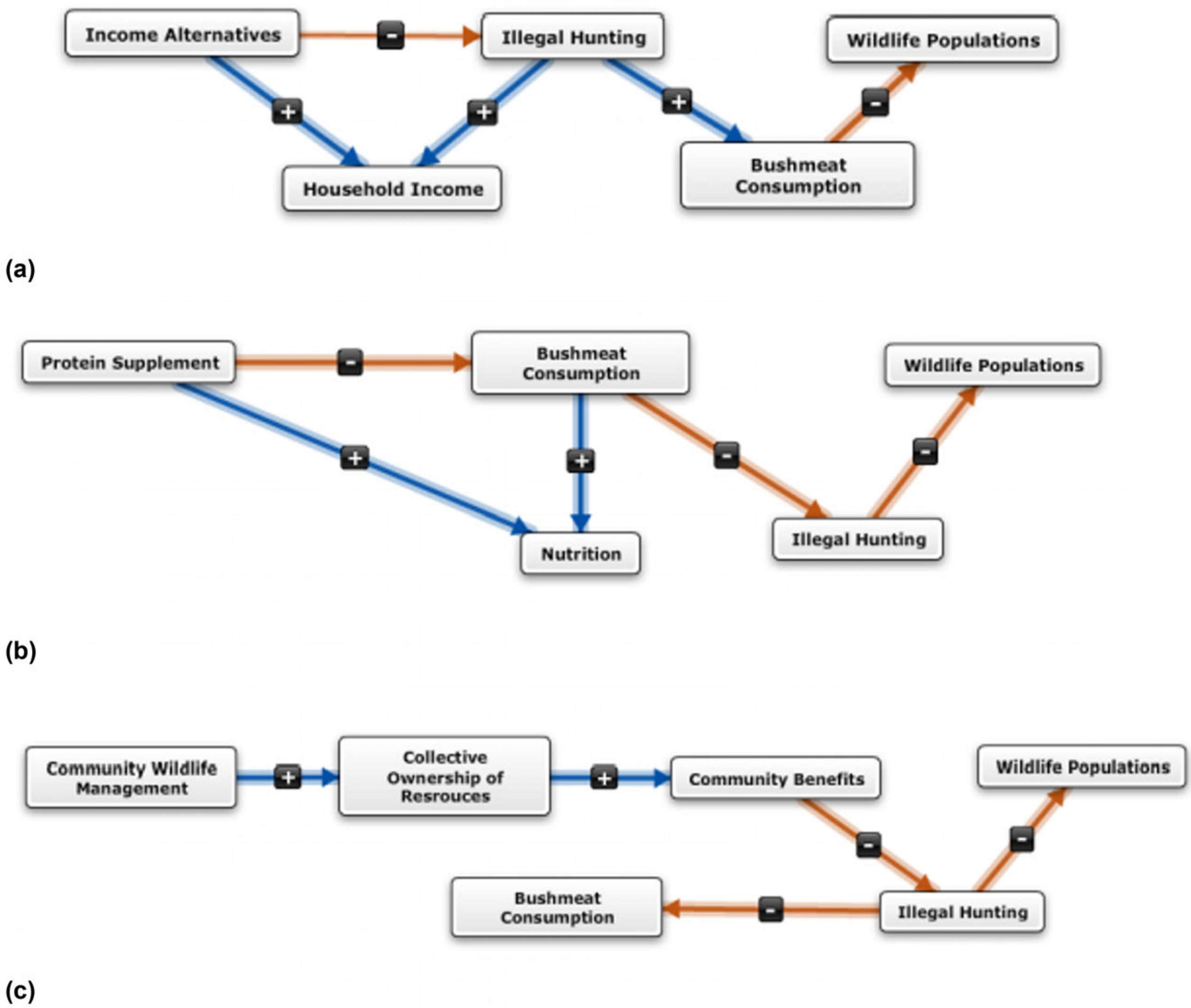

Figure 2. Logic-based models of 3 bushmeat conservation polices that represent policy assumptions based on a review of the literature constructed with fuzzy-logic cognitive mapping software Mental Modeler (Gray et al. 2013 [http://www.mentalmodeler.org/]): (a) dynamics of income alternatives in relation to bushmeat consumption, illegal hunting, household income, bushmeat consumption, and wildlife populations, (b) protein alternatives in relation to bushmeat consumption, nutrition, illegal hunting, and wildlife populations, and (c) community wildlife management in relation to collective ownership, community benefits, bushmeat consumption, illegal hunting, and wildlife populations (blue lines, positive relationships between components; red lines, negative relationships).

relative to central variables, as evidenced by more variation in the driving variables, although there were several driving variables that were included across several of the group models. For example, a majority of group models included collaborative law enforcement and low income as major drivers of bushmeat trade. Food crop scarcity and human population increases were mentioned by 5 groups, followed by crop destruction from animals and existence of a bushmeat market and demand for bushmeat. Lack of environmental education, alternative income generating activities, cultural preference, and weather were all mentioned by a third of the groups. Meat scarcity, benefits from tourism and wildlife management areas, and proximity to protected areas were mentioned by 2 groups. Disease control, wildfires, bushmeat income generating activities, and inadequate knowledge of business and lack of skills were also mentioned as significant drivers (Fig. 5).

Table 1. Comparison of village-generated model assumptions of bushmeat dynamics with conservation policy assumptions of bushmeat dynamics.

Village and work group (n)	*Conservation policy*	*Variable included in the work group model linked to hunting and wildlife*	*Policy assumption match*		
			reduce bushmeat consumption	*increase wildlife populations*	*reduce illegal hunting*
Nyamburi 1 (26)	income alternatives	alternative income sources	no	yes	yes
	protein alternative	low price of bushmeat	yes	yes	yes
	community management	community-supported hunting	yes	yes	yes
Nyamburi 2 (12)	income alternative	lack of employment opportunities	yes	yes	yes
	protein alternative	poultry farming projects	yes	yes	yes
	community management	difficult legal hunting requirements	yes	yes	yes
Nyamburi 3 (15)	income alternative	alternative income sources	yes	yes	yes
	protein alternative	high price of legal meat	yes	yes	yes
	community management	community benefits from wildlife	yes	yes	yes
Robanda 1 (12)	income alternative	income from tourism	yes	yes	yes
	protein alternative	few fish available/expensive meat	yes	yes	yes
	community management	establishment of CWA	yes	yes	yes
Ronanda 2 (10)	income alternative	alternative income sources	yes	yes	yes
	protein alternative	reduced legal meat price	yes	yes	yes
	community management	establishing CWA	yes	yes	yes
Bonchugu 1 (19)	income alternative	alternative income sources	yes	yes	yes
	protein alternative	n/a	no	no	no
	community management	lack of legal hunting areas	yes	yes	yes
Bonchugu 2 (25)	income alternative	alternative income sources	yes	yes	yes
	protein alternative	n/a	no	no	no
	community management	n/a	no	no	no
Bonchugu 3 (15)	income alternative	low household income	yes	yes	yes
	protein alternative	n/a	no	no	no
	community management	enhanced collaborative protection	yes	yes	yes
Bisarara 1 (23)	income alternative	income generating activities	yes	yes	yes
	protein alternative	scarcity of beef/goat meat	yes	yes	yes
	community management	unaware of legal hunting process	yes	yes	yes

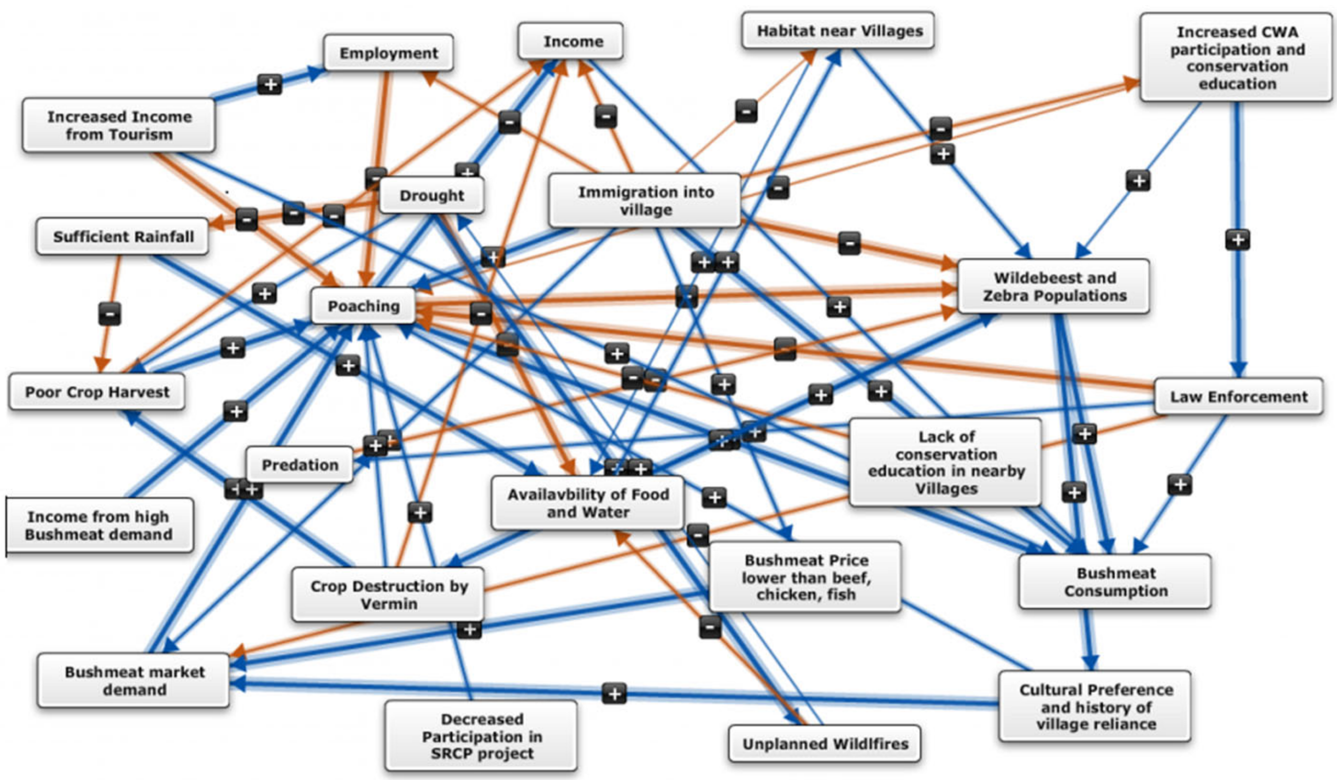

Figure 3. Example of a community-generated model of bushmeat trade dynamics constructed in Mental Modeler software from the 15 individuals that took part in the third workshop in Nyamburi whose model included 23 variables and 74 connections (blue lines, positive relationship; red lines, negative relationship; line width, strength of relationship; SRCP, is a local micro-credit lending program; CWA, community wildlife area).

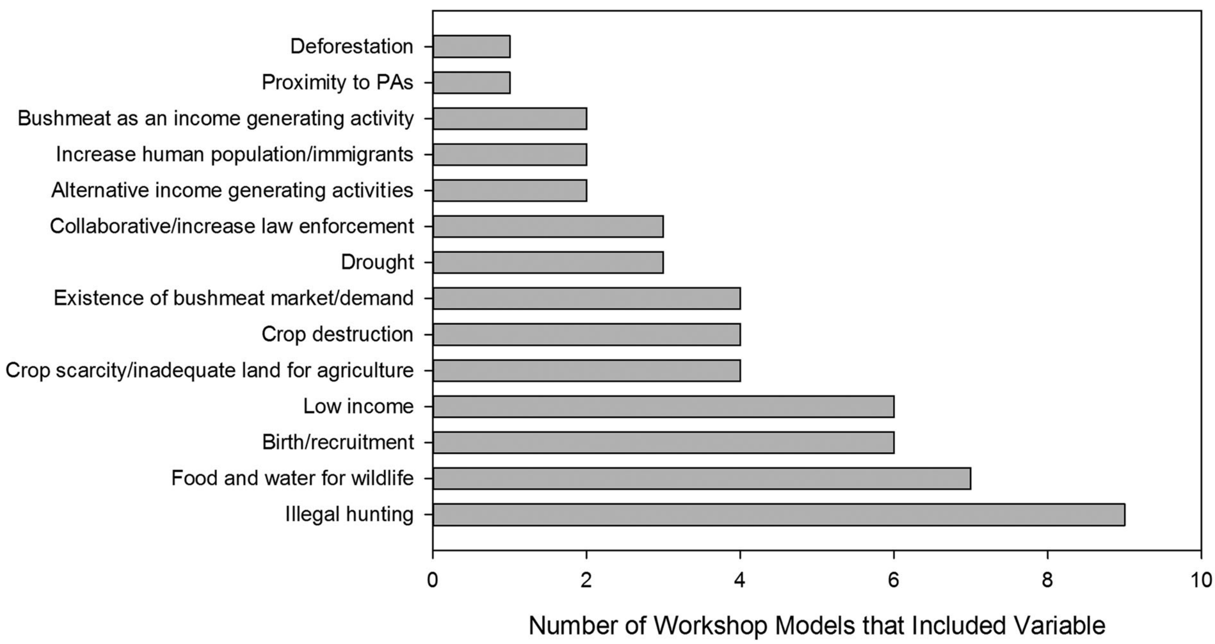

Figure 4. Variables with the highest centrality scores (y-axis) in community models of bushmeat trade dynamics (PA, protected area).

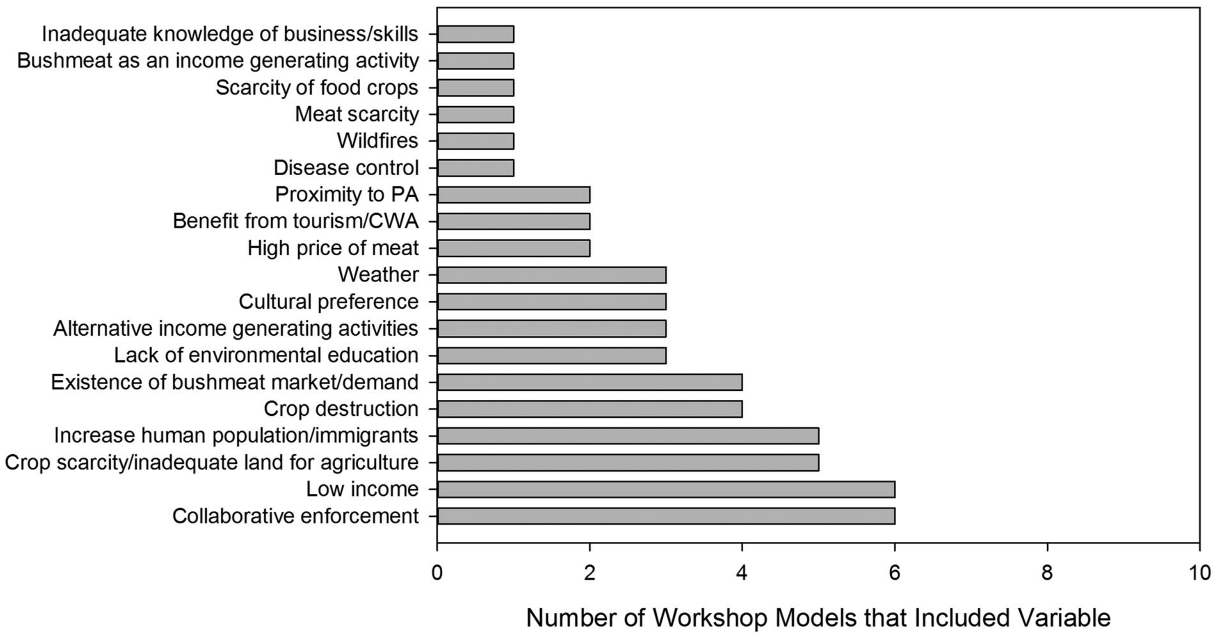

Figure 5. Most heavily weighted driving variables (y-axis) included in community models of bushmeat trade dynamics (PA, protected area; CWS, community wildlife area).

Discussion

Participatory Modeling in Groups as a Conservation Tool

Accurately characterizing the dynamics of the illegal bushmeat trade is difficult given the sensitive nature of the data collected, especially on the individual level (Nuno et al. 2013). Community-based modeling in small workgroup settings provides an alternative for collecting sensitive information, which also helps conservation organizations understand how communities define the structure of environmental and social problems. By adopting this approach, community members are freer to provide their ideas, discuss, and reach consensus about their shared beliefs about a social-ecological issue (Gray et al. 2012). In particular we used FCM, which allowed group-level knowledge about the ecosystem and social systems to be examined together in one conceptual model which promoted considerable discussion between communities and conservationists about the future direction of the bushmeat trade. Further, an emergent property of the modeling process was a list of community-defined management strategies intended to mitigate the negative and unwanted impacts of the bushmeat trade given anticipated environmental (e.g., drought) and social (e.g., increased human migration to the villages) changes.

For example, during FCM workshop participants provided options to reduce bushmeat consumption by asking wildlife managers to control bushmeat markets not only in villages bordering protected areas, but also in other areas outside these communities where the bushmeat is sold. They added that the problem might be addressed if there could be more collaborative law enforcement between defined communities (that included geographic or socially relevant boundaries), members of which could work with protected area staff to relay information about legal wildlife use, management, legal procedures, and how the benefits of these resources were redistributed to communities. These findings mirror results from Kaltenborn et al. (2005), who found that community members supported several conservation policies including stricter law enforcement, provided that more information was provided to community members about management arrangements and if community involvement was increased.

Aligning Policy and Community Perspectives

Communities adjacent to SNP showed homogeneity in terms of the central variables relevant to the bushmeat system that matched policy assumptions. Community members across groups agreed that illegal hunting and low income, and to a lesser extent the availability of food crops and crop destruction, were important. These results support previous research that indicates many community members obtain their income from a mix of small scale agriculture, livestock raising, and bushmeat hunting (Loibooki et al. 2002; Kalteborn & Nyahongo 2005; Mfunda & Røskaft 2010). However, food and water for animals, recruitment, and drought were also variables repeatedly mentioned by communities, indicating awareness of the ecological dynamics that influence wildlife production and allow hunting to be sustained. The relationships between these elements as central to bushmeat trade are supported by Rentsch (2012), who revealed that illegal hunting is most frequent during animal migration, driven by precipitation and habitat-related phenology, when large number of animals are available for a short period of time.

Even though models showed homogeneity in beliefs about the central variables, there was heterogeneity in the periphery beliefs and secondary drivers of bushmeat trade dynamics, many of which have not been accounted for to date. Indeed, most current conservation policies reviewed in our analysis focused on the central variables and their relationships for reasons of parsimony, and less attention has been paid to secondary drivers of the bushmeat trade. However, cumulatively, the secondary driving variables (e.g., lack of adequate land for agriculture) may have considerable impacts on illegal hunting rates and should be considered when bushmeat policies are revised through adaptive management. Additionally, emerging issues, such as cultural preferences for bushmeat, including the community view that bushmeat is considered organic and a healthier alternative to other animal protein options, are not something to be dismissed. As rural communities near protected areas continue to transition from subsistence to market-based economies facilitated by globalization (Tadie & Fischer 2013), traditional market forces, such as consumer preferences for wildlife products, should be monitored in tandem with the primary drivers of the bushmeat trade.

The most significant secondary (i.e., not income or protein) driver mentioned in community models was collaborative law enforcement. These variables, in addition to other reoccurring intermediate variables included in several models (e.g., lack of community benefits, lack of knowledge about legal hunting procedures), highlight the community perception that conservation policies are potentially enigmatic, with rules that are not easily understood by locals and do not generate clear and transparent benefits to local communities. This finding is supported by Kideghesho (2008), who revealed that local communities living adjacent to protected areas who have contributed their land to conservation efforts have many costs associated with wildlife conservation programs (e.g., loss of crops and livestock, damage, disease transmission) but receive only minimal benefits. The costs to local communities and what qualifies as a benefit to villages from legal tourism hunting and the establishment of no-take areas are likely more salient in the minds of local communities members. However, these costs might be less understood by NGOs from outside the region when conservation policies are being developed.

We suggest that participatory modeling, and FCM in particular, can provide researchers a novel tool to evaluate consistencies across communities within a region, help define the boundaries of different communities, and reveal local-scale differences that are useful in crafting more locally relevant management responses. Indeed, although recently scholars have warned resource managers and scientists about generating simple models of social-ecological systems that provide overly general solutions to the overuse of resources (see "panacea trap" in Ostrom et al. 2007), flexible methodologies that allow local-scale complexities to be identified are currently underdeveloped.

The inability of diverse stakeholders groups to develop a shared vision of conservation problems has recently been identified as a major impediment when translating conservation assessments into sustained on-ground outcomes (Biggs et al. 2011). This is especially true for sensitive conservation issues that rely heavily on social science data collected from community members to accurately describe human pressures on the environment, which some researchers have found can over- (Loibooki et al. 2002) or underestimate these pressures (Knapp et al. 2010) given the measurement errors associated with different approaches. We suggest that FCM may address some of these issues by providing a neutral conceptual space for the negotiation of conservation dynamics that can involve both the communities affected by conservation policies and the researchers and managers that seek to implement policies using model-based reasoning to describe human interactions with the environment and define shared conservation goals.

Collecting data about the bushmeat trade will remain a complex effort as the social and ecological dynamics near protected areas continue to change. We suggest that applying unilateral policies based on sound, but incomplete, scientific information and failure to take into account the heterogeneity in local scale social-ecological dynamics and community understanding may complicate conservation efforts. However, participatory modeling and allowing assumptions about conservation dynamics to be represented, debated, and used to develop codefined or competing hypotheses may support dialog between conservationists and communities. Further, empirically validating these co-developed models may provide a new way for collaborative conservation to proceed in the future.

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