Expert elicitation as a method for exploring illegal harvest and trade of wild meat over large spatial scales

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Abstract New evidence of commercialization and consumption of wild meat in Amazonian cities has exposed an alarming yet poorly understood threat to Neotropical biodiversity. In response to the limitations of field sampling for large-scale surveys, we sought to develop a method of rapidly assessing wildlife harvest and trade in multiple areas using expert knowledge. Using caiman as a model taxon, we surveyed experts across the Brazilian Amazon. Expert responses to a Likert-style questionnaire suggest that caiman hunting, generally considered a localized rural activity, is in fact common and geographically widespread. Contrary to previous assumptions we found evidence that urban demand is partly driving the harvest, including via interstate trafficking. We highlight the need for further field validation of wild-meat trade and urban consumption patterns in Amazonia. We conclude that expert elicitation is a simple, cost-effective technique that can be a valuable precursor to inform and direct applied conservation research, especially where there are significant knowledge gaps and at large spatial scales.

Keywords Amazonia, Brazil, caiman harvest, expert elicitation, wild-meat consumption, wild-meat trade

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Introduction

The harvesting of wild meat for human consumption is among the greatest threats to tropical wildlife and is a primary cause of population declines (Bennett et al., 2007). Aside from conservation concerns, unsustainable harvesting of wild meat can also jeopardize livelihoods and food security (Nasi et al., 2011). Characterizing the dynamics of wild-meat harvesting and consumption is challenging because of interactions among bio-physical variables (e.g. urban remoteness, species ecology) and social factors (e.g. poverty, cultural preferences; Brashares et al., 2011; Dupain et al., 2012). Despite its inherent complexity, harvesting of wild meat is frequently dichotomized as a subsistence activity for the marginalized rural poor (de Merode et al., 2004) or a lucrative commercial endeavour supplying urban markets with a luxury heritage item (East et al., 2005). Legislation often reinforces this polarization by allowing the former but not the latter. The commercialization of wild meat for urban markets is considered to be the primary driver of the bushmeat crisis in West and Central Africa (Bennett et al., 2007).

In the Neotropics, examination of wild-meat harvesting and consumption has centred on the rural subsistence paradigm (Peres, 2000). In Amazonia research has focused mainly on the determinants and ecological impacts of rural hunting practices (Peres & Nascimento, 2006). Regional estimates of bushmeat consumption have been extrapolated from rural village-level offtake studies (Peres, 2000; Fa et al., 2002) but these estimates ignore commercial trade and urban consumption, instead assuming that urban Amazonians do not eat forest wildlife (Nasi et al., 2011). This assumption must now be re-examined, given evidence of high levels of commercialization and consumption of wild meat in Amazonian cities (Parry et al., 2014; van Vliet et al., 2014). With rapid growth of cities, aggregate urban consumption of wild meat in Amazonia could be vast and increasing, yet the interacting dynamics of rural harvest, trade networks and urban markets remain under-studied.

Urban consumption of wildlife often requires long-distance trade networks connecting distal forests with metropolitan consumers. In Asia, for example, turtle meat is traded across international borders (Nijman, 2010) and significant quantities of African bushmeat end up in illegal meat markets in Europe (Chaber et al., 2010). Even within national boundaries networks can span vast distances, and harvesters will travel further to meet demand as wildlife populations decline (Lindsey et al., 2013). Examining wildlife harvest and trade over large spatial scales is problematic for researchers because of the time and cost of fieldwork, and the difficulty of studying an often illegal and cryptic activity (Razafimanahaka et al., 2012). In Amazonia, where so little is known about the scale and nature of urban consumption of wild meat, an important step is to synthesize present understanding and define key knowledge gaps to inform applied research and policy interventions. We use an expert elicitation approach to gauge knowledge, using caiman as a model taxon for understanding large-scale patterns of wildlife harvest, trade and consumption.

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Caiman: a model taxon

There is a significant lack of knowledge about current levels of harvesting, trade and consumption of caiman in Amazonia. Harvest studies tend to focus on terrestrial mammals, as they are considered to be preferred by hunters and have long been studied by tropical ecologists (Bodmer, 1995; Peres & Nascimento, 2006). In contrast, caimans are considered to be a localized, secondary source of protein (Thorbjarnarson, 2010), and as such their extent and role in Amazonian diets is comparatively unknown. Two caiman species in particular are harvested and consumed in Amazonia: the black caiman *Melanosuchus niger* and the spectacled caiman *Caiman crocodilus*. They are the two largest crocodilian species in the region and both have a long history of human exploitation, having been commercially hunted for their skins to supply international demand for exotic leather throughout much of the 20th century. Sanctions on international trade facilitated the recovery of many populations, notably those of the black caiman, which were all but decimated by overharvesting, and both species are categorized as Least Concern on the IUCN Red List (Crocodile Specialist Group, 1996; Ross, 2000).

Based on a few localized rural harvest studies, consumption of caiman has been recorded in various localities across Amazonia (Ojasti, 1996); using extrapolated data Peres (2000) estimated annual harvest rates of caiman meat by the rural poor in the Brazilian Amazon to be 240–589 t (by 25,000–62,000 individuals). There is now some evidence that caiman meat is traded commercially and consumed in urban areas (Baía et al., 2010; Parry et al., 2014); however, much of our knowledge remains anecdotal (Thorbjarnarson, 2010). Additionally, caiman meat may be sold fraudulently as a high-value prestige fish (Peres & Carkeek, 1993). Fraudulent meat substitution is a global concern (e.g. Europe's horsemeat scandal; Di Giuseppe et al., 2015) and an important conservation issue (von der Heyden et al., 2010). The use of caiman (together with river dolphins *Inia geoffrensis*) as fish bait is also a concern following increased international demand for the catfish *Calophysus macropterus* (Mintzer et al., 2013). Our aim here was to enhance understanding of what is a potentially multifaceted and spatially extensive harvesting and trade system.

Methods

We used an expert survey approach to obtain information on patterns and drivers of harvesting and trade of caiman across the Brazilian Amazon. The increasing use of expert elicitation in conservation research and planning has been driven by the need to characterize dynamic systems, with limited resources (Martin et al., 2012). The method is an expedient approach for obtaining a regional synthesis of a politically invisible issue about which local experts may be aware (van Vliet et al., 2013).

We approached 122 experts to participate in the survey, based on relevant professional experience and/or current employment. We targeted people working in situ on caiman harvesting or management in the Brazilian Amazon, as well as other locally based individuals with current expert knowledge and professional experience of conservation and natural resource management. We identified potential respondents as follows: (1) authors identified in relevant literature, (2) reserve managers (including of federal and state protected areas), and (3) researchers and analysts from academic institutions or federal government environmental institutions, such as the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA, responsible for enforcing environmental law outside protected areas) and the Chico Mendes Institute of Biodiversity Conservation (ICMBio, with a mandate for enforcement within federal protected areas). Contact was made via e-mail during September–November 2013; e-mail addresses were obtained through known contacts, via author information provided with published articles, or from institutional websites. An initial e-mail explained the objectives of the research, sought consent to participate and included a questionnaire as an attachment. Respondents were asked to indicate other potential participants, thus expanding our contact database. In total we received 52 responses (whether accepting or declining the invitation to participate), with 24 completed questionnaires (20% of the 122 approached). This response rate is consistent with other expert surveys (23%, Lyytimäki & Hildén, 2011; 23%, Quijas et al., 2012).

The questionnaire (Supplementary Material 1) consisted of 11 statements, which participants were asked to rate on a Likert scale (Likert, 1932), from 1 (completely disagree) to 5 (completely agree). Statements were related to relevant topics and knowledge gaps identified in a literature review, including the following: occurrence and drivers of caiman harvesting and trade, characteristics of harvesters, fraudulent meat substitution, and use of caiman meat as fish bait. We included a 2-year qualifier for questions that related to temporal trends (such as harvesting levels and caiman populations). This relatively short qualifier was chosen to focus on current harvesting (as opposed to historical trends) and also accounts for the rotation (change of location) of staff in government agency positions. Respondents also provided information on their employment role and the area or municipality from which their experience was derived. At the end of the questionnaire respondents were invited to explain the rationale for their responses and offer any other relevant information on hunting and trade of caiman in their region.

The 24 responses covered a wide area of the Brazilian Amazon, from the eastern city of Belém to the western border town of Tabatinga. The majority of responses were from
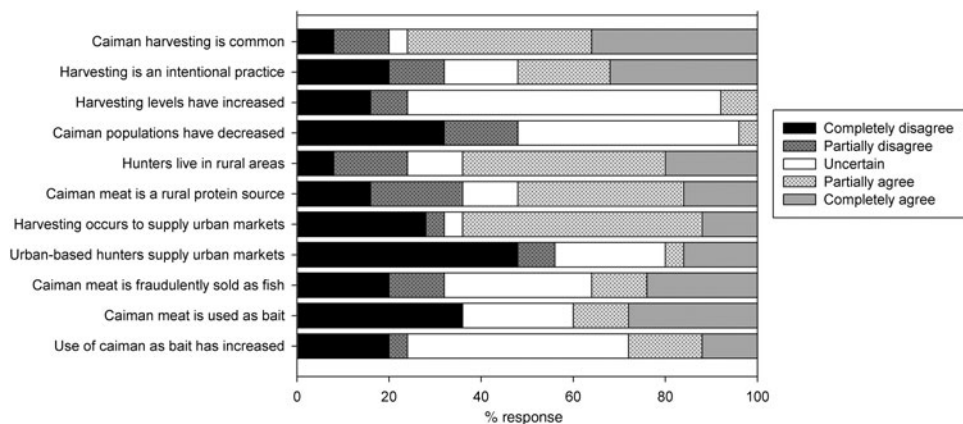
FIG. 1 Expert responses on the scale and drivers of caiman harvesting and trade in the Brazilian Amazon. Respondents rated each statement on a five-point scale, based on their perceptions and experience within their locale.

experts based in Amazonas State (17 questionnaires, 71%). Of the remaining seven questionnaires five were from experts based in Pará State (21%). We also received one response each from the states of Mato Grosso and Mato Grosso do Sul; however, as these responses were from outside the Amazon biome we focus on Amazonas and Pará, which together cover 56% of the Brazilian Legal Amazon and are home to 48% of the region's human population (IBGE, 2010).

Results

The majority of experts (76%; Fig. 1) agreed (partially or completely) that caiman hunting was a common occurrence, extending across the Brazilian Amazon, from Santarém to Tabatinga on the Brazil—Colombia border (Fig. 2). Whether caiman hunting was premeditated rather than opportunistic (e.g. by fishers) generated a more mixed response (Fig. 1), even between proximate localities. Temporal trends in harvesting pressure were also unclear, with 68% of experts unable to affirm or refute that the occurrence of caiman hunting had increased in the previous 2 years. There was no apparent indication of a contemporary, widespread decline of caiman populations. Only one respondent considered local caiman populations to be decreasing, whereas 43% disagreed with this assertion and 52% were uncertain (Fig. 1).

Our results indicated that demand for caiman meat came from both urban and rural consumers. Urban demand for caiman meat was recognized by 64% of the experts (Fig. 1), and harvesting caiman to supply urban markets was reportedly concentrated along the River Solimões—Amazonas and proximate sections of its tributaries (Fig. 2). Suggestive of distal source areas, a respondent in Belém stated that caiman meat was sold in urban markets and consumed in local rural areas but was not harvested locally (Fig. 2). A respondent based in Amazonas [R1] elaborated on this potential long-distance trade:

Ribeirinho [river-dwellers] hunters kill caiman indiscriminate of species or sex...100% of the meat is salted and dried, to be sold to traders from the state of Pará. From there it is sold in urban markets around the capital of Belém.

Another respondent based in Amazonas [R18] attributed this to different regional food preferences:

I always hear talk that people who like caiman meat are from Pará, and that people from Amazonas do not like caiman meat.

Whether hunters supplying the urban market were from rural or urban areas was unclear. More than half the experts disagreed that urban-based hunters were operating. However, 24% of respondents were uncertain and 16% completely agreed that urban hunters contribute significantly to the caiman meat market. Overall, there was stronger evidence that caiman were predominantly hunted by rural people (64%), and that harvesting was to supply rural people with animal protein (52%). The clearest evidence (i.e. strong agreement) of rural consumption came from around the major urban centres (Fig. 2). In summary, expert opinion indicates that caiman are hunted mainly by rural people, providing a source of protein to rural communities close to larger cities, and a source of income when sold to urban markets, particularly along the main River Solimões—Amazonas.

There was uncertainty regarding whether caiman were hunted for fish bait or whether caiman meat was sold fraudulently as fish (Fig. 1). The strongest evidence of fishers using caiman meat as bait was from along the River Solimões—Amazonas, from Santarém through to Tabatinga. There was disagreement or uncertainty in most other locations (Fig. 2). It was unclear whether this practice was increasing, as half of the respondents were uncertain of any temporal trend. Fraudulent selling of caiman meat as high-value fish appeared to be less widespread than using caiman as fish bait, with approximately equal numbers of experts expressing uncertainty (32%), agreeing that this happens in their area (36%), and disagreeing (32%). Strong agreement that such fraud occurs came from around the major cities of Manaus, Santarém and Belém (Fig. 2).
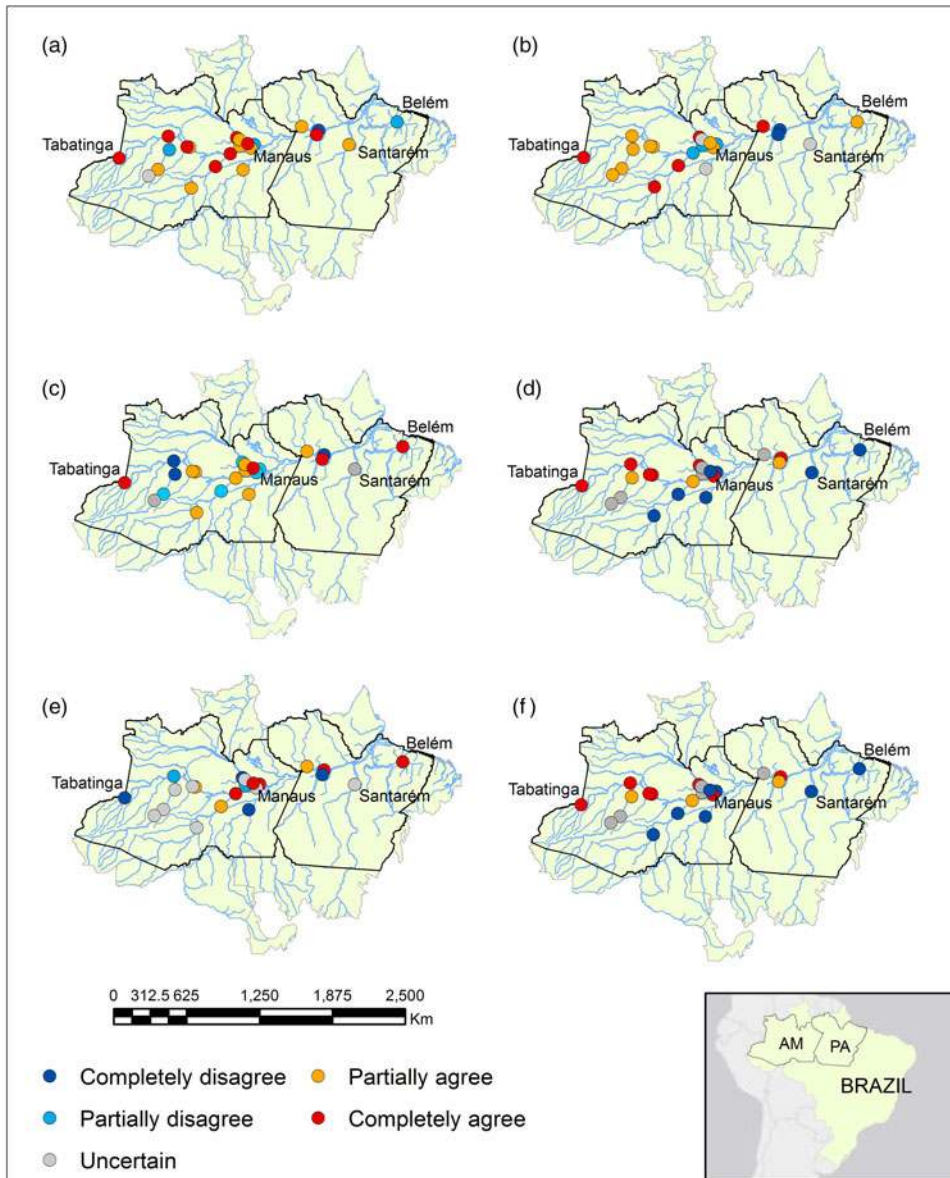
FIG. 2 Spatial distribution of expert responses, on a Likert scale, to the following statements regarding the harvesting and trade of caiman in the Brazilian states of Amazonas (AM) and Pará (PA): (a) Caiman hunting is a common occurrence. (b) Caiman hunters live in rural areas. (c) Caiman meat is a source of protein in rural areas. (d) Caiman are hunted to supply urban markets. (e) Caiman meat is sold fraudulently as high-value fish. (f) Caiman are hunted for bait to capture piracatinga *Calophysus macropterus*.

Discussion

Our findings demonstrate that expert elicitation is an effective method for evaluating wildlife harvest over large spatial scales. The respondents offered novel insights into a complex harvest system in the Brazilian Amazon, including widespread harvesting, urban demand and long-distance trade, and the extent of lesser-known secondary drivers. We acknowledge the limitations of the use of expert surveys for generating knowledge from individual judgement, given potential bias and varying levels of expertise (Kynn, 2008). Nonetheless we believe expert elicitation is an appropriate, cost-effective approach to perform a rapid regional synthesis of a poorly known and complex issue. Viewed pragmatically, the information we obtained here is a valuable precursor to empirical data collection and we highlight the

need for validating the expert knowledge underlying our findings (Kynn, 2008; Keane, 2013).

Key insights and interpretations

It was assumed that Amazonia had avoided a bushmeat crisis on the basis of urbanization and assertions that the only wild meat eaten by city-dwellers was fish (Nasi et al., 2011). However, expert opinion indicates that killing caiman for meat, previously considered a localized rural activity (Peres, 2000), is in fact common and widespread across the Brazilian Amazon. We also found that urban demand is a significant driver of the harvest, with trade of caiman meat concentrated around large urban centres. Spatial patterns of expert responses and direct quotes support previous

anecdotal evidence of long-distance trade in caiman meat from the state of Amazonas to Pará (Da Silveira & Thorbjarnarson, 1999). Long-distance trade suggests substantial demand that offsets higher costs for processing and transport, together with the presence of commodity chains and trade networks (Lindsey et al., 2013). It also implies that demand for caiman meat cannot be fulfilled by local sources and could therefore be a symptom of local overharvesting and depletion (Lindsey et al., 2013).

Market price data from a study in Pará showed that caiman meat is cheaper than fresh or dried beef, with prices comparable to chicken, shrimp and fish (Baía et al., 2010). This implies that caiman meat in the Amazon does not fit the luxury good paradigm often documented in urban wild-meat consumption (Bennett, 2002). Instead, we infer that caiman meat provides a cheap alternative protein option for the urban poor, congruent with evidence of poverty-linked caiman consumption in two provincial cities (Parry et al., 2014). Regardless of access to domestic protein sources, poverty will drive demand for cheaper alternatives. With > 70% of the rapidly growing population in the Brazilian Amazon living in cities, including millions living in urban poverty (IBGE, 2010), we predict demand for caiman meat will remain high (or increase). Furthermore, rural–urban migrants often remain dependent on rural livelihoods (Parry et al., 2014) and many Amazonian households can be described as multi-sited, participating in rural–urban networks (Padoch et al., 2008). Such patterns have important implications for wild-meat consumption, including the persistence of rural food preferences in Amazonian cities (Padoch et al., 2008). Parry et al. (2014) found that urban households with strong rural linkages are more likely to eat not just caiman but a range of wildlife.

Knowledge gaps and research priorities

Areas of uncertainty in expert opinion highlighted important knowledge gaps, which are crucial to identifying research priorities. Quantifying the role of urban demand on caiman harvesting and trade is a key knowledge gap. Data on trade routes, market structure and the drivers of hunter and consumer behaviour are needed, following a commodity-chain approach (Cowlishaw et al., 2005; Allebone-Webb et al., 2011). The African bushmeat crisis, defined as a critical conservation and development issue, has been studied extensively (Milner-Gulland & Bennett, 2003; Allebone-Webb et al., 2011; Lindsey et al., 2013), and consequently we should reflect on this body of research to identify appropriate strategies and anticipate challenges. What is clear is the inherent variability and complexity of wild-meat trade and consumption patterns (Brashares et al., 2011), which limits broad generalizations and often requires case-specific information from both social development and ecological perspectives.

The fraudulent substitution of dried caiman meat for the sought-after fish *Arapaima gigas* is perhaps the biggest unknown factor in this study. We found that this fraud occurs around the large urban centres where food demand is highest, and recommend that this practice be quantitatively assessed to draw conclusions on its extent and impact. As this is a global issue in food production systems, there has been significant advancement in food authentication techniques (Mafra et al., 2008). DNA barcoding offers a relatively quick and inexpensive means of species identification and has been successfully used in bushmeat trade studies to confirm species misidentification (Minhós et al., 2013); it is a viable option for assessing caiman–fish substitution.

The use of caiman (and river dolphins) as catfish bait has already been recognized as a significant concern, and the implementation of a 5-year moratorium on *Calophysus macropterus* fishing in Brazil is intended to curtail this practice (MMA, 2014). However, environmental governance in Amazonia is often poor because of limited resources and low enforcement over such a large area (Parry et al., 2014). Continued assessment and monitoring is recommended.

Conclusion

The multidisciplinary nature of conservation means researchers must often utilize a diverse array of data sources and methods (Keane, 2013). There is increasing recognition of the role of alternative approaches in wildlife conservation and management; for example, the use of recall data for species consumption rates (Golden et al., 2013) and of local ecological knowledge for wildlife abundance and distribution trends (Anadón et al., 2009). Such methods are particularly apposite in resource-limited and spatially extensive tropical contexts (Parry et al., 2014). We used a simple expert elicitation method to gain insight into a complex and multifaceted harvesting system, and in doing so identified critical focal areas for further study, both thematically and spatially. Nonetheless we reiterate the importance of rigorous implementation of methods with regards to questionnaire design and interpretation of results (Martin et al., 2012). Expert opinion is not a like-for-like substitute for empirical research but is a complementary, cost-effective tool that can inform and direct more intensive data collection, especially when confronting complex dynamic systems across large spatial scales.

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