Pangolin hunting and trafficking in the forest–savannah transition area of Cameroon

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Abstract Pangolins have long been hunted for food and for their scales, but information on local hunting strategies in African range countries and the patterns of pangolin trafficking around sourcing areas is limited. Such knowledge is vital to inform monitoring approaches and conservation interventions. We administered questionnaires to 367 people from 20 villages around two national parks in Cameroon to gain insights into local hunting practices, and trading and trafficking patterns. We found that tracking was the preferred method of hunting pangolins. Trapping was also used, and setting traps on fallen logs and near burrows improved the likelihood of catching pangolins. The white-bellied pangolin *Phataginus tricuspis* was the most traded species, and the giant pangolin *Smutsia gigantea* was the most sought after. We found no evidence of trade in the black-bellied pangolin *Phataginus tetradactyla*. Most respondents stated that pangolin prices had increased over the last 5 years, and scarcity of pangolins was the primary reason given for this increase. We identified a pangolin scale trafficking network operating from rural communities to neighbouring cities. Although most respondents recognized that hunting pangolins is illegal, c. 30% indicated that they were engaged in pangolin hunting.

Keywords Hunting, illegal wildlife trade, local communities, local ecological knowledge, Manidae, *Phataginus*, *Smutsia*, wildmeat

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Introduction

Hunting of wild animals can contribute significantly to the annual household income in rural areas of tropical Africa (Brashares et al., 2011; Ingram et al., 2021). The meat of wild animals (often referred to as bushmeat or wildmeat) can also be a major source of protein in areas where access to domestic meat and fish is limited (Wilkie et al., 2016). Across parts of Asia and Africa, pangolins (order: Pholidota) are consumed as a luxury meat. They are also considered the most trafficked mammals in the world, with large quantities of pangolin scales being smuggled from Africa to Asia for use in traditional medicines (Ingram et al., 2019; Emogor et al., 2021).

Despite increasing awareness of their plight, pangolins remain poorly studied. Their ecology and lifestyle make them difficult to observe and monitor in the wild (Willcox et al., 2019), and there is a crucial need for improved detection methods and/or technology to be developed (Khwaja et al., 2019). Furthermore, quantifying exploitation and trafficking is challenging because of detection biases and underestimation of the level of exploitation (Ingram et al., 2018). More information is needed on pangolin ecology, hunting and trafficking patterns to inform effective conservation actions.

Recent decades have seen a substantial increase in the trafficking of African pangolin scales following the drastic population decline in Asian species (Challender et al., 2020). Cameroon has been identified as a major hub for the trafficking of pangolins and their parts (Ingram et al., 2019), and it was already one of the major pangolin exporters in Africa before the 2016 inclusion of all pangolin species in CITES Appendix I (Ingram et al., 2019). During 2012–2018, internationally trafficked pangolins were exported primarily from Cameroon and Nigeria (Ingram et al., 2019; Emogor et al., 2021). Recent evidence indicates that Cameroon still supplies the illegal trade of pangolins and their derivatives (TRAFFIC, 2019).

Of the eight species of pangolin globally, three occur in Cameroon: the white-bellied pangolin *Phataginus tricuspis*, the black-bellied pangolin *Phataginus tetradactyla* and the giant pangolin *Smutsia gigantea*. All are exploited for their meat and scales and traded in local and regional markets. The white-bellied and giant pangolins are the species primarily targeted for the international, illegal trade of pangolin scales (Ingram et al., 2019, Emogor et al., 2021).

Monitoring efforts for pangolins in Cameroon using camera-trap surveys (Bruce et al., 2018b; Hongo et al., 2020; Simo et al., 2020) and community-based approaches (Difouo et al., 2020; Mouafo et al., 2021; Nguyen et al., 2021) have regularly detected pangolins. However, only limited attention has been given to how pangolins are typically targeted by local people for their own use or trade (Difouo et al., 2020; Mouafo et al., 2021, 2022). The strategies of local hunters for capturing pangolins and the structure of local trafficking networks remain largely unexamined, despite the potential of such work to inform monitoring approaches. Tailoring pangolin monitoring approaches to their ecology could facilitate their observation in the wild (Khwaja et al., 2019; Simo et al., 2020). Here, we gathered information about techniques for hunting pangolins and the trade in pangolin meat and scales from local people living near two protected areas in Cameroon. We aimed to improve monitoring approaches of pangolin populations in the wild, and to determine trafficking patterns and inform conservation interventions targeting the illegal trade.

Study area

We conducted our study in the Centre and East regions of Cameroon, around Mpem et Djim and Deng-Deng National Parks (Fig. 1), both of which comprise a mosaic of forest and savannah habitats. Mpem et Djim and Deng-Deng National Parks were established in 2004 and 2010, respectively. The communities around these protected areas belong to the native Vouté and Baveck groups around Mpem et Djim National Park and to the Képéré, Boblis, Pôl and Gbaya groups around Deng-Deng National Park (Diangha, 2015; Difouo et al., 2020).

Methods

Questionnaire survey

We invited local community members around Mpem et Djim and Deng-Deng National Parks to complete questionnaires during 8–16 March and 21 August–3 September 2018. Prior to the fieldwork, we tested our questionnaire amongst the research team to standardize the delivery approach and determine the time needed to conduct an interview. We subsequently adjusted some questions for more effective data collection. We surveyed community members in 10 villages spread around each protected area (Fig. 1). We selected these villages to ensure appropriate representation of the diverse communities (e.g. ethnic diversity), and all villages were within 7 km from the respective protected area.

In each village, a local guide facilitated data collection through a targeted snowball sampling approach (Newing, 2010). At least 10 people per village completed the questionnaire, allowing us to capture the breadth of experiences and opinions present within the local communities. We used a semi-structured questionnaire containing open-ended and closed-ended questions (Nash et al., 2016; Difouo et al., 2020). Questionnaires were completed verbally, interviews lasted less than 1 hour, and we questioned only one individual per household (Nash et al., 2016). The questionnaire (Supplementary Material 1) had three sections: (1) socio-demographic information, (2) pangolin identification, perceived population trends, conservation and threats, cultural beliefs and medicinal uses (Difouo et al., 2020), and (3) exploitation of pangolins.

We showed respondents photographs of pangolins before they completed the questionnaire (Nash et al., 2016). When respondents could identify a pangolin species, we asked them about the local exploitation of pangolins, whether the respondents themselves hunted pangolins, and, if so, which techniques they used for capturing each species, whether they hunted during the day or at night, whether the rainy or dry season was best for hunting pangolins, and how many pangolins they typically captured per hunting trip. We also asked whether respondents had bought pangolins before, what the price was for each species and whether they had ever eaten pangolin (at home or at a restaurant). Further questions enquired about the most traded pangolin species, price trends and the rationale for any observed variation in price.

Pangolin scale sampling

During 28 October–30 November 2018 we carried out additional surveys aimed at collecting samples of pangolin scales from local people (for use in a genetic analysis project) and understanding sourcing areas and methods used in the trafficking of scales between local areas and on intercontinental markets. We went door to door asking people whether they had any pangolin scales that we could collect for laboratory studies. We had informal discussions and asked open-ended questions to determine why people kept pangolin scales after eating the animal, the pricing of scales from different pangolin species and who purchased the scales. We provided no financial incentives to respondents for the scales or for taking part in the discussions.

Analyses

We conducted all statistical analyses in *R 4.0.5* (R Core Team, 2020) and we set statistical significance at the 5% probability level. We performed univariate analyses to describe the socio-demographic structure of respondents and aspects of pangolin exploitation such as hunting techniques (type of trap, location of trapping, distance of capture

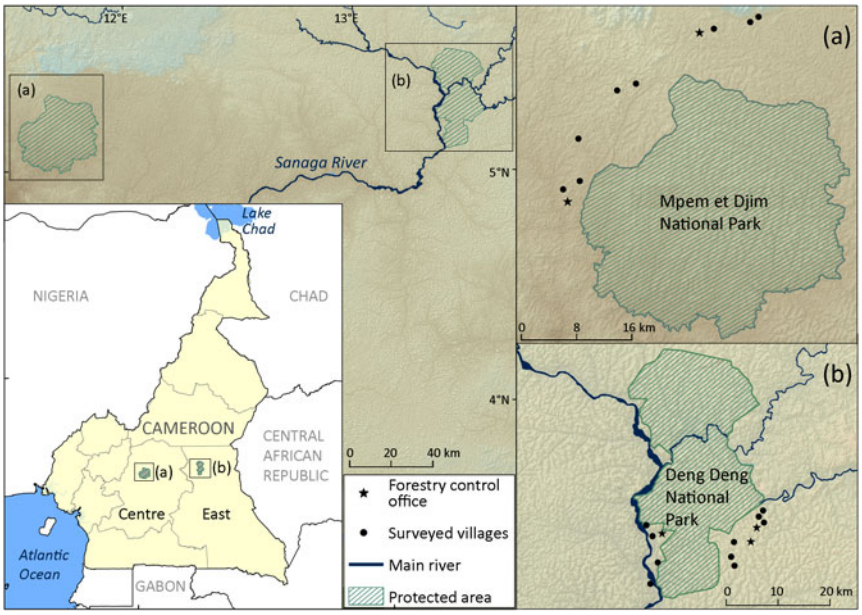

FIG. 1 Locations of the surveyed villages and the forestry control offices around (a) Mpem et Djim and (b) Deng-Deng National Parks in the Centre and East regions of Cameroon, respectively.

location from the village and hunting season), reasons for hunting and the nature of the local pangolin trade (most traded species, prices and price changes over the last 5 years). We used χ^2 tests to compare variable frequencies.

To ensure proper sample size and interpretability, we grouped respondent occupations and ethnicities before conducting an inferential analysis. We classified ethnic groups depending on whether they were native to the study area (i.e. Vouté, Baveuck and Tikar around Mpem et Djim National Park and Képéré, Gbaya, Boblis, Pôl, Kako, Mbimo and Mbeten around Deng-Deng National Park) or non-native (i.e. Moudang, Guidar, Massa, Betsi, Foulbé, Manguissa, Sanaga, Mbom, Etinga, Faly, Bassa, Toupouri, Biatchota, Wimboum, Bamiléké, Nyamsong and Djanti). We assigned ethnic groups to the native or non-native category based on the geographical distribution of the population and the number of people belonging to each group. We investigated the hypothesis that native people would hunt pangolins more than non-native people. We grouped educational levels into three categories: (1) no formal education, (2) primary education and (3) secondary education and higher, the latter including respondents who had been educated from secondary to university level. We grouped respondents by age based on physical ability to hunt in the area: young (18–35 years), adult (36–55 years) and older adult (> 55 years). Although it has been shown that high-level hunting skills are maintained throughout much of adulthood, the mean age of peak performance is 30–35 years (Koster et al., 2020). We grouped occupations into two general categories: outdoor workers who were more likely to have contact with wildlife (e.g. hunters, fishers, farmers, foresters, or people with no occupation), and indoor workers (e.g. drivers, students, carpenters, barbers).

We applied a logistic regression model using the *nnet* package (Ripley & Venables, 2022) with a binomial error structure and a logit link function to investigate the variables influencing whether respondents had hunted, traded, bought or eaten pangolins. We tested for multicollinearity in our independent variables with variance inflation factors. We tested for overdispersion by fitting two models, the first with a binomial error structure and the second with a quasi-binomial error structure. We then used the χ^2 test to compare the two models, and the model was judged as over-dispersed if the resulting P-value was significant ($P < 0.05$; Kabacoff, 2015). Once model assumptions were met, we applied a stepwise regression method with the direction argument set to 'both' to automatically select the set of covariates to be included in the best model (Zhang, 2016). For response variables that are ordered categorical variables such as the perceived population trend (decreasing, stable, increasing), we applied ordinal logistic regression models using the function *clm()* of the package *Ordinal* (Christensen, 2019). We also applied a Brant test (Brant, 1990) to check whether the final model met the proportional odds assumption. We removed respondents who did not answer the questions regarding the response variables from the dataset before performing the analyses. We tested the following response variables: age category, ethnicity, gender and work category.

Results

Socio-demographic characteristics of respondents

A total of 367 persons completed questionnaires around Deng-Deng and Mpem et Djim National Parks (Table 1).

TABLE 1 Demographics of the respondents interviewed in villages (Fig. 1) around Deng-Deng and Mpem et Djim National Parks, Cameroon.

Demographics	East Region, Deng-Deng National Park (n = 234) Number of respondents (%)	Centre Region, Mpem et Djim National Park (n = 133) Number of respondents (%)	*Total* (n = 367) Number of respondents (%)
Gender			
Male	194 (82.9)	109 (82.0)	303 (82.6)
Female	40 (17.1)	24 (18.0)	64 (17.4)
Age (years)			
Young (18–35)	101 (43.2)	81 (60.9)	182 (49.6)
Adult (36–55)	87 (37.2)	40 (30.1)	127 (34.6)
Older adult (> 55)	46 (19.6)	12 (9.0)	58 (15.8)
Ethnicity			
Native	152 (65.0)	111 (83.5)	263 (71.7)
Non-native	82 (35.0)	22 (16.5)	104 (28.3)
Occupation			
Farmers	144 (61.6)	92 (69.2)	236 (64.3)
Hunters	19 (8.1)	11 (8.3)	30 (8.2)
Other	71 (30.3)	30 (22.5)	101 (27.5)
Level of education			
None	20 (8.6)	4 (3.0)	24 (6.5)
Primary	110 (47.0)	54 (40.6)	164 (44.7)
Secondary	99 (42.3)	72 (54.1)	171 (46.6)
University	5 (2.1)	3 (2.3)	8 (2.2)

We recorded 42 ethnic groups, of which 18 were native and 24 non-native.

Hunting practices and motivations

Not all respondents answered all of the questions. Overall, 30.2% (n = 111) of those surveyed acknowledged involvement in pangolin hunting, 53.4% (n = 196) said they were not involved and 16.4% (n = 60) did not respond. Amongst those who said they were not involved in pangolin hunting and some who did not answer that question (n = 120), the reasons given included that they were not hunters (50.0%, n = 60), that pangolins were scarce (16.7%, n = 20), that pangolin hunting was illegal (14.2%, n = 17) and that it was not possible to target pangolins (5.8%, n = 7). Other reasons included rare encounters with pangolins (10.0%, n = 12) and their nocturnal behaviour (3.3%, n = 4). A total of 133 respondents (including some who did not themselves hunt pangolins) provided reasons why pangolins were hunted: meat consumption (75.9%, n = 101), trade (22.6%, n = 30) and cultural use (1.5%, n = 2)

Amongst those who acknowledged involvement in pangolin hunting, most (76.6%, n = 85) reported pangolins were hunted primarily during the night, some (15.3%, n = 17) reported hunting at daytime, and a few (8.1%, n = 9) said that pangolins were hunted during both day and night. Most respondents who were involved in hunting (96.4% of those involved in hunting, n = 107) provided information on the distance of pangolin hunting locations from the villages. Many reported pangolins were usually captured < 10 km from the villages (71.0% of those who provided information on hunting locations, n = 76), and only a minority (29.0%, n = 31) said pangolins were captured > 10 km from the village. Amongst pangolin hunters, most (53.2% of those involved in hunting, n = 59) reported that the number of pangolin individuals usually caught during a hunting trip was less than two. However, some (10.8%, n = 12) reported typically capturing between two and four pangolins per trip, and a few (2.7%, n = 3) said that more than four pangolins could be caught during a hunting trip. The remainder did not answer this question.

Strategies and methods of capture

Our survey revealed several pangolin hunting methods. Amongst those who answered this question (n = 173), the main method used was tracking (55.5%, $\chi^2(df = 3, n = 96) = 84.626$, $P < 0.001$). Another common method was trapping (39.9%, n = 69). Amongst those who mentioned trapping, eight respondents (4.6% of the respondents who provided information on capture methods) reported hunting with dogs, and three (1.7%) used baits. Amongst those who reported tracking as their hunting method (n = 96), manual capture was the most commonly used technique (68.8% of those who used tracking; $\chi^2(df = 3, n = 66) = 60.695$, $P < 0.001$), meaning that pangolins were caught alive without the use of a tool or weapon. Other capture techniques involved cutlasses/clubs (22.9% of those who used tracking,

n = 22) and guns (8.3%, n = 8). The locations reported by the respondents (n = 101) for the installation of traps included fallen logs (22.8%, n = 23), burrows (17.8%, n = 18), termite/ant nests (17.8%, n = 18), trees (15.8%, n = 16) and tree tufts, which are intertwined tree branches or clusters of lianas (4.0%, n = 4). The remainder did not mention any specific locations. Some respondents reported capturing pangolins along roads (10.9%, n = 11), on farms (6.9%, n = 7) or beside rivers (4.0%, n = 4). We found moderate evidence (61.1%, χ^2(df = 1, n = 80) = 4.982, P = 0.0268) that pangolins were more frequently captured during the dry season than during the rainy season (38.9%, n = 51).

Trading of pangolin species

The most traded species, according to the 360 respondents who answered this question, was the white-bellied pangolin (77.2%, n = 278) followed by the giant pangolin (8.3%, n = 30). No trade in the black-bellied pangolin was reported, and 14.5% of respondents (n = 52) said that they did not know which species was the most traded. Prices per individual for the white-bellied pangolin ranged from XAF 2,500 to 10,000 (USD 4–15), and the majority of respondents did not know the price for the black-bellied pangolin. Although most respondents (78.8%, n = 253) did not know about the pricing of giant pangolins, a small proportion (21.2%, n = 68) gave estimates between XAF 20,000 (USD 31) and > XAF 80,000 (> USD 124; Table 2).

Perceived fluctuation of pangolin trading prices

Of the respondents who answered the question about trends in pangolin trading prices (n = 229), most (70.7%, n = 162) perceived prices to have increased, 15.7% (n = 36) perceived prices to be stable and 13.6% (n = 31) perceived a decrease in trading prices. Including respondent gender (χ^2 = 10.910, df = 1, P < 0.001) and region (χ^2 = 24.490, df = 1, P < 0.001) as predictors for perceived fluctuations in trading prices improved model fit significantly. There was strong evidence that women perceived an increase in pricing more than men (generalized linear model (GLM): odds ratio = 0.20, 95% CI = 0.05–0.57, P = 0.006) and that respondents from the East Region were more likely to perceive an increasing price trend compared to those from the Centre Region (GLM: odds ratio = 5.63, 95% CI = 2.87–11.20, P < 0.001). Strong evidence indicates that the primary reason for the perceived price increase (n = 328) was scarcity of pangolins (32.0%, χ^2(df = 4, n = 105) = 47.250, P < 0.001), but respondents also mentioned many other reasons for this price trend (Fig. 2). Some respondents who perceived a decreasing price trend reported pangolins still being abundant as the main reason for this (1.2%, n = 4), but most did not know the reasons behind such price fluctuation (10.4%, n = 34).

Table 2 Prices estimated by survey respondents from villages around Mpem et Djim and Deng-Deng National Parks, Cameroon, for three pangolin species.

Price range in XAF (USD)	Number of respondents (%)
White-bellied pangolin (n = 331)	
< 2,500 (4.0)	136 (41.1)
2,500–5,000 (4.0–8.0)	114 (34.4)
5,000–7,500 (8.0–11.5)	5 (1.5)
7,500–10,000 (11.5–15.0)	5 (1.5)
Do not know	71 (21.5)
Black-bellied pangolin (n = 331)	
< 2,500 (< 4.0)	6 (1.8)
Do not know	325 (98.2)
Giant pangolin (n = 321)	
20,000–40,000 (31.0–61.5)	33 (10.3)
40,000–60,000 (61.5–92.3)	10 (3.1)
60,000–80,000 (92.3–123.0)	17 (5.3)
> 80,000 (> 123.0)	8 (2.5)
Do not know	253 (78.8)

Factors influencing pangolin exploitation

Hunting We built a binomial GLM to examine which factors influenced whether the respondent hunted pangolins. Including gender (χ^2 = 11.980, df = 1, P < 0.001), ethnicity (χ^2 = 14.950, df = 1, P < 0.0001) and occupation (χ^2 = 10.22, df = 1, P = 0.001) in this model improved model fit significantly. There was strong evidence that men were more likely than women to report pangolin hunting (GLM: odds ratio = 4.94, 95% CI = 1.94–13.30, P = 0.001). Non-native people were less likely to report pangolin hunting than respondents belonging to native groups (GLM: odds ratio = 0.30, 95% CI = 0.16–0.55, P < 0.001). Similarly, indoor workers were less likely to report pangolin hunting than outdoor workers (GLM: odds ratio = 0.30, 95% CI = 0.16–0.55, P < 0.001). Independent of their categorization as indoor or outdoor workers, the likelihood of hunting pangolins was greater when respondents were of native compared to non-native communities. Similarly, independent of their ethnicity, the likelihood of hunting pangolins was greater for outdoor workers than those who worked primarily indoors. Independent of whether they worked indoors or outdoors, and of their ethnic affiliation, men were more likely to report hunting pangolins than women (Fig. 3).

Buying pangolins Amongst those who responded to the questions about buying pangolins (n = 229), there was strong evidence (63.8%, χ^2(df = 1, n = 146) = 7.570, P < 0.001) that most had bought pangolins or their meat before, with only 36.2% (n = 83) reporting that they had never done so. Including occupation in a binomial GLM examining whether the respondent had bought pangolins or their

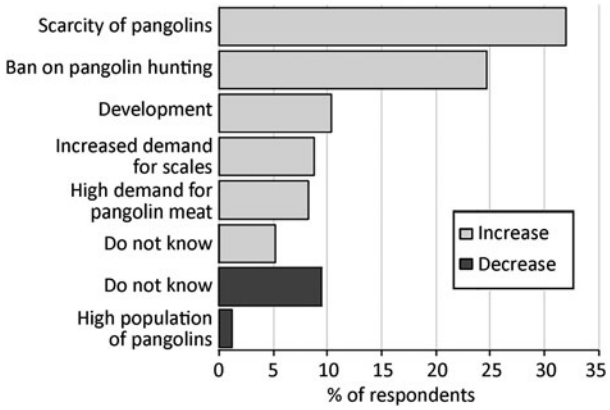

FIG. 2 Reasons provided by respondents for the fluctuation in pangolin prices.

meat before improved the model fit significantly: indoor workers were more likely to report buying pangolins (GLM: odds ratio = 0.32, 95% CI = 0.16–0.65, P = 0.002) than outdoor workers.

Eating pangolins Almost all respondents who answered the question on pangolin consumption (n = 229) had eaten pangolin meat before (99.1%, n = 227), with only two respondents stating they had never done so (0.9%). We found no statistically significant predictors of whether respondents had eaten pangolin meat.

Scale trade and trafficking chain We identified five households located around Deng-Deng National Park and three near Mpem et Djim National Park that held pangolin scales, all from the white-bellied pangolin (Plate 1a,b). Local residents said the scales of the black-bellied pangolin, which they referred to as *pangolin sorcier* (meaning witchcraft pangolin), were more expensive than those of other pangolin species, presumably because of their scarcity and the mystical attributes associated with them in the study area. Some local people preserved pangolin scales that they removed after soaking the animal in boiling water so that the scales could be removed without damaging the flesh. Local residents also mentioned hearing about a final destination for pangolin products involving a Chinese national, suggesting that local communities did not contact international purchasers directly but possibly worked through middlemen. In one of the surveyed villages, we found a collector of pangolin scales who reported buying the scales from local residents and, when he has a sufficient quantity, transporting them to the cities by smuggling them in goods vehicles (carrying smoked fish from a reservoir and other goods from the railway station), paying bribes when necessary to evade the authorities at control checkpoints. Once in the city, he sells the scales to other middlemen, who prepare them for transport to the next stage of the trade chain. The scales removed from an individual adult white-bellied pangolin were estimated by c. 25 people to be worth XAF 500 (USD 0.76), and 1 kg of scales (approximately the weight of scales from five adult white-bellied pangolins; Emogor et al., 2021) was estimated to be worth XAF 2,500 (USD 3.84). The scales of the giant pangolin were estimated by six people to be worth XAF 40,000 (USD 61.53) per kg, which is more than 15 times the value estimated for the scales of the white-bellied pangolin. These price estimates were similar amongst respondents from around Deng-Deng and Mpem et Djim National Parks. We recorded no information on the estimated prices for the scales of the black-bellied pangolin.

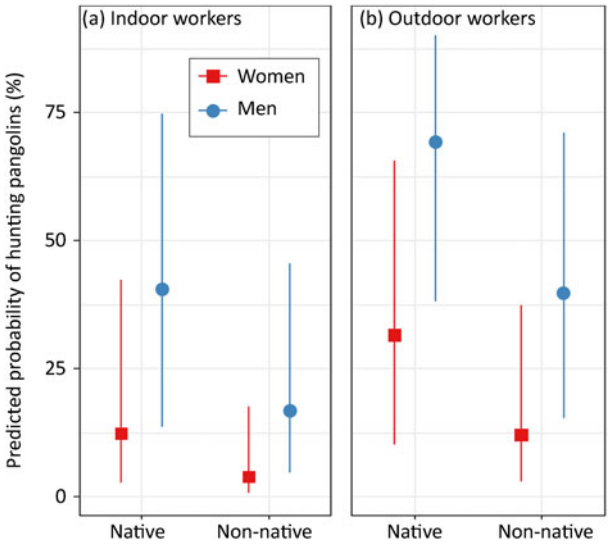

FIG. 3 Predicted probabilities of reporting pangolin hunting amongst survey respondents, taking into account indoor and outdoor workers, native and non-native ethnic groups, and gender.

Discussion

In settlements around Mpem et Djim and Deng-Deng National Parks, pangolins are hunted and consumed locally, either directly by the hunters or after being sold to neighbours. Hunters typically catch pangolins by hand and they also set targeted traps on fallen logs, ant/termite mounds and burrows. Trade of pangolin scales is well established; scales are collected and sold to middlemen who transport them to urban and semi-urban areas for sale on to international markets.

Many respondents refused to say whether they engaged in pangolin hunting, which is illegal in Cameroon. Threat of disclosure and/or social desirability bias could mean that people may not always admit hunting pangolins (Olmedo et al., 2021). However, we recorded open acknowledgement of pangolin hunting, indicating ongoing tolerance for

PLATE 1 (a,b) White-bellied pangolin *Phataginus tricuspis* scales held in local households around Deng-Deng National Park. (c) Traditional trap set on a fallen log targeting white-bellied pangolins. (d) A white-bellied pangolin caught in a traditional trap in Mpem et Djim National Park. Photos: F.T. Simo.

pangolin exploitation in the region. Pangolins are sold openly in wildmeat markets and restaurants in Cameroon despite the presence of wildlife authorities, probably as a result of weak enforcement or ineffective public communication about wildlife-related rules and regulations (Nguyen et al., 2021). Many respondents stated that pangolins were once observed frequently in their communities (Difouo et al., 2020; Mouafo et al., 2021), and, although pangolins were reported as most often being captured <10 km from settlements, hunting >10 km away was also reported, which could indicate local depletion.

Methods commonly used to hunt pangolins

Pangolins were often reported as being hunted by tracking or trapping. Tracking involves visiting pangolin microhabitats and collecting any animals encountered. Trapping, mainly with snares, was the second most prevalent hunting method. Similar observations have been reported from around the nearby Mbam et Djerem National Park (Mouafo et al., 2021). Snares are inexpensive and widely available, and they can catch a wide range of wildlife species (Wright & Priston, 2010). Traps for pangolins in the area are fashioned from local materials (Fig. 4c), although wire snares are also employed. The design of the trap and/or its targeted placement could facilitate the capture of specific species. A few respondents reported using bait on traps and snares to capture pangolins, but did not share details regarding the type of bait. If such baiting is successful, then learning more about it could help with monitoring approaches (e.g. baited camera trapping) or pangolin husbandry. However, pangolins have specialized diets consisting mainly of ants and termites (Pietersen et al., 2016; Difouo et al., 2021) and thus could be difficult to attract using baits. We recorded hunting with dogs and the use of cutlasses/clubs and guns. There are anecdotal reports from Cameroon of giant pangolin hunters increasingly using dogs to locate animals in burrows, a practice driven by the increasing value of giant pangolins in the illegal wildlife trade. Hunting with guns was not commonly reported, probably because arboreal pangolins can be caught easily using manual methods (Ingram et al., 2018) and hunters may prefer to save their bullets for hunting animals that are more difficult to catch such as wild ungulates and monkeys.

Respondents reported often installing traps for white-bellied pangolins on fallen logs. We recorded such traps in Deng-Deng National Park near a chilli farm (Plate 1d), and another in Mpem et Djim National Park, suggesting that this technique may be widespread in Cameroon. Burrows and termite/ant nests have been reported as ideal observation locations and favourable microhabitats for this particular species (Difouo et al., 2020), with camera traps set up in these locations recording large numbers of photographic events in a pilot study (Simo et al., 2020; Simo et al., in press). Furthermore, camera traps installed at burrow entrances recorded giant pangolins in the Dja Faunal Reserve, Cameroon (Bruce et al., 2018a,b), and in Deng-Deng and Mpem et Djim National Parks (F.T. Simo

et al., unpubl. data, 2019). Recent evidence from Uganda also indicates that targeting camera traps at burrows increases the probability of detecting the giant pangolin (Matthews et al., 2023).

Pangolin hunters claimed a higher capture rate during the dry season. One hunter reported that pangolins, as they forage, drag their tails over dry leaves, which makes a distinct sound and allows hunters to locate the animals easily. Desiccation of vegetation during the dry season would also increase pangolin visibility in the undergrowth. Seasonal and weather-dependent variation in activity levels has been described for the white-bellied pangolin (Pagès, 1975; Jansen et al., 2020). Pangolins may be more active during the dry season because their food is less available during this period and they need to spend more time foraging (Pagès, 1975; Jansen et al., 2020).

Drivers of pangolin hunting

The main reason for hunting pangolins in our study area was for meat consumption, as reported by previous studies in Cameroon (Mouafo et al., 2021; Nguyen et al., 2021). Pangolin meat is popular with wildmeat consumers and ranks high in preference studies (Nguyen et al., 2021; Brittain et al., 2022). Men reported pangolin hunting more than women. Prior research on hunting in West and Central Africa described it as a male-dominated activity (LeBreton et al., 2006; Randolph et al., 2022), with women operating more as opportunistic hunters in agricultural areas or as marketers of wildlife meat.

Rural people may also eat pangolin meat for cultural and spiritual reasons (Soewu et al., 2020). Two elder Képéré women (East Region) said that consuming pangolin scale infusions helped them deliver their babies. Overall, however, the evidence that cultural and medicinal usage drives pangolin hunting in the region was minimal, which contrasts with previous research in West Africa (Boakye et al., 2015; Soewu et al., 2020).

Trading in pangolins

The white-bellied pangolin was the most traded species, with pricing of XAF 2,500–10,000 (USD 4–15) per individual, similar to prices reported previously for Central Africa (Ingram et al., 2018) and for Cameroon (TRAFFIC, 2019). The black-bellied pangolin was not reported as being harvested or traded. Although a large proportion of pangolin hunting was reported to take place at night, the black-bellied pangolin is a diurnal, arboreal species (Gudehus et al., 2020), which could account for the lack of information on this species. Additionally, black-bellied pangolins are associated locally with bad luck, which could lead some people to avoid the species (Difouo et al., 2020). A whole giant pangolin sells for XAF 20,000 (USD 31) in rural areas and for up to XAF 80,000 (USD 124) in cities, the same price as indicated by TRAFFIC (2019), but lower than estimated by Ingram et al. (2018) for urban markets. In the Republic of the Congo, estimated prices were XAF 10,000–40,000 (USD 15.0–61.5; Swiacká et al., 2022). Given the pricing of giant pangolin scales, the value of a full specimen could vary significantly depending on whether or not it has scales attached. Most respondents claimed pangolin prices have risen over time, possibly as a response to increased demand that hunters are unable to satisfy because of depletion of local pangolin populations (Soewu et al., 2020). Men were less likely than women to perceive a rise in trade prices, perhaps because women are more involved in the pangolin trade at markets and in restaurants (LeBreton et al., 2006). Respondents from the East region were more likely to report an increase in pangolin prices. There are numerous development projects in this region, such as the construction of Lom Pangar hydroelectric dam, the Chad–Cameroon oil transportation pipeline and the national railway line, all of which have brought in trade, transport and outsiders, leading to increased demand and higher prices for wildmeat (Diangha, 2015).

Implications for conservation

Local pangolin hunting strategies targeting forest microsites such as fallen logs, feeding locations and burrows could be used to improve ecological monitoring of pangolins. Researchers or rangers could target these microsites using camera traps to determine whether pangolins are present at a given location, and to focus snare removal efforts on areas where pangolin presence has been confirmed. Recent monitoring efforts using an adapted camera-trapping approach targeting microsites successfully recorded the three pangolin species known to occur in Cameroon (Simo et al., in press; Difouo et al., in press).

Both wire snares and homemade traps were common hunting tools in the area. Snares are highly destructive to vertebrate populations (Gray et al., 2018), with their high availability further increasing their impacts on threatened species such as pangolins. Patrol teams often remove snares from protected areas but the low opportunity cost of replacing snares makes removal alone ineffective (Gray et al., 2018). Pangolin hunting was not restricted to professional hunters and could support the livelihoods of many local people. Our findings show that the two key drivers of pangolin hunting are meat consumption and trade. We recommend that wildlife managers combine anti-hunting patrols with community-based incentives that address these two essential human needs and discourage local communities from setting snares. Snare removal, arrests and the prosecution of snare-setters only address the symptom

(hunting) but not the underlying causes (the need for food and income). Further, persecution of local subsistence hunters compromises the relationship between local communities and conservationists. Given that pangolins and other species are exploited for protein and for income, conservationists should work with local communities and focus on addressing these core drivers.

The practice of intermediaries collecting scales within the community represents the beginning of a well-organized trafficking chain (ENACT, 2019; Challender et al., 2020). We suggest that enforcement efforts should target local traffickers and aim to obtain intelligence on transnational criminal networks. Traditional leaders and wildlife managers should discourage the collection of pangolin scales whilst promoting alternative livelihood opportunities that address the needs for dietary protein and income.

Author contributions Study design: FTS, GFD, IGI, DJI, DO; data collection: FTS, GFD; data analysis: FTS; writing: FTS, GFD; revision: all authors.

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Conflicts of interest None.

Ethical standards This research abided by the *Oryx* guidelines on ethical standards. We obtained research authorization from the University of Yaoundé I and research permits from the Ministry of Scientific Research and Innovation and from the Ministry of Forest and Wildlife. We followed the ISE Code of Ethics (ISE, 2006) for ethical issues at the individual and community level. Before each individual interview, we informed the respondents of the objectives of the project. All participants were volunteers who gave free, informed consent before interviews and had the option of remaining anonymous. We only surveyed people above 18 years of age.

Data availability The datasets used during the current study are available from the corresponding author on reasonable request.

References

Albrechtsen, L., Macdonald, D.W., Johnson, P.J., Castelo, R. & Fa, J.E. (2007) Faunal loss from bushmeat hunting: empirical evidence and policy implications in Bioko Island. *Environmental Science & Policy*, 10, 654–667.

Boakye, M.K., Pietersen, D.W., Kotzé, A., Dalton, D.-L. & Jansen, R. (2015) Knowledge and uses of African pangolins as a source of traditional medicine in Ghana. *PLOS ONE*, 10, e0117199.

Brant, R. (1990) Assessing proportionality in the proportional odds model for ordinal logistic regression. *Biometrics*, 46, 1171–1178.

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

Brittain, S., Kamogne Tagne, C.T., Roe, D., Booker, F., Mouamfon, M., Maddison, N., et al. (2022) The drivers of wild meat consumption in rural Cameroon: insights for wild meat alternative project design. *Conservation Science and Practice*, 4, e12700.

Bruce, T., Amin, R., Wacher, T., Fankem, O., Ndjassi, C., Ngo Bata, M., et al. (2018a) Using camera trap data to characterise terrestrial larger-bodied mammal communities in different management sectors of the Dja Faunal Reserve, Cameroon. *African Journal of Ecology*, 56, 759–776.

Bruce, T., Kamta, R., Tabue Mbobda, R.B., Talla Kanto, S., Djibrilla, D., Moses, I., et al. (2018b) Locating giant ground pangolins (*Smutsia gigantea*) using camera traps on burrows in the Dja Biosphere Reserve, Cameroon. *Tropical Conservation Science*, 11, 1940082917749922.

Challender, D.W.S., Heinrich, S., Shepherd, C.R. & Katsis, L.K.D. (2020) International trade and trafficking in pangolins, 1900–2019. In *Pangolins. Science, Society and Conservation* (eds D.W.S. Challender, H.C. Nash & C. Waterman), pp. 259–276. Academic Press, Cambridge, USA.

Christensen, R.H.B. (2019) *ordinal: Regression Models for Ordinal Data*. CRAN.R-project.org/package=ordinal [accessed 7 November 2021].

Diangha, M.N. (2015) The effects of habitat heterogeneity and human influences on the diversity, abundance, and distribution of large mammals: the case of Deng Deng National Park, Cameroon. PhD thesis. Bradenburg University of Technology, Cottbus, Germany.

Difouo, G.F., Simo, F.T., Kekeunou, S., Ichu, I.G., Ingram, D.J. & Olson, D. (2020) Understanding local ecological knowledge, ethnozoology, and public opinion to improve pangolin conservation in the center and east regions of Cameroon. *Journal of Ethnobiology*, 40, 234–251.

Difouo, G.F., Simo, F.T., Kekeunou, S., Titti Ebangue, G., Ndoh, L.G. & Olson, D. (2021) Ant and termite prey of the giant pangolin *Smutsia gigantea* Illiger, 1815 in forest–savannah mosaics of Cameroon. *African Journal of Ecology*, 59, 548–553.

Difouo, F.G., Simo, T.F., Kekeunou, S., Olson, D. & Ingram, D.J. (in press) Black-bellied pangolins *Phataginus tetradactyla* documented in Deng-Deng National Park, Cameroon, using camera traps. *Oryx*, in press.

Emogor, C.A., Ingram, D.J., Coad, L., Worthington, T.A., Dunn, A., Imong, I. & Balmford, A. (2021) The scale of Nigeria's involvement in the trans-national illegal pangolin trade: temporal and spatial patterns and the effectiveness of wildlife trade regulations. *Biological Conservation*, 264, 109365.

ENACT (2019) *Organised Crime Index Africa 2019*. Institute for Security Studies, Pretoria, South Africa, and Interpol, Lyon, France. globalinitiative.net/wp-content/uploads/2019/09/enact_report.pdf [accessed January 2023].

Gray, T.N.E., Hughes, A.C., Laurance, W.F., Long, B., Lynam, A.J., O'Kelly, H., et al. (2018) The wildlife snaring crisis: an insidious and pervasive threat to biodiversity in Southeast Asia. *Biodiversity and Conservation*, 27, 1031–1037.

Gudehus, M., Pietersen, D.W., Hoffmann, M., Cassidy, R., Cassidy, T., Sodeinde, O., et al. (2020) Black-bellied pangolin *Phataginus tetradactyla* (Linnaeus, 1766). In *Pangolins: Science, Society and Conservation* (eds D.W.S. Challender, H.C. Nash & C. Waterman), pp. 123–138. Academic Press, Cambridge, USA.

Hongo, S., Dzefack, Z.C.B., Vernyuy, L.N., Minami, S., Nakashima, Y., Djiéto-Lordon, C. & Yasuoka, H. (2020) Use of multi-layer camera trapping to inventory mammals in rainforests in southeast Cameroon. *African Study Monographs*, Supplementary Issue 60, 21–37.

Ingram, D.J., Coad, L., Abernethy, K.A., Maisels, F., Stokes, E.J., Bobo, K.S., et al. (2018) Assessing Africa-wide pangolin exploitation by scaling local data. *Conservation Letters*, 11, e12389.

Ingram, D.J., Coad, L., Milner-Gulland, E.J., Parry, L., Wilkie, D., Bakarr, M.I., et al. (2021) Wild meat is still on the menu: progress in wild meat research, policy and practice from 2002-2020. *Annual Review of Environment and Resources*, 46, 221–254.

Ingram, D.J., Cronin, D.T., Challender, D.W.S., Venditti, D.M. & Gonder, M.K. (2019) Characterising trafficking and trade of pangolins in the Gulf of Guinea. *Global Ecology and Conservation*, 17, e00576.

ISE (International Society of Ethnobiology) (2006) *ISE Code of Ethics* (with 2008 additions). International Society of Ethnobiology, Gainesville, USA. ethnobiology.net/code-of-ethics [accessed January 2023].

Jansen, R., Sodeinde, O., Soewu, D., Pietersen, D.W., Alempijevic, D. & Ingram, D.J. (2020) White-bellied pangolin *Phataginus tricuspis* (Rafinesque, 1820). In *Pangolins: Science, Society and Conservation* (eds D.W.S. Challender, H.C. Nash & C. Waterman), pp. 139–156. Academic Press, Cambridge, USA.

Kabacoff, R. (2015) *R in Action: Data Analysis and Graphics with R*. 2nd edition. Simon and Schuster, New York, USA.

Khwaja, H., Buchan, C., Wearn, O.R., Bahaa-el-din, L., Bantlin, D., Bernard, H., et al. (2019) Pangolins in global camera trap data: implications for ecological monitoring. *Global Ecology and Conservation*, 20, e00769.

Koster, J., McElreath, R., Hill, K., Yu, D., Shepard, G., van Vliet, N., et al. (2020) The life history of human foraging: cross-cultural and individual variation. *Science Advances*, 6, eaax9070.

LeBreton, M., Prosser, A.T., Tamoufe, U., Sateren, W., Mpoudi-Ngole, E., Diffo, J.L.D., et al. (2006) Patterns of bushmeat hunting and perceptions of disease risk among Central African communities. *Animal Conservation*, 9, 357–363.

Matthews, N., Nixon, S., von Hardenberg, A., Isoke, S. & Geary, M. (2023) Targeting burrows improves detection in giant pangolin *Smutsia gigantea* camera-trap surveys. *Oryx*, published online 1 February 2023.

Mouafo, A.D.T., Ingram, D.J., Binda, V.A., Ngwayi, I.C.N. & Mayaka, T.B. (2022) Not just an issue in forested regions: investigating the consumption and trade of pangolins in a forest–savannah mosaic area of Cameroon. *Tropical Conservation Science*, 15, 19400829221114844.

Mouafo, A.D.T., Ingram, D.J., Tegang Pagning, R., Nfor Ngwayi, I.C. & Mayaka, T.B. (2021) Local knowledge and use of pangolins by culturally diverse communities in the forest–savannah transition area of Cameroon. *Tropical Conservation Science*, 14, 194008292110281.

Nash, H.C., Wong, M.H.G. & Turvey, S.T. (2016) Using local ecological knowledge to determine status and threats of the Critically Endangered Chinese pangolin (*Manis pentadactyla*) in Hainan, China. *Biological Conservation*, 196, 189–195.

Newing, H. (2010) *Conducting Research in Conservation*. Routledge, Abingdon, UK.

Nguyen, L.B., Fossung, E.E., Nkoa, C.A. & Humle, T. (2021) Understanding consumer demand for bushmeat in urban centers of Cameroon with a focus on pangolin species. *Conservation Science and Practice*, 3, e419.

Olmedo, A., Veríssimo, D., Milner-Gulland, E.J., Hinsley, A., Dao, H.T.T. & Challender, D.W.S. (2021) Uncovering prevalence of pangolin consumption using a technique for investigating sensitive behaviour. *Oryx*, 56, 412–420.

Pagès, E. (1975) Étude éco-éthologique de *Manis tricuspis* par radio-tracking. *Mammalia*, 39, 613–642.

Pietersen, D.W., Symes, C.T., Woodborne, S., McKechnie, A.E. & Jansen, R. (2016) Diet and prey selectivity of the specialist myrmecophage, Temminck's ground pangolin. *Journal of Zoology*, 298, 198–208.

R Core Team. (2020) *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. R-project.org [accessed January 2023].

Randolph, S.G., Ingram, D.J., Curran, L.M., Holland Jones, J. & Durham, W.H. (2022) Urban wild meat markets in Cameroon: actors and motives. *World Development*, 160, 106060.

Ripley, B. & Venables, W. (2022) *nnet: Feed-Forward Neural Networks and Multinomial Log-Linear Models*. cran.r-project.org/web/packages/nnet/nnet.pdf [accessed March 2023].

Simo, F., Difouo Fopa, G., Kekeunou, S., Ichu, I.G., Esong Ebong, L., Olson, D. & Ingram, D.J. (2020) Using local ecological knowledge to improve the effectiveness of detecting white-bellied pangolins (*Phataginus tricuspis*) using camera traps: a case study from Deng-Deng National Park, Cameroon. *African Journal of Ecology*, 58, 879–884.

Simo, F.T., Difouo, G.F., Kekeunou, S., Ichu, G.I., Olson, D., Deere, N.J. & Ingram, D.J. (in press) Adapting camera-trap placement based on animal movement patterns for rapid detection: a focus on the Endangered white-bellied pangolin (*Phataginus tricuspis*). *Ecology and Evolution*, in press.

Soewu, D., Ingram, D.J., Jansen, R., Sodeinde, O. & Pietersen, D.W. (2020) Bushmeat and beyond: historic and contemporary use in Africa. In *Pangolins: Science, Society and Conservation* (eds D.W.S. Challender, H.C. Nash & C. Waterman), pp. 241–258. Academic Press, Cambridge, USA.

Swiacká, M., Ingram, D.J., Bohm, T. & Ceacero, F. (2022) Perceptions and uses of pangolins (Pholidota) among remote rural communities in the Republic of the Congo: a baseline study from the Odzala-Kokoua National Park. *Conservation Science and Practice*, e12839.

TRAFFIC (2019) *Status of Pangolin Trade in Cameroon and between Cameroon and Destination Countries*. TRAFFIC, Yaoundé, Cameroon and Cambridge, UK.

Wilkie, D.S., Wieland, M., Boulet, H., Le Bel, S., van Vliet, N., Cornelis, D., et al. (2016) Eating and conserving bushmeat in Africa. *African Journal of Ecology*, 54, 402–414.

Willcox, D., Nash, H.C., Trageser, S., Kim, H.J., Hywood, L., Connelly, E., et al. (2019) Evaluating methods for detecting and monitoring pangolin (Pholidata: Manidae) populations. *Global Ecology and Conservation*, 17, e00539.

Wright, J.H. & Priston, N.E.C. (2010) Hunting and trapping in Lebialem Division, Cameroon: bushmeat harvesting practices and human reliance. *Endangered Species Research*, 11, 1–12.

Zhang, Z. (2016) Variable selection with stepwise and best subset approaches. *Annals of Translational Medicine*, 4, 136.