



Wildlife and Livelihoods in the Cardamom Mountains, Cambodia

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This study provides a preliminary assessment of the use of wild meat and fish by rural communities in the Northern Cardamoms, Cambodia. We used a case-study approach in three villages, to identify key characteristics and drivers of wildlife use, with a view to informing the design of future larger-scale investigations of wild meat and fish use in the Cardamoms. Interviews with 41 households, conducted from August to October 2013, were used to investigate the main livelihood activities of each household, including hunting and fishing activity, key hunting techniques and hunted and consumed species. Group discussions with households and hunters were used to determine the relative importance of hunting and fishing as a livelihood activity and food source. We found that over 80% of interviewed households hunted, and similarly over 90% fished. Hunters employed a range of techniques, and caught at least 38 different mammal, bird and reptile species. However, our results suggest that arable farming is the backbone of livelihoods in these villages, providing the bulk of household incomes, and that most households are hunting to prevent crop-raiding, or opportunistically, rather than to supply the commercial trade. While households expressed a preference for wild meat, bought domestic meats and fish were eaten more frequently. A potentially lucrative commercial trade with high profits per animal exists but catches are unpredictable, and hunting is dangerous. However, as many species populations are already heavily depleted, even low hunting offtakes could have significant impacts on vulnerable species. Previous research suggests that commercial hunting which targets larger-bodied and high-value species for the international wildlife trade is mainly conducted by professional hunting groups, external to local communities. The importance of agricultural trade to local communities suggests that “wildlife-friendly farming” initiatives may help to both secure a fair and reliable price for village agricultural products, while promoting conservation of biodiversity in the Cardamoms mountains. However, due to the likely larger impacts of commercial hunting groups, declines in biodiversity are likely to continue without stricter enforcement of wildlife trade laws in Cambodia’s towns and cities, and the reduction of demand for wildlife products in consumer countries.

Keywords: hunting, wildmeat, mammals, community, wildlife, trade, nutrition, household

OPEN ACCESS

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Specialty section:

This article was submitted to
Conservation,
a section of the journal
Frontiers in Ecology and Evolution

Received: 23 January 2019

Accepted: 24 July 2019

Published: 27 August 2019

Citation:

Coad L, Lim S and Nuon L (2019)
Wildlife and Livelihoods in the
Cardamom Mountains, Cambodia.
Front. Ecol. Evol. 7:296.
doi: 10.3389/fevo.2019.00296

INTRODUCTION

The Cardamom mountains, in southwest Cambodia, represent one of the largest, most diverse, and least developed extents of lowland deciduous forest in mainland Southeast Asia (Daltry and Momberg, 2000), and are internationally recognized as a hotspot for biodiversity conservation (BirdLife International, 2019), supporting diverse and abundant populations of large bodied mammals, including leopards (*Panthera pardus delacouri*, *Neofelis nebulosi*), Asiatic black bear (*Ursus thibetanus*), gaur (*Bos gaurus*), and other large ungulates (Gray and Phan, 2011). In 2000, the first, and most recent biodiversity survey of the Cardamom Mountains revealed that they represent a disproportionately large amount of Cambodia's biodiversity; the Mountains cover about 6% of Cambodia's land area but support half of the country's known resident bird, reptile and amphibian species, and most of Cambodia's large mammal species (Daltry and Momberg, 2000). Historically, human population densities in the Cardamom mountains have been low, and until the early 1990s, the main inhabitants of the Cardamoms were the indigenous Mon Khmer Pear (also known as "Por" or "Khmer Dauem"), whose livelihoods, cultures and beliefs were, and still are intimately linked with the forest (Sarou, 2009).

However, events since the 1960's have had devastating impacts on the Cambodian people, their livelihoods and their wildlife. Initial civil conflicts (1968–1975), subsequent rule under the Khmer Rouge (KR; 1975–1979), and then conflicts between government forces and the remnant KR groups (1979–1997), claimed the lives of millions of Cambodians, and displaced millions of others, mainly into rural areas (Terry, 2002). Many areas of the mountains and fields surrounding the villages were heavily mined during the conflict, and mine clearance is still ongoing (Daltry and Momberg, 2000; pers. obs.). By 1991, an estimated 319,500–462,500 weapons were stockpiled nationally, with 136,000–200,000 soldiers and 250,000 militia trained in their use (Loucks et al., 2009). The Cardamom mountains were one of the last strongholds of the KR (Terry, 2002), and while the KR controlled the Cardamoms, thousands of Mon Khmer Pear were driven from their homes (Sarou, 2009). In the early 1980's, conflict, starvation and outbreaks of malaria forced many communities in the Northern Cardamoms to evacuate to the Thai border camps, only returning to their villages in the Cardamoms after the arrival of peace in 1999 (Terry, 2002). Armed militia were re-integrated into society after 1999, and many KR members settled in the Cardamom mountain villages.

In the 1990's there was a boom in the timber trade, and large tracts of forest were licensed to private timber and agricultural companies, resulting in rapid deforestation. Between 2001 and 2012 Cambodia lost over 14% of its forest cover; this deforestation rate was the fifth fastest in the world during this time period (Hansen et al., 2013). Lowland forests in eastern Cambodia have been cleared faster than in the less accessible western Cardamom Mountains, but as high-value timber species become harder to find in the eastern forests, deforestation pressure is increasing in the southwest of Cambodia (Hansen et al., 2013; visualizations accessed 06/01/2019). Logging concessions and agricultural expansion

have brought new road networks, providing increased access to once-remote forest; one of the most significant road expansions for the Cardamoms has been the upgrading of Route 5 between 2000 and 2005, which connects Phnom Penh with the Thai border, via Battambang. The availability of employment with logging and agricultural companies has attracted many lowland Khmer to settle in the Cardamoms, and now the vast majority of inhabitants of the Cardamom mountains originate from the lowland Khmer (Sarou, 2009).

All of these changes in the Cardamom mountains have driven an increase in the commercial wildlife trade. During the civil conflict in the 1970–90s, military training and the availability of firearms resulted in more traditional hunting methods, such as crossbows, being replaced with more efficient firearms (Drury, 2005). After the end of the conflict, many returning indigenous communities and ex-militias were reliant on hunting and collection of other NTFPs, due to the loss of their villages and livelihoods, and the unavailability of agricultural lands due to the danger of landmines (Drury, 2005). Growing affluence in China, and the influx of Vietnamese and Chinese, often with foreign timber companies, in the late 1990s then further increased the demand for wildlife products for traditional medicine. Road expansion made forest more accessible to commercial hunters, and reduced travel times to major markets (Drury, 2005). Following the conflict, limited rule of law, particularly concerning environmental management, meant that the chances of being caught or sanctioned were low. In addition to village community hunting, the potential profits to be gained from supplying the market for traditional markets drove the formation of commercial hunting gangs external to communities, often formed from ex-militia (Wutty and Simms, 2005). An influx of lowland peoples, following employment opportunities and settling agricultural lands, as well as an increase in the commercial trade in NTFPs, eroded the customs and traditions of the indigenous communities, although many retain their traditional beliefs, and many groups in the Cardamoms have lost their language through long periods of interaction with the more dominant lowland Khmer culture (Sarou, 2009).

Biodiversity impacts of the conflict are thought to have been significant, although no quantitative baseline data exist for comparison. However, interviews with hunters in NE Cambodia suggest that species abundance many have halved from 1950 to 2000 (Loucks et al., 2009). Several larger-bodied mammals have been nationally extirpated through over-hunting including the Javan Rhinoceros (*Rhinoceros sondaicus*), with no confirmed sightings in the Cardamoms or Cambodia since the 1980's (Daltry and Momberg, 2000) and the Indochinese tiger (*Panthera tigris tigris*), which was declared functionally extinct in Cambodia in 2016 (WWF, 2016). The Indochinese leopard (*Panthera pardus delacouri*) was found to have declined in abundance by 72% between 2009 and 2014 in the Srepok Wildlife Sanctuary, Eastern Cambodia, most probably due to widespread snare hunting, and is now under threat of national extirpation (Rostro-García et al., 2018). In 2000, of the 67 mammal species recorded in the Cardamom mountains, 26 were threatened or near-threatened according to the IUCN Red list, with the greatest threat coming from commercial hunting (Daltry and Momberg, 2000).

From the 1990s onwards, significant measures have been taken by the Cambodian government to conserve Cambodia's forests and wildlife. Cambodia's protected areas (PAs) were established under the 1993 Royal Decree on the Protection of Natural Areas, and recent estimates suggest that over 40% of Cambodia is covered by some sort of PA. PAs cover a large proportion of the Northern Cardamom Mountain forests; Phnom Samkos Wildlife Sanctuary (3,307 km²), the Central Cardamom Mountains Protected Forest (4,010 km²), and Mount Aural Wildlife Sanctuary (2,544 km²) (UNEP-WCMC IUCN, 2018). Cambodia's principal wildlife legislation, the Law on Forestry (Kingdom of Cambodia, 2003) was enacted in 2003 and is overseen by the Ministry of Agriculture, Forestry and Fisheries. Under this legislation, wildlife is considered State property. Hunting which uses "dangerous means," is conducted during the closed season (which has not yet been defined) and of rare and endangered species (as categorized by separate Ministerial Declarations), is illegal. Local communities are allowed to hunt "common" wildlife using traditional methods, for "customary subsistence use" (this important term has never been clearly defined), although "common" wildlife may not be transported and traded in "an amount exceeding that necessary for customary use." This does not apply to the core-zones of PAs, under the 2008 Law on Natural Protected Areas (Kingdom of Cambodia, 2008). The uncertainties surrounding the definitions of "dangerous means," the closed season and "customary use" effectively makes most wildlife trade potentially illegal.

Wildlife trade volumes in the Cardamoms, while still significant, are thought to have reduced from a 1990s peak, partly due to reduced wildlife populations and partly due to the removal of many of the guns from general circulation by the local authorities, beginning in 2001 (Oul and Cheam, 2005). However, the use of non-selective and cheap wire and nylon snares have increased, and in 2013 over 13,000 snares were removed from the Southern Cardamom National Park by law enforcement patrols; this had increased to almost 28,000 by 2015 (Gray et al., 2018). Informant networks employed in 2005 identified both commercial village hunters and commercial external hunting gangs, and the Central Cardamoms as one of the "hotspots" for wildlife trade. Most of the wildlife traded in the Cardamoms is now likely to leave Cambodia for the international market, traveling first to traders within the Cardamoms, then to Phnom Penh along Routes 4 and 5, and finally exported to China, Vietnam and Thailand (Wutty and Simms, 2005).

While forest area and wildlife populations have reduced, wildlife still thought to be important culturally and economically to both the lowland Khmer and indigenous Mon Khmer Pear living in the Cardamoms (Daltry and Momberg, 2000; Fox, 2006; Sarou, 2009). Socio-economic surveys of over 40 villages within the Phnom Samkos Protected Area, between 2004 and 2006, found that arable crops provided the backbone of local livelihoods, with other activities including livestock rearing, market gardening, fishing, and hunting (Fox, 2006). Fishing was a daily activity for most households, providing an important source of protein. Direct questions on hunting frequency were not included in the survey due to the illegality of hunting, but researchers observed that crop raiding was common, and farmers

would catch wild pig, deer and porcupine around their arable fields. Researchers also observed that Sunda pangolin (*Manis javanica*), Malay sun bear (*Helarctos malayanus*), tiger, gaur, and banteng (*Bos javanicus*) were sold by hunters, who were sometimes contracted by town traders. A later evaluation of livelihoods in the Central Cardamoms Protected Forest again stressed the importance of agriculture for local communities (Sarou, 2009). While 80% of households reported fishing only 15% reported hunting; however, the author noted that ranger presence in the villages was high and that when asked about hunting "in the past," over 50% of households reported hunting, which may provide a truer reflection of current hunting levels.

STUDY AIMS

While previous studies suggest that wildlife is still part of local livelihoods in the Cardamoms, there is still limited information on the role wildlife plays a part in overall community livelihood strategies. To gain a preliminary understanding of contemporary use of wildlife by local communities in the Cardamom mountains, we used a case-study approach in three villages in the northern Cardamoms. We aimed to describe and investigate:

- The number of households engaging in hunting and fishing, key techniques used, and the most commonly hunted species.
- The main livelihood activities of households in the study villages.
- The relative importance of hunting and fishing as a source of household cash income, including information on the main traded species, prices and buyers.
- The relative importance of hunting and fishing as a source of household non-cash income.
- The relative importance of wildmeat and fish as a source of protein, and the frequency of consumption of different species.

To this end, we employed semi-structured interviews with households and hunters, as well as group PRA techniques, situating wildlife use within the wider livelihood strategies of local communities. We use our results to build preliminary hypotheses as to the drivers of wildlife use by communities in the Cardamom mountains. We then discuss how these results and hypotheses, could be used to design further in-depth studies of wildlife use, and might inform wildlife management policies in the region.

METHODS

Study Area

We conducted our research in three rural villages in the Northern Cardamom Mountains, in the Battambang and Pursat provinces (**Supplementary Material S1**). We conducted an initial scoping trip in August 2013, visiting three communes (an administrative unit comprising several villages). We selected one village in each commune to work in based on their proximity to the forest and how comfortable they seemed with our presence and preliminary questions; our aim was not to create a systematic sample of all villages in the Cardamoms, but rather to form

preliminary hypotheses on the use of wildlife in villages bordering the Cardamom mountains forest.

The three study villages are located directly on the northern border of the Phnom Samkos Wildlife Sanctuary, at between 180 and 400 m above sea level, at the base of the Cardamom mountains. To the north of the villages, most of the landscape is below 200 m, and habitat has been converted to farmland and rice fields. To the south, the mountains within the Phnom Samkos Wildlife Sanctuary are covered by relatively intact tropical moist broadleaf forests (the Cardamom mountains Rain Forest Ecoregion; WWF, 2019), rising to 1,700 m above sea level. Climatic conditions in the Ecoregion are relatively stable, with a rainy season from May to October, mean annual rainfall between 2,000 and 4,000 mm, and average temperatures between 29 and 32°C. The ecoregion is thought to be home to over 100 mammals species and over 450 bird species (WWF, 2019).

All three villages had <100 households, were majority Khmer ethnic group (>95% of the population) and were evacuated in the 1990s during the Cambodian war. Villages 1 and 2 were ex-Khmer Rouge (KR) villages, and still have significant densities of land mines in the surrounding fields and forests. As defined by the Cambodian Government's National Policy Framework for Poverty Reduction, 40, 100, and 50% of households in Village 1, 2, and 3, respectively are in poverty, and eligible for state assistance (Ministry of Planning, Kingdom of Cambodia, 2012). **Supplementary Material S2** provides basic characteristics of each village, and the study timetable. The exact location and name of each village has been kept anonymous.

Asking for Local Permission to Conduct the Study

During the initial scoping trip we presented the project to commune chiefs, asking for their permission and support to conduct the study, and providing them with our letter of introduction from the University of Phnom Penh (UPP). On arrival at each of the potential study villages we met with the village chief and gave him our letter of introduction. We discussed the interviews and PRA activities that we wished to conduct and asked his permission to carry out research interviews in the village. All villages chiefs that we asked gave their permission. We then conducted surveys in three villages (1 per commune) on three separate field trips, over 6–7 days, in September and October 2013.

Household Interviews

We used semi-structured household interviews to familiarize ourselves with the main livelihood activities of households in each of the study villages. Interviews took ~2 h and were conducted by two Cambodian researchers (LN and SL), with LC present. Households were selected using a systematic random sample, following Starkey (2004). We first counted the number of households in the village, and then divided this number by the aimed-for sample size of 15 households (i.e., if there were 60 household in the village, $60/15 = 4$). We then visited every n th household (i.e., in our example every fourth household), using this calculation, starting at one end of the village and counting along the houses. Where household members were working in

their fields, we did not attempt to interview them due to the number of land mines still present in the fields. In this case, where no-one was available in the household to be interviewed, we would then move onto the next adjacent household to the selected household.

On arrival at each household, we introduced ourselves and the aim of the project, and we asked if they would be willing to be interviewed. We emphasized that participation was completely optional, and that the identity of all villages and interviewees would stay anonymous. Everyone that we asked agreed to be interviewed. Names of interviewees or households were not recorded at any point. Details were recorded in small notebooks rather than on questionnaire sheets, to reduce the formality of the interview. We completed 14 interviews in Villages 1 and 2, and 13 interviews in Village 3, representing 19, 38, and 13% of all households in each village, respectively. In each village, the number of interviews was limited by the time available. As a token of thanks, each interviewee was given a *krama* (a small sarong) at the end of the interview. Interview questions are provided in **Supplementary Material S3**.

Interviewees were asked to describe their main livelihood activities, including:

- The frequency of the activity (trips per day/week/month/year).
- The amounts of the product made or harvested (per day/week/month/year).
- The money made from selling the product (per day/week/month/year).

The mainly illegal timber trade is a highly contentious subject in the study area, and we quickly removed the question on the use of timber from our list of questions, after observing the reaction of interviewees. Direct observation of livelihood activities was not possible due to the continued presence of land mines in the surrounding fields and forests, and responses provide us simply with the interviewee's estimate of frequencies and amounts.

Additionally, where interviewees were happy to discuss hunting, we asked how frequently the household consumed different animal species (i.e., whether a species was consumed daily, fortnightly, monthly, quarterly, or yearly). To prompt discussion, we showed the interviewee a set of 41 cards, depicting different common and rare species thought to be present in the Cardamom mountains (Daltry and Momberg, 2000; **Supplementary Material S4**). We included a card for each of the large mammal species recorded as present by Daltry and Momberg (2000). We did not include all bird and reptile species to species-level, instead choosing key species known to be hunted, and including other cards to represent key groups (i.e., turtle sp., land lizard sp. bat sp.; see **Supplementary Material S4**). We included one "wildcard" species—Javan rhinoceros—known to no longer occur in the area.

Where interviewees seemed comfortable to talk further about hunting we continued to discuss broader questions on hunting, including methods, preferred species and which species had been hunted by the household in the previous year. To prevent any potential unease in discussing the illegal wildlife trade, we did not attempt to estimate the amount of household income made from wildlife sales, and only asked follow-up questions on wildlife

trade when information on the trade had been given unprompted and interviewees seemed comfortable with the discussion. We were not able to identify fish using binomial nomenclature, as we did not have a fisheries expert as part of the team, but wrote down the name of fished species in Khmer. Our analyses therefore do not attempt to break down results for fish by species.

Hunter Interviews

We conducted a group interview with 3–4 hunters at the end of each village visit (to allow time for trust to develop). Hunters were identified through household interviews (i.e., where a member of the household that we interviewed engaged in hunting regularly), through discussions with village elders, and also through general conversations during the day between LN and village men. The opportunistic sampling strategy may mean that hunter interviews were not representative of village hunters as a whole, and our results should be taken as preliminary, with the aim of helping to develop more in-depth studies in the future.

Interviews were kept anonymous and informal in tone, conducted while sharing a meal or drink. We showed the interviewee the set of 41 species cards (predominantly mammals), and asked about the hunting techniques, frequency of capture, use and village prices for each species. In addition, we asked about more generally about the drivers of hunting in the village, the characteristics of local hunters, the level of hunting enforcement and changes in the availability of wildlife in the area.

Participatory Rural Appraisal (PRA)

Livelihood Analysis

We used the IUCN's Poverty Forestry Livelihood Analysis Toolkit (PFLA) Tool 6 (PROFOR, 2008) to investigate the relative importance of different cash income and non-cash income activities for rural households. Cash income refers to income brought into the household in the form of money (such as agricultural sales, income from employment, sales of NTFPs etc.). Non-cash income refers to products brought into the household, which are then used directly by the household (i.e., agricultural products which are eaten rather than sold, NTFPs used for food, construction, or medicine, etc.).

Following the completion of 14 household interviews, toward the end of our visit in each village, we invited the household to send an adult representative of the household to attend one of two half-day PRA sessions (seven interviewees in each group), one of which was conducted in the morning and the other in the afternoon of the same day. Together with participants, we wrote a list of the different livelihood activities in the village, in Khmer, onto A0 paper. We then asked each participant to distribute 50 "counters" (we used 50 pieces of corn) between the different livelihood activities so that the number of counters given to each activity illustrated the amount of income from that livelihood activity. This was done twice—once for cash-income sources (illustrating the value of the items produced/procured which were then sold) and one for non-cash income sources (the value of produced/procured items which were then used by the household, not sold). As described in the PFLA (PROFOR, 2008), this was conducted in front of the participants from other households, which may have influenced the results of each

household, but also resulted in illuminating group discussions on the use and importance of different products.

During the exercise, we discussed each livelihood activity with the group. We only discussed wildlife and timber sales if the participants brought it up unprompted, because both activities are illegal. At the end of each meeting we provided participants with lunch or an evening meal and gave them each a krama to thank them for their participation.

In Villages 1 and 2, the consumption of insects did not come up in household interviews, and insects were therefore not included in any of the PRA exercises. In Village 3, grasshoppers and beetles were reported and observed to be consumed, and in we therefore added insects as a category for the PRA exercise.

Consumption of Meat and Fish

We used a similar method to the PFLA toolkit to look at the importance of different fish and animal protein sources in the household diet. We asked participants from each household to distribute 50 pieces of corn to illustrate the importance of beef, pork, chicken, market-bought fish (from outside the village), caught fish (including crabs, shrimp and small fry), and wild meat, for feeding their household, over the course of a year. For Village 3, an additional category of "insects" was added after household interviews highlighted that insects were an important part of the diet.

Data Analyses

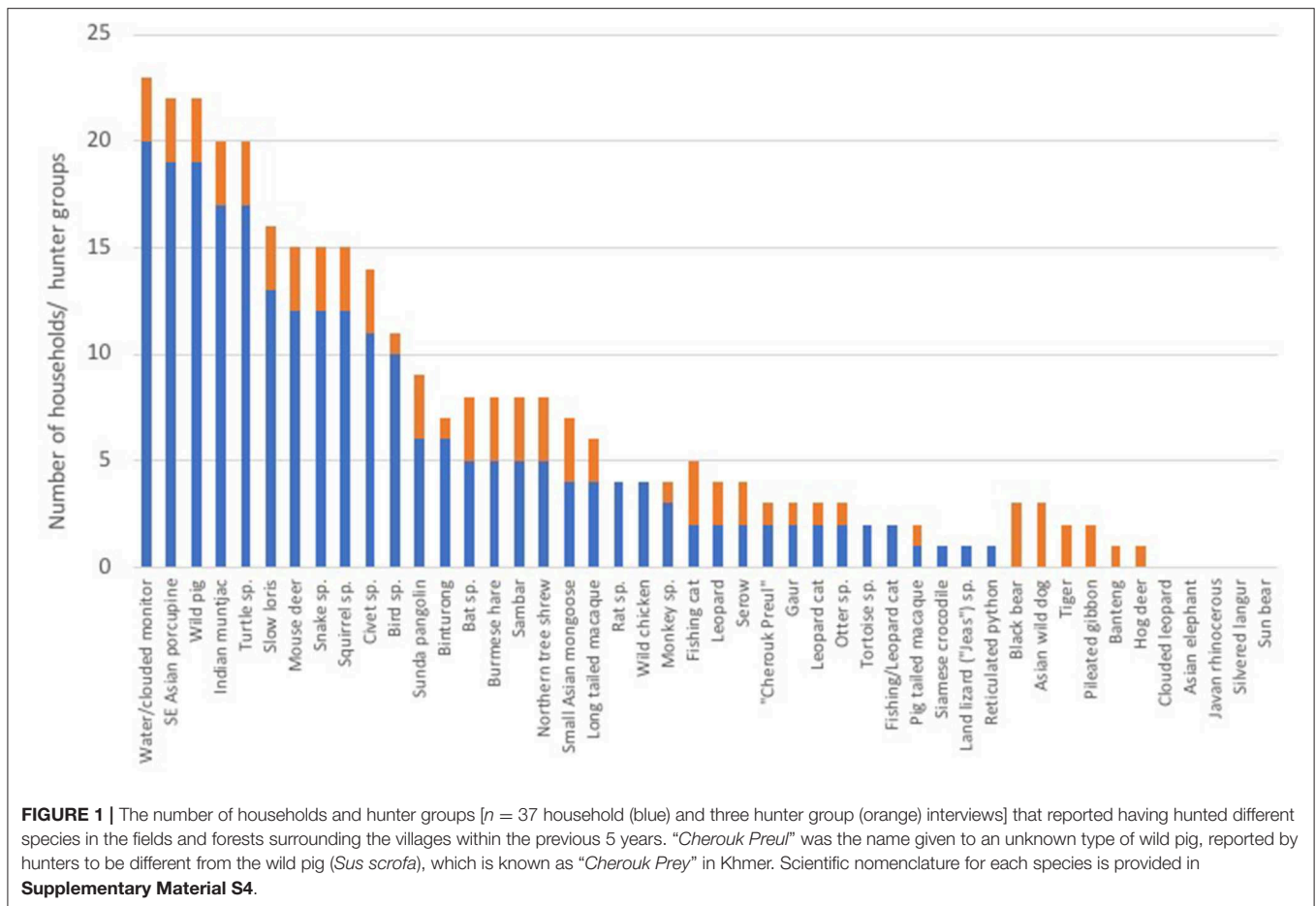
We have used the results of these interviews and PRA exercises to build a first look at the livelihood activities of, and the use of wildlife by, local communities in the Cardamom mountains. Specifically we analyse and present:

- the number and percentage of surveyed households that reported engaging in hunting or fishing, as well as the number using different hunting and fishing techniques.
- the number of surveyed households reporting hunting individual species in their household interviews.
- The average number of counters (and associated standard errors) allocated in the PRA exercises to each product, representing their relative importance as sources of cash and non-cash incomes, by village and in total.
- The frequency of consumption of different species as reported by interviewed households.
- The average number of counters (and associated standard errors) allocated in the PRA exercises to each type of meat (including wild meat) representing their relative importance to the household diet, by village and in total.

In some specific cases, we have used Pearson's product moment correlations to further explore correlations between livelihood activities.

Qualitative information on household livelihood activities collected during household and hunter interviews is presented with these quantitative results, providing contextual details on individual activities, and potential explanations and hypotheses for the quantitative results.

Data were analyzed using Microsoft Excel and R computing language (R Core Team, 2016).



RESULTS

Hunting Frequency, Species, and Methods

Most households (83%) reported having hunted during the previous year. At least 38 species were reported to have been caught in the village territories (Figure 1). The five most frequently reported hunted species were monitor lizard (*Varanus sp.*), SE Asian porcupine (*Hystrix brachyura*), wild pig (*Sus scrofa*), Indian muntjac (*Muntiacus muntjac*), and turtle species (*Bataguridae* and *Trinychidae sp*) (see Figure 1 and Supplementary Material S4 for full species list and scientific names). Households had not observed Javan rhinoceros, tiger or wild dog (*Cuon alpinus*) in the forest areas surrounding the village, agreeing with the findings of Daltry and Momberg (2000). A few hunters said that tigers had been seen over 2 years ago in the more remote, mountainous sections of the northern Cardamoms, and reported catching wild dog in the past 5 years. Hunters and households reported that they did not catch clouded leopard (*Neofelis nebulosi*), elephant (*Elephas maximus*), silvered langur (*Trachithecus cristatus*), or Malay sun bear (*Helarctos malayanus*), although they were thought to exist in the surrounding forest.

The main hunting methods were snares, slingshots, dogs and homemade “pump guns” (Supplementary Materials S5, S6).

Snares (wire cable or nylon) were used by 76% of households, generally for crop protection (other crop-raiding deterrents used are outlined in Supplementary Material S7). If households did not set traps it was often because there was no adult man within the household, rather than a lack of need. The main crop-raiding species were porcupine, wild pig, Indian muntjac, squirrels species, and civet species. Large herds of wild pigs, or group of macaques (*Macaca nemestrina*, *M. fascicularis*), coming through a plantation could result in high losses in agricultural yields. The two most frequently used snare types were foot snares, to catch larger animals, such as wild pig, Indian muntjac, and small cats (*Prionailurus bengalensis*, *P. viverrinus*) (although they are indiscriminate and will catch a wide range of species; Supplementary Material S6), and neck snares, to catch smaller animals, such as snakes and rats. In addition to crop protection, households and hunter groups reported that a few commercial hunters in each village (men who used hunting as a primary livelihood activity, and source of income) would set snares in the forest. One hunter focus group reported that these hunters would commonly set around 50–90 snares in the forest at one time and check these snares every 3 days.

Over half (56%) of households used slingshots for short hunting trips in the evening or night, when coming home from the fields, or after setting fishing rods in the river. Although

the animals procured with slingshots tend to be small and of low value [birds, Slow loris (*Nycticebus coucang*), snakes, and civets] slingshot hunting reliably catches something for the cooking pot and is easy to fit around other livelihood activities. A similar proportion (54%) of households hunted with dogs. Although dogs can help hunters to catch a range of species (**Supplementary Material S6**), dogs are primarily trained to catch Sunda pangolins (*Manis javanicus*), which are traded for their scales, and attract high prices on the black market. Trained dogs track and point at pangolins, which roll into a ball when attacked and are easily picked up by the hunter.

Twenty nine percentage of households used homemade “pump guns.” Interviewees explained that between 10 and 20 years ago, shotguns were readily available, a legacy from the civil war in the 1990’s. Shotguns have now mainly been confiscated or hidden, but homemade guns are cheap and easy to make, and are used frequently for night hunting. Pump guns operate using loose shot rather than cartridges or bullets and use a pump-action fashioned from a bicycle pump. Manufacture is cheap and parts easy to come by. Although pump guns are effective at killing medium-sized animals (such as muntjac), hunters reported that they were not capable of killing larger mammals, such as gaur, wild pig, sambar (*Cervus unicolor*), and bear species.

In addition to these main hunting techniques, animals are also harvested when field are cleared and burned (generally monitor lizards, turtles and snakes), poison is used to catch small birds and tree shrew species, and leopard cats (*Prionailurus bengalensis*) are sometimes hunted with a crossbow.

Fishing Activity and Methods

Almost all households (95%) fished. Crab and shrimp and small fry were caught by women, using a scoop net. While they only provide a small amount of food, crab and shrimp can be collected on the way home from working in the fields and were added to forest and farm vegetables to create a low-cost meal, the only purchased good being rice (which is not often grown in these upland villages). In larger rivers, men caught river fish and eels with a fishing line, rod or net. These fish are still quite small (5–15 cm in length), and men reported catching between 0.5 and 1 kg per trip, or enough for 1 or 2 meals. Several men reported that rod or line fishing and hunting activity tended to coincide; men would set their lines in the evening, and then go night hunting (or “lamping”) with a torch and a slingshot or pump gun. On their return from hunting they would then check and retrieve their lines. **Supplementary Material S8** provides further details on fish types and fishing techniques.

Electric shock fishing was practiced in all three villages. A car battery is used to provide a high voltage shock into the river, killing or stunning the fish (and turtles), which are then easily collected by hand. Electric shock fishing is illegal, and most respondents talked about “their neighbor” using this technique. It is therefore hard to gauge its popularity. However, as our stay in the villages progressed, and villagers became more trusting, several interviewees suggested that most households used electric shock fishing, and a few respondents suggested that over-use of electric shock fishing was one reason for the current low fishing returns.

Fishing activity varied with the season; in Village 1 which had a small river, households reported fishing more often during the wet season, when water levels were high enough for fish (rather than small fry, shrimp and crab) to be found. In Villages 2 and 3, some households reported reducing their fishing activity during the wet season months, when water levels were too high, and nets would get torn.

In the first month of the wet season (April/May) over 80% of households caught frogs 2–3 times a week in their fields and nearby ponds, by hand. Households reported catching up to 3 kg of frogs per trip. Frog catching is highly seasonal, and after the first month households reported that they did not catch frogs because the water in the fields and ponds became too high for them to easily catch them, and that further into the wet season frogs would often be full of worms and therefore inedible.

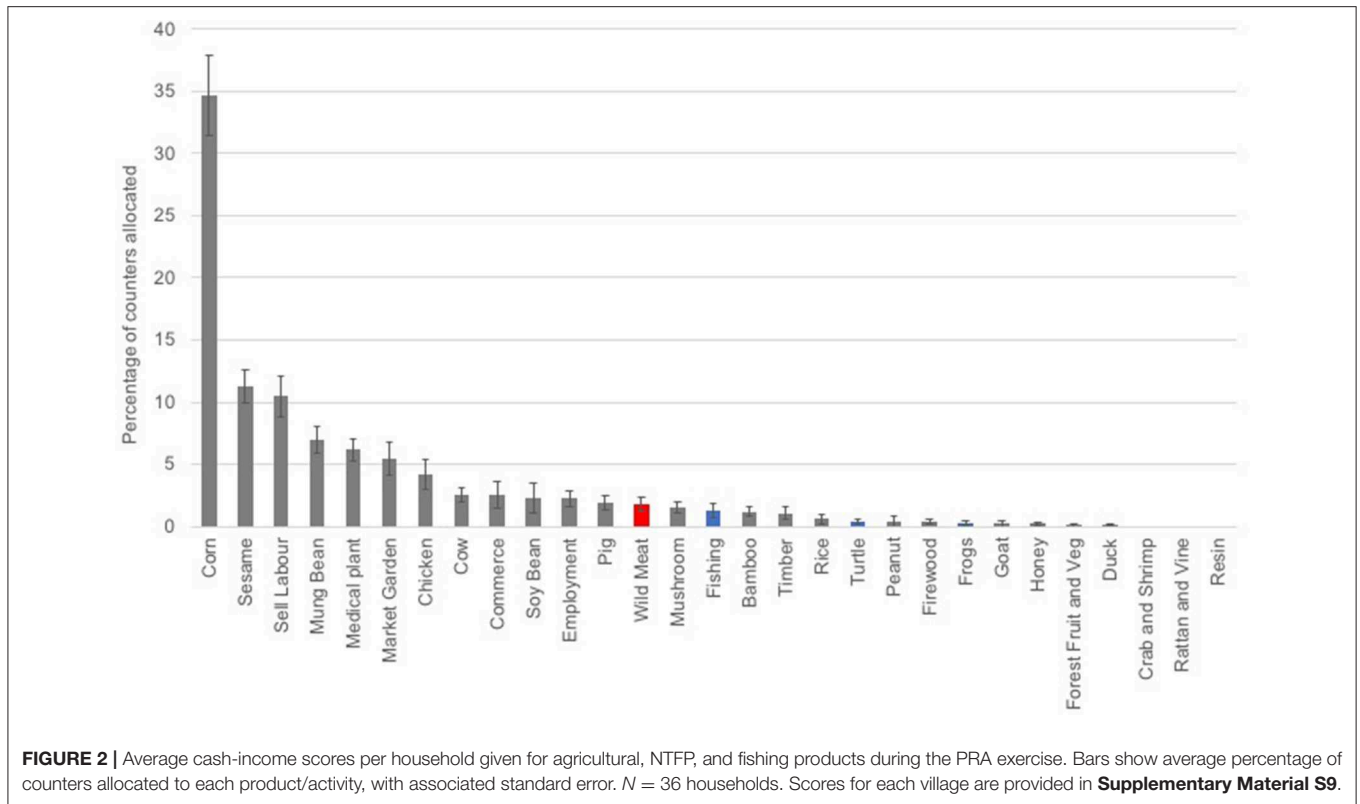
Sources of Cash Income, and the Relative Importance of Wild Meat and Fish

During the PRA exercise to identify the relative importance of different household activities for household cash incomes, households allocated 62% (SE \pm 2.8) of counters to arable farming on average. Salaried work or commerce was allocated 15% (SE + 1.9), forest products 12% (SE \pm 1.7) [including 1.7% (SE \pm 0.5) for wild meat], livestock 9% (SE \pm 1.4), and fishing (including shrimp, crabs, and turtle) 1.8% (SE \pm 0.7) of counters (**Figure 2**).

Arable Farming

All three villages relied heavily on arable farming for cash incomes (mainly corn, mung bean, sesame, and some soy bean; **Figure 2**). Households sold almost all of their crop harvest, except for rice, which was grown for household consumption only. Crops were sold twice a year to town traders, with trade generally organized by the village as a collective. Households therefore had good knowledge of the quantity and price of each crop sold, allowing yearly gross agricultural incomes to be estimated from our one-off household interviews. However, without conducting a longer-term study of household incomes and outgoings, estimates of net profits will remain imprecise. With this in mind, average gross income/year/household were \$2,000/year (SE \pm 260), ranging from \$6,500/year for the largest farm to only \$80/year for the smallest. Average gross income was highest for Village 3 (\$2,940/year/household, SE \pm 600), followed by Village 1 (\$2,160/year/household, SE \pm 260), and lowest for Village 2 (\$950/year/household, SE \pm 260). Participants of the PRA exercises agreed that in an average year (one in which a normal harvest was achieved) \sim 1/3 of farm incomes might be spent on herbicides, pesticide and additional labor. Net arable profits might therefore be in the region of \$1,900, \$1,400 and \$600/year/household for Villages 3, 1, and 2, respectively. Smaller farmers reported making overall losses, either due to existing debt, land rents or crop failures.

Village 2 had relatively low incomes from arable crops and households allocated the lowest number of counters to arable incomes in the PRA exercise [48% (\pm 2.9) compared to 73% (SE \pm 3.6) and 69% (SE \pm 4.9) for Villages 1 and 3, respectively; **Supplementary Material S9**]. Households in



Village 2 also owned/used fewer hectares of arable fields than in the other two villages [an average of 3.8 ha (SE \pm 0.76) for Village 1, 3.1 (SE \pm 0.38) for Village 3, and only 1.5 (SE \pm 0.35) for Village 2]. At the time of our study, Village 2 had the government land mine clearance organization camped in the village. Many of the fields were not yet cleared of land mines, were therefore not being used by their owners. This may explain the lower profits from agriculture in Village 2. Several interviewees in Village 2 highlighted the issue of land tenure rights for rural households. Interviewees reported that while they were obviously keen to see land mines cleared from their fields, they were also concerned that after clearance, the land would be leased to multinational agricultural companies and that, paradoxically, the clearance of land mines would therefore lead to the loss of their lands.

Every household in the three villages had a market garden (a small area behind the house), containing vegetables, such as eggplant, chili, herbs, gourd, cabbage, pumpkin, cassava, and beans, and fruit, such as oranges, mango, banana, papaya, coconut, milk fruit, lemon, and jackfruit. Households generally did not sell much produce for their market gardens, however there was a strong barter economy in the villages and households reported that they would often give fruit and vegetables to their neighbors for free and know that they would get the same in return. In Village 2, market gardening scored as highly as many agricultural products in terms of cash incomes (11% of beans allocated; **Supplementary Material S9**), and this may again be due to the smaller size of agricultural fields in Village 2, leading to a diversification of livelihood activities.

Employment, Commerce, and Labor

There were very few employment opportunities available in the three villages. Aside from several government jobs (village chief, deputies and one teacher, paid \$7–15 a month), nine households contained members with either army pensions or disability allowances (often due to war wounds, or landmine injuries). Few households engaged in commerce (two households baked cakes, making between \$1.25 and \$4 a day, one household owned a truck, and had set up a corn trading business between the village and corn traders in the nearby town, earning a reported \$500 a year. One household ran a village shop, and another had just set up a restaurant). Most employment came in the form of households with small farms selling their labor to households with larger farms in the planting and harvesting season. Of the 41 households interviewed, 28 sold their labor at some point during the year. One day's labor cost \sim \$3, and households reported making between \$10 and \$50 dollars from selling labor over the year. Although this does not represent a large income when compared to the money that can be made from arable farming, for poorer households with little land, incomes from selling labor can still be important. In the PRA exercise the land-poor Village 2, where field sizes are limited by the number of remaining land mines, incomes from selling labor scored more highly [17.2% (SE \pm 3.1)] than Village 1 or 3 [5.1% (SE \pm 1.1) and 6.3% (SE \pm 1), **Supplementary Material S9**]. The scores that an individual household gave to "selling labor" as a cash-income were also negatively correlated with the gross agricultural incomes of

the household (Pearson's product moment correlation, $n = 32$, $p = 0.019$, $R^2 = 0.14$).

Livestock

Household generally kept a few animals, with each household owning on average 10 chickens, and 1–2 cows or pigs. Livestock in the study villages is not often kept for household consumption, and instead is used in the same way as a savings account, providing source of emergency funds, or to pay for one-off purchases. 16 of the 41 households interviewed sold livestock over the last year, and household received, on average, \$430 (SE \pm 134) from livestock sales, not accounting for rearing costs. Cows and pigs were the main species sold, and of the 10 households that sold cows in the previous year, 5 of these did so to buy a mini tractor (“*koyun*”), or to invest in building a new house.

NTFPs

The two main sources of income from forest products, aside from wild meat and fish, were mushrooms and medicinal plants. Three main species of medical plants were sold to traders from town, known locally as “Tacao,” “Krawine,” and “Moi Roi Kun” (or “100 uses”). Medicinal plants were collected by 30 of the 41 surveyed households and sold to town traders by 21 of these households, with profits of \sim US \$100/year. The main collecting season was June–September, and families might spend a few weeks collecting plants in June and July. “Pok” Mushrooms were collected by 36 of the 41 surveyed households and sold by 11 of these households. The Pok mushroom season runs for a few months (June–August) during the wet season and is sold to town traders. Pok mushrooms sell for \$2.5–3/kg, and households reported making between 10 and 50 dollars each year.

In Eastern Cambodia, the most valuable NTFP is often resin, which is tapped from dipterocarp trees. Although resin trees exist in the study villages, they are of a different species and the resin produced is much less valuable (US \$0.5 per kilo). It is used to caulk boats, and was only collected by five of the 41 households, generally by younger boys. Unlike in Eastern Cambodia, there are no resin collectives in the village.

In Village 3, insects were included as a category in the PRA exercise. However, no counters were allocated to insects for cash incomes.

Fishing and Hunting

While fishing and hunting was conducted by most households, they were only reported as primary income-generating activities by a few households. Households allocated a mean of 1.8% (SE \pm 0.41) counters to fishing incomes and 1.7% (SE \pm 0.54) of counters to wild meat (Figure 2), and 16 and 30% of households sold fish or wildmeat, respectively. Only 1 of the interviewed households allocated more than 10% of counters to wild meat, and only 2 households for fishing.

Interviewees explained that the amount of fish caught in a night was often only enough for 1 or 2 meals, leaving no excess to sell. Hunter interviews suggested that only a few men in each village were “commercial hunters” engaging in as a primary livelihood activity and source of income. These men would hunt almost every day, penetrate further into the forested hills around

the village, and were more likely to catch larger-bodied and higher-value species. Interviewees gave four explanations for the low number of commercial hunters in each village.

- *Hunting is a risky strategy*: If a man focuses on his arable farming, he can buy rice and feed his family. A small amount of hunting can then supplement his food and income. However, to be a big hunter, the time needed away in the forest would mean that the arable farming would suffer. Farming is a steady and safe form of food and income for the family, whereas hunting can provide large one-off profits (such as from the capture of a pangolin), but incomes are unsure and sporadic. “*You can stay alive on your own just hunting, but you can't feed your family*” (hunter interview, ID18, 29th September 2013).
- *Households need more than 1 adult male*: In households with 2 or 3 male children at least one of these men can focus on hunting, as the family is large enough to spare the labor from the farm, and the risks of sporadic hunting returns are mitigated by the steady incomes that the household receives from farming.
- *Young men are often afraid of the forest* due to the dangers of wild animals (pigs and bears) and land mines: In Village 3 a wild pig had recently killed a young hunter, while he was trying to lay snares. All three villages were in areas of high land mine density, the surrounding forest had not been cleared, and there had been several fatalities from land mines in the last few years.
- *Young men are moving away from the village* to seek job opportunities in factories in Thailand. All villages were close to the Thai border, and number of families had young men working, or looking for work in Thai factories.

Low PRA scores for hunting may also reflect an unwillingness to talk about hunting, rather than true low sales. This was probably partially true in Village 1 (where households allocated 0.18% (SE \pm 0.18) of counters to hunting incomes on average, **Supplementary Material S9**), which was located close to a protected area ranger station and had been visited by conservation NGOs in the past. However, hunters in Villages 2 and 3 [which allocated 2.6% (SE \pm 1.07) and 2.2% (SE \pm 0.96) of counters to hunting, respectively], while being aware of the wildlife law, were quite happy to talk about catching protected species. Wild meat was sold in front of us, and we were offered wild meat (wild pig, porcupine, slow loris, and monitor lizard eggs) to eat.

Hunters reported that wild meat for consumption (rather than medicinal use) was sold almost exclusively within the village, and that demand for wild meat was high because of its perceived health benefits compared with meat from the market; there is therefore no need to sell to traders. In Village 1, the trade in meat seemed to be kept hidden; hunters reported that they would sell meat at their house to the neighbors that they trusted, as there was a spy in the village (whose identity was well-known to everyone), and he might tell the authorities. In Villages 2 and 3 trade in meat was out in the open, and women would come around with meat (generally wild pig) for sale while we were conducting interviews.

Species sold to traders outside the village were generally sold for their perceived medicinal properties (Table 1), rather than as a source of meat. Many species are used as a general health tonic,

thought to cure a range of ailments. For example, one preferred species for medicinal use was the slow loris. Households said that slow lorises were easy to find and could be used to treat “101 medical ailments” (“*moi roy kun*”), including joint pain. One of the households that we interviewed demonstrated its use for us. The slow loris had been smoked (charred) over a fire to preserve the carcass, and small amount of the charred flesh was then grated into rice wine and drunk as a tonic. Bones and antlers of animals were also used medically, and serow bone, porcupine jawbone, and sambar antler could all be grated into, or rubbed into, rice wine/rice water to create a health tonic. In addition to medical uses, deer antlers were traded for decoration, and we saw both sambar and Indian muntjac horns used in this way in small towns close to the study villages. Animal parts could also be used as good luck totems (for example, loris tattoo paint, pangolin scales, and bear claws).

Hunters universally identified the Sunda pangolin as the species that they most hope to catch, due to its high market value. Two pangolins were caught while we were in the study villages, both weighing 1.5 kg (with a value of ~\$220 each), and were sold immediately to traders in Battambang, who were contacted by mobile phone. Hunters with a good pangolin dog might catch 1–2 pangolins per month (2–3 if exceptional, but in some years, as few as 1–2 per year might be caught), and well-trained dogs can sell for \$1,000–2,000. In each village, only a few (1 or 2) hunters possessed trained pangolin-hunting dogs. Although animals like serow and black bear can fetch high prices (Table 1), both species were difficult and dangerous to catch. Only 2 of 31 households reported having caught a serow in the previous year; none of the interviewed households reported having caught a black bear.

Hunters in Village 2 reported that if they caught a high-value species, such as Sunda pangolin, serow, gaur, or bear, they would immediately hide the animal bones/skin/horns somewhere safe. They would then call/text a trader in Battambang, who would come and collect the animal. Less frequently a hunter might hold onto the wildlife items, such as bone, horn and skin) until his next trip to Battambang. In Village 1, households reported that there used to be a Battambang trader who would make frequent trips to the village to buy animals for traditional medicine trade, but the chance of being caught and fined by the rangers stopped him from making the trip, and now hunters transport the animals themselves to Battambang. Hunters from Village 3 also reported that commercial hunting groups would come from Pursat and Battambang to hunt in the forest around the village.

Hunters were aware that the trade in wildlife was illegal and were taking precautions to keep the trade secret from the local authorities, although they also seemed happy to talk to us about the trade and their activity. Hunters only reported problems with buyer demand in the case of snakes (boa) and monkeys (pet trade); all other trades that we discussed with the hunters reported no problems with finding a buyer.

Source of Non-cash Income, and the Relative Importance of Wild Meat and Fish

During the PRA exercise to identify the relative importance of different household activities for household non-cash incomes,

households allocated 41% (SE ± 2.5) of counters to arable farming on average, of which 13% (SE ± 1.2) were for market garden products. Forest products were allocated 37% (SE ± 2.1) [including 4% (±0.6) for wild meat], fishing 16% (SE ± 1.4), and livestock 7% (SE ± 0.8) of counters. While arable crops were the main source of cash-income for households, non-cash incomes were more diversely spread between different products from both farms and forest (Figure 3), with no one product represented by more than 13% of the counters on average.

Arable Farming

All surveyed households in the villages, as is common in Cambodia, used rice as their staple carbohydrate and a main source of calories. However, in the Cardamom mountains, the hilly terrain does not provide a good growing environment for rice. In the three study villages, only 40% of households grew their own rice, and kept it for personal consumption. No households grew enough rice to support the family for the whole year (only one household could grow enough rice to feed the family for more than 6 months). Interviewees suggested that households would use the bulk of their arable incomes to buy rice. During this study, we were unable to determine what percentage of arable incomes were used to buy rice, but we suspect that households with low arable yields may have been in “rice debt,” unable to afford the amount of rice needed to support their families. The level of “rice debt” in the cardamoms warrants further investigation. Market gardens also gained a high score for non-cash incomes, in comparison with their use as a source of cash incomes, suggesting that these gardens are an important source of food for local people.

Livestock

Households ranked chicken as the only real non-cash input in terms of livestock, with pigs and cows reared for their value (and as a form of household savings) rather than household consumption.

Hunting and Fishing

Both fishing and hunting were allocated a larger proportion of counters as a source of non-cash incomes (i.e., for food and medicine) than as a source of cash incomes. Wild meat is seasonally available to most households, with wild pig, muntjack, and civet crop raiding during the harvest seasons. As with produce from market gardens, wild meat is bartered between households; a household fortunate enough to catch a wild pig in their fields will not be able to eat or store the whole pig for personal use, and so instead will share with his neighbors, who will then return the favor when they catch an animal. As with cash incomes, non-cash income from wild meat was not correlated with agricultural activity or land ownership.

Other NTFPS

In comparison with cash-income activities (where only *pok* mushrooms and *tacao* medical plants are sold in any quantity) households in all three villages use a range of forest products. Most households in used firewood for cooking—which explains

TABLE 1 | Uses and prices of wild meat species (from hunter and household interviews).

Species	Price (USD\$) for meat in 2013	Price (USD\$) for whole animal in 2013	Uses (apart from as a food)	Price (body part, USD\$)
Bat sp.	Not sold	Not sold	Eases stomach pain	Not given
Binturong	2.5	Not given	Meat for food, teeth, and stomach for traditional medicine	Not given
Black bear	Not given	Not given	Gallbladder: tonic for general good health Nail/fang necklace makes children strong and smart Traders insist on seeing the bear head before buying bones/gallbladder/skin	Gallbladder: 500–1,000 All bone and skin: 200 Bone: 10/kg
Civet sp.	Not given	5–7.5 (m)	Not given	Not given
Crocodile	3.75–4		Generally not hunted	Not given
Fishing cat		10 (m)	Meat only	Not given
Gaur	Not given	Not given	Unknown	Skeleton: 200
Monitor lizard	1.5	Not given	Meat only	Not given
Mouse deer	Not given	2–2.5 (m)	Meat eaten to treat complications after childbirth	Not given
Muntjac	3.75–4.5	Not given	“Gallbladder” ^a when eaten provides general good health. Decoration: antlers added to deer statues	“Gallbladder”: 35 Head and horn: 7.5–12.5
Otter	Not given	Not given	Penis: erectile dysfunction	Penis: 100–200
Pangolin	\$125–150/kg for the first 1–5 kg \$100–120/kg for pangolins heavier than 6 kg	Only sold by KG	PPKG are for pangolins sold alive. Scales treat “101 diseases” when mixed with wine Necklace from pangolin scales brings good health and good luck High demand from Chinese buyers	Not given
Porcupine	1.25–2	Not given	Stomach: good for pregnant women to eat. Only sold in the dry season, when porcupines eat medical plants. In the wet season they eat corn, and so have no medicinal power Jawbone: used to reduce a fever	Stomach: 12.50–20 Jaw: 7.50–10
Sambar	3.75–6.25	Not given	Antler grated and added to rice wine as a health tonic Decoration: antlers added to deer statues	Antler: 50
Serow	6.25	1,000–2,000 (m, tm)	Bone: For stomach ache and healing injuries, bruises and sprains. Mix old rice water (from cooking rice) with the bone. Rub the bone with the rice water and drink the water	Bone alone: 500–800
Slow Loris	Not given	5–10 (tm)	Charred loris: grated into a rice-wine tonic: Joint pain; backache; childbirth; general health tonic; mixed with tattoo paint to provide luck in war	Not given
Snake sp.	2–2.5	Not given	Stomach use for traditional medicine sometimes; only bought alive by town traders	Not given
Sun Bear	Not given	Not given	Gallbladder: tonic for general good health	Not given
Tiger ^b	Not given	Not given	Tiger whisker creates a poison Decoration: Bone and skin	Skin and bone: 4,000–5,000
Turtle	5–7.5	Not given	Burnt gallbladder/head/whole turtle added to rice wine and honey. Used after giving birth. Women’s medicine	Not given
Wild Pig	3–4	Not given	Stomach: Mixed with rice wine for ladies after childbirth and children that have a fever. Fangs that are removed from tree stumps have powers and will protect you from harm if you wear them. This is not true of fangs that have been removed from a dead pig.	Not given

m, meat; tm, traditional medicine, d, decorative. Prices are those given by hunters and households during the study in 2013.

^aWhile the organ used for medicine was described as the “gallbladder,” and was reported to be found in the front quarters (where the liver, lungs and heart are found), Muntjac do not have gallbladder, and so this must be a different organ.

^bTigers were not seen or caught during the study period, and were declared functionally extinct in Cambodia in 2016.

its relatively high PRA ranking—as well as forest fruit and vegetables, mushroom, and medicinal plants. In Village 3, where insects were included as a PRA category, insects were allocated 4.9% (SE ± 1.5) of counters on average (**Supplementary Material S10**).

Wild Meat and Fish as a Component of the Household Diet

Both household interviews (where we asked about the frequency of consumption of different meat proteins in terms of whether it was eaten daily/weekly etc.)

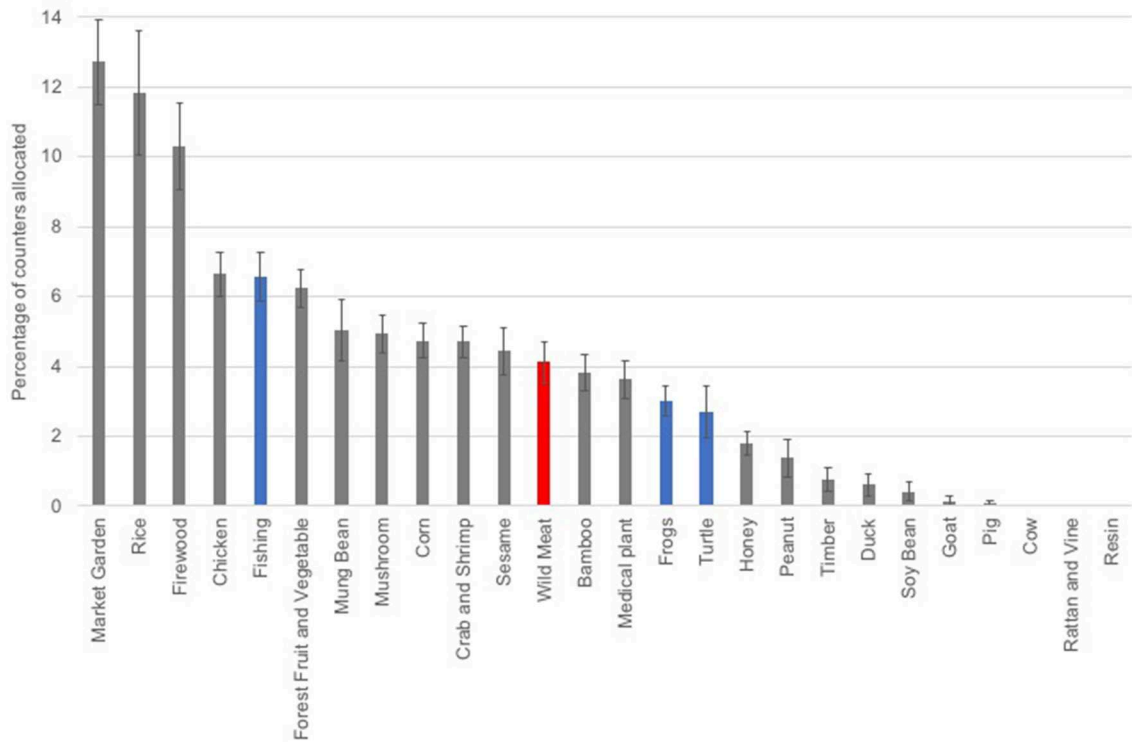


FIGURE 3 | Average non-cash income scores per household given for agricultural, NTFP, and fishing products during the PRA exercise. $N = 35$ households.

and PRA exercises (where we asked households to distribute counters to illustrate the importance of different meat proteins to the household diet) highlighted the importance of fish in the daily diet. In all three villages households allocated, on average, over 47% ($SE \pm 2.0$) of counters to fish, and most households ate fish daily or weekly (**Figures 4, 5**).

In comparison, wild meat was ranked second to last as a source of meat protein in the PRA exercise (**Figure 4**), and species, such as wild pig, muntjac, and porcupine, while eaten at some point in the year by most households, were generally eaten on a monthly or quarterly basis (**Figure 5**). Wild meat consumption is highly seasonal, occurring only for a month or so before harvest and we visited villages during the wet season harvest, when crops were ready to harvest. At this time, crop-raiding by these three species was frequent, and wild pig meat was observed hanging to dry outside village houses. Several households during interview expressed a preference for wild meat over meat bought from local markets, describing wild meat as being healthier, and bought meat as containing “chemicals.” Several households said that they preferred wild meat because they could not tell where the bought meat had come from, or what had been done to it. In Village 3, where insects were included in the PRA exercises, we found that, while scoring lower [9% ($SE \pm 1.4$)] than all other forms apart from beef, insects probably still represent an important component of freely available protein, which can be gathered from around the fields and village.

Both the PRA exercise and household interviews highlight the frequency of consumption of bought meat protein. Bought meat protein represented, on average, approximately half of the allocated counters in total in the PRA exercise. Pork, beef, and frozen fish were all bought from traders traveling from Battambang by motorbike each week, and the prices for different proteins are shown in **Table 2**. The cheapest bought protein was frozen fish (often sea fish), which interviewees suggested was imported from Vietnam and Thailand. All three villages allocated a similar proportion (23–27%) of counters to frozen fish in the PRA exercise (see **Supplementary Material S11** for score by village). Although frozen fish was consumed more than pork, several households reported a preference for pork, when given the choice. One woman, when asked why she ate frozen fish instead of pork said that “*when you are poor, frozen fish tastes excellent. But when you are rich, pork tastes better.*” Very few households consumed beef, which was reported as being too expensive, not often provided by traders coming into the village, and bad for the health. Although the price of town chicken is less than pork, all but a few households ate chicken from their own stock rather than buying from traders. This may partly be due to availability, as traders brought pork every week, but did not seem to be trading chicken. The lack of trade in chicken may be because of the long journey time to the villages from Battambang, in which time chicken might spoil.

Village 1 allocated a higher proportion of counters to bought meat and fish [57% ($SE \pm 5.1$)] than Village 2 [48% ($SE \pm 3.1$)]

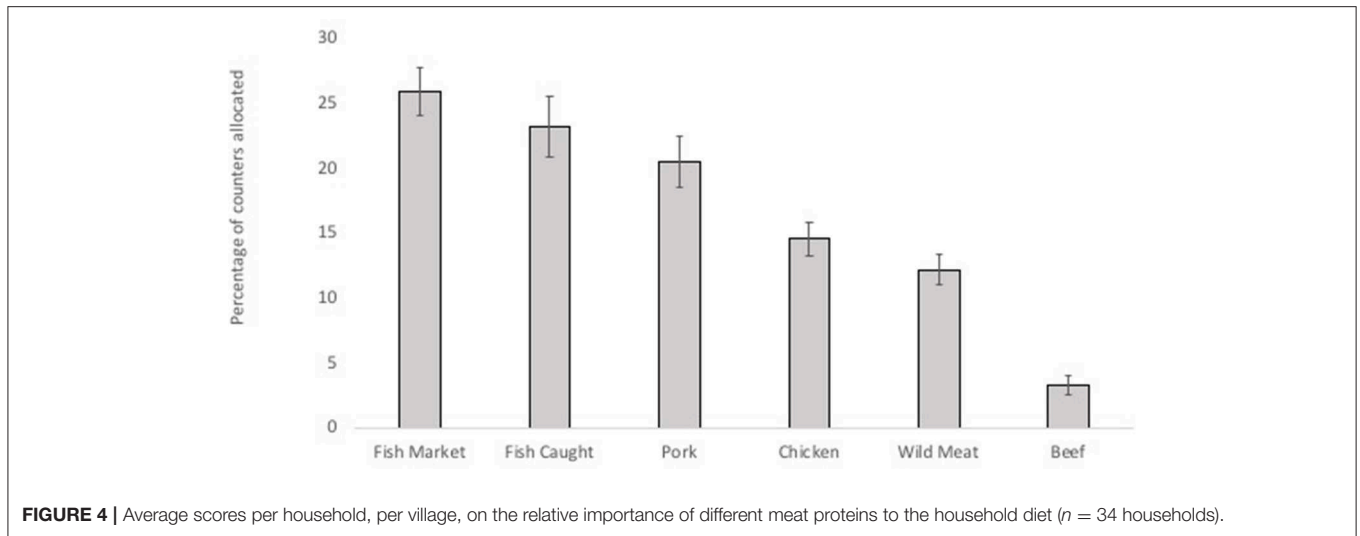


FIGURE 4 | Average scores per household, per village, on the relative importance of different meat proteins to the household diet (n = 34 households).

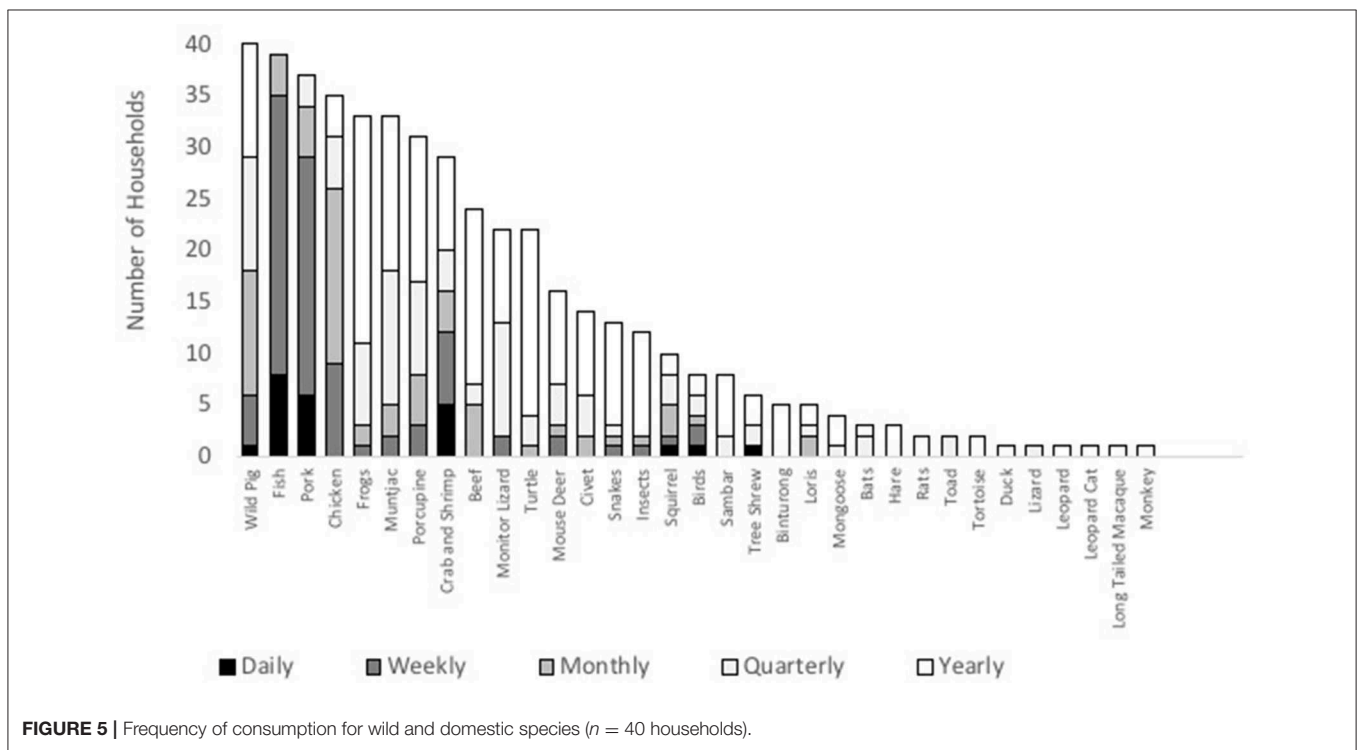


FIGURE 5 | Frequency of consumption for wild and domestic species (n = 40 households).

and Village 3 [39% (SE ± 5.6)]. This may be explained by market and river access. Village 1 was situated on a small stream, where large fish could not easily be found, and fishing was focused on shrimp, crab and small fry. In comparison Villages 2 and 3 were situated next to sizeable rivers, where catfish and trout could be fished. In addition, Villages 1 and 2 had road access to Battambang, whereas Village 3 was more remote, and during the wet season (when the study was conducted), access to the village, even by motorbike, can be difficult, and interviewees reported that trader visits to the village during months with heavy rain reduced from weekly visits to monthly visits.

DISCUSSION

What Are the Key Characteristics and Drivers of Current Wildlife Use in the Study Villages?

Our exploratory surveys in three Cardamom mountain villages suggest that most households hunt, and that most mammal species in the Cardamom mountains are harvested. At the same time, they also suggest that hunting incomes represent a low proportion of household incomes, and a low proportion of the household meat consumption. Household incomes are

TABLE 2 | Prices of traded domestic meats, brought into the village by traders on motorbikes, from Battambang.

Domestic meat	Price (USD)
Beef	5.00–6.25
Pork	4.50–5.00
Chicken	3.75
Frozen seafood (Market)	2.00
Frozen riverfish (Market)	3.75

Prices were obtained in 2013, from local shops in the villages.

predominantly agricultural, and both fishing and hunting only provide small additional incomes for most households. Own-caught fish, and even bought fish, pork, and chicken, are reported to be consumed much more than own-caught wildmeat.

The relative importance of fish over wildmeat in local diets has been observed in villages in Southern Cambodia, where a survey conducted in 2003 (Richardson, 2003) found that locally-made fermented fish paste (*Prahoc*) was the dominant protein source, with about half of the meals including some fish paste (but commonly only five grams or less per person), compared to wild/domestic meat protein used in 10 percent of meals, and no protein in 40 percent of meals. Most households reported experiencing protein shortages. In this study we did not quantify the amounts of meat and fish consumed by households, and it is therefore possible that households in the Cardamoms are similarly consuming less than the recommended level of protein or other micronutrients per day. While hunting incomes are lower than agricultural ones, and consumption of fish and bought proteins are higher than consumption of wild meat, the additional income and protein may therefore represent the difference between producing a deficit and breaking even, financially and nutritionally speaking. A preference for wildmeat over domestic meats was stated by several interviewees, and low levels of wild meat consumption may be due to low availability, rather than preference for bought meat. Nutritional surveys, to further investigate the amount of protein and other nutrients that are gained from different food sources, would help to better understand the role and importance of wild meat and fish in the diet.

It seems surprising that remote rural households would buy more meat than they hunt. However, with more context in terms of village characteristics and livelihood strategies, some plausible hypotheses for why this might be emerged. Village livelihoods in the Cardamoms have been shifting generally from subsistence use to a more trade-based system. Prior to the civil conflict, in most *Por* communities, produce from shifting cultivation, fishing and hunting would have been primarily for own-consumption (Sarou, 2009). However, there have been high levels of immigration of lowland Khmer peoples since the conflict, for whom rice is a culturally important staple food. Rice does not grow well or easily in the high-sloped Cardamom Mountains, and so households grow other arable crops more suited to the area, such as corn, mung bean, and sesame, and sell almost all of it. The profits from these crops are mainly used to buy rice.

In addition to this increased agricultural trade, and due to a combination of factors, it has become more cost effective, and less risky, to buy domestic meat rather than to hunt wildmeat. Where there are only a few adult men in a household, interviewees suggested that households will prioritize their available labor for agricultural work, which brings in stable household incomes, over hunting where incomes are unpredictable. Furthermore, there are still high densities of landmines in the forest surrounding these villages, and therefore the risk of hunting to life is significant. Wildlife population densities, following high levels of hunting pressure during the conflict, are also low, which reduces the potential return (CPUE) from hunting, compared with other livelihood activities which bear less risk. At the same time, improvements in road networks, and agricultural trade between the villages and nearby towns, has increased the availability of cheaper pork and sea fish.

While most households hunt, and a wide range of species are consumed over the year, the primary aim of hunting is often crop protection, with meat from hunting a welcome by-product. Some men also hunt during the pursuit of other livelihood activities, such as fishing. Only a few men in each village hunt commercially, to capture the potentially high incomes from species, such as pangolin, which are in high demand due to their perceived medicinal properties. Likewise, wildlife traders did not make scheduled trips to the study villages, maybe in part due to the low capture rate of wildlife and the remoteness of the area, and in part to hide their trade from wildlife authorities. However, interviews and past surveys (Wutty and Simms, 2005) suggest that commercial hunting gangs, unconnected to village communities in the Cardamoms, are highly active, and could be harvesting much higher numbers of large-bodied, target species which have naturally low population densities and reproductive rates and are therefore even more vulnerable to overhunting (Ripple et al., 2015). These results reflect those of Mckenney et al. (2004), who found that, in villages surrounding Preah Vihear and Kampong Thom (Northern and Central Cambodia, respectively), only 10% of households contained a skilled trapper or hunter, with other households generally only hunting and trapping around their agricultural fields. McKenney et al. also note the existence of military-trained hunting groups external to the village, taking part in the wildlife trade.

Even low levels of hunting can have high impacts on biodiversity where target species populations are already depleted from past levels of hunting, and therefore natural levels of replenishment are low (Milner-gulland and Mace, 1998; Coad et al., 2018). Rarity can increase demand and in turn price, which means that even when species populations and catch-per-unit-effort (CPUE) decline, hunting can remain financially worthwhile (Challender et al., 2015b; Shairp et al., 2016). Pangolins are a prized animal in China, thought to cure a range of ailments, which has result in swift declines in Chinese pangolin populations and increases in their value (Challender et al., 2015a). This has driven a voracious demand for pangolins from neighboring Asian countries, and as these populations decline, is now incentivizing international trade of pangolins from Africa to China (Mambeya et al., 2018). The price of a

live pangolin in Cambodia has increased dramatically since 2005, when Wutty and Simms (2005) recorded the price for a premium quality live pangolin at \$60; hunter interviews conducted for this study suggest that the price in 2013 was between \$150–200 per live animal. As pangolin populations decline due to high demand, the chance of catching pangolins becomes too much of a gamble for hunting to be relied on as a core income-generating activity. However, for households with two or three men—enough to cover agricultural labor requirement—allocating additional man-hours to hunting, where returns are unreliable but potentially lucrative, can be worth the risk.

Under What Circumstance Might Village Hunting Activity Increase?

All three villages studied here were highly dependent on agricultural incomes to buy staple foods—rice, fish, and domestic proteins. Households in each village collectively agree each year on which crops to grow, which are then harvested at the same time and sold to traders in town in bulk. However, the reliance on arable incomes and this strategy of bulk sales comes with risks, mainly due to the declining road network. To conduct our survey, it took us 1–2 days by motorbike from Battambang to reach each study village. For Village 2 we were unable to reach the village on the first attempt because a bridge had recently washed away. The possibility that the corn truck to take produce to market would not be able to get to Village 2 was causing great worry to the community. Due to the current state of the roads, only a few traders with good trucks can reach the villages, and this, combined with a lack of storage for crops, means that prices are set by traders and fluctuate with demand. If roads continue to decline, and traders can no longer reach these villages, households could easily lose most of their season's income. Households may then fall back on incomes from wildlife, which is easily transported by motorbike and can provide a high per kilo profit, as well replacing bought meats with wildmeat and fish. This was shown to be the case in Veal Veng in the Central Cardamoms, where during the wet season road access to villages can be completely cut off, limiting trade in agricultural products, and increasing local dependence on forest products for consumption, such as wild meat (Daltry and Momberg, 2000). There is mixed evidence from our results as to whether smaller agricultural incomes might result in a higher reliance on wildmeat. Village 2 gave the highest scores for wildmeat and had the lowest availability of agricultural land and agricultural incomes. However, analyzing our results by household, we found no correlation between agricultural incomes and wildmeat scores. Further investigation of how households respond to “shocks,” such as large losses at harvest-time would help form a better understanding of the links between agricultural production and security, and wildmeat use.

If These Findings Are Taken to Be Representative, Which Management Approaches for Sustainable Hunting Might Be Most Appropriate in These Villages?

Our results suggest that despite low animal abundance, and the relatively higher availability and consumption of domestic meats,

hunting continues in these Cardamom mountain village due to a combination of factors:

- The need to protect crops from crop-raiding species during the harvest seasons.
- The local use of wildlife for traditional medicine.
- Low levels of law enforcement in most villages and towns for the commercial trade in wildlife for medicinal and decorative use.
- High potential (albeit risky and unreliable) profits for the few hunters focusing on the commercial trade, which is supplying both domestic and international demand (ultimately from China).
- External (non-community) hunting by commercial hunting gangs, supplying a specific trader or market (Wutty and Simms, 2005).

In addition, it may be that only small amounts of fish and domestic meat are eaten by households, and in this case even small amounts of wildmeat could have an important impact on household nutrition. We were unable to measure amounts of fish and domestic proteins consumed by households, but this should be a priority for further surveys.

In these three case study villages we suggest that there are three main types of hunters, who may respond to different management approaches:

1. **“Farm” hunters:** for whom arable farming is their main livelihood activity. Most men will set snares to protect their crops and provide meat for the family; hunting increases in the harvest seasons and we hypothesize that it may also increase during times of low fish or crop production. Key species include wild pig, porcupine, muntjac, monitor lizard, turtle, mouse deer. The importance of arable farming (and possibly the relatively low densities of wildlife) mean that these farmers do not have the time to monitor large trap lines far into the mountains. We would suggest that a deeper understanding of how arable farming and forest use (including hunting) interact would be of great use in designing conservation strategies in this region. Where livelihoods and community concerns are focused predominantly on income from arable farming, “wildlife friendly farming” approaches (e.g., Clements et al., 2010) may have potential to help local communities sell their agricultural produce at a fair price, while also benefiting biodiversity. These projects provide benefits to farmers in the form of increased arable yields (providing technical help to farmers), increased access to arable markets (providing reliable transport of crops to market) and guaranteed sales and prices for arable products. In return farmers sign an agreement which may include an agreement not to expand arable fields further into the forest, not to hunt key conservation species, and/or not to use certain hunting methods. In addition, help should be provided to farmers to protect their fields from crop-raiding species that are not in the list of species that can be hunted. Wildlife-friendly farming projects often focus on target species for conservation or reducing habitat conversion (such as large-bodied species at risk from over-exploitation, and protected species), as a total cessation of

hunting for most rural communities is impractical (and often, in the case of small-bodied, fast reproducing, crop-raiding species, unwarranted). These agreements rely on a local level of project monitoring, to ensure that agreements are being adhered to.

Examples of successful “wildlife friendly farming” projects in Cambodia include the “Ibis Rice” model (Clements et al., 2010), where rice farmers in the Northern Plains are given a favorable price for their rice in return for not using certain herbicides and pesticides on their fields, and not clearing forests, with the aim of protecting habitat for the Giant Ibis and other bird species. Rice is then sold within Cambodia under the “Ibis Rice” Wildlife Friendly-certified brand, and profits reinvested into the project. To determine whether wildlife-friendly farming (for crops other than rice) is an option for communities in the Cardamoms, more detailed baseline studies over a larger number of study sites, including value-chain analyses, would be needed to better understand the farming practices and the importance of farming incomes for local communities in the Cardamoms, and how agricultural practices interact with hunting practices and habitat loss. Meetings with local communities to discuss their main livelihood concerns, and how shocks (such as loss of incomes) are mitigated for, would help to inform the development of conservation projects, as well as developing important lines of communication between conservation organizations and local communities.

Most conservation/development interventions aiming to work with local communities to support biodiversity-friendly land practices will require security of land tenure, whether this is customary or private (Robinson et al., 2018). Interviews in Village 2 suggest that local people feel little security of land tenure, to the extent where local people are concerned about the removal of land mines from agricultural fields, due to the potential of re-classification and redistribution of these areas for large-scale commercial agricultural plantations (e.g., rubber) once they are clear. In addition, under current wildlife laws most hunting is illegal, or legality is ambiguous, and therefore management approaches aiming to promote sustainable harvests may find themselves to be operating illegally. Land tenure insecurity and impractical wildlife laws are common issues facing sustainable wildlife practices in many tropical regions of the world (Coad et al., 2018).

2. **“Forest” hunters:** men belonging to households that have enough able-bodied men and women to cover the labor requirements of arable farming, so that at least one male family member has time to dedicate to more “high risk/high return” livelihood strategies, such as hunting. Hunting may focus more on high value species, such as pangolin, sambar, and bear species. In this case, where “Wildlife friendly farming” agreements are signed at a household or community level, and agreements are monitored, younger members of families engaging in hunting may be instructed by older members to adhere to agreements not to hunt key species. However, where monitoring and implementation of agreements is

low, the trade in commercial species could easily continue. In the case of the commercial trade, enforcement may be better targeted at wildlife traders in Battambang and Pursat, or on reducing demand from consumers, rather than at village hunters.

3. **Commercial external hunters:** while we did not collect data on external hunters, Wutty and Simms (2005) suggest that groups of town and forest-based hunters (external to village hunters) target large-mammals for the commercial trade. Hunters in Village 3 reported meeting groups of hunters who were not from the village in the forests surrounding the village. These hunters are unlikely to be influenced by conservation approaches at the village level. Conservation approaches may include increased wildlife trade law enforcement within Cambodia and demand-reduction strategies in consumer countries.

Thoughts on Future Research Priorities

Our preliminary study was based on four short field visits of 10 days each, in only three villages; these results and discussion of management scenarios should therefore be taken as first hypotheses, based on preliminary field visits. We would strongly encourage further research into village livelihoods in the Cardamom mountains and would especially prioritize studies into the nutritional importance of wild meat and fish, especially in times of economic stress. Household nutritional surveys, and more in-depth surveys of daily hunting returns where possible, would also help better gauge the number of hunted species; our species cards and questions focused on large and medium-bodied mammals and therefore the true number of species hunted (especially birds, reptiles and amphibians) is likely to be much higher.

The continued decline of wildlife populations in the Cardamoms is already flagged as a conservation priority for Cambodia but could also have significant impacts on local rural communities, especially in the context of declining road networks, where closed roads could result in large losses of income for rural farmers, and an increased reliance on own-caught wild meat and fish. In addition, it seems likely that international demand (especially from China) for medicinal wildlife products will continue to incentivize the creation and activity of specialized hunting groups in the Cardamom mountains. This external demand will likely have negative impacts on both biodiversity and in turn local food security, unless there are greater efforts at the international level to change consumer behavior and enforce national and international wildlife trade regulations.

ETHICS STATEMENT

This study was carried out in accordance with the recommendations of Fauna and Flora International, and following PROFOR guidelines as outlined in their Poverty-Forests Linkages Toolkit, with verbal informed consent from

all subjects. All subjects gave verbal informed consent in accordance with the Declaration of Helsinki. The protocol was approved by Fauna and Flora International. Verbal consent was taken rather than written consent. This was due to the low level of literacy in the communities that we were working with. In addition, written documents are often perceived to be very official, and asking for signatures could have caused concern and upset to community members. We therefore decided that verbal consent was more culturally appropriate in this circumstance. As detailed in the manuscript, we emphasized that participation was completely optional, and the identity of all villages and interviewees was kept anonymous. Names of interviewees or households were not recorded at any point.

AUTHOR CONTRIBUTIONS

All authors designed the study, conducted the fieldwork, and collaborated on drafting the manuscript. LC conducted analyses of the field data.

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FUNDING

We would like to thank USAID for funding the field surveys and for further funding to analyse the data and write the manuscript (under award no. AID-BFS-IO-17-00005).

ACKNOWLEDGMENTS

Many thanks to the three communities that we worked with during this study; we are so grateful for your hospitality, kindness and friendliness. Special thanks to the commune and village chiefs who gave their permission. Many thanks to the University of Phnom Penh for their support and advice. Thanks to Mathew Maltby who commissioned an oversight of the project and was a huge help with logistics.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fevo.2019.00296/full#supplementary-material>

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

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