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Bushmeat hunting and trade in Myanmar's central teak forests: Threats to biodiversity and human livelihoods

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1. Introduction

Excessive wildlife hunting and trade is a leading contributor to biodiversity loss and a potential driver of the spread of infectious diseases throughout Asia (Phelps et al., 2010; Rao et al., 2010). By depleting vertebrate populations, unsustainable levels of bushmeat hunting may also drive declines in human welfare in regions where livelihoods are dependent on wild animals (Golden et al., 2011; Duffy et al., 2016). Understanding the human dimensions of hunting and associated zoonotic disease risks in these areas is critical to both saving wildlife species and protecting public health. The best-known ethnographic studies that have shaped policy and perceptions on bushmeat hunting come from Africa and South America (Peres, 2000; Fa et al., 2002; Walsh et al., 2003; Brashares et al., 2004) with very little research being performed in Southeast Asia, where habitat loss and forest degradation are viewed as the more visible threats to biodiversity (Corlett, 2007). Further research on the human dynamics of bushmeat hunting in the rapidly changing forests of Southeast Asia is needed. This is especially true in Myanmar, as it supports the largest number of intact natural habitats and wildlife species communities remaining on the Indo-Chinese peninsula

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(Tordoff et al., 2005; WCS, 2013) and is experiencing extensive forest degradation (Bhagwat et al., 2017) – a scenario that places new hunting pressures on previously isolated wildlife populations and brings people into contact with potentially zoonotic pathogens (Daszak et al., 2001; Bell et al., 2004; Patz et al., 2004; Karesh et al., 2005; Wolfe, 2005; Karesh and Noble, 2009; Keesing et al., 2010; Coker et al., 2011; Horby et al., 2013; Jones et al., 2013; Murray and Daszak, 2013). The impact of these practices on wildlife and human health have received few comprehensive assessments in Myanmar (Phelps et al., 2010; Rao et al., 2010).

Degraded forests, such as the previously logged teak forests of Myanmar, are capable of harboring a significant portion of a region's vertebrate biodiversity but are often overlooked as viable wildlife habitats worthy of conservation (IUCN, 2017). This is due in part to previously logged forests being particularly vulnerable to increased hunting pressures through improved access to wildlife and the presence of larger human populations associated with timber extraction. Undamaged tropical forests, viewed as more optimal conservation sites, may also be deceivingly heavily hunted with dramatic impacts on ecosystems, potentially contributing to altered forest dynamics due to loss of ecological interactions (Peres and Palacios, 2007) and collapse of trophic cascades (Estes et al., 2011). Thus, understanding differences in the underlying drivers of bushmeat hunting in both of these landscapes has important implications for the implementation of conservation strategies in Myanmar and worldwide.

The distinctions between subsistence and commercial hunting practices are also critical for conservation and public health practitioners to understand, as they impact the diversity and intensity of human – wildlife interaction and are associated with different effective mitigation strategies (Pullin and Knight 2001, 2003; Nichols and Williams, 2006). While the bulk of the documented volume of hunted wildlife in Southeast Asia is used for subsistence, much of the diversity of species hunted goes into regional and international trade networks (Corlett, 2007). Traders today take a huge variety of species that are used for many reasons including consumption, cultural and medicinal purposes. The use of wildlife parts in medicine is particularly important in countries bordering China, such as Myanmar, where there is a high demand for wild animal components in traditional Chinese remedies (Mak and Song, 2018). This trade has been fueled by increasing prosperity, porous borders, and both the decline in China's own wildlife and increased enforcement of the laws protecting it (Corlett, 2007).

Myanmar is divided into eight unique biodiversity corridors that contain key biodiversity areas (KBAs) with unusually high numbers of mammalian species (Tordoff et al., 2005) including the Bago Yoma range corridor containing the North Zamari KBA. The North Zamari Wildlife Sanctuary, where this study was conducted, is located within the North Zamari KBA and was established specifically to protect the endangered Asian elephant which serves as a flagship species for the preservation of other flora and fauna (MONREC, 2015) (Fig. 1). For over 50 years, the greater Bago Yoma has served as the country's major teak hardwood resource, which has been used to build the city of Yangon and fueled a lucrative export trade. Most of the Bago Yoma has long been overlooked as a conservation site, due to extensive logging, until 2016 when the Ministry of Natural Resources and Environmental Conservation banned logging in the Bago Yoma for 10 years as part of

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the National Reforestation and Rehabilitation Program in Myanmar. In 2019, Myanmar's parliament also passed the Protection of Biodiversity and Conservation Areas Law that further enforced punishments for hunting and illegal wildlife trade country-wide, potentially bringing new opportunities for wildlife population numbers to rebound as well as new prospects for wildlife-based tourism and wildlife reintroduction in the Bago Yoma.

An evaluation of the Bago Yoma as a location for future wildlife conservation and wildlife-based tourism investment requires a better understanding of the hunting pressures and motivations as well as the potential public health risks associated with wildlife contact existing in the region. The objectives of this study were therefore to (1) characterize patterns of wildlife hunting and trade in the North Zamari KBA (one of the isolated protected areas in the Bago Yoma), (2) define hunting motivations to better inform future conservation strategies and (3) gauge understanding of zoonotic diseases among local communities engaged in bushmeat harvesting to assess public health risks associated with the introduction of wildlife-based tourism.

2. Methods

2.1. Study area and population

This study was part of a US-Myanmar collaborative project entitled "Epidemiology of zoonotic viruses in forest communities in KBAs of rural Myanmar". The overarching goal of this work was to collect medical and behavioral data and biological specimens from people and wild animals in KBAs to investigate viral sharing between humans and wildlife. Data for this manuscript, which includes ethnographic and behavioral information on wildlife contact were collected from June 2016–August 2018 in five villages in and near the Yenwe Forest Reserve of Kyauktaga township, near the southeastern border of the North Zamari KBA. Villages were selected based on proximity to the river; the major route of transportation for study personnel. Villages were separated by a minimum of 10 km and dispersed throughout the accessible Yenwe Forest Reserve in order to maximize representativeness of our study participants. Study habitat consisted of mixed deciduous forest, with patchworks of unlogged, predominantly teak forest, surrounded by previously logged forest. In maintaining compliance with ethical regulations in Myanmar, village names and specific locations are not being disclosed.

2.2. Questionnaires and focus groups

We implemented a quantitative questionnaire, comprised of closed-ended and semi-closed-ended questions designed to collect information on demographics, livelihoods, hunting practices, consumption of bushmeat, wildlife trade patterns and knowledge of zoonotic diseases. We also implemented focus group discussions to further elucidate bushmeat hunting behaviors and understanding of risk associated with wild animal contact. Study questionnaire and focus group questions were developed in the local language (Myanmar language). Questionnaires were first pre-tested and then administered in Myanmar by a team of three interviewers consisting of a medical doctor, sociologist and wildlife biologist. During the pre-testing phase, to minimize incorrect species identifications, a series of photo identification cards were used to identify mismatches between local taxonomy and western species definitions and surveys were adjusted accordingly. For species that were identified in questionnaires 5 times or less, follow up discussions were performed during focus groups and photo cards were used to confirm species ranging in the study area. Participation in the quantitative surveys and focus group discussions were voluntary and each individual was required to give their written consent to participate. Quantitative surveys were recorded from between 75 and 85% of village members in each site and was based on their availability and willingness to participate on the survey day. Focus group discussions were first described to the village leader and recruitment of participants was facilitated by the village leader. Given the legal repercussions potentially associated with hunting wildlife, anonymity of participants was maintained by separating personal identifying information from questionnaire and focus group responses. Study protocols were reviewed independently, and ethical approval was provided by the Institutional Review Board and Institutional Animal Care and Use Committee (#19520) at the University of California, Davis (#889159–2), the Ethics Review Committee of the Department of Medical Research (#012816), the Forest Department of the Ministry of Natural Resources and Environmental Conservation, the Livestock Breeding and Veterinary Department and the Myanmar Timber Enterprise.

2.3. Hunter collected data

Three field assistants were trained to collect data directly from self-identified hunters (n = 12). Hunters were first identified through the use of quantitative questionnaires described above. People that were willing to self-identify as a hunter were then asked to participate further in the study. All participation was voluntary and not associated with any form of compensation. Field assistants were trained to collect data on species, sex, age class and health condition of animals caught by hunters and brought back to villages. They were also trained to collect data from hunters on hunting techniques, destination of bushmeat and price if applicable. Each field assistant worked with a fixed group of 3–5 hunters over the course of the study period, recording all kills that the group brought into the village during random bi-monthly visits and soliciting information on past kills over the preceding 1–2 months (since the previous visit). Hunters were instructed on keeping daily hunting records and sharing this data with research assistants. Field assistants made efforts to choose established “regular” hunters, avoiding individuals very new to hunting and immigrants from other areas of the country. Hunters remained completely anonymous, i.e., no hunter names were recorded, and hunters were not given identification numbers on any data sheets. This facilitated full disclosures of kills, including rare and protected species. Several measures were taken to ensure that additional hunting was not encouraged: hunters were not compensated for their participation in this research; no incentives were given for volume of data collected so that increased hunting effort would not be rewarded; and field assistants visited the camps at random time intervals. Field assistants met with the hunting groups at least bi-monthly to discuss study progress, collect qualitative hunting information, cross-check data sheets and maintain hunter compliance with study protocols.

2.4. Statistical analysis

To evaluate associations between human demographic and animal contact behaviors, all demographic factors, including age, sex, and livelihood, were first evaluated for associations with animal contact behaviors to assess confounding. Pearson X^2 tests were initially used to determine associations between high risk human-animal contact behavior such as hunting and slaughtering animals and demographic factors as well as other animal contact behaviors. Statistical tests were considered significant at the level of $P < 0.05$. Multivariable logistic regression was then used to assess the association between high-risk wild animal contact behaviors and other risk factors that were significant on bivariate analysis. Similar methods were also used to evaluate associations between an animal's threatened status and different hunting pressures including whether or not that species had a human medicinal use, methods used for hunting and purpose of hunting (i.e., home consumption, local vs. international sale). Variables were included if they significantly improved model fit, based on the likelihood ratio test ($P < 0.1$), while minimizing the Akaike information criterion. Overall model fit was assessed using the Hosmer-Lemeshow goodness-of-fit test. All statistical analyses were performed using Stata (StataCorp, College Station, TX).

3. Results

3.1. Socio-demographic characteristics of surveyed populations

A total of 161 people (65 female and 96 male) residing in five study villages participated in questionnaires. The median age of participants was 36 years (range = 16–67 years). The predominant ethnic group was Burma and Karen (specific ethnic identity of participants was not asked in accordance with ethical considerations in Myanmar). Eighty-nine percent of participants (n = 143/161) had the equivalent of a primary school education or less, 9% had a secondary school education (n = 15/161), 1% finished 10th standard (the equivalent of a high-school education; n = 2/161), and 1% had a college or university degree (n = 2/161). Thirty-seven percent (n = 60/161) of participants reported their primary occupation as a protected area worker, 19% (n = 30/161) natural resource extraction (timber or charcoal), 13% (n = 21/161) animal health care, 9% (n = 15/161) hunting, 7% (n = 11/161) migrant labor, 4% (n = 6/161) crop production, and less than 1% (n = 1/161) farm animal production (individuals were allowed to name more than one occupation). A total of 12 self-identified hunters from this group agreed to participate in focus group discussions and ground truthing of hunting data collected through the quantitative questionnaires by keeping personal and village-based hunting records and disclosing daily kills when research assistants visited the camps.

3.2. Bushmeat hunting activities

During our focus group discussions, people reported hunting 34 species of wild animals, including several species designated as critically endangered (Sunda pangolin *(Manis javanica)*), endangered (tiger *(Panthera tigris)*, Burmese mountain tortoise *(Manouria emys)*, elongated tortoise *(Indotestudo elongate)*, Phayre's langur *(Trachypithecus phayrei)*) and vulnerable (Burmese python *(Python bivittatus)*, king cobra *(Ophiophagus hannah)*, sambar *(Rusa unicolor)*, northern pig-tailed macaque *(Macaca leonine)*, Asiatic black bear *(Ursus thibetanus)*, Malayan sun bear *(Helarctos malayanus)*, fishing cat *(Prionailurus viverrinus)*, binturong *(Arctictis binturong)*, and leopard *(Panthera pardus)*) by the IUCN Red List of Threatened Species (Table 1). From hunter collected data, 15 species were documented as being hunted or freshly killed and brought back into camps. The most frequently hunted species recorded from hunters was (Fig. 2) Phayre's langur followed by lesser bamboo rat *(Cannomys badius)*, common palm civet *(Paradoxurus hermaphroditus)* and jungle cat *(Felis chaus)* (Table 2). Hunting methods included the use of trained hunting dogs for small ground dwelling species, bow or gun for ungulates and arboreal species, and traps for large felids (Table 1). The most commonly reported purpose for hunting was for home consumption or medicinal use (130 out of 170 individual species reports listed home use as the major hunting purpose). Primates and pangolins were the most likely to be hunted for sale to others for consumption or product use, although the most common reason for hunting was still home consumption (Fig. 3). Hunters were also asked about the abundance of each hunted species and whether they were perceived to be increasing or decreasing. The majority, 30 out of 34 species, were reported to be decreasing in abundance. Preference for hunting or eating a particular species was not associated with IUCN status or perceived abundance of a species.

3.3. Medicinal use of wildlife

Half of the species (n = 17/34) reported as hunted had local medicinal and/or trade value for medicinal use in other parts of Myanmar and/or China (Table 3). These included all of the species categorized as critically endangered (Sunda pangolin) and endangered (tiger, Burmese mountain tortoise, elongated tortoise, Phayre's langur) and the majority of the species categorized as vulnerable (Burmese python, king cobra, sambar, northern pig-tailed macaque, Asiatic black bear, Malayan sun bear, and leopard) by the IUCN Red List of Threatened Species. Species with a medicinal use for a body part were 24 times as likely to be categorized as threatened (critically endangered, endangered or vulnerable) compared to species without a medicinal use for a body part (OR = 24; P = <0.001), and this was the only factor, among the factors evaluated, significantly associated with an animal's threatened status.

3.4. Wildlife movement and trade

While the majority of people reported consumption or use of animal products at home as the predominant use for hunted wildlife (n = 2/2 reports on use of rodents; n = 1/1 chiroptera; n = 28/37 primate; n = 31/37 avian; n = 7/7 carnivora; n = 71/76 artiodactyla; n = 7/10 pholidota) (Figs. 3), 97% of species hunted (n = 33/34) also had a reported known value as a trade commodity either within Myanmar or in China (Table 4). Trade routes included local trade among neighboring villages surrounding the North Zamari KBA, as well as through the towns of Nyaung Lay Pin and Myo Chaung (Fig. 1), both of which act as middle markets for resale to China in the border town of Mong la. Given the sensitive nature of reporting on wildlife movement and trade, anecdotal information on endangered species was more likely to be offered in focus group discussions, than recorded in quantitative questionnaires. Of note was the description of a decrease in trade value for wild pangolins in 2018 compared to 5 years prior. This scenario was described by three separate focus groups in three separate villages.

3.5. Characteristics of people hunting, butchering and engaging in other contact with wild animals

Regardless of reported hunter occupational status (only 15 individuals self-identified as a hunter), fifty percent (n = 80/161) of study participants reported hunting wild animals and 67% (n = 106/161) reported slaughtering wild animals. All people reporting hunting (n = 80) were male, and wildlife hunting was positively associated with being a protected area worker, being a migrant laborer, and engaging in extractive industries (i.e., timber and/or charcoal extraction). People reporting being a dependent were less likely to report hunting (when age was evaluated as a potential confounder) (Table 5). Slaughtering wild animals was positively associated with being male but was not significantly associated with any other demographic factors or occupational activities (Table 5). Age and formal education level were not significantly associated with either hunting or slaughtering animals. People reporting hunting animals ranged in age from 16 to 67 years (median = 33 years) and 88% had finished primary school or a lesser equivalent.

A subset of participants were asked about sources of meat available for consumption in the study area: 82% (n = 75/92) reported meat being locally caught or hunted and available for sale or trade within study communities, 72% (n = 66/92) farmed onsite, 28% (n = 26/92) farmed and purchased from nearby communities, 12% (n = 11/92) purchased from wholesale markets, and 3% (n = 3/92) did not know. People reporting access to domestic animal meat sources did not have a significantly lower likelihood of hunting wild animals (34 people with access to domestic animal meat, reported hunting wildlife, compared to 46 people without access to domestic animal meat). People reporting personally raising, slaughtering or consuming domestic animal meat also did not have a significantly lower likelihood of hunting wild animals.

3.6. Evaluation of zoonotic disease awareness

Of those who reported having slaughtered an animal, 45% (n = 48/106) reported having been cut or injured while slaughtering and proceeding as usual with handling animal parts and body fluids without taking any protective precautions. Study participants were asked whether they thought there were any health risks associated with slaughtering or butchering a wild animal while having an open wound and 31% (n = 33/106) thought there was a health risk but didn’t know what it was, 21% (n = 22/106) didn’t know, 18% (n = 19/106) thought there was no health risk, 7% (n = 7/106) thought it could infect them with an infectious disease, 2% (n = 2/106) thought it could make them sick, 1% (n = 1/106) thought it could poison them, and 19% (n = 20/106) declined to answer. Fourteen percent (n = 22/161) of study participants reported eating an animal that they found dead, 9% (n = 15/161) reported having eaten a wild animal that was known to be sick, and 4% (n = 6/161) reported selling an animal that they found already dead.

4. Discussion

Our findings document some of the social-cultural contexts of wildlife contact in the North Zamari Key Biodiversity Area (KBA) with implications for conservation, human livelihoods as well as public health in Myanmar and other wildlife hunting communities in

Southeast Asia. We found that hunting of wild animals was largely for local consumption, medicinal use or trade within the villages surrounding the North Zamari KBA as opposed to international trade. Understanding the drivers of hunting is essential to working with indigenous communities to develop conservation strategies that are impactful. Finding that local consumption and use of animal parts predominates over international trade has implications for the conservation strategies that will be effective in the Bago Yoma (Coad et al., 2010; Macdonald et al., 2011; Suwannarong and Schuler, 2016). A market for international trade exists in the Bago Yoma but has been declining. As described in three focus group discussions in three separate villages, international prices for pangolins have decreased over the past five years, making local consumption and trade between neighboring villages more appealing than international markets. This is consistent with trends noted by other studies where “boom and bust” patterns often occur at any one site where hunting rates initially increase when remote forests become connected to markets, then rapidly decline as wildlife populations are depleted and/or supply chains change (Bennett et al., 2002).

Eliminating hunting may not be feasible in many indigenous societies, including the Bago Yoma because of its symbolic, economic and subsistence importance. The conservation challenge in these areas is to work collaboratively with indigenous groups for long-term co-management, which is of benefit to both humans and wildlife. This requires an understanding of the complexity of human-wildlife social and ecological connections and using this knowledge to collectively develop and implement methods for harvest management and education. The data collected in this study is a first step towards generating future predictive models on hunting sustainability for the region which could contribute towards education campaigns on hunting management (Shaffer et al., 2018). Another conservation strategy which is best utilized in communities involved in directly consuming wildlife is public health education. Studies conducted in west Africa have shown that people with knowledge of the zoonotic disease risks associated with hunting and consuming wildlife are less likely to engage in bushmeat hunting (Subramanian, 2012).

Identifying a significant proportion of study participants engaged in the hunting, consumption and trade of primates raises concern over the potential for spillover of new and emerging pathogens to humans. Given their close genetic similarity to humans and ability to adapt to environments shared with humans, primates harbor a much larger proportion of known zoonotic viruses compared to other taxa (with the exception of bats) and are expected to be a source of future emerging zoonotic diseases (Kreuder Johnson et al., 2015; Olival et al., 2017). The evolution of simian immunodeficiency virus (SIV) to human immunodeficiency virus (HIV) (Hirsch et al., 1989; Huet et al., 1990; Gao et al., 1999) at the interface of primates and humans engaged in bushmeat hunting in Africa underpins the importance of understanding retroviral transmission risks in other high-risk primate bushmeat hunting communities. While SIV has not been detected in wild Asian primates (Apetrei et al., 2004), other retroviruses with known zoonotic potential and incompletely characterized evolution when transmitted to humans are highly prevalent, including simian foamy virus (SFV) (Jones-Engel et al., 2008) and simian T-cell lymphotropic virus (STLV) (Ayouba et al., 2013). Cercopithecine herpesvirus-1 (Herpes B virus) is also a known zoonotic risk in Asia causing a highly fatal encephalitis in humans (Cantlay et al., 2017). A more thorough understanding of viruses circulating in primate and human symbiotic communities is needed to better characterize true risks associated with bushmeat hunting and other primate exposures. To date, more research has focused on such communities in Sub-Saharan Africa; however, our findings suggest similarly high primate consumption rates and associated disease transmission risk in Myanmar. Similarly, spillover of zoonotic pathogens from humans to primates, poses conservation risks for primate species, as exemplified through documented outbreaks of human respiratory pathogens in endangered great apes (Palacios et al., 2011; Spelman et al., 2013). Serological evidence of primate exposure to human pathogens has also been documented in Asia, among wild macaques in Sulawesi (Jones-Engel et al., 2001; Schillaci et al., 2006).

A strong preference for hunting and consuming primate meat as well as a perception of its medicinal value among North Zamari KBA communities, coupled with trade in primate parts, has implications for future reintroduction and wildlife-based tourism projects involving primates in this region. One of Myanmar's most iconic species, the western hoolock gibbon *(Hoolock hoolock)*, historically ranged in the southern Bago Yoma but has become functionally extinct in this region due to loss of habitat and hunting pressures (Geissmann et al., 2013). With the Ministry of Natural Resources and Environmental Conservation's (MONREC) forest rehabilitation program and logging ban currently underway, the southern Bago Yoma is in the process of restoring suitable food and habitat necessary to support gibbon populations in future. Gibbons are highly adaptable to rehabilitated forests as long as sufficient food resources (fruiting trees make up a significant proportion of their diets) are available (Cheyne, 2006). Our findings stress that despite efforts to restore habitats, significant primate hunting pressures remain and must be addressed for any primate conservation campaigns to be successful. Translocations have been considered a critical component to the survival of some gibbon species (Campbell et al., 2015) and could play a role in Myanmar's gibbon conservation action plans in the future. Our findings stress the importance of incorporating community education campaigns regarding zoonotic disease risks and efforts to educate on sustainable hunting practices in any future primate reintroduction or conservation efforts in the Bago Yoma.

The endangered Phayre's langur was the most frequently documented hunted species. In neighboring China and Thailand, the major threat to this langur species is hunting for traditional medicine and bushmeat (Bleisch et al., 2008). In Bangladesh, where this species' population has declined by more than 80% in the last 20 years, habitat disturbance and fragmentation in addition to hunting are major pressures (Bleisch et al., 2008). In Myanmar, there is very little information concerning the species' status. Additional research is needed to estimate population size and structure of Phayre's langur in the Bago Yoma and whether this forest area may be a stronghold for the species and necessary for species conservation. Preference for hunting Phayre's langur was high among people in our study, and medicinal, trade, as well as subsistence uses were all recorded. The majority of people reported home uses as the major reason for hunting, indicating that the population will likely decline without conservation interventions focused on curbing subsistence hunting.

Other commercially valuable species previously present in the Bago Yoma (tiger (Lynam et al., 2006), gaur (Duckworth et al., 2016), western hoolock gibbon (Geissmann et al., 2013)) were completely absent from current harvest records and likely have already been hunted to extinction or are in significant decline in the southern Bago Yoma. Of note was the report of a tiger harvested in 2015, but no subsequent successful harvests of tigers were reported in this study. Other species that are known to be in decline globally, were successfully hunted according to hunter records, during our study period including Burmese tortoise, elongated tortoise, Asiatic black bear and Sunda pangolins, indicating their presence but likely significant declines in the region.

This study had several limitations that were inherent to collecting data on sensitive activities in remote forest locations. Our study design relied solely on voluntary participation, which could have biased our study population towards people less likely to be engaged in hunting. Our study was also based on human recall, which has a natural element of inaccuracy as well as the potential for people to omit details they may feel are incriminating. To improve the representativeness of our data, we incorporated multiple data collection tools that allowed people to anonymously report on their own activities, but also those of other members of their village – a tool used to increase accurate reporting of species hunted. We also included repeat focus group discussions with the same groups over the course of our study period in order to improve trust and understanding between study subjects and research personal to encourage honest reporting. In addition, despite measures to combat species misidentification, we also acknowledge that species misclassification is widespread in this region and some degree of misidentification is inevitable in this type of research.

Identifying the value of bushmeat in the forest communities surrounding the North Zamari KBA as a dietary staple and medicinal source as well as an international trade commodity is vital for targeting future conservation interventions and, equally important for predicting the impacts of wildlife declines on human livelihoods. If the demand from China for wildlife parts were to greatly diminish, the majority of people interviewed in our study had alternative motivations for hunting wildlife – for personal consumption, medicinal use or local trade. Therefore, demand reduction and/or increased regulation of trade with China, a common focus by international conservation organizations as an intervention point, would not bring a stop to the illegal poaching of wildlife in the Bago Yoma. Similarly, the availability of domestic animal meat sources did not reduce the likelihood of a person hunting wild animals, indicating that providing alternative protein sources might not be an effective intervention tool at this time. Conservation efforts in the Bago Yoma should be focused on education surrounding sustainable hunting methods and potential zoonotic disease risks associated with consuming bushmeat in addition to ongoing efforts by the Myanmar government and international NGOs on curbing the poaching and local/ international sale of wildlife. The introduction of wildlife-based tourism has also been a successful model in other countries for providing incentives to preserve wildlife by providing alternative livelihoods and financing anti-poaching activities (Buckley et al., 2016). Lessons can be learned from wildlife-based tourism campaigns such as those introduced for mountain gorillas (McNeilage, 1996), African large cats (Mossaz et al., 2015), and Asian elephants (Servaes, 2017) regarding successful engagement of community members and the positive and negative effects of tourism.

Unsustainable hunting of wildlife has potential far-reaching impacts beyond individual species decline and public health risks – it stands to significantly impact ecosystem functioning in the Bago Yoma, which is of importance to Myanmar policy makers. Tropical forests depleted of large vertebrates can experience reduced seed dispersal, altered patterns of tree recruitment, and shifts in the relative abundance of plant species (Terborgh et al., 2001; Andresen and Laurance, 2007; Stoner et al., 2007; Wright et al., 2007), counteracting efforts to replant and protect regenerating forests, which is the major goal of MONREC's National Reforestation and Rehabilitation Program in Myanmar. Government as well as national and international conservation organizations focused on forest rehabilitation should therefore also be addressing conservation of key wild animal populations, such as primates, and other large vertebrates, critical to seed dispersal. In addition, biodiversity in tree species for replantation should be considered in forest plantation manuals, to provide an abundance of food types for wildlife (Montagnini, 2005). Successfully regenerated and rehabilitated secondary forests in the Bago Yoma have the potential to serve as reintroduction sites for wildlife species (DeWalt et al., 2003), particularly primates such as western hoolock gibbons (Yusof and Faridah-Hanum, 2008), and slow lorises (Kenyon et al., 2014), which would have a synergistic contribution to forest restoration activities.

5. Conclusions

Our findings underpin the role that wildlife plays in human livelihoods in the Bago Yoma forest of East-central Myanmar. As forest restoration efforts continue and wildlife-based tourism enterprises are introduced in this region, wildlife conservation and public health efforts, particularly regarding the potential for primate zoonoses, will increasingly rely on a strong understanding of human-wildlife livelihood relationships. Efforts to support humans and wildlife living symbiotically with each other in the Bago Yoma will depend on strengthening disincentives for illegal hunting and trading, increasing incentives for wildlife stewardship, promoting a better understanding of high-risk behaviors for zoonotic diseases, and supporting livelihoods that are associated with more sustainable wildlife harvesting methods and not wildlife decimation.

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References

Andresen E, Laurance SGW, 2007. Possible indirect effects of mammal hunting on dung beetle assemblages in Panama. Biotropica 39, 141–146.

Apetrei C, Robertson DL, Marx PA, 2004. The history of SIVS and AIDS: epidemiology, phylogeny and biology of isolates from naturally SIV infected nonhuman primates (NHP) in Africa. Front. Biosci 9, 225–254. [PubMed: 14766362]

Ayouba A, Duval L, Liegeois F, Ngin S, Ahuka-Mundeke S, Switzer WM, Delaporte E, Ariey F, Peeters M, Nerrienet E, 2013. Nonhuman primate retroviruses from Cambodia: high simian foamy virus prevalence, identification of divergent STLV-1 strains and no evidence of SIV infection. Infect. Genet. Evol 18, 325–334. [PubMed: 23612320]

Bell D, Roberton S, Hunter PR, 2004. Animal origins of SARS coronavirus: possible links with the international trade in small carnivores. Philos. Trans. R. Soc. Biol. Sci 359, 1107–1114.

Bennett E, Eves H, Robinson J, Wilkie D, 2002. Why is eating bushmeat a biodiversity crisis? Conserv. Biol. Pract 3, 28–29.

Bhagwat T, Hess A, Horning N, Khaing T, Thein Z, Aung KM, Aung KH, Phyo P, Tun Y, Oo A, Neil A, Thu W, Songer M, Connette K, Bernd A, Huang Q, Connette G., Leimgruber, 2017. Losing a jewel -rapid declines in Myanmar's intact forests from 2002–2014. PLoS One 12, e0176364. [PubMed: 28520726]

Bleisch B, Brockelman W, Timmins RJ, Nadler T, Thun S, Das J, Yongcheng L, 2008. Trachypithecus phayrei. The IUCN Red List of Threatened Species 2008.

Brashares JS, Arcese P, Sam MK, Coppolillo PB, Sinclair ARE, Balmford A, 2004. Bushmeat hunting, wildlife declines, and fish supply in west Africa. Science 306, 1180–1183. [PubMed: 15539602]

Buckley RC, Morrison C, Castley JG, 2016. Net effects of ecotourism on threatened species survival. PLoS One 11, e0147988. [PubMed: 26886876]

Campbell C, Cheyne S, Rawson B, 2015. Best Practice Guidelines for the Rehabilitation and Translocation of Gibbons. IUCN SSC Primate Specialist Group, Gland, Switzerland, p. 56.

Cantlay JC, Ingram DJ, Meredith AL, 2017. A Review of zoonotic infection risks associated with the wild meat trade in Malaysia. EcoHealth 14, 361–388. [PubMed: 28332127]

Cheyne S, 2006. Wildlife reintroduction: considerations of habitat quality at the release site. BMC Ecol. 6, 5. [PubMed: 16611369]

Coad L, Abernethy K, Balmford A, Manica A, Airey L, Milner-Gulland E, 2010. Distribution and use of income from bushmeat in a rural village, central Gabon. Conserv. Biol 24, 1510–1518. [PubMed: 20507352]

Coker RJ, Hunter BM, Rudge JW, Liverani M, Hanvoravongchai P, 2011. Emerging infectious diseases in southeast Asia: regional challenges to control. Lancet 377, 599–609. [PubMed: 21269678]

Corlett R, 2007. The impact of hunting on the mammalian fauna of tropical asian forests. Biotropica 39, 292–303.

Daszak P, Cunningham AA, Hyatt AD, 2001. Anthropogenic environmental change and the emergence of infectious diseases in wildlife. Acta Trop. 78, 103–116. [PubMed: 11230820]

DeWalt SJ, Maliakal SK, Denslow JS, 2003. Changes in vegetation structure and composition along a tropical forest chronosequence: implications for wildlife. For. Ecol. Manag 182, 139–151.

Duckworth JW, Sankar K, Williams AC, Kumar NS, Timmins RJ, 2016. Bos guarus. The IUCN red list of threatened species. 10.2305/IUCN.UK.2016-2.RLTS.T2891A46363646.en.

Duffy R, John FAS, Buscher B, Brockington D, 2016. Toward a new understanding of the links between poverty and illegal wildlife hunting. Conserv. Biol 30, 14–22. [PubMed: 26332105]

Estes JA, Terborgh J, Brashares J, Power M, Berger J, Bond W, Carpenter S, Essington T, Holt R, Jackson J, Marquis R, Oksanen L, Oksanen T, Paine R, Pikitch E, Ripple W, Sandin S, Scheffer M, Schoener T, Shurin J, Sinclair A, Soule M, Virtanen R, Wardle D, 2011. Trophic downgrading of planet earth. Science 333, 301–306. [PubMed: 21764740]

Fa JE, Peres CA, Meeuwig J, 2002. Bushmeat exploitation in tropical forests: an intercontinental comparison. Conserv. Biol 16, 232–237.

Gao F, Bailes E, Robertson D, Chen Y, Rodenburg C, Michael SF, Cummins LB, Arthur LO, Peeters M, Shaw GM, Sharp PM, Hahn B, 1999. Origin of HIV-1 in the chimpanzee Pan troglodytes troglodytes. Nature 397, 436–441. [PubMed: 9989410]

Geissmann T, Grindley ME, Lwin N, Aung SS, Aung TN, Htoo SB, Momberg F, 2013. The Conservation Status of Hoolock Gibbons in Myanmar. Gibbon Conservation Alliance, Zurich, Switzerland.

Golden CD, Fernald LC, Brashares JS, Rasolofoniaina BR, Kremen C, 2011. Benefits of wildlife consumption to child nutrition in a biodiversity hotspot. Proc. Natl. Acad. Sci 108, 19653–19656. [PubMed: 22106297]

Hirsch VM, Olmsted RA, Murphey-Corb M, Purcell RH, Johnson PR, 1989. An African primate lentivirus (SIVsm) closely related to HIV-2. Nature 339, 389–392. [PubMed: 2786147]

Horby PW, Pfeiffer D, Oshitani H, 2013. Prospects for emerging infections in east and southeast Asia 10 years after severe acute respiratory syndrome. Emerg. Infect. Dis 19, 853–860. [PubMed: 23738977]

Huet T, Cheynier R, Meyerhans A, Roelants G, Wain-Hobson S, 1990. Genetic organization of a chimpanzee lentivirus related to HIV-1. Nature 345, 356–359. [PubMed: 2188136]

International Union for the Conservation of Nature, 2017. Forest Landscape Restoration: Meeting National and International Biodiversity Commitments. Gland, Switzerland. https://www.iucn.org/sites/dev/files/content/documents/20170807_iucn_forest-brief_18_flr-biodiversity_final.pdf.

Jones BA, Grace D, Kock R, Alonso S, Rushton J, Said MY, McKeever D, Mutua F, Young J, McDermott J, Pfeiffer DU, 2013. Zoonosis emergence linked to agricultural intensification and environmental change. Proc. Natl. Acad. Sci. U.S.A 110, 8399–8404. [PubMed: 23671097]

Jones-Engel L, Engel GA, Schillaci MA, Babo R, Froehlich J, 2001. Detection of antibodies to selected human pathogens among wild and pet macaques (Macaca tonkeana) in Sulawesi, Indonesia. Am. J. Primatol 54, 171–178. [PubMed: 11443632]

Jones-Engel L, May C, Engel G, Steinkraus K, Schillaci M, Fuentes A, Rompis A, Chalise M, Aggimarangsee N, Feeroz M, Grant R, Allan J, Putra A, Wandia I, Watanabe R, Kuller L, Thongsawat S, Chaiwarith R, Kyes R, Linial M, 2008. Diverse contexts of zoonotic transmission of simian foamy viruses in Asia. Emerg. Infect. Dis 14, 1200–1208. [PubMed: 18680642]

Karesh WB, Noble E, 2009. The bushmeat trade: increased opportunities for transmission of zoonotic disease. MSJM (Mt. Sinai J. Med.) 76, 429–434. [PubMed: 19787649]

Karesh WB, Cook RA, Bennett EL, Newcomb J, 2005. Wildlife trade and global disease emergence. Emerg. Infect. Dis 11, 1000–1002. [PubMed: 16022772]

Keesing F, Belden L, Daszk P, Dobson A, Harvell C, Holt R, Hudson P, Jolles A, Jones K, Mitchell C, Myers S, Bogich T, Ostfeld R, 2010. Impacts of biodiversity on the emergence and transmission of infectious diseases. Nature 468, 647–652. [PubMed: 21124449]

Kenyon M, Streicher U, Loung H, Tran T, Tran M, Vo B, Cronin A, 2014. Survival of reintroduced pygmy slow loris Nycticebus pygmaeus in South Vietnam. Endanger. Species Res 25, 185–195.

Kreuder Johnson C, Hitchens P, Smiley Evans T, Goldstein T, Thomas K, Clements A, Joly D, Wolfe N, Daszak P, Karesh W, Mazet J, 2015. Spillover and pandemic properties of zoonotic viruses with high host plasticity. Sci. Rep 5, 14830. [PubMed: 26445169]

Lynam AJ, Khaing ST, Zaw KM, 2006. Developing a national tiger action plan for the Union of Myanmar. Environ. Manag 37, 30–39.

Macdonald DW, Johnson PJ, Albrechtsen L, Dutton A, Seymour S, Dupain J, Hall A, Fa JE, 2011. Association of body mass with price of bushmeat in Nigeria and Cameroon. Conserv. Biol 25, 1220–1228. [PubMed: 21967092]

Mak GJK, Song W, 2018. Transnational norms and governing illegal wildlife trade in China and Japan: elephant ivory and related products under CITES. Camb. Rev. Int. Aff 31, 373–391.

McNeilage A, 1996. Ecotourism and mountain gorillas in the Virunga Volcanoes. In: Taylor VJ, Dunstone N (Eds.), The Exploitation of Mammal Populations. Springer, Dordrecht.

Ministry of the Natural Resources and Environmental Conservation of Myanmar Forest Department, 2015. National Biodiversity Strategy and Action Plan 2015–2020.

Montagnini F, 2005. Attempting to restore biodiversity in even-aged plantations. In: Mansourian S, Vallauri D, Dudley N (Eds.), Forest Restoration in Landscapes: beyond Planting Trees. Springer, New York.

Mossaz A, Buckley RC, Castley JG, 2015. Ecotourism contributions to conservation of African big cats. J. Nat. Conserv 28, 112–118.

Murray KA, Daszak P, 2013. Human ecology in pathogenic landscapes: two hypotheses on how land use change drives viral emergence. Curr. Opin. Virol 3, 79–83. [PubMed: 23415415]

Nichols JD, Williams BK, 2006. Monitoring for conservation. Trends Ecol. Evol 21, 668–673. [PubMed: 16919361]

Olival KJ, Hosseini PR, Zambrana-Torrelio C, Ross N, Bogich TL, Daszak P, 2017. Host and viral traits predict zoonotic spillover from mammals. Nature 546, 646–650. [PubMed: 28636590]

Palacios G, Lowenstine L, Cranfield M, Gilardi K, Spelman L, Kukasik-Braum M, Kinani JF, Mudakikwa A, Nyirakaragire E, Bussetti A, Savji N, Hutchison S, Egholm M, Lipkin I, 2011. Human metapneumovirus infection in wild mountain gorillas, Rwanda. Emerg. Infect. Dis 17, 711–713. [PubMed: 21470468]

Patz JA, Daszak P, Tabor G, Aguirre A, Pearl M, Epstein J, Wolfe N, Kilpatrick A, Foufopoulos J, Molyneux D, Bradley D, 2004. Unhealthy landscapes: policy recommendations on land use change and infectious disease emergence. Environ. Health Perspect 112, 1092–1098. [PubMed: 15238283]

Peres CA, 2000. Effects of subsistence hunting on vertebrate community structure in Amazonian forests. Conserv. Biol 14, 240–253.

Peres CA, Palacios E, 2007. Basin-wide effects of game harvest on vertebrate population densities in Amazonian forests: implications for animal-mediated seed dispersal. Biotropica 39, 304–315.

Phelps J, Webb EL, Bickford D, Nijman V, Sodhi NS, 2010. Boosting CITES. Science 330, 1752–1753. [PubMed: 21205655]

Pullin AS, Knight T, 2001. Effectiveness in conservation practice: pointers from medicine and public health. Conserv. Biol 15, 50–54.

Pullin AS, Knight TM, 2003. Support for decision making in conservation practice: an evidence-based approach. J. Nat. Conserv 11, 83–90.

Rao M, Htun S, Zaw T, Myint T, 2010. Hunting, livelihoods and declining wildlife in the Hponkanrazi wildlife sanctuary, North Myanmar. Environ. Manag 46, 143–153.

Schillaci MA, Jones-Engel L, Engel GA, Kyes RC, 2006. Exposure to human respiratory viruses among urban performing monkeys in Indonesia. Am. J. Trop. Med. Hyg 75, 716–719. [PubMed: 17038700]

Servaes L, 2017. Elephants in tourism. Sustainable and practical approaches to captive elephant welfare and conservation in Thailand. In: Malikhao P (Ed.), Communication, Culture and Change in Asia. Springer, Singapore.

Shaffer CA, Milstein MS, Suse P, Marawanaru E, Yukuma C, Wolf TM, Travis DA, 2018. Integrating ethnography and hunting sustainability modeling for primate conservation in an indigenous Reserve in Guyana. Int. J. Primatol 39, 945–968.

Spelman LH, Gilardi KV, Lukasik-Braum M, Kinani JF, Nyirakaragire E, Lowenstine LJ, Cranfield MR, 2013. Respiratory disease in mountain gorillas (Gorilla beringei beringei) in Rwanda, 1990–2010: outbreaks, clinical course, and medical management. J. Zoo Wildl. Med 44, 1027–1035. [PubMed: 24450064]

Stoner KE, Vulinec K, Wright SJ, Peres CA, 2007. Hunting and plant community dynamics in tropical forests: a synthesis and future directions. Biotropica 39, 385–392.

Subramanian M, 2012. Zoonotic disease risk and the bushmeat trade: assessing awareness among hunters and traders in Sierra Leone. EcoHealth 9, 471–482. [PubMed: 23408099]

Suwannarong K, Schuler S, 2016. Bat consumption in Thailand. Infect. Ecol. Epidemiol 6 10.3402/iee.v6.29941.

Terborgh J, Lopez L, Nunez P, Rao M, Shahabuddin G, Orihuela G, Riveros M, Ascanio R, Adler G, Lambert T, Balbas L, 2001. Ecological meltdown in predator-free forest fragments. Science 294, 1923–1926. [PubMed: 11729317]

Tordoff AW, Eames JC, Eberhardt K, Baltzer MC, Davidson P, Leimgruber P, Uga U, Than UA, 2005. Myanmar: Investment Opportunities in Biodiversity Conservation. Critical Ecosystem Partnership Fund.

Walsh PD, et al. , 2003. Catastrophic ape decline in western equatorial Africa. Nature 422, 611–614. [PubMed: 12679788]

Wildlife Conservation Society, 2013. Myanmar Biodiversity Conservation Investment Vision. Wildlife Conservation Society, Yangon, Myanmar.

Wolfe ND, 2005. Bushmeat hunting, deforestation, and prediction of zoonotic disease emergence. Emerg. Infect. Dis 11, 1822–1827. [PubMed: 16485465]

Wright SJ, Hernandez A, Condit R, 2007. The bushmeat harvest alters seedling banks by favoring lianas, large seeds, and seeds dispersed by bats, birds, and wind. Biotropica 39, 363–371.

Yusof E, Faridah-Hanum I, 2008. Assessing habitat suitability for reintroduction of Hylobates lar (gibbon) in Ayer Hitam forest Reserve, Seangor, peninsular Malaysia. Malays. For. 71, 29–36.

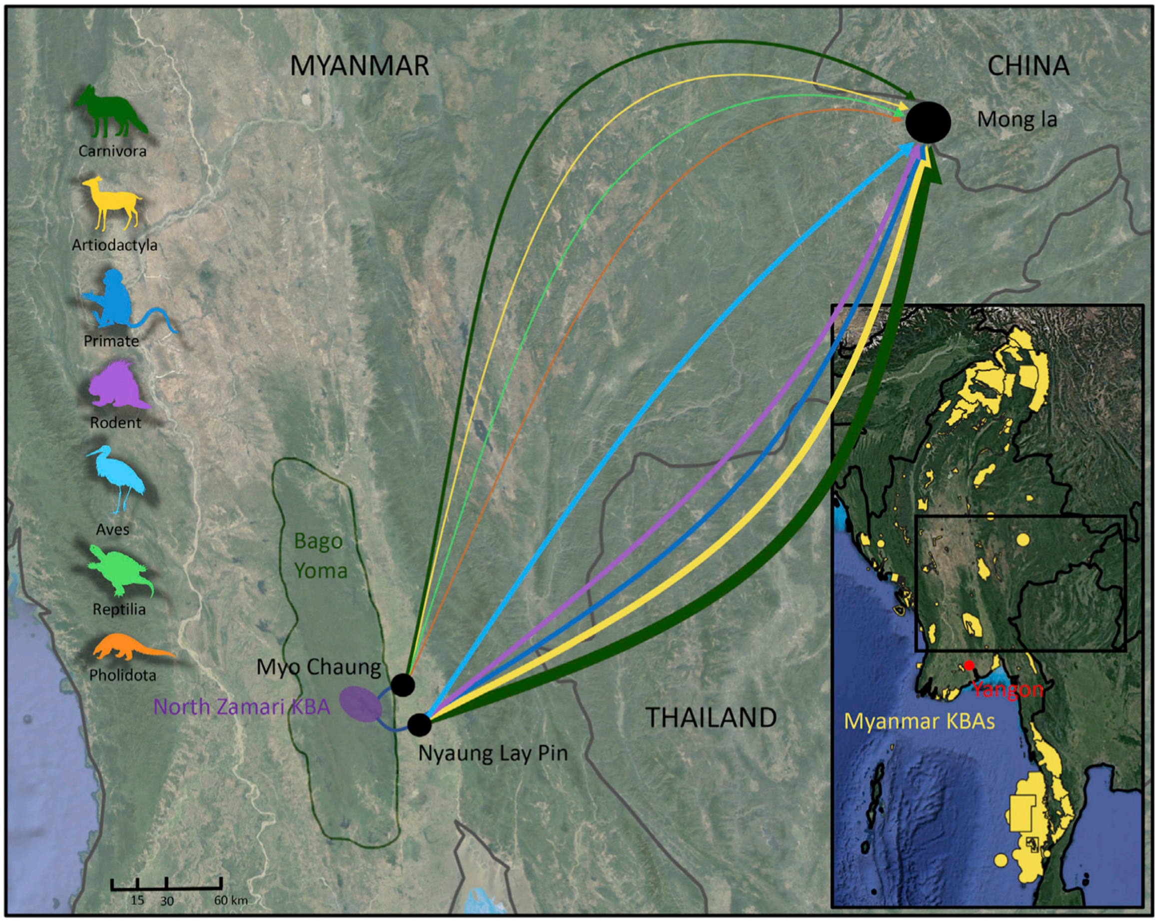

Fig. 1.

Wildlife trade routes identified from the North Zamari Key Biodiversity Area (KBA) to middle markets in Nyaung Lay Pin and Myo Chaung, with the ultimate destination of the border town of Mong la. Designated Myanmar KBAs are identified in yellow. Data were collected on location of middle markets and ultimate sale destination, not exact trade routes. Edge widths of location connections between middle markets and Mong la represent number of species per order identified as traded between sites.

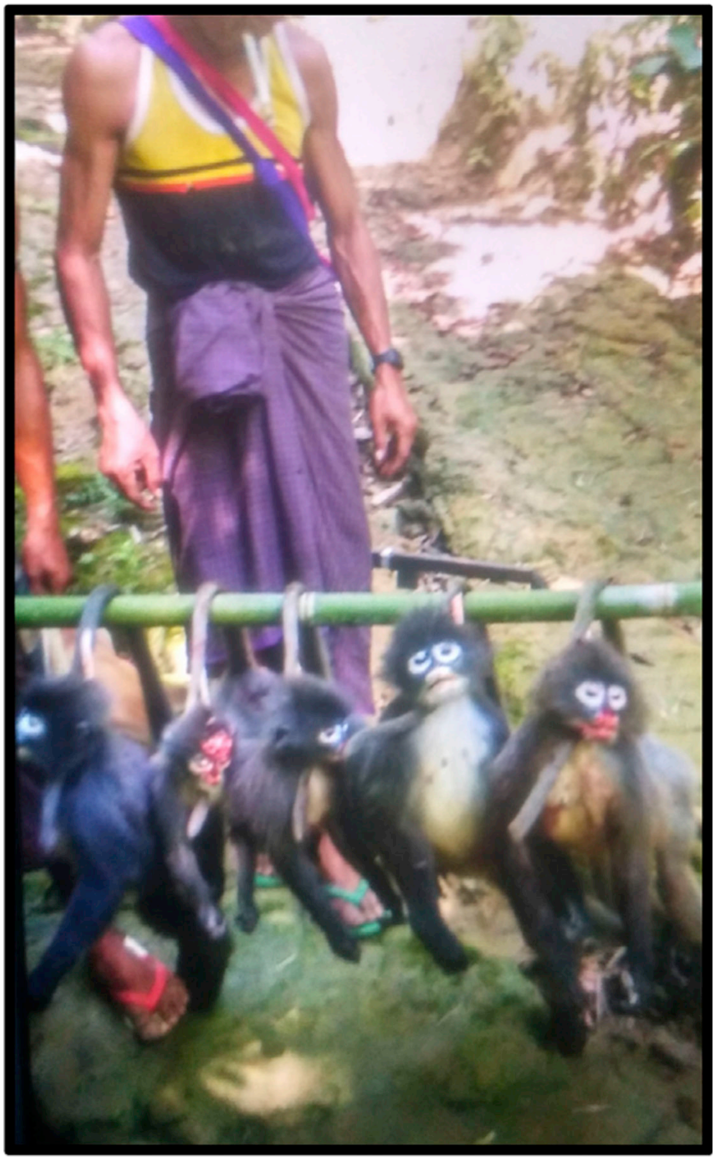

Fig. 2.
Phayre's langur hunted near the North Zamari Key Biodiversity Area in Myanmar. Photo from unidentified hunter's phone.

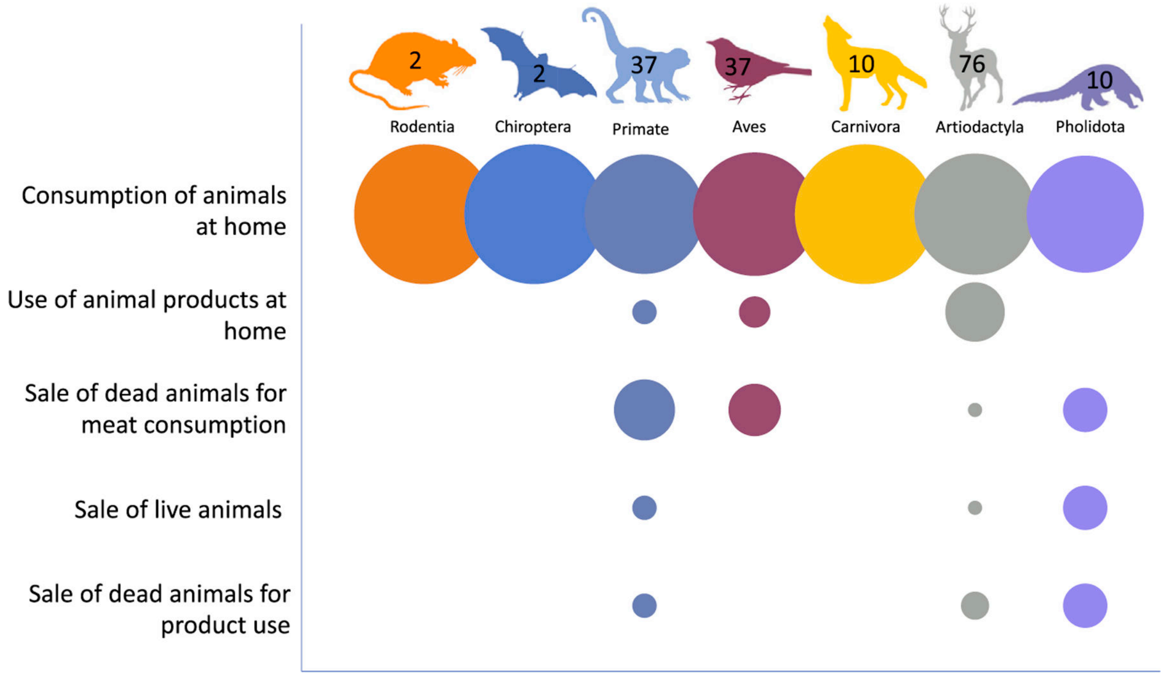

Fig. 3.

Designated purpose for wild animals hunted in the North Zamari Key Biodiversity Area during June 2016–August 2018. Bubble size represents percentage of people reporting using an animal in each order/class for a specific purpose, as assessed through retrospective questionnaires. The number of people who answered questions about the designated purpose for each wild animal order/class are represented in animal figure logos.

Table 1

Characteristics of wild animal species hunted in the North Zamari Key Biodiversity Area.

Order/Class	Animal hunted	CITES Classification	IUCN Status	Hunting Method[a]	Hunter Perceived Species Abundance[b]	Hunter Preference for Harvest[c]	Season Hunted[d]
Reptilia	Burmese python *(Python bivittatus)*	II	VU	Dog, knife	Decrease	low	All
	Bengal monitor lizard *(Varanus bengalensis)*	I	LC	Dog	Decrease	High	Hot
	king cobra *(Ophiophagus hannah)*	II	VU	Dog	Decrease	low	All
	Burmese mountain tortoise (*Manouria emys*)	II	EN	Dog	Increase	Medium	All
	elongated tortoise (*Indotestudo elongata)*	II	EN	Dog	Increase	Medium	All
Artiodactyla	Chinese serow (*Capricornis milneedwardsii*)	NR	NT	Gun	Decrease	Low	Hot
	red muntjac (*Muntiacus muntjak*)	NR	LC	Bow, gun	Decrease	High	Cold, Hot
	sambar (*Rusa unicolor*)	NR	VU	Bow, gun	Decrease	High	Cold, Hot
	Eurasian wild pig (*Sus scrofa*)	NR	LC	Trap, gun	Normal	High	All
Primate	Phayre's langur *(Trachypithecus phayrei*)	II	EN	Bow, gun	Decrease	High	All
	northern pig-tailed macaque (*Macaca leonina*)	II	VU	Bow, gun	Decrease	Medium	All
	rhesus macaque (*Macaca mulatta*)	II	LC	Bow, gun	Normal	Medium	All
Rodentia	Himalayan porcupine *(Hystrix brachyura*)	NR	LC	Dog, bow	Decrease	Medium	Cold
	lesser bamboo rat (*Cannomys badius*) and similar sp.	NR	LC	Dog	Decrease	High	Cold, Hot
	Phayre's squirrel (*Callosciurus phayrei*)	NR	LC	Bow	Decrease	Medium	Cold, Hot
Carnivora	Asian black bear (*Ursus thibetanus*)	I	VU	Gun	Decrease	Medium	All
	sun bear (*Helarctos malayanus*)	II	VU	Gun	Decrease	Medium	All
	jungle cat (*Felis chaus*)	NR	LC	Bow, Gun	Decrease	Medium	Cold, Hot
	marbled cat (*Pardofelis marmorata*)	NR	LC	Bow, Gun	Decrease	Medium	Cold, Hot
	leopard cat (*Prionailurus bengalensis)*	NR	NT	Bow, Gun	Decrease	Medium	Cold, Hot
	fishing cat *(Prionailurus viverrinus)*	NR	VU	Bow, Gun	Decrease	Medium	Cold, Hot
	common palm civit (*Paradoxurus hermaphroditus*)	NR	LC	Bow, Gun	Decrease	High	All
	large Indian civit (*Viverra zibetha*)	NR	LC	Bow, Gun	Decrease	Medium	All

Order/Class	Animal hunted	CITES Classification	IUCN Status	Hunting Method[a]	Hunter Perceived Species Abundance[b]	Hunter Preference for Harvest[c]	Season Hunted[d]
	small Indian civit (*Viverricula indica*)	NR	LC	Bow, Gun	Decrease	Medium	All
	masked palm civit (*Paguma larvata*)	NR	LC	Bow, Gun	Decrease	High	All
	binturong (*Arctictis binturong*)	III	VU	Bow	Decrease	High	All
	spotted linsang (*Prionodon pardicolor*)	I	LC	Bow, Gun	Decrease	Medium	All
	leopard (*Panthera pardus*)	I	VU	Gun, Trap	Decrease	Medium	All
	tiger (*Panthera tigris*)	I	EN	Gun, Trap	Decrease	High	All
Chiroptera	large flying fox *(Pteropus vampyrus)*	II	NT	Bow, catapult	Decrease	Low	All
Aves	great hornbill (*Buceros bicornis*)	I	NT	Bow	Decrease	Low	All
	red jungle fowl (*Gallus gallus*)	NR	LC	Trap, bow	Decrease	High	All
	pied hornbill (*Anthracoceros albirostris*)	II	LC	Bow	Decrease	Low	All
Pholidota	Sunda pangolin (*Manis javanica)*	I	CR	Dog	Decrease	High	All

[a]Hunters were asked to describe their methods for hunting each species.

[b]Hunters were asked to describe their perceived abundance trends for each species and whether they thought a particular species had decreased, increased or stayed in a normal steady state over the preceding five years.

[c]Individual hunters were asked to describe their relative preference for hunting each species, during focus group discussions given the category of “low”, “medium”, or “high”. Groups were then asked to come to a consensus measure of preference during these group discussions.

[d]Hunters were asked to name the seasons in which they hunted each species, Hot season = March–May, Cool season = October–February, Wet season = June–September.

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Table 2

Number of individual animals hunted by species as recorded from hunter records and observed kills in the North Zamari Key Biodiversity Area between 2016 and 2018.

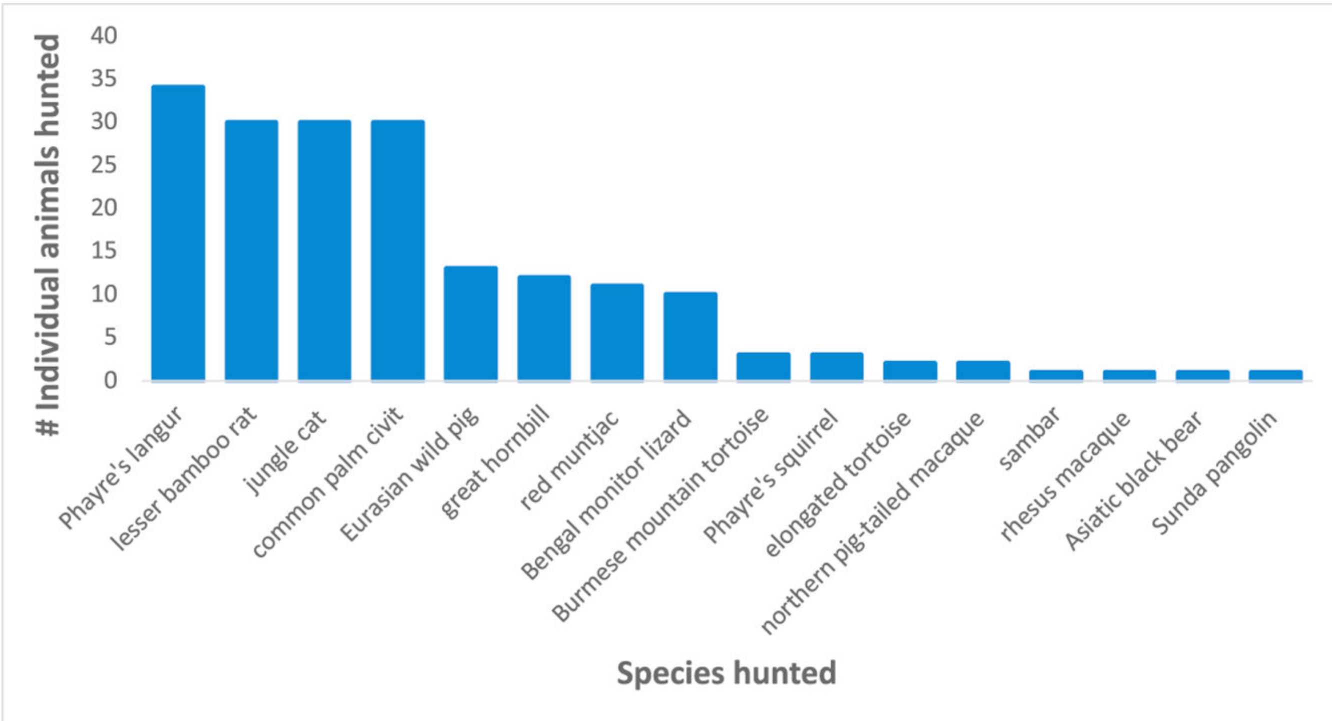

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Table 3

Reported medicinal use of wild animal parts from species hunted in the North Zamari Key Biodiversity Area.

Species hunted	Animal Part	Medicinal Use
Burmese python (*Python bivittatus*)	Gall bladder	Treatment for tetanus
Bengal monitor lizard (*Varanus bengalensis*)	Tongue	Venom antidote
king cobra *(Ophiophagus hannah)*	Gall bladder	Treatment for paralysis
Burmese mountain tortoise (*Manouria emys*)	Gall bladder	Treatment for low energy/stamina and glaucoma
elongated tortoise *(Indotestudo elongata)*	Gall bladder	Treatment for low energy/stamina and glaucoma
Chinese serow *(Capricornis milneedwardsii)*	Oil - arthritis	Treatment for arthritis
Chinese serow *(Capricornis milneedwardsii)*	bone	Treatment for gastrointestinal disease
red muntjac *(Muntiacus muntjak)*	Horn	Treatment for fatigue
sambar (*Rusa unicolor*)	Horn	Treatment for fatigue
Phayre's langur (*Trachypithecus phayrei*)	Stomach	Treatment for kidney disease
Phayre's langur (*Trachypithecus phayrei*)	Skull	Treatment for "childhood illness and hysteria" (behavioral problems)
northern pig-tailed macaque (*Macaca leonina)*	Skull	Treatment for "childhood illness and hysteria" (behavioral problems)
rhesus macaque *(Macaca mulatta)*	Skull	Treatment for "childhood illness and hysteria" (behavioral problems)
Himalayan porcupine *(Hystrix brachyura*)	Ground quill ash	Treatment for arterial stenosis
Asiatic black bear (*Ursus thibetanus*)	Gall bladder	Treatment for general illness; treatment for liver disease
Malayan sun bear (*Helarctos malayanus*)	Gall bladder - general illness	Treatment for general illness; treatment for liver disease
leopard *(Panthera pardus)*	Bone	Wide medicinal anti-inflammatory properties
leopard *(Panthera pardus)*	Canine tooth	Wide medicinal anti-inflammatory properties
tiger (*Panthera tigris*)	Bone	Wide medicinal anti-inflammatory properties
tiger (*Panthera tigris*)	Canine tooth	Wide medicinal anti-inflammatory properties
Sunda pangolin (*Manis javanica)*	Scales	Treatment for "childhood illness and hysteria" (behavioral problems)

Table 4

Characteristics of wild animal species traded in the North Zamari Key Biodiversity Area.

Species hunted	Parts traded	Average price ($USD)[a]	Location of Trade
Burmese python *(Python bivittatus)*	Gall bladder, skin	$10–100	local
Bengal monitor lizard *(Varanus bengalensis)*	Whole (dead)	$4–50	local
king cobra *(Ophiophagus hannah)*	Whole (dead)	$4–50	local
Burmese mountain tortoise (*Manouria emys*)	Whole (live)	$20	Nyaung Lay Pin
elongated tortoise *(Indotestudo elongata)*	Whole (live)	$20	Nyaung Lay Pin
Chinese serow (*Capriconis milneedwardsi*)	Horn, meat, and oil	Not determined	Nyaung Lay Pin
red muntjac (*Muntiacus muntjak*)	Whole (dead) and horn	Not determined	Local, Myo Chaung
sambar (*Rusa unicolor*)	Horn	$28	Local, Myo Chaung
Phayre's langur (*Trachypithecus phayrei*)	Skull, meat, stomach	$10/kg meat; $13/kg stomach	Local, Myo Chaung
northern pig-tailed macaque (*Macaca leonina*)	Whole (dead), stomach	$10/kg meat; $13/kg stomach	Local, Myo Chaung
rhesus macaque (*Macaca mulatta*)	Whole (dead), stomach	$10/kg meat; $13/kg stomach	Local, Myo Chaung
Himalayan porcupine *(Hystrix brachyura*)	Whole (dead), quill	$10/kg meat	Local, Myo Chaung
lesser bamboo rat *(Cannomys badius)* and similar sp.	Whole (dead)	$4/kg	Local, Myo Chaung
Phayre's squirrel (*Callosciurus phayrei*)	Whole (dead)	$4 – $10/kg	Local, Myo Chaung
Asiatic black bear (*Ursus thibetanus*)	Gall bladder, canine tooth, paw	$40 – 100	Local, Myo Chaung
Malayan sun bear (*Helarctos malayanus*)	Gall bladder, canine tooth, paw	$40 – 100	Local, Myo Chaung
jungle cat (*Felis chaus*)	Whole (dead)	$7/Kg meat	Local, Myo Chaung
marbled cat *(Pardofelis marmorata)*	Whole (dead)	$7/Kg meat	Local, Myo Chaung
leopard cat *(Prionailurus bengalensis)*	Whole (dead)	$7/Kg meat	Local, Myo Chaung
fishing cat (*Prionailurus viverrinus*)	Whole (dead)	$7/Kg meat	Local, Myo Chaung
common palm civit (*Paradoxurus hermaphroditus*)	Whole (dead)	$7/Kg meat	Local, Myo Chaung
large Indian civit (*Viverra zibetha*)	Whole (dead)	$7/Kg meat	Local, Myo Chaung
small Indian civit (*Viverricula indica*)	Whole (dead)	$7/Kg meat	Local, Myo Chaung
masked palm civit (*Paguma larvata*)	Whole (dead)	$7/Kg meat	Local, Myo Chaung
binturong (*Arctictis binturong*)	Whole (dead)	$7/Kg meat	Local, Myo Chaung
spotted linsang (*Prionodon pardicolor*)	Whole (dead)	$7/Kg meat	Local, Myo Chaung
leopard *(Panthera pardus)*	Skin, canine tooth, skull, penis, paw	$1500 – $2000 whole leopard	Nyaung Lay Pin
tiger (*Panthera tigris*)	Skin, canine tooth, skull, penis, paw	$2000 whole tiger	Nyaung Lay Pin
Eurasian wild pig (*Sus scrofa*)	Meat pieces	Not determined	Local, Myo Chaung
great hornbill (*Buceros bicornis*)	Bill, meat, feather	Not determined	Local, Myo Chaung
red jungle fowl (*Gallus gallus*)	Whole (live)	$4 – $10/kg	Local, Myo Chaung
pied hornbill (*Anthracoceros albirostris*)	Bill, feather	Not determined	Local, Myo Chaung
Sunda pangolin (*Manis javanica)*	Whole (live), scales	$69–100/pangolin; $34/10 scales	Nyaung Lay Pin

[a]Average price was determined by responses of individuals to questionnaires and by focus group discussions.

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Table 5

Factors impacting participation in hunting and slaughtering of bushmeat in the North Zamari Key Biodiversity Area.

Model	Predictor	OR (95% CI)	P-value
Hunting			
	Male	N/A[a]	N/A
	Protected area worker	11.5 (3.7–35.2)	<0.001
	Extractive industry worker	5.3 (1.6–18.1)	0.008
	Migrant laborer	13.7 (1.4–133.2)	0.025
	Dependent	0.1 (0.0–0.6)	0.017
Slaughtering			
	Male	19.4 (8.4–44.8)	<0.001

[a]Being male was 100% correlated with hunting and therefore odds ratios could not be calculated.