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Research Article

Empty Forest Syndrome: Are we there yet? A preliminary Analysis of the Hunting and Poaching Activities in Selected Areas in Sabah, Malaysia.

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ABSTRACT

Hunting poses a longstanding threat to tropical wildlife conservation, now reaching critical levels. In Borneo, Malaysia, around six million animals were hunted yearly in the 1990s, about 36 per sq. km. High demand for game meat, facilitated by improved transportation, drives unsustainable consumption across the tropics. Depletion of animal populations leads hunters to new areas. Roughly 18% of rainforests are protected, yet pressures persist, endangering species due to weak regulations, limited resources, and external threats. This study examines wildlife hunting trends in Sabah, uncovering insights from community interviews regarding hunting impact and resource dependence. A total of 45 people were interviewed in six study areas: Sandakan, Tawau, Kota Belud, Tambunan, Keningau and Tenom. It was found that local communities hunt for food and that hunting is a common way of life for them. Based on the arrests of hunters by the Wildlife Rescue Unit, a report on animal hunting was compiled by the Sabah Wildlife Department and analysed. The most commonly hunted animal is the bearded pig. Parts of bearded pigs were found in the cars of 76.97% of hunters arrested, followed by parts of sambar deer (13.7%). Throughout Sabah, the empty forest syndrome (EFS) is becoming a dangerous silent disaster. While most "simple" forest features are attractive to the eye, they are

gradually losing their ecological function. Although this study is not exhaustive, the preliminary findings point to a serious EFS scenario in Sabah if everyone continues to neglect the syndrome and do nothing about it.

Keywords: Empty Forest Syndrome (EFS); Hunting; Poaching; Community; Bush Meat; Sabah; Borneo

Introduction

Hunting behaviour is more strongly related to the current number of species in tropical forests than forest type, habitat size or conservation status (Woodroffe and Ginsberg, 1998; Peres, 2009). For example, tiny patches of forest near fishing settlements in Borneo may have abundant wildlife, while large, isolated protected areas may have declining numbers due to over-exploitation by local people (Bennett et al., 2000; McConkey and Chivers, 2004). Peres and Palacios (2007) observed that untamed populations in the Amazon Basin indicate the availability of an area to trackers rather than its conservation status, although Brashares et al. (2004) found that the extent of bushmeat hunting in West Africa depends largely on the accessibility of selected protein sources. At the point when the respective regulators had a viable interest in advancing non-hunting or hunting governance in their concessions, both logging (Clark et al., 2009; Berry et al., 2010) and oil palm (Laurance et al., 2008) concessions became important conservation areas for wildlife.

There is no doubt that the authorities of protected areas do not tolerate violations and that eradications occasionally occur in protected areas. It is therefore difficult to get a clear picture of how wildlife is faring in most protected areas. However, most tropical protected areas can be classified as empty forests, based on hunting literature. From southern China (Fellowes et al., 2004) to Laos (Nooren & Claridge, 2001), Myanmar (Rao et al., 2010), Cambodia (Loucks et al., 2009), Thailand (Brodie et al., 2009), Malaysia (Bennett et al., 2000; Wong, 2012; Kurz et al., 2021) and Indonesia (Corlett, 2007), there have been recent widespread decline in vertebrate populations in protected areas throughout Southeast Asia (Lee, 2000). Other tropical populations (Dunham et al., 2008; Golden, 2009), West and Central Africa (Fa & Brown, 2009), the Brazilian Atlantic Forest (Galetti et al., 2009) and Oceania appear to be in a similar situation (McConkey & Drake, 2006).

The inaccessibility of forests in parts of Amazonia, Congo and New Guinea certainly provides some protection for wildlife (e.g. Peres, 2009). However, given the current extent of mining, wildlife populations in these regions are

expected to decline as contact expands (Levi et al., 2009). In Sabah, for example, accessibility has become another dilemma between people and wildlife. In 2017, there was an outcry among conservationists over the RM79 million Kinabatangan Bridge proposed by a member of the legislative assembly to provide access to about 2,000 people from Sukau to Litang Tomanggong (Chan, 2017). The project would also require the paving of an unpaved road, which would lead to more traffic in the area. The situation would endanger wildlife in Kinabatangan as traffic would increase. The project has been stopped, but it may only be a matter of time before it is revived under a different guise.

Only about 35%, 9% and 1% of sites in the Neotropical, Afrotropical and Indo-Malay zones, respectively, have combined megafauna populations (over 20 kilogrammes) (Morrison et al., 2007). With the exception of a few hunting-tolerant animals, virtually all species larger than two kilogrammes are extirpated or live at densities well below historical population ratios outside these regions (Corlett, 2007; Peres, 2009). Indeed, the focus on megafauna has made it difficult to understand the extent of hunting. Previous studies of defaunation in tropical Asia, for example, focused on reserves with megafauna ecosystems that were still fully or almost fully conserved, but with reduced densities (e.g. Datta et al., 2008). Therefore, the study seeks to address the challenge of understanding the dynamics of wildlife conservation in the face of hunting pressures, especially in protected areas. By analysing communities' perspectives, the study aims to shed light on the widespread decline of vertebrate populations due to hunting. Ultimately, the study intends to contribute to the broader understanding of conservation efforts and the management of hunting-related threats to tropical wildlife.

The Role of Wildlife in Livelihoods

Forest products and services play a crucial role in supporting rural employment in sub-Saharan Africa, Asia, and Latin America (Angelsen et al., 2014). Low-income families, in particular, rely significantly on forest resources for their annual income, in contrast to high-income families (Angelsen and Dokken, 2015). This dependence on forests implies that these families might encounter additional challenges if factors such as protective measures, access to, or utilization of forests become restricted. The significance of this reliance becomes even more apparent when considering the various ways in which forests contribute to their well-being. The yield from forests serves a multifaceted purpose. It contributes to essential needs such as energy, food, medicines, and building materials, functioning as a vital network of wealth for these families

(Angelsen et al., 2014; UN, 2020). For instance, game meat, derived from wild animals and often referred to as hedgerow meat, holds particular significance. Low-income families frequently turn to game meat not only for sustenance but also as a means to bridge gaps in their resources (De Merode et al., 2004; Schulte-Herbruggen et al., 2013; Nielsen et al., 2018). This reliance on forest resources, including game meat, serves as a crucial buffer for rural families, helping them withstand unexpected shocks and preventing them from falling into destitution (Angelsen and Wunder, 2003; Babulo et al., 2009; UN, 2020).

A global comparative survey conducted by Nielsen et al. in 2017 revealed that hunting was a prevalent practice, with participation from 39% of the surveyed households. This statistic suggests that approximately 150 million families residing in forested regions engage in the collection of wild meat from the forests, highlighting its importance as a source of sustenance for a significant portion of the population. The extent of reliance on wild meat in rural areas varies widely, depending on factors such as local fauna populations and the availability of payment methods. This variability is explored in studies by Angelsen et al. (2014), Tieguhong (2009), and Kuempel et al. (2010). Despite its limited contribution to cash wages, wild meat serves as a vital source of protein, fat, and essential micronutrients in many regions, as indicated by research conducted by Sarti et al. (2015) and Rowland et al. (2017). Animals are hunted for personal subsistence needs, but there is also a thriving market for game meat and other animal products at local, national, and international levels. These markets function as commodities traded between countries. The global wildlife trade is a substantial industry, estimated to be worth between USD4-20 billion annually, encompassing both regulated and unregulated, legal and illegal trade (Morton et al., 2021). A study by Scheffers et al. (2019), published in Science, delves into the scale of the global wildlife trade. It reveals that vertebrate species constitute a significant portion, accounting for 24% of globally traded species (**see Figure 1**). While wildlife meat consumption may have traditional and subsistence aspects, the global wildlife trade demonstrates a growing commercial demand for wildlife meat and products, often driven by economic, cultural, and other factors. This increased demand can have complex implications for both wildlife conservation and the global economy. Therefore, efforts to regulate and manage wildlife trade are essential to address these challenges and ensure the sustainability of ecosystems and wildlife populations.

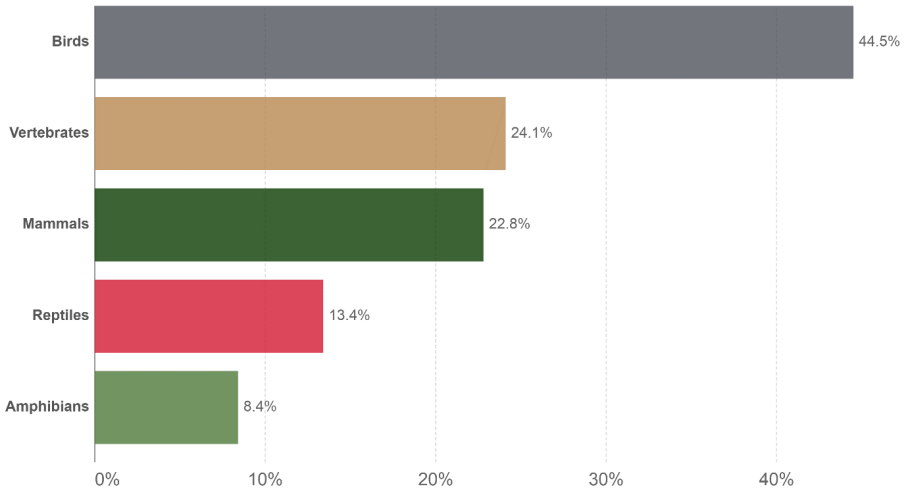

Figure 1. Share of species that are traded (Scheffers et al., 2019).

Emptying the Forest

While concerns about the direct impact of hunting on specific species are often at the forefront of conservation discussions, research into the broader effects of hunting, often referred to as de-hunting, has consistently demonstrated the significant disturbance of seriously hunted forests. One notable consequence is the selective targeting of creatures that feed on tree-based organic products, a practice that has been extensively documented (Harrison, 2011). This targeted hunting has had severe repercussions, particularly for larger frugivorous vertebrates and birds. These species play a pivotal role as seed dispersers within the ecosystem due to their ability to consume larger seeds and transport them over substantial distances. Consequently, in forests subjected to extensive hunting pressures, the recovery of plant species that rely on larger seeds for propagation is significantly impeded. Many of these plant species are slow-growing canopy species, which contrasts with species dispersing smaller seeds or seeds distributed abiotically (McConkey & Drake, 2006; Nuñez-Iturri & Howe, 2007; Wang et al., 2007; Terborgh et al., 2008; Brodie et al., 2009; Holbrook & Loiselle, 2009; Sethi & Howe, 2009).

In addition to the impacts on seed dispersal, hunting has been linked to a range of other disruptions to natural ecological processes. These include alterations in seed predation (Roldán & Simonetti, 2001; Beckman & Muller-Landau, 2007; Dirzo et al., 2007; Wright et al., 2007b), increased seedling mortality rates (Roldán & Simonetti, 2001; Nuñez-Iturri et al., 2008), changes in home range

predation dynamics (Posa et al., 2007), and shifts in food availability for larger predators within the ecosystem.

When populations of wildlife species in tropical protected areas are not effectively safeguarded from hunting pressures, restoration efforts are often necessary to mitigate the ecological damage. It is increasingly clear that even supposedly "secured" or "protected" forests are unlikely to maintain their unique ecological structure and functions in the face of ongoing and intensive hunting pressures. Thus, this research not only enhances clarity but also provides a more comprehensive understanding of the ecological consequences of hunting on forest ecosystems, emphasizing the importance of conservation efforts to preserve these fragile environments based on insights gained through community interviews. The research findings are informed by community interviews, making it clear that community perspectives contribute to the understanding of the ecological consequences of hunting and the need for conservation.

Materials and Method

Study Areas

The study was conducted in six selected districts in Sabah, Malaysia, namely Sandakan, Kota Belud, Tambunan, Keningau, Tawau and Tenom (**Figure 2**). The demographic profiles of the respondents are shown in **Figure 4**. A seven-days visit was conducted in Sandakan district in June 2020; Tambunan, Keningau and Tenom in July 2020; Tawau in September 2020; and Kota Belud in October 2021.

Survey Methodology

In this study, a comprehensive multi-method approach was employed for data collection, encompassing both qualitative and quantitative methods. The questionnaire featured a combination of open and closed-ended questions, administered during semi-structured interviews with residents from the six selected districts. The interviews were conducted exclusively in the local language, Malay, chosen for it being used comfortably by participants, and for their convenience.

A total of 45 responses were gathered, reaching data saturation after the 34th interview. A snowball sampling method was applied to overcome challenges in identifying potential participants, particularly hunters. This approach relied on research participants' assistance in recruiting others to participate in the study.

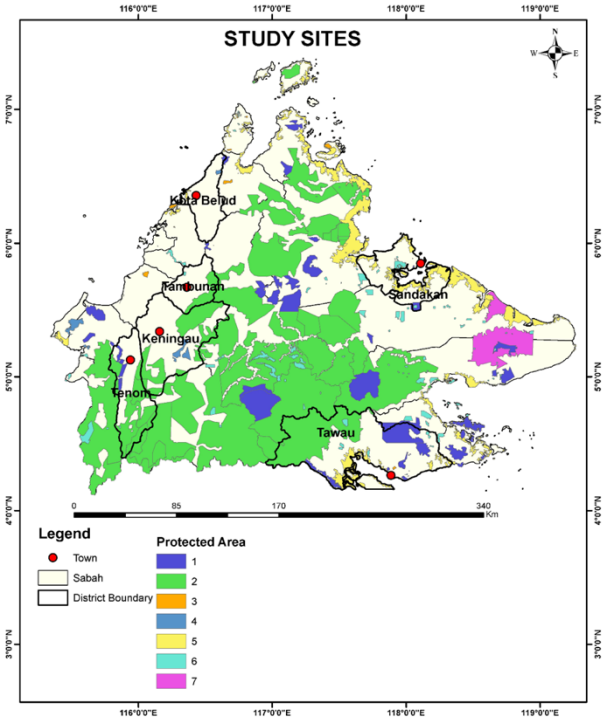

Figure 2. Map showing the selected districts for the study.

Transcriptions of the interviews were carried out verbatim, and the resulting transcripts underwent content analysis using Leximancer analysis software. However, it's important to acknowledge a limitation of the snowball sampling method. This approach hinges on referrals, with the initial participants recruiting subsequent ones. As a result, participants often share similar characteristics and connections, potentially introducing sampling bias, which must be considered. All participants in the interviews possess substantial experience in wildlife meat consumption, with some actively engaged in wildlife hunting activities in Sabah.

Leximancer is a programme that analyses material from interviews from large amounts of qualitative data, extracts information and presents the results visually in the form of a concept map (Leximancer, 2010). For key concepts, the programme extracts a thesaurus of terms and uses these to create a coding scheme, which in turn shows the frequency and co-occurrence of concepts. Two (2) languages are used in this programme, namely "concept" and "topics". The

analysis of the frequency, occurrence and context of words shapes the system. The "concepts" were created from the semantic and rational associations of the terms, while the "themes" were derived from interrelated concepts combined from a higher-level concept. The "themes" are represented by coloured bubbles, and the linkage points within the bubbles are also referred to as "concepts'," which are text extracts from the collected data. Haynes et al. (2019) and Ho et al. (2011) found that the use of text mining was coherent with other conventional analyses of qualitative content, so recognition of coherence could justify the use of this software as an analytical tool.

The data analysis consisted of several important steps. The first step was formatting the transcripts. All responses were translated from Malay into English without affecting the meaning of the sentence. Each transcript was entered using Microsoft Word. Leximancer software processed the standard programmed concepts and thesauri. The result is displayed in the conceptual map and spider network configuration (Leximancer, 2010).

The document analysis was also carried out using the same qualitative method of coding the content into themes, similar to the analysis of focus groups or interview transcripts. Due to the increase in cases of Covid-19 in Sabah, reports on hunting and poaching in Sabah were obtained from the Sabah Wildlife Department.

Results

Figure 3 shows female and male respondents in the sample population are balanced: 22 or 48.89% are female and 51.11% or 23 are male. In terms of age group, the majority of the respondents are young professionals, 20 persons (44.44%). In terms of educational background, majority of the respondents have completed at least primary school (44.44%). The majority of the respondents are farmers (46.67%) and most of them belong to the B40 income group (86.67 %).

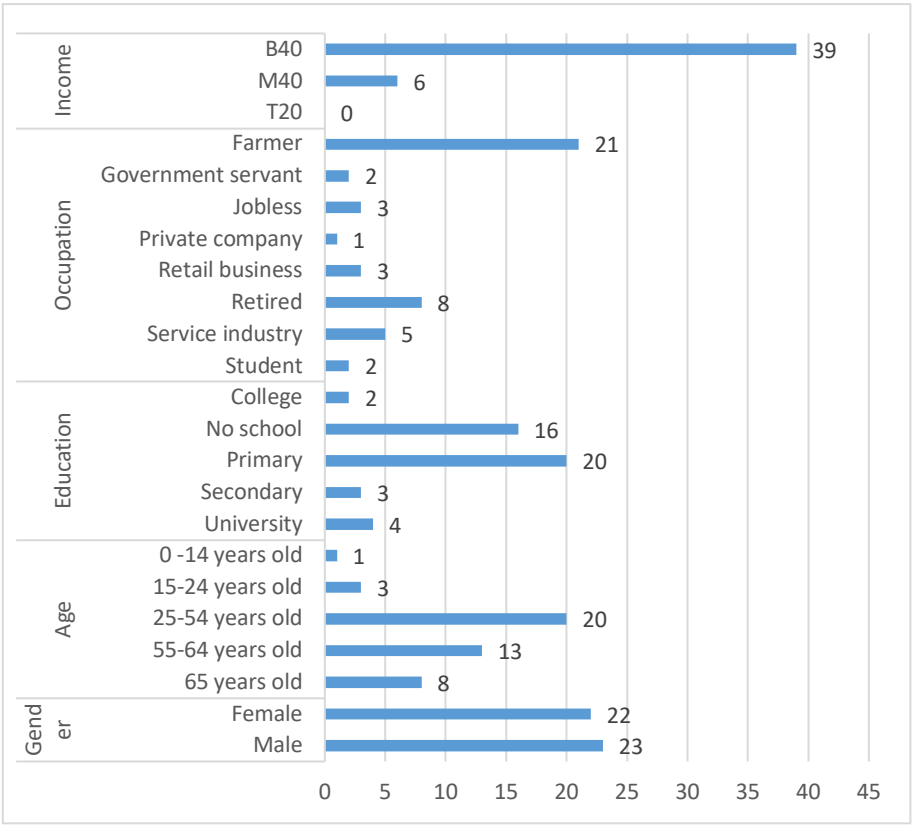

Figure 3. Demographic profile of the respondents.

Age distribution

A total of 44.44% of the respondents were in the 25–54 years age group, another 28.89% were between 55 and 64 years and 17.78% were 65 years and above. In addition, the age distribution for the study was found to be left skewed to cover the 25 to over 65 age group as this is the age group that has sufficient personal knowledge and experience of wildlife hunting in the villages (**Figure 4**).

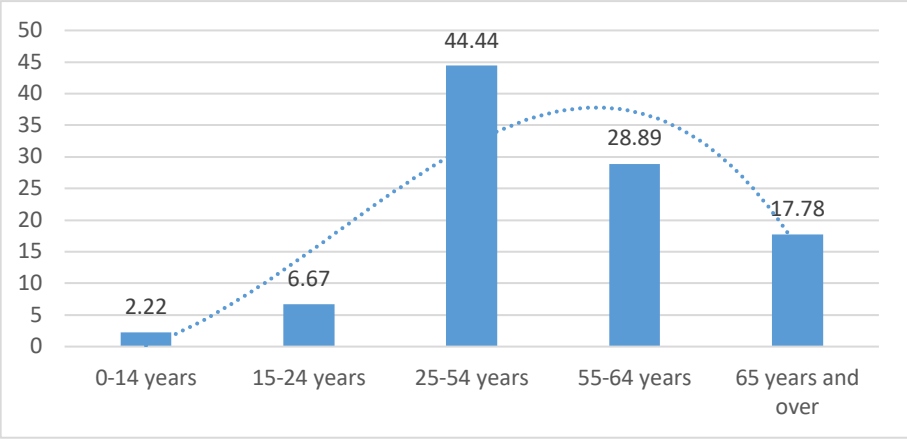

Figure 4. Distribution of age groups in this study which percentage based on the Malaysia Age Structure Index.

Wildlife Hunting Hotspots in Sabah

Wildlife hunting hotspots in Sabah were mapped based on Sabah Wildlife Department reports (**Figure 5**). It shows that hunters frequently hunt on the east coast of Sabah.

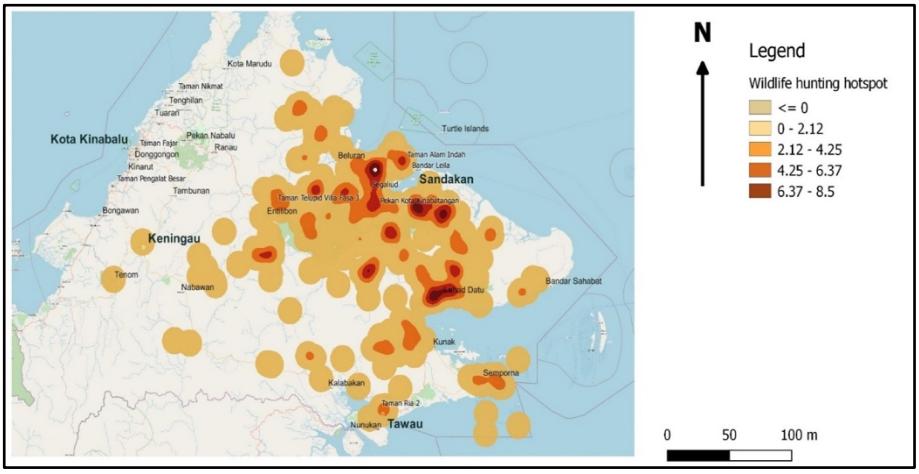

Figure 5. The hotspot of the hunting area in Sabah.

Types of Wildlife Hunted

Based on the document analysis of Sabah Wildlife Department's reports, it shows that bearded pigs are the most frequently hunted animals (**Figure 6**). For example, 76.97% of hunters were arrested for possessing meat and parts of bearded pigs in their vehicles, followed by sambar deer at 13.7 % and green turtles at 3.5% (**Table 1**).

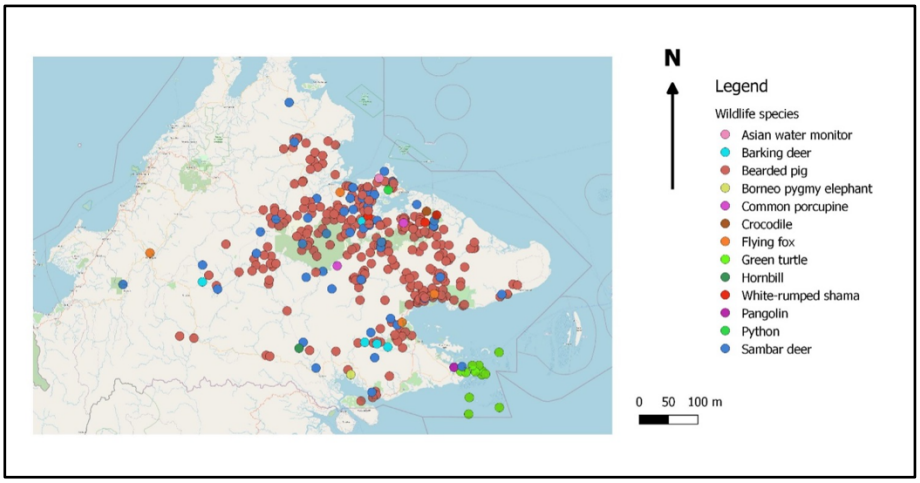

Figure 6. Types of wildlife hunted based on locations.

Table 1. Types of wildlife confiscated by the Sabah Wildlife Department.

Class	Scientific name	Common name	Percentage of respondent consumed wildlife, %	Hunting cases reported
Mammalia	*Sus barbatus*	Bearded pig	76.97	264
	Rusa unicolour	Sambar deer	13.7	47
	Muntiacus	Barking deer	1.46	5
	Pteropus vampyrus,	Flying fox	1.17	4
	Manis javanica	Pangolin	0.29	1
	Hystrix brachyura	Common porcupine	0.58	2
	Elephas maximus borneensis	Borneo pygmy elephant	0.29	1
Reptilia	*Chelonia mydas*	Green turtle	3.5	12
	Malayopython reticulatus	Pythons	0.29	1
	Crocodylinae	Crocodile	0.29	1
	Varanus salvator	Asian water monitor	0.29	1
Aves	*Copsychus malabaricus*	White-rumped shama	0.87	3
	Bucerotidae	Hornbill	0.29	1

Reasons to Hunt Wildlife

The Leximancer analysis indicates that the themes of "community" and "hunting" were identified as the most prominent and interconnected concepts in the concept map. These themes were found to be highly related and could not be separated or expanded upon, highlighting the strong connection between them.

In the Paths mode of Leximancer, the frequency and weight of individual words in a sentence are displayed. In this context, a block of two sentences represents an influence on the evidence collected for the concept. In our specific scenario, the theme of "community" contributed 100% and the theme of "hunting" contributed 57% to the reasons for hunting.

Figure 7 of the analysis displays the results of interviews, where ten words (represented by red circles) signify the reasons for hunting within the community. These reasons include elements such as local culture and tradition, market demand, alternative livelihood, substitute meat, medicinal purposes, food purposes, free food, and hunting as a hobby. This finding aligns with the expectation that hunting plays a significant economic role for indigenous ethnic groups and contributes to the preservation of their cultural identity.

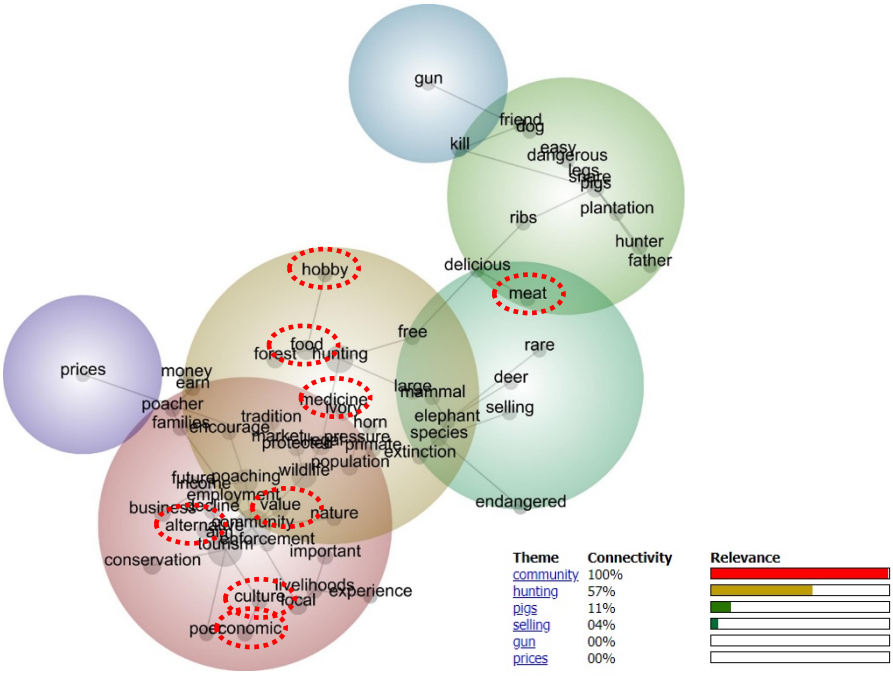

Figure 7. Conceptual map based on reasons to hunt.

Food procurement was the most frequently mentioned hunting motivation, with 125 occurrences of the word in the data pool; other important hunting motivations were market demand (98 occurrences of the word) and culture (71 times) **(see Figure 8**). Thirty-eight respondents emphasized the significant role of game meat as a primary dietary resource. Examples of statements made by respondents in relation to the hunting motivation include:

Respondent 24	*It is the most important source of food for people in the city. We ate it pretty much at every dinner.*
Respondent 1	*It is our life. We know how to hunt since we were 4 years old. If we do not hunt, we do not have food! The wild animals in our forests are our food.*
Respondent 25	*We cannot just stop eating them. They are our main source of food.*

Market demand for game meat was mentioned by respondents as a secondary motivation for hunting, with the word occurring 98 times in the data set, followed by mention of culture, which occurred 71 times in the data pool. For some respondents who regularly or occasionally sold wildlife meat, the sale was an important source of income.

Hunting has a fundamental impact on human development and is firmly linked to social aspects, including virtues, use and appropriation of assets, and political elements (van Vliet 2018). Hunting is thus one of the most important and enduring links between people and wildlife. Respondents were positive about the culture of wildlife hunting and when asked why, some of them emphasised their cultural attachment to nature and wildlife. The forest is important to fulfil their sense of belonging to their homeland and to evoke their childhood memories and experiences. Examples of statements made by respondents in relation to the linkages of hunting to their social aspects include:

Respondent 12	*I was born in a forested village where my house is surrounded by lush trees and there are wild animals everywhere. We give and take from each other. The forest gave us food - meat - and in return we took care of it. And after generations, it became our culture to protect our food in the forest.*
Respondent 42	*We have been hunting for a long time. The skill has been passed on from one generation to the next. This ensures that the tradition is preserved and not forgotten.*

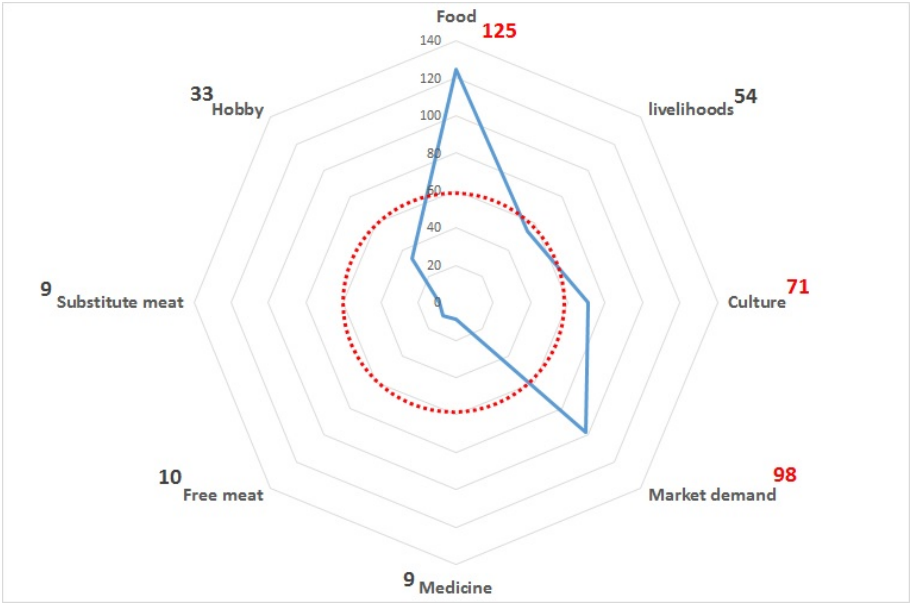

Figure 8. The rationales behind hunting activity among the respondents based on frequency on words occurrence in the interview data set.

A total of 76.97% of the wild animals killed were bearded pigs, 13.70% sambar deer, 3.50% green turtles, 1.46% barking deer and 1.17% fruit bats **(Figure 9**). Only 0.29% of the respondents reported hunting pangolins, hornbills, crocodiles and pygmy elephants, and 0.58% porcupines for their body parts (fur and ivory). The threat status of the Red List of reported hunted species included one Critically Endangered, one Endangered, two Vulnerable, two Threatened, and one Near Threatened species were among the reported hunted species on the Red List. The remaining five (5) were Least Concerned. The Bornean pygmy elephant (*Elephas maximus borneensis*) was the endemic species reported as hunted.

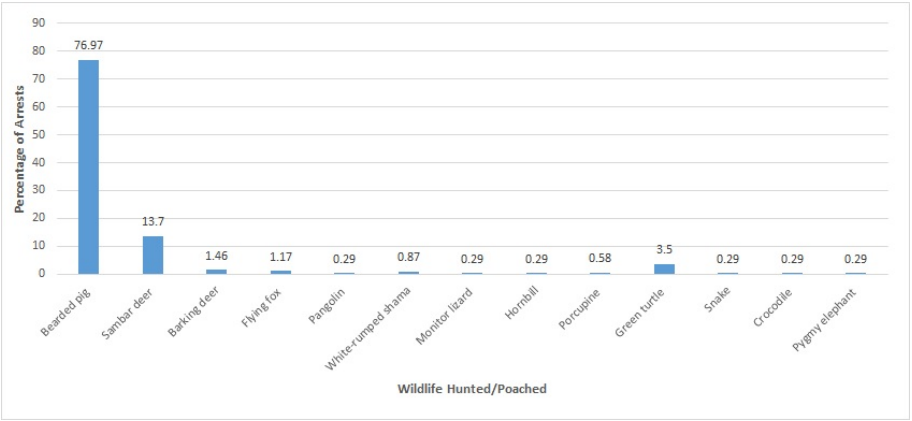

Figure 9. Wildlife species hunted in Sabah.

Hunting Areas in Sabah

The conceptual map shows that there are three areas where the respondents hunt (areas marked in dashed red). These are their own land or garden, the forest and the oil palm plantation (**Figure 10**). The analysis shows that the theme "areas" has 10 hits in the data sets, indicating that the respondents mainly hunt in the garden areas or their own land and the oil palm plantation. The theme "border" also has 10 hits, indicating that hunting wildlife, especially bearded pigs, is easy in the border areas between the forest and the oil palm plantation. The majority of respondents indicated that there are many footprints and tracks of bearded pigs in the border areas compared to other places, with the theme "footprint" recording 3 hits. The theme "protected" and "animals" with 11 and 3 hits respectively means that the respondents hunt in a protected area.

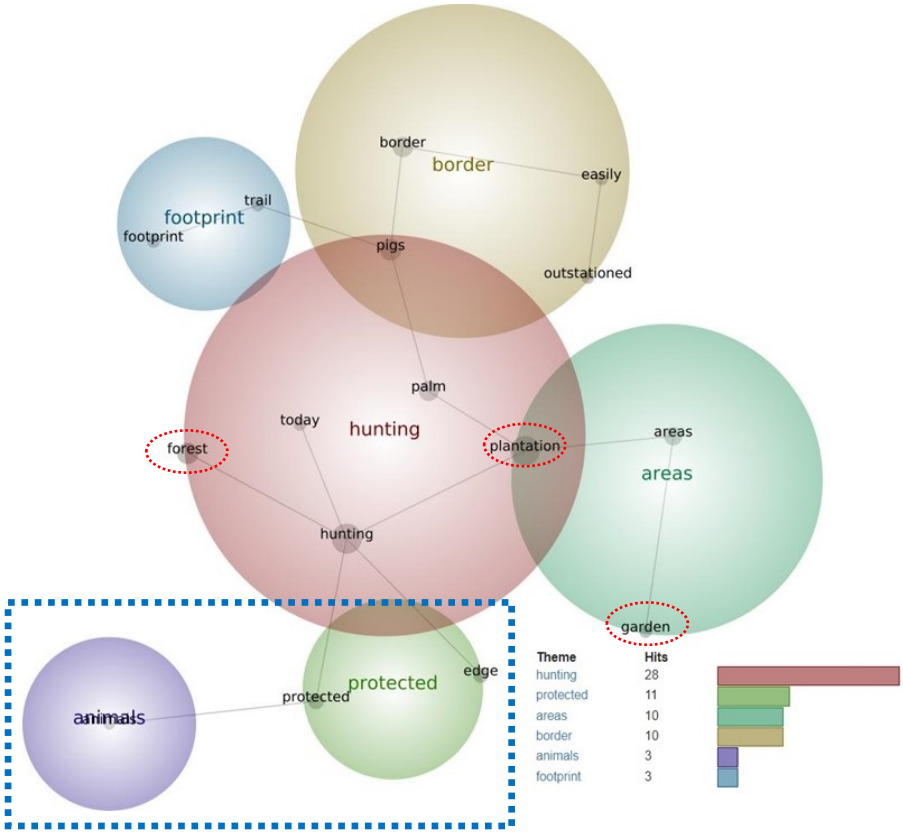

Figure 10. Conceptual map on hunting preferences.

Discussion

Sabah's communities engage in hunting activities in the vicinity of their settlements. This behaviour can be attributed to factors such as easy accessibility resulting from past logging activities or the presence of diverse wildlife. Predominantly, wildlife is targeted in plantation areas, where the conversion of land into agricultural estates has created favourable conditions for hunters. Notably, many oil palm plantations are strategically situated in proximity to wildlife sanctuaries, nature reserves, protected areas, and forest reserves, especially when compared to regions on the west coast.

An intriguing demographic trend emerges when considering the age groups of hunters, with individuals aged between 25 and 54 exhibiting the highest concentration (as depicted in **Figure 8**). This observation suggests that age plays a pivotal role in hunting effectiveness and resource knowledge. Surprisingly, age exhibits a statistically significant but negative correlation in this context, indicating that individuals under 24 tend to name more species than those over 54—a pattern not consistently validated by other research. Conversely, another statistically significant variable displays a positive correlation with the number of reported species, namely, the age of the hunter. This finding aligns with existing literature, which asserts that older hunters tend to be more effective, possess a deeper understanding of taxonomic diversity, and master a broader range of hunting techniques (Barbosa et al., 2020; Nunes et al., 2020; Silva Neto et al., 2017; Batista Santos et al., 2020; Francesconi et al., 2018). However, it is worth noting that alternative viewpoints are presented by Barbosa de Lima et al. (2021) and da Silva Nogueira Santos et al. (2020), both of whom found no statistical correlation between age and the number of species hunted.

Memory, a distinctive process within socioecological systems, sheds light on the negative correlation between age and the number of species referenced. Often overlooked, memory plays a pivotal role in shaping human interactions with nature, preserving vital information crucial for survival and reproduction. Within this context, memory profoundly influences an individual's comprehension of their local ecology, peaking during adulthood and middle age while either remaining stable or diminishing in old age (Albuquerque et al., 2020).

Research by Oliviera et al. (2019) elucidates that when individuals recall knowledge-related memories, they tend to prioritize recent experiences. This perspective aligns seamlessly with the study's context, as older participants engage in hunting less frequently compared to their more active counterparts, consequently recalling fewer game species. Consequently, a positive relationship emerges between the variable of hunting frequency and the number of mentioned species, corroborating the theory that individuals are more likely to lose their environmental knowledge if they are not actively engaged in it (Silva Neto et al., 2017).

Drawing from data provided by the Sabah Wildlife Department, it appears that the bearded pig is the most commonly encountered animal, with individuals often found in possession of its products. Nevertheless, it's imperative to acknowledge that the available data may not directly reflect the frequency of bearded pig hunting, rendering it challenging to definitively assert that they are

indeed the most frequently targeted species. The introduction of the concept of EFS adds a new layer of awareness concerning hunting and poaching among Sabah's local communities. Embracing a more holistic perspective could prompt stakeholders to prioritize wildlife conservation efforts within Sabah's forests.

In village settings, a notable trend emerged where a greater number of respondents consumed bearded pig meat on a weekly basis compared to other sources of animal protein, with domestic chicken being the sole exception. Additionally, hunting bearded pigs was recognized as a vital means of pest control to mitigate disruptions caused by bearded pigs in oil palm plantations, encompassing both industrial and smallholder operations, as well as in subsistence crops like cassava and durian.

While subsistence hunting is extensively documented, instances where market demand serves as the primary motivation have been highlighted (Silva Santos et al., 2019). Within the scope of this study, hunters identified the primary reason for engaging in wildlife hunting as sustenance, followed by market demand and cultural factors (**see Figure 8**). The sustenance aspect pertains to the pivotal role of wildlife as a source of protein and nourishment for the communities involved. Market demand, on the other hand, denotes the commercial markets' desire for wildlife products, including restaurants and the exotic meat trade, where certain wildlife species are esteemed for their flavour or perceived medicinal attributes. In the realm of hunting, provisioning benefits serve as potent incentives, as they directly contribute to the sustenance and well-being of individuals or communities (Gill et al., 2012; Luz et al., 2015; Wilkie et al., 2005; Fa et al., 2009; Godoy et al., 2010; Brashares et al., 2011; Luz et al., 2015).

The hunting motives observed among local communities in select areas of Sabah closely align with the findings of Bennett et al. (2000) in Sabah and Sarawak, as well as Kurz et al. (2021), where meat procurement emerged as the primary motivation for wildlife hunting, particularly in the case of bearded pigs. It is probable that meat procurement has historically been the chief driving force for indigenous communities that have engaged in hunting across Borneo for millennia. This supposition is supported by archaeological discoveries featuring bearded pig bones at consumption sites (Medway, 1964). Confirming this perspective, Kurz et al. (2021) revealed that trackers widely indicated the current high cost of bearded pork, typically ranging from MYR 10-15/kg, in stark contrast to the advertised cost of approximately MYR 3-5/kg a decade ago (and significantly lower when adjusted for inflation). Monthly earnings from pig

hunting are reported to reach as high as MYR 5,000 (~USD 1,194) in favourable months, surpassing remuneration levels in the oil palm plantation sector. **Table 2** provides a comparative analysis of the market value of wildlife in the black market as opposed to the monthly income of Sabah's rural communities.

Table 2. Global illegal wildlife trade estimates versus rural income of Sabah.

Wildlife	Black Market Value USD, million, per year	Rural Income USD, annually
Live Animals		8,160
Primates	132	
Birds of prey	5	
Cage birds	11	
Reptiles	38	
Ornamental fish	358	
Animal Products		
Mammal furs	6,623	
Reptile skins	371	
Corals and shells	144	
Natural pearls	76	
Game meat	674	
Reptile meat	4	
Edible snails	102	

Source: van Uhm, 2016 and Department of Statistics Malaysia, 2020.

This phenomenon can be attributed to the findings of Bennett et al. (2000) and Mojiol et al. (2013), who highlight the widespread practice of hunting bearded pigs in various rural areas of Sabah, with bearded pig meat remaining a significant dietary resource for specific communities in the region. This observation is congruent with the research conducted by Kurz et al. (2021), which underscores food acquisition as the most commonly cited motivation for bearded pig hunting, particularly within the Kadazan-Dusun-Murut (KDM) ethnic group in Sabah. Additionally, Kurz et al. (2021) identified other motivational factors driving bearded pig hunting among KDM communities, including for pest control, gift-giving, and recreational pursuits.

The inclusion of market demand as a motivation for hunting in this study implies a market-driven component within hunting practices in Sabah. It suggests that certain hunters engage not only in subsistence hunting but also seek to fulfil the demand for wildlife products in commercial markets (Silva Santos et al., 2019). Furthermore, culture emerges as a motivating factor for hunting in this study. Cultural influences can significantly shape hunting practices, as specific wildlife species may hold cultural significance or be integral to traditional customs and rituals (Kurz et al., 2021). The act of hunting for cultural reasons underscores

the importance of preserving cultural heritage and identity within the community. It is essential to recognize that motivations for hunting can vary significantly from individual to individual and from one community to another, influenced by a complex interplay of socio-economic, cultural, and ecological factors. The motivations elucidated in this study provide valuable insight into the multifaceted nature of hunting practices in Sabah, where the pursuit of sustenance, market demand, and cultural value collectively drive the hunting of bearded pigs and other wildlife species.

The primary areas where respondents engage in hunting—namely, their own land or gardens, the forest, and oil palm plantations—are closely connected to the concept of the "empty forest syndrome" (as depicted in **Figure 10**). In their own land or gardens, respondents target wildlife species that either inhabit or pass through these areas. The motive of pest control emerged prominently among our respondents (Kurz et al., 2021), emphasizing the significant influence of garden cultivation on hunting behaviour (Peres & Palacios, 2007). A notable majority of respondents cited pest control as a key reason for hunting wildlife. Depending on the intensity of hunting pressure and the targeted species, this practice can lead to a decline in wildlife populations within the immediate vicinity. Such localized reductions in wildlife populations contribute to the overall emptiness of the forest ecosystem.

However, hunting within forests can also exert more extensive consequences on wildlife populations. Forests typically harbour diverse species, including mammals, birds, reptiles, and insects. When hunting remains unsustainable or unregulated, it can result in predation and the depletion of wildlife populations (Joppa et al., 2008; Rhett, 2011). This disruption of the ecological balance diminishes biodiversity and further exacerbates the empty forest syndrome. Oil palm plantations, vast agricultural landscapes often replacing natural forests, introduce a unique dimension to this issue. While these plantations do not provide the same level of biodiversity and ecological services as natural forests, they can still support certain adaptable wildlife species (Shah et al., 2019).

Nonetheless, hunting within oil palm plantations can intensify the depletion of already diminished wildlife populations, pushing them closer to extinction in these areas and exacerbating the empty forest syndrome. The act of hunting within these three key domains—own land or gardens, the forest, and oil palm plantations—collectively contributes to the empty forest syndrome by directly diminishing wildlife populations and disrupting the ecological equilibrium within forest ecosystems.

Conclusion

The relationship between hunting for sustenance, market demand, cultural factors, and the emergence of the empty forest syndrome is intricate and interconnected. When hunting primarily serves as a means for securing food, it can inadvertently lead to the depletion of wildlife populations. If hunting remains unregulated and lacks effective enforcement measures, this can result in the overexploitation of target species. Such actions disrupt the delicate ecological equilibrium within the forest ecosystem, potentially culminating in the empty forest syndrome.

Conversely, a robust market demand for wildlife products, such as bushmeat, exotic animal parts, or live animals for the pet trade, can intensify hunting pressure on vulnerable species. This heightened demand can stem from cultural beliefs, traditional medicinal practices, or the desire for luxury and novelty items. Unsustainable hunting practices driven by market demand can yield severe repercussions for wildlife populations, ultimately contributing to the onset of the empty forest syndrome.

Cultural influences also play a pivotal role, as cultural practices and traditions can significantly mould hunting behaviours. When a particular species holds cultural significance or forms an integral part of traditional rituals and ceremonies, it often leads to increased hunting pressure. Cultural norms and beliefs do not always align with conservation principles or sustainable hunting practices. In such scenarios, cultural motivations for hunting can exacerbate the depletion of wildlife populations, potentially paving the way for the empty forest syndrome.

It is essential to emphasize that not all hunting practices or cultural traditions result in the empty forest syndrome. Sustainable hunting practices, guided by stringent regulations and quotas, can enable the responsible utilization of wildlife resources while safeguarding their long-term conservation. Furthermore, communities deeply attached to their natural environment and possessing a strong conservation ethic can actively contribute to the protection and sustainable management of their forests, thereby helping to prevent or mitigate the empty forest syndrome.

Furthermore, it's crucial to acknowledge that hunting within oil palm plantations can exert particularly damaging effects on wildlife populations. Given that these plantations often replace natural forests, they already contribute to the empty

forest syndrome by reducing available habitat for numerous species. When hunting occurs within these oil palm plantations, it can further decimate already depleted wildlife populations, potentially pushing certain species in these areas closer to the brink of extinction. This amplifies the gravity of the empty forest syndrome and underscores the necessity for conservation measures addressing both hunting practices and habitat loss associated with activities like oil palm cultivation.

In summary, the adoption of sustainable hunting practices, effective regulation of wildlife trade, community engagement, and educational initiatives are paramount in combating the empty forest syndrome. Additionally, addressing the ecological impacts of industrial activities, notably oil palm plantations, is vital to mitigate further wildlife population declines and promote habitat conservation, ultimately safeguarding both wildlife populations and the integrity of forest ecosystems.

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Declarations

Ethical Approval

Informed consent was obtained from all subjects involved in this study, and all subjects participating in the study gave their consent to the use of all information and data analysed for the purpose of publication.

Competing interests

The authors declare no potential conflicts of interest concerning the research, authorship, and publication of this article.

Authors' contributions

The authors confirm their contribution to the paper as follows: study conception and design: Fiffy H. S., Nurin S. M. Y., Azniza M. Senthilvel K. S. S. N. and Hussien M.; data collection: Fiffy H. S., Nurin S. M. Y., Arnie H., Maximus L. L. K. F., Julia G. K., Petherine A. J., Mohd. Afifi M. N., Cornelius P., Juliana, A. and Mahadimenakbar M. D.; analysis and interpretation of results: Fiffy H. S., Nurin S. M. Y., Nordiana M. N., Nor Akmar A. A. and Norhuda S.; draft manuscript

preparation: Fiffy H. S. and Nurin S. M. Y. All authors reviewed the results and approved the final version of the manuscript.

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Availability of data and materials
The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Declaration of generative AI and AI-assisted technologies in the writing process
During the preparation of this work, the author(s) used ChatGPT in order to help in generating new ideas and expand on existing ones. The ChatGPT had provide fresh perspectives on a topic and helped overcome the author's block. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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