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Caption: *Cyrtodactylus myintkyawthurai*, endemic to Myanmar. Medium: Water colours on watercolor sheet. © Aakanksha Komanduri

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ARTICLE

Local hunting practices and perceptions regarding the distribution and ecological role of the Large Flying Fox (Chiroptera: Pteropodidae: *Pteropus vampyrus*) in western Sarawak, Malaysian Borneo

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Abstract: Pteropodids such as flying foxes are declining rapidly across their range due to human activities, despite their benefit to humans through ecosystem services. The Large Flying Fox *Pteropus vampyrus* had a wide distribution across Borneo, but is now severely reduced in numbers, and rarely sighted. In order to develop effective conservation and management prescriptions for this species, updated information on its distribution, movement patterns, and the impact of anthropogenic pressure on its survival is crucial. As such, a questionnaire survey was conducted in western Sarawak to determine the occurrence of this species, and the conservation awareness for the species amongst local communities. The survey was conducted at nine sites during November 2018 – March 2019, involving a total of 123 respondents, including hunters (20%) and consumers (35%) of *P. vampyrus*. Respondents reported that *P. vampyrus* appears sporadically around the western tip of Borneo, and around the interior parts of western Sarawak, with more than half (51%) of the reported sightings in the interior occurring at fruit orchards during the fruiting and flowering seasons. Despite hunting and consuming this species, over 60% of the respondents felt that *P. vampyrus* could become an eco-tourism product in their area. Although many respondents viewed flying foxes as pests (47%) or food (52%), there was remarkably high awareness of the ecological roles and conservation needs of this species (76%), suggesting potentially strong support for flying fox conservation at the local level. Challenges associated with the enforcement of wildlife law in the remote parts of Sarawak need to be addressed, alongside strategic education and awareness efforts, which are all vital to achieve successful conservation and protection of this ecologically important species.

Keywords: Bats, conservation, indigenous, local communities, Malaysia, Palaeotropics, wildlife.

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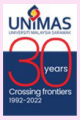

INTRODUCTION

Despite providing crucial ecosystem services such as seed dispersal and pollination, populations of Old World fruit bats (Chiroptera: Pteropodidae) are rapidly decreasing across their range due to multiple anthropogenic threats (Fujita & Tuttle 1991; Kunz et al. 2011; Aziz et al. 2021). In Southeast Asia, pteropodids have been well-documented as critical pollinators of the economically important durian (*Durio zibethinus*) fruit, which is worth millions of USD to the economies of producing countries (Bumrungsri et al. 2009; Aziz et al. 2017a: Sheherazade et al. 2019). Despite these benefits, pteropodid bats, especially flying foxes (*Pteropus* spp., *Acerodon* spp., *Desmalopex* spp.), have been widely hunted for food and medicinal purposes in many Asia-Pacific cultures (Mildenstein et al. 2016; Low et al. 2021). Additionally, they are also persecuted and culled as fruit crop pests throughout their range (Aziz et al. 2016).

Pteropus vampyrus, the Large Flying Fox, is distributed throughout much of mainland and insular Southeast Asia (Bates et al. 2008). It is the largest bat found on Borneo, and is also the only known flying fox species found in Sarawak (Aziz et al. 2019). Like other pteropodids, this species plays a critical role in pollination and seed dispersal (Gould 1997; Gumal 2001; Mohd-Azlan et al. 2001; McConkey & Drake 2006; Aziz et al. 2017a). Although this species is under threat and legally protected in Sarawak under the Sarawak Wild Life Protection Ordinance 1998, it is listed as only Near Threatened on the global IUCN Red List, despite a decreasing trend noted for its global population (Bates et al. 2008) which is still being hunted/traded as a delicacy and for its perceived medicinal qualities (Fujita & Tuttle 1991; Mildenstein et al. 2016; Low et al. 2021). In general, most communities across Borneo share the belief that consumption of flying fox meat and liver is a cure for general malaise and respiratory ailments (Fujita 1988; Mohd-Azlan & Fauzi 2006; Low et al. 2021).

Like many other fruit bats in Southeast Asia, *P. vampyrus* is at high risk of becoming extinct by the end of the century, not only due to intense hunting pressure (Epstein et al. 2009) but also due to high deforestation rates across the region (Lane et al. 2006). In Sarawak, the last state-wide survey on *P. vampyrus* roosting sites was conducted during 1997–2000, and only five maternity colonies were found: in Patok Island, Sarang, Loagan Bunut, Limbang, and Sedilu (Gumal 2001). Therefore, for the conservation management of this species in Sarawak, more recent data on its distribution and status are urgently needed.

In addition to its outdated distribution and population data in Sarawak, little is known about local community perceptions, knowledge, and awareness of *P. vampyrus*, as no prior studies have been conducted on these aspects. Hence, as community-based wildlife surveys are known to be an effective tool to help elucidate the distribution of wildlife species and their interactions with humans (Fitzgibbon & Jones 2006), we employed this approach in western Sarawak to obtain information on *P. vampyrus,* namely: (i) the current distribution patterns; (ii) hunting and consumption by local communities; and (iii) their perception of the ecological role of this species.

MATERIALS AND METHODS

Study Site

Sarawak, Malaysia (1.553278°, 110.359213°; Figure 1) is located in northwestern Borneo and has a population of ~2.8 million (Department of Statistics Malaysia 2019). Sixty-two percent of the state is still forested, with peat swamp forests dominating the coastal lowlands to hill dipterocarp forests towards the interior, and montane forests in the interior highlands (Forest Department of Sarawak 2020). The climate is uniformly humid and warm throughout the year, with the north-east monsoon occurring during November–February, and the south-west monsoon occurring during June–October (Hazebroek & Abang Kashim 2000).

Approximately 29% of Sarawak's population belongs to the Iban indigenous group making up the majority, followed by 23% of ethnic Malays, Chinese (22%), Bidayuh (8%), Melanau (5%), other indigenous groups (6%), other non-indigenous groups (1%), and lastly, non-Malaysian citizens make up 6% of the population (Department of Statistics Malaysia 2019). Christianity is the most professed religion in Sarawak (43%), followed by Islam (32%), Buddhism (13%), Confucianism, Taoism, and Tribal religions (6%), Hinduism (0.2%), others (1%), no religion (3%), and unknown religion (2%) (Department of Statistics Malaysia 2010). Ethnic Malays do not hunt bats for consumption due to Islamic dietary restrictions, but may still kill fruit bats for fruit crop protection (Aziz et al. 2017b), or for sale to non-Muslims (Low et al. 2021).

Our survey was conducted at nine sites in western Sarawak: Sri Aman, Lubok Antu, Lubok Subong, Maludam, Sebuyau, Sematan, Simunjan, Serian, and Tanjung Manis (Figure 1). These locations were selected based on previous information on markets where flying foxes were sold (Gumal et al. 1997), and our own preliminary enquiries regarding popular sites for bushmeat trading.

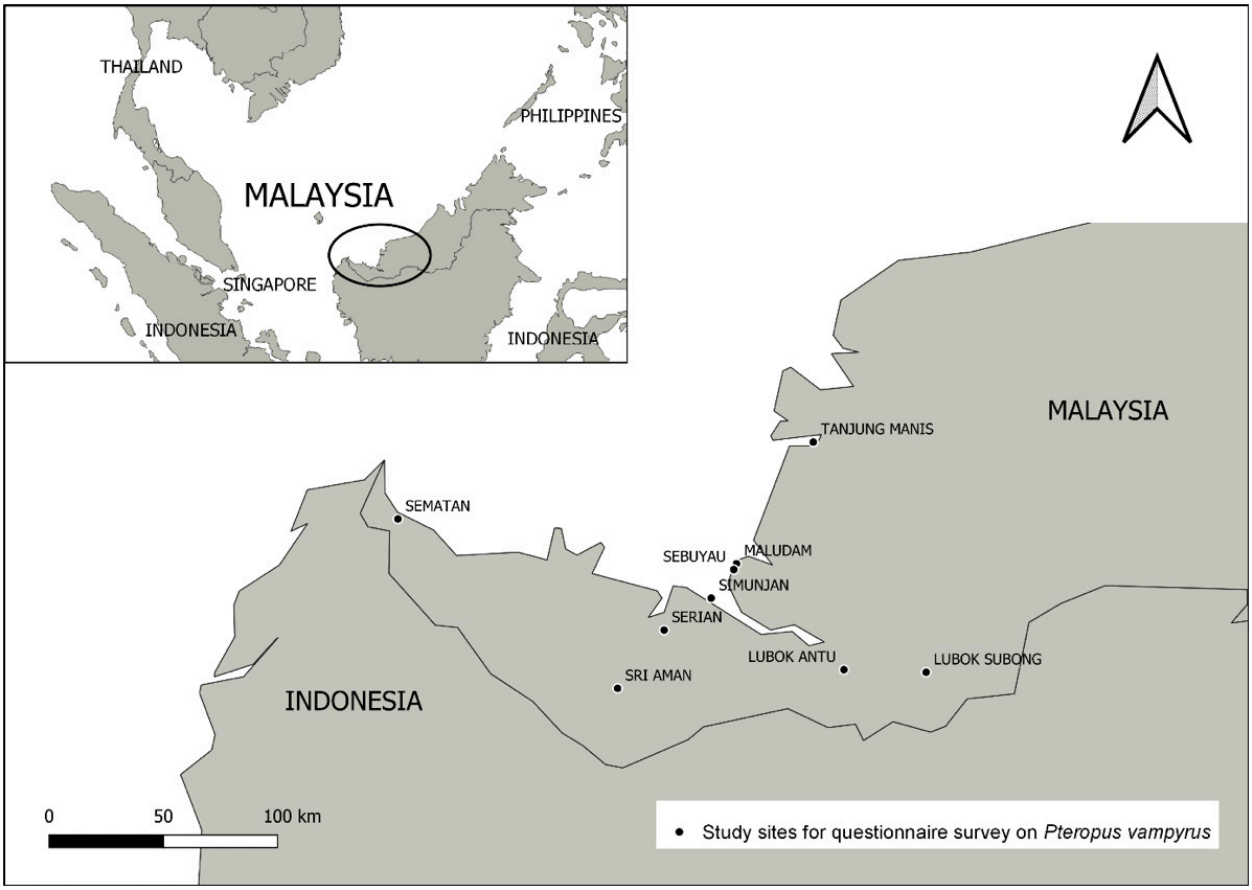

Figure 1. Study sites in western Sarawak, Malaysian Borneo (Generated by QGIS 3.6).

Study Species

Pteropus vampyrus is one of the largest bats in the world, weighing up to 1.1 kg and with a wingspan of up to 1.5 m (Image 1). It is listed as 'Near Threatened' on the IUCN Red List (Bates et al. 2008), although there appears to be a sharp population decline in Sarawak (Gumal 2001), and in Peninsular Malaysia due to over-harvesting (Epstein et al. 2009). It is listed as Endangered on the Red List of Mammals for Peninsular Malaysia (PERHILITAN 2017). In Sarawak all bat species including *P. vampyrus* are protected under the Wild Life Protection Ordinance 1998, and hunting is not allowed.

Currently**,** little is known about the population and distribution of *P. vampyrus* in Sarawak, as the last state-wide survey was conducted by Gumal (2001) around two decades ago. That survey found that all five of the reported roosts were located in remote and inaccessible areas such as peat swamps and mangroves.

Data Collection

A questionnaire survey (Table 1) consisting of open-ended and closed questions was designed to obtain data on (1) local community socio-demographics; (2) *P. vampyrus* sightings; (3) consumption and hunting of this species by local communities*;* and (4) local community perceptions of the species. A pilot survey was first conducted on 35 individuals comprising members of the general public and students from Universiti Malaysia Sarawak (UNIMAS) in Kota Samarahan.

The questionnaire survey was conducted during November 2018–March 2019, at local markets in the nine study sites. Respondents were surveyed opportunistically using snowball sampling, starting first with a durian vendor who then recommended other people known to hunt or consume flying foxes (Image 2). Respondents were then selected based on preliminary questioning to ascertain whether they were: (i) familiar with *P. vampyrus*; (ii) hunters; or (iii) consumers of the species.

Before the questionnaire commenced the respondents were first asked to identify *P. vampyrus* by displaying an image of the species with a corresponding measurement scale to convey size, and this was used to set the benchmark for the reliability of the respondents'

Table 1. Questionnaire used for survey on community knowledge, perceptions and interactions with *Pteropus vampyrus* (referred to as simply 'flying fox' in local languages during interviews) in western Sarawak.

QUESTIONNAIRE
Part 1. Flying Fox Sightings
i) Have you ever seen a flying fox? Yes No
ii) If yes, what type of habitat did you last see a flying fox in? a) Mangrove swamp forest b) Peat swamp forest c) Secondary forest d) Primary forest e) Gardens or field f) River g) Market
iii) If yes, when did the last time you saw a flying fox? a) January–March b) April–June c) July–September d) October–December
iv) Has anyone in the area you reside been hunting flying foxes? Yes No
v) If yes, how many hunters are there? a) 1–3 individuals b) 3–6 individuals c) 6–9 individuals d) 9–12 individuals e) >12 individuals
vi) If yes, how long have you been hunting? a) weeks b) months c) years
Part 2. Flying Fox Hunters and Consumers
(i) Have you ever hunted or killed flying foxes before? Yes No
(ii) If yes, for what purpose? a) Food b) Traditional medicine c) Pest control d) Source of income
(iii) If yes, where did you hunt or kill flying foxes? a) Swamp area b) Coastal area c) Forest edge d) Forest interior e) Fruit orchard f) Rubber plantation g) Oil palm plantation
(iv) If yes, how did you get to the hunting area? a) Boat b) Car c) Lorry d) Motorcycle e) On foot
(v) What method do you use to hunt flying foxes? a) Net b) Shotgun c) Traditional method (stringing up hooks on fishing line) d) Cutting down roost tree
(vi) At what time do you usually hunt flying foxes? a) 0600 hrs–0900 hrs b) 0900 hrs–1200 hrs c) 1200 hrs–1500 hrs d) 1500 hrs–1800hrs e) 1800 hrs–2100 hrs f) 2100 hrs–0000 hrs g) 0000hrs–0300 hrs h) 0300 hrs–0600 hrs
(vii) On average, how much is the total cost of a flying fox hunting trip? a) <RM50 b) RM51–RM100 c) RM101–RM300 d) RM301–RM600 e) RM601–RM1000 f) >RM1000
(viii) On average, how many flying foxes do you catch per hunting trip? a) <10 individuals b) 11–20 individuals c) 21–40 individuals d) 41–60 individuals e) 61–80 individuals f) >80 individuals
(ix) On average, what is the market price of flying fox meat? a) RM10–RM15 b) RM16–RM30 c) RM31–RM60 d) RM61–RM80 e) RM81–RM100 f) RM100–RM120
(x) What motivates you to hunt?
(xi) Do you get moral support from your local community to hunt flying foxes? Yes No
(xii) How does the local community in the area you reside feel about you hunting flying foxes?
(xiii) Have you ever consumed or cooked flying fox meat? Yes No
(xiv) If yes, how did you process the meat?
(xv) If yes, what other ingredients did you mix with the flying fox meat?
(xvi) Which parts of a flying fox are used as traditional medicine?

Part 3. Local perceptions towards flying foxes					
Statements	**Strongly Agree**	**Agree**	**Not Sure**	**Disagree**	**Strongly Disagree**
Occasionally consuming flying fox meat is fine.					
Consuming flying fox meat can cure respiratory ailments.					
Flying foxes can damage agricultural crops.					
Hunting & selling flying foxes can damage their populations in the long term.					
Deforestation causes more negative impacts on flying fox populations compared to hunting activities.					
Sarawak's wildlife law has been effective in protecting flying foxes.					
Flying foxes can be an important aspect in promoting tourism.					
Flying foxes play an important role in dispersing seeds.					
Awareness programs in schools will help to increase efforts to conserve flying foxes.					
Besides the Sarawak wildlife law, flying foxes also need to be protected at the village level.					
There are traditional beliefs or taboos related to flying foxes.					

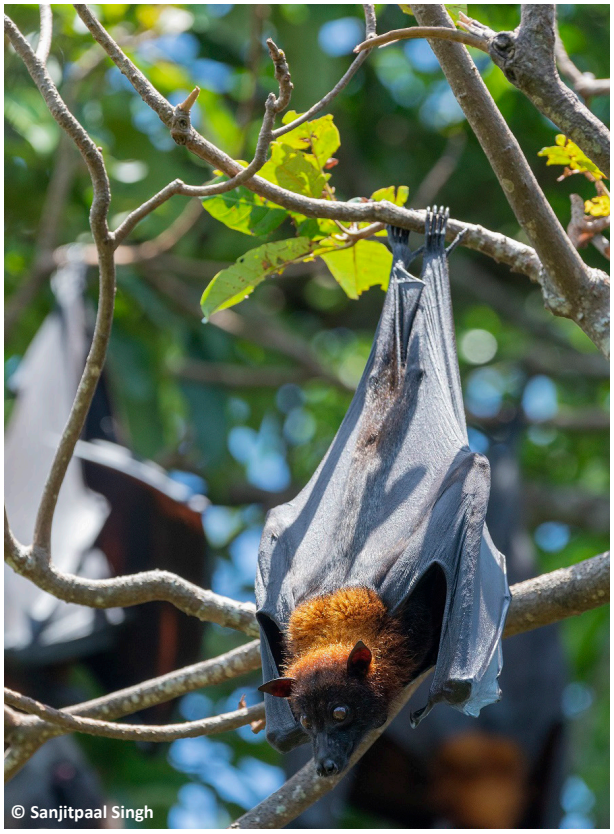

Image 1. *Pteropus vampyrus* roosting in Peninsular Malaysia.

Image 2. Flying fox meat in Sarawak is considered a delicacy and perceived to have medicinal qualities.

answers. As flying foxes (*Pteropus* spp., *Acerodon* spp., *Desmalopex* spp.) often have specific local names to distinguish them from all other bats (e.g., Tanalgo et al. 2016; Low et al. 2021), wherever applicable we used the relevant local name according to a respondent's ethnicity (Supplementary Table 1).

The questionnaire was administered by three female enumerators, who were all Malaysian students at Universiti Malaysia Sarawak (UNIMAS), via face-to-face interviews conducted in Iban, Melanau, and standard colloquial Malay. Enumerators targeted respondents that were adults, i.e., aged 18 and above. Prior to commencing an interview, the student enumerators first started with an introduction of their background, i.e., UNIMAS students conducting research on flying foxes, and also showed their university student identification cards when introducing themselves. Each question was read aloud by the enumerator to the respondent, and

the respondent's answers were then recorded using the Open Data Kit Collection (ODK) version 1.18.0 application.

This study complies with the research ethics criteria designated by Universiti Malaysia Sarawak (UNIMAS), conducted under research permits NPW.907.4.4(JLD.14)-71 and WL043/2017. Before initiating any interview, the survey purpose and goals were explained first to the respondent, and free, prior, & informed consent (FPIC) was obtained. Respondent identities were kept anonymous, and they were informed of the confidentiality of their identity and information shared. The respondents were also informed in advance that they have the right to choose not to continue with the interview at any time during the process should they feel uncomfortable.

RESULTS

Out of 200 people approached, 123 (40 women and 83 men; Supplementary Table 2) responded. Most of the 38.5% of people who declined to be interviewed claimed not to have any knowledge on the topic, but some appeared to be intimidated. The biggest group (43%) of respondents was those above 55 years old (n= 53). The Iban ethnic group comprised half of all respondents, and 60% of respondents professed Christianity as their religion. A large majority (86%) resided in rural areas, with 72% having received some form of formal education (i.e., school or university), and 37% having received an education beyond primary level (i.e., >12 years old).

Sixty-one percent of respondents were self-employed, owning small businesses such as restaurants, food stalls or wet market stalls. Twenty-one percent were unemployed retirees from either the government or private sector. Sixty-nine percent had an income of less than MYR (Malaysian ringgit) 900 (~USD 213) a month, with their livelihoods dependent on the selling of forest products at markets.

Flying fox sightings

The majority (91%) of respondents were familiar with *Pteropus vampyrus*, with 51% of respondents stating that flying foxes were most commonly found during the fruiting season. Hunters reported that Engkelili, Lingga, Entumpi, Engkalong, Roban, Kampung Temiang, and Simunjan are flying fox hotspots. Seventy-nine percent of respondents stated that the highest occurrence of flying fox sightings was in July–December, with July–September being the most likely time to encounter flying foxes (Figure 2). Fifty-nine percent of respondents stated that flying foxes forage on langsat (*Lansium parasiticum*), rambutan (*Nephelium lappaceum*), and *Syzygium cephalophorum* fruits, and 51% of respondents stated that flying foxes forage on durian (*Durio* spp.) flowers.

Fifty-two percent of respondents stated that flying foxes can be seen in fruit orchards. The species was also reported as being sighted near secondary and primary forests (Figure 3). Three respondents had sighted dead flying foxes being sold at the Pasar Tamu Sri Aman, Pasar Serian, and Pasar Lubok Antu markets. An additional 10% of respondents had sighted flying fox roosting sites,

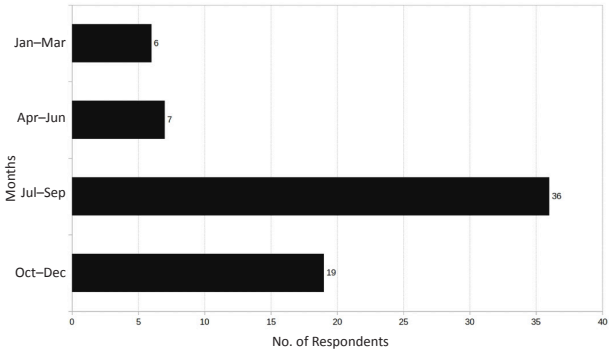

Figure 2. Time of year when *P. vampyrus* is most likely to be encountered according to respondents (n= 68) in western Sarawak, Malaysian Borneo.

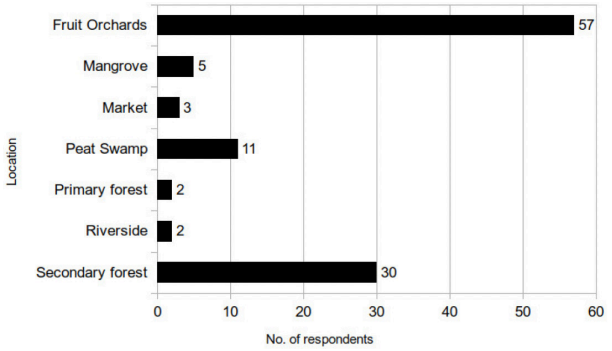

Figure 3. Habitat types where *P. vampyrus* has been sighted by respondents (n= 110) in western Sarawak, Malaysian Borneo.

Table 2. The reported price of *P. vampyrus* meat at the time of last purchase by 23 respondents in western Sarawak, Malaysian Borneo.

Price range per bat (MYR)	Number of Respondents	%
10–15	7	30
16–30	15	65
31–60	1	4

having seen the bats flying near mangrove and peat swamp forests in the Simunjan and Tanjung Manis areas around 20–30 years ago.

Hunting and consumption of flying foxes

Twenty-one percent (n= 51) of respondents were flying fox hunters, but 53% of these hunters no longer hunted due to the difficulty of locating roosting sites (Supplementary Table 3). A slight majority (58%) of hunters hunted flying foxes for food, while 35% hunted because flying foxes were viewed as pests, and the remainder hunted flying foxes for supplementary income. According to 15 respondents, price per bat ranged from MYR 16–30 (approximately USD 4–7) (Table 2), and even the lowest price of MYR 10 (approximately USD 2.50) was higher than the local price of chicken, which is MYR 8.50/kg (approximately USD 2/kg).

Forty-one percent of hunters preferred hunting in groups of 3–6 people, and 83% of hunters preferred hunting from dusk till midnight. Seventy-five percent of hunters stated that they hunted in fruit orchards. The most common hunting technique employed by the hunters was shooting the flying foxes with shotguns (46%), followed by traditional hunting techniques involving hooks and strings (29%). Many (67%) of the hunters reported that they only managed to hunt less than 10 individuals per hunting trip.

Thirty-five percent of respondents had consumed flying foxes before, while the others (65%) who had not, cited a variety of reasons including religious reasons (46%), fear (38%), and a dislike of the smell of flying foxes (16%). Those that consumed flying foxes stated that soups and stews with an assortment of herbs and spices were the main methods (86%) of cooking, whereby the fur is first removed by burning, and the animal is then skinned to eliminate its odour. The carcass (Image 2 is cleansed with either lime juice or tamarind juice to further remove any remaining odour, and the meat is then marinated with lemongrass, ginger, chilli, pepper, garlic, and onion. Some respondents claimed that the wings are a delicacy, with a chewy texture resembling the black fungus (*Auricularia polytricha*).

Our survey also revealed that people who bought flying fox meat preferred it to be as fresh as possible. To meet this demand, hunters string fine-meshed nets over waterways, or above/around fruit trees near their village. This method is the preferred method of Iban hunters, as it is an efficient and common method for capturing live bats to meet consumer demand for freshness. Live flying foxes trapped in the nets are harvested in the morning and brought to the market immediately to be sold, and only killed once a sale is made. Flying foxes caught by nets are sold at higher prices compared to those that are shot, as shot bats have wounds on their wings, and

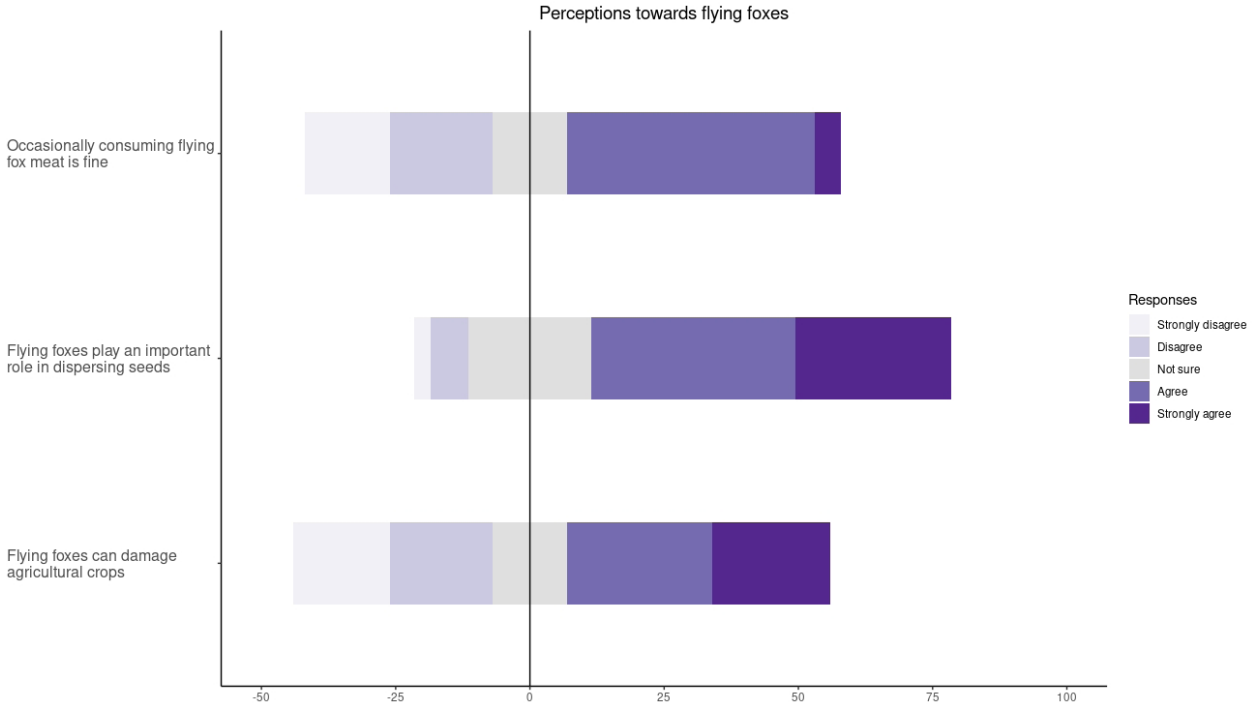

Figure 4. Perceptions of local communities towards flying foxes (*P. vampyrus*) in western Sarawak, Malaysian Borneo (n= 120).

those that survive do not stay alive for long – thereby less desirable to consumers. However, another hunting method, considered to be more traditional, involves stringing up a fishing line tied with large fishing hooks above the canopy of a fruiting or flowering tree. As the bats get caught easily on the hooks during flight, this is sometimes used due to its ffectiveness and low cost, with one hunter reporting that as many as 30 bats could be caught from just one tree in one night using this method.

Perceptions of local communities towards flying foxes

Fifty-one percent of respondents felt that the current consumption of flying fox meat does not negatively impact flying fox populations (Figure 4), although 71% of respondents conceded that hunting and selling of flying fox meat would become a threat in the long term. Sixty-nine percent of respondents believed that deforestation is a bigger threat to flying fox populations compared to hunting. Slightly more than half (55%) of the respondents were unsure of the claimed medicinal properties of flying foxes. For perceptions of flying foxes as agricultural pests, respondents were divided between those perceiving flying foxes to be pests (48%), and those who did not (38%), with the rest being unsure (14%) (Figure 4). Despite this, 66% of the respondents were aware of the role played by flying foxes in seed dispersal (Figure 4). To prevent fruit losses, growers typically set up nets around their fruit trees so that the bats are trapped before reaching the fruits. The nets are often set up in the afternoon, and taken down late at night (0000–0300 h) or the following morning.

Half of all respondents felt that flying foxes could be used to develop local eco-tourism, and 51% of respondents agreed to participate in school events such as talks or seminars conducted by the relevant conservation authorities on the importance of flying foxes. Forty-four percent of respondents believed that flying fox conservation requires management at the village or local community level in order to prevent excessive hunting. Lastly, 39% of respondents felt that the Sarawak Wild Life Ordinance 1998, which makes it illegal to hunt, capture, sell, import or export bats, is ineffective at conserving flying foxes.

DISCUSSION

Our survey has provided important and novel data on the opinion and perceptions of local communities regarding *Pteropus vampyrus* in western Sarawak. To our knowledge, this is the first attempt to collect empirical data on the knowledge and opinions of people in Malaysian Borneo regarding this species. Our study confirmed that hunting and trade of *P. vampyrus* still occurs despite the decline in sightings, and the implementation of legal protection for this species – partly due to cultural beliefs and practices, and partly due to perceptions or experiences of flying foxes as orchard pests. Indeed, the highest occurrence of *P. vampyrus* sightings now coincides with the durian flowering season in Sarawak, and the fruiting seasons of langsat, rambutan, and *Syzygium cephalophorum.* Similar trends in hunting pressure, trade and drivers were reported from Peninsular Malaysia, whereby it was predicted that legal hunting levels alone would lead to species extinction anytime between 6–81 years (Fujita 1988; Epstein et al. 2009; Cantlay et al. 2017).

Trends in hunting and trade

While the scale and intensity of flying fox hunting in western Sarawak do not seem as severe as that previously reported for Kalimantan (Indonesian Borneo; Struebig et al. 2007; Harrison et al. 2011) and Sulawesi (Sheherazade & Tsang 2015), we believe this is likely because intense hunting pressure in the past has already caused drastic population reductions in Sarawak, pushing the species to more remote/inaccessible areas, and rendering it increasingly rare. The beliefs and practices reported in our study support those of other studies across Southeast Asia (Low et al. 2021).

Concurrently, this study also yielded qualitative details that helped to supplement empirical data. For example, during this survey we found that flying fox meat was not commonly seen in markets, but respondents reported it as being easily acquired at the Serian Wet Market. We did find *P. vampyrus* being sold openly at Pasar Tamu Sri Aman, despite hunting and selling of bats being illegal. A stall owner even commented that she could sell as many as 10–15 flying foxes in one single sale. Such information corroborates earlier surveys of wildlife meat availability by TRAFFIC Southeast Asia, that found flying fox meat still available for purchase at certain markets, restaurants and roadside stalls across Sarawak (K. Krishnasamy pers. comm.; Cantlay et al. 2017). This explains why the majority of our respondents felt that legal protection of *P. vampyrus* has not deterred or reduced hunting activity, as there was perceived to be a clear lack of enforcement.

One reason *P. vampyrus* is a highly valued wild meat amongst locals is the belief that it is a remedy for a variety of ailments and diseases, such as asthma, kidney ailments, gynaecological problems, and lung ailments

(Mildenstein et al. 2016; Low et al. 2021). Flying fox liver and bile are also believed to cure asthma. One respondent even claimed that an alcoholic drink made by soaking an infant flying fox in 'langkau' (a particularly potent, locally brewed rice spirit) for a few weeks is an effective cure for asthma if consumed daily. Due to Islamic dietary restrictions, all Muslim respondents stated that it is forbidden for them to consume flying foxes. However, in Sebuyau, one Muslim respondent claimed that it is permissible to consume flying fox if this is done with the intent of curing illnesses, and not to consume it as a delicacy. This suggests that the perceived benefits of flying fox meat, which appears to be a widespread belief across their entire regional distribution (Mildenstein et al. 2016; Low et al. 2021), might be used by some as justification to override religious restrictions or aversions. Indeed, Harrison et al. (2011) reported similar attitudes in Indonesian Borneo, and cautioned that if this widely-held belief regarding health benefits is left unaddressed it would likely cause unsustainable hunting of flying foxes to continue. There is an urgent need to address this belief and practice by conducting community outreach and education for raising awareness, but also to implement targeted intervention strategies that leverage on social psychology approaches for incentivising behavioural change (Kingston 2016; St. John et al. 2018).

Worryingly, unlike in Indonesian Borneo (Harrison et al. 2011), more than half of the respondents did not feel that consumption of flying foxes had a negative impact on flying fox populations. The reason given was the belief that flying foxes breed rapidly, and therefore local hunting would not severely reduce populations, especially since hunting only occurs during the flowering and fruiting seasons. Indeed, almost 70% of the respondents stated that deforestation is a bigger threat due to it being the direct cause of flying fox habitat loss. Scientific research has shown that flying foxes actually have long lifespans and slow reproductive rates, so their populations would take a long time to recover from hunting pressure (Mildenstein et al. 2016). While *Pteropus* flying foxes are easily able to persist in human-dominated areas with sufficient food resources (e.g., Tait et al. 2014; Aziz et al. 2017b), this proximity can render them more accessible and vulnerable to hunters (Chaiyes et al. 2017; Aziz et al. 2021). Also, low abundance of flying foxes can negatively affect their ecological roles, such as seed dispersal in forest ecosystems, long before these populations actually become extinct (McConkey & Drake 2006; Luskin 2010). Therefore, we concur with Harrison et al. (2011) that overhunting remains the biggest threat to this species, and there is an urgent need to communicate such implications of intense or uncontrolled hunting pressure to local communities. Obtaining empirical long-term data on the hunting of flying foxes, and on the ecosystem services they provide, is necessary to ascertain whether current offtake levels are sustainable or not – not just in terms of population numbers, but also in terms of their ecological roles and the wider impact they have on ecosystem health.

Negative interactions due to crop-raiding

Loss (whether real or perceived) of fruits and flowers is clearly a major source of conflict between local fruit growers and flying foxes, and is also a factor driving the hunting of *P. vampyrus* in western Sarawak. Fruit growers stated that economic loss is their main motivation for killing *P. vampyrus*, as it is believed that eradication of this species can prevent such loss. Fruit growers at Pasar Tamu Sri Aman and Pasar Tani Lubok Antu even admitted to doing so despite stating that flying foxes foraging on their fruit trees would help disperse seeds to other areas. Flying foxes were still regarded as fruit pests even amongst fruit growers who acknowledged the bats' role as durian pollinators. This suggests that knowledge of flying fox ecosystem services alone is not enough to prevent killings, and therefore education and awareness-raising must be complemented by enforcement of regulations (e.g., see review by Aziz et al. 2016). Efforts are clearly needed to investigate and quantify fruit/flower losses attributed to *P. vampyrus*, and to trial non-lethal mitigation methods for protecting crops without killing or harming bats. These can be done following some of the potential methods reviewed and summarised by Aziz et al. (2016), but more recent studies have also been conducted for the Madagascan Flying Fox *P. rufus* and the Mauritian Flying Fox *P. niger*, whereby fruit loss from flying foxes was found to be minimal, and the use of organic deterrents, plastic flags, bells, and nylon net bags were found to be effective at reducing feeding in cultivated fruit trees (Raharimihaja et al. 2016; Oleksy et al. 2018; Tollington et al. 2019) .

Support for flying fox conservation

Finally, our survey uncovered some encouraging attitudes towards *P. vampyrus*: even though many respondents viewed flying foxes as pests and/or food, ecological and conservation awareness were relatively high, and there was grassroots-level support among some communities. Slightly more than half of our respondents, comprising hunters, consumers, and fruit growers, were willing to cooperate with wildlife agencies to protect *P.*

vampyrus at the village level to prevent overhunting, as they still perceived flying foxes to be important for seed dispersal or tourism. The same number also agreed to participate in school events aimed at conserving flying foxes, as they believed these events are important for educating the younger generation on the importance of biodiversity conservation, and the ecosystem services provided by flying foxes. When asked further, these respondents mentioned that they were willing to attend conservation education programmes for communities in rural areas, such as talks or seminars on flying foxes. Those that strongly disagreed to participate in awareness programs stated that they didn't see the point of such efforts due to the fact that *P. vampyrus* numbers are now too low – suggesting that further efforts are needed to convince them that appropriate conservation interventions can indeed be effective. However, those that were unsure about participating said that they felt so because they were still unsure about the importance of flying foxes. This group of people clearly needs to be targeted as a priority audience for awareness and education campaigns.

Our results suggest that there is some support for flying fox conservation amongst local communities, as almost half of the respondents felt that *P. vampyrus* can be an iconic species for ecotourism, particularly if there are protected areas to safeguard populations. Those who disagreed provided mixed reasons; some stated that population numbers are so greatly reduced that it would be difficult to view the species in the wild, whereas others feared or viewed flying foxes as gruesome, and therefore did not see any ecotourism potential. Given that this species was traditionally respected and even revered in local Malaysian cultures (Low et al. 2021), it is unclear where such negative perceptions come from. As noted from other countries, properly managed and regulated bat tourism can indeed serve as an effective strategy for bat conservation (Pennisi et al. 2004; Aziz et al. 2017b; Tanalgo & Hughes 2021). A sustained effort to revive positive local beliefs and imagery related to flying foxes, possibly in the form of Conservation Pride campaigns (Butler et al. 2013; de Pinho et al. 2014), could potentially help overcome such aversions by creating a mere-exposure effect (Zajonc 2001), hopefully predisposing both locals and tourists to start viewing bats positively.

CAVEATS AND RECOMMENDATIONS

Many of the respondents appeared to be candid in their comments, although on several occasions when they felt intimidated or suspected the enumerator to be a government official, they became very reluctant to provide details on the quantities and capture locations of flying foxes that were hunted and sold. Indeed, only 61.5% of the 200 people we approached agreed to be interviewed, and some who declined could have done so due to fear. As flying foxes are protected in Sarawak, hunting and consumption are illegal, and thus it is possible that some people did not want to participate in the survey because they feared their identity could be leaked to the authorities.

This underscores the difficulty of obtaining accurate data on flying fox hunting and trade, and highlights the need to employ more appropriate survey methods to reduce social desirability bias when asking sensitive questions that seek to understand illicit behaviour (Nuno & St. John 2015; Mildenstein et al. 2016). A more suitable approach for wildlife conservation research, such as the unmatched count technique, should be explored in future work (Hinsley et al. 2019). Additionally, the current COVID-19 situation has introduced new complexities with regards to wildlife hunting and trade, as fears of disease risk could potentially reduce such activities (Low et al. 2021), but at the same time sensationalist media reports have increased negative perceptions of bats amongst the general public (Zhao 2020; Rocha et al. 2021). Since COVID-19 could potentially erode public support for bat conservation (Rocha et al. 2020), follow-up surveys are vital.

Although our results are preliminary, the information uncovered by our exploratory survey is a useful first step to provide a better understanding of the current situation, which will be important for guiding appropriate conservation strategies for the species and its habitats. We hope that both the quantitative and qualitative data yielded by this study will prove useful in helping to direct future efforts to conserve flying foxes in Sarawak, and also provide helpful insights for flying fox conservation efforts elsewhere.

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Supplementary Table 1. 'Flying Fox' in local Sarawakian languages.

Ethnic group	Local names for flying foxes
Iban	Entambah/Semawak
Malay	Keluang
Salako	Ka'uangk
Bidayuh	Jingawat
Melanau	Keluang/Nawai

Supplementary Table 2. Socio-demographic characteristics of respondents in the study area, western Sarawak, Malaysian Borneo.

Characteristics	Number of Respondents	%
Gender		
Male	83	68
Female	40	32
Age range		
<21	1	1
22-34	10	8
35-44	19	15
45-54	40	33
≥55	53	43
Religion		
Christian	74	60
Muslim	37	30
Buddhist	5	4
Atheist	4	3
Taoist	1	1
Bahai	2	2
Ethnicity		
Iban	62	50
Malay	26	21
Chinese	7	6
Bidayuh	8	7
Selako	13	11
Melanau	7	6
Others	1	1
Working Sector		
Unemployed	26	21
Self-employed	75	61
Employed in the government sector	7	6
Employed in the private sector	15	12
Income		
<RM999	85	69
RM1000-2499	32	26
RM2500-3500	4	3
>RM10000	2	2
Residency Area		
City	1	1
Town	16	13
Rural	106	86
Education		
No formal education	34	28
Primary school	33	27
Secondary school	46	37
Post-school skill certificate	5	4
Pre-university foundation course	2	2
Diploma	3	2

Supplementary Table 3. *P. vampyrus* hunting activities in the study area, western Sarawak, Malaysian Borneo.

Details	Number of Respondents	%
Hunting experience		
Have more than a year of experience	24	100
Number of hunters in a group		
1-3 person/s	10	42
3-6 people	10	42
6-9 people	2	8
9-12 people	1	4
>12	1	4
Time of the hunt		
0600hrs-0900hrs	2	8
1800hrs-2100hrs	8	34
2100hrs-0000hrs	12	50
0000hrs-0300hrs	1	4
0300hrs-0600hrs	1	4
Hunting area		
Swamp area	1	4
Forest edge	5	21
Fruit orchard	18	75
Transportation		
Car	1	4
Motorcycle	7	29
On foot	16	67
Hunting Method		
Net techniques	6	25
Shot gun	11	46
Traditional methods	7	29
Cost of hunting tools		
<MYR 50	16	67
MYR 51-100	5	21
MYR 101-300	3	12
Average number of individual bats caught		
≤10	16	67
11-20	6	25
21-40	2	8
Hunting purpose		
Food	13	54
Pest	9	38
Source of income	2	8

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