*Research Article*

# Lack of Pollination Knowledge Among Durian Growers Presents Challenges and Opportunities for Fruit Bat Conservation

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## Abstract

**Background:** Pollinators provide an essential ecosystem service for global agricultural production and food security. However, the majority of pollinator conservation focuses on bees. Efforts to understand grower knowledge and perceptions regarding non-bee pollinators are limited. In the case of durian (Durio zibethinus), one of the most popular and economically important fruits in Southeast Asia, fruit bats are the primary natural pollinators, but a large gap in conservation efforts and policies related to this persists.

**Methods:** Data on the perception of 59 Malaysian durian growers towards bat pollinators were collected between 2019 and 2021. Firth's logistic regression was conducted to investigate the effect of age, gender, ethnicity, and education on farming practices and knowledge of durian pollination ecology.

**Results:** All growers surveyed were aware of wildlife visiting their farms, and 57% felt that killing certain species, which were perceived as most destructive to their crop, was necessary. The importance of bats as pollinators was recognised by 47% of growers, while 29% thought that bees played an important role equal to bats, and 7% said that other taxa act as pollinators. Most growers (96%) did not implement any pollinator-friendly practices and did not express concern that declining bat pollinator populations would result in deleterious outcomes for their crops. Older and ethnic Chinese growers were more likely to practise organic farming, whereas ethnic Malay growers were more likely to have knowledge of durian pollination ecology.

**Conclusion:** Our results showed a deficiency in grower knowledge of durian pollination ecology, which was reflected in their pollination practices and farming approaches.

**Conservation Implications:** Our findings reveal the need for more effective, culturally appropriate communication between conservationists, growers, researchers, and policymakers to disseminate critical durian ecological knowledge and awareness of how certain farming practices may impact the health of pollinating bat populations and associated chiropterophilous crops.

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## Introduction

Pollinators provide an essential ecosystem service for agricultural production and food security. Globally, studies have estimated the value of crop pollination services to range between US $235–577 billion (IPBES, 2016; Lautenbach et al., 2012; Porto et al., 2020). However, anthropogenic pressures have placed many pollinator populations under threat and have raised concerns of a global pollinator crisis (Steffan-Dewenter et al., 2005). The decline of pollinators, therefore, needs to be urgently addressed and prioritised for interventions (Tylianakis, 2013) to maintain ecosystem function and human wellbeing (Potts et al., 2016).

Despite the impending crisis, pollinator conservation continues to be overlooked in many sectors of society. Even in food systems, the roles of pollinators and their dynamics within the ecosystem are often complex and poorly understood (Klein et al., 2007). Consequently, the importance and value of pollinators are not always reflected in growers' knowledge and practices on the ground (Hevia et al., 2021). As such, it is crucial for growers to be aware of, understand, and consider the importance of pollination services to achieve long-term sustainability of their crops (Allen-Wardell et al., 1998; Oliveira et al., 2020).

To date, pollination research has mainly been conducted in high-income countries, with a strong emphasis on maintaining food security (Bartomeus and Dicks, 2019). These studies have mainly focused on diurnal pollinators (Macgregor and Scott Brown, 2020) and insect pollination, particularly bees (Ellis et al., 2020; Klein et al., 2007; Osterman et al., 2021; Rader et al., 2020). The importance of nocturnal and vertebrate pollinators such as bats has received little research or conservation attention in comparison (Ratto et al., 2018; Stewart et al., 2024). As hunting (Mildenstein et al., 2016; O'Shea et al., 2016), culling (Aziz et al., 2016; Florens and Baider, 2019), habitat destruction (Meyer et al., 2016), and climate change (Aziz et al., 2021) become major threats to pollinating bats (Frick et al., 2020), the corresponding risk of pollination failure for chiropterophilous plants (i.e., those reliant on bat pollinators) needs to be investigated and addressed. This need is becoming increasingly urgent, as declines in pollinating bat populations are already being documented (Mildenstein et al., 2022; Stewart et al., 2024), and bat-pollinated plants are disproportionately vulnerable to these pollinator losses (Ratto et al., 2018).

In Global South regions such as Southeast Asia, there is mounting evidence that Old World fruit bats (Family: Pteropodidae) are crucial for fruit crop production, such as durian (*Durio* spp.) (see Aziz, Clements, McConkey, et al., 2017; Bumrungsri et al., 2009; Chaiyarat et al., 2019; Low, Zulfemi, Shukri, et al., 2021; Sheherazade et al., 2019; Sritongchuay, Hughes, Memmott et al., 2019; Sritongchuay et al., 2022). *Durio zibethinus,* a seasonal fruit native to equatorial Southeast Asia, is one of the most commercial and widely grown durian species, and has arguably become the most popular and economically important fruit in Southeast Asia (Bowie, 2018; Bumrungsri et al., 2009). It is also highly prized as the 'king of fruits' due to its deep-rooted sociocultural significance that has developed over centuries in the region (Airriess, 2020; Howell, 1984; Montanari, 2011; O'Gara et al., 2004; Thorogood et al., 2022). Seed-planted semi-wild durian (known as '*durian kampung*' in Malay, and '*thurian baan*' in Thai) has traditionally been cultivated for household consumption in Malaysia, Indonesia, and southern Thailand (Bumrungsri et al., 2009; O'Gara et al., 2004). Commercially, various durian cultivars developed through tree-grafting are now being planted intensively across Southeast Asia as well as in other tropical or subtropical regions, e.g., southern China, northern Australia, Hawai'i, South America, and Africa (Feng & Fu, 2024; Lim & Luders, 1998; Nulimaimaiti, 2023; O'Gara et al., 2004; Safari et al., 2018). Indeed, the international durian market has grown tremendously over the past two decades (Thorogood et al., 2022), with a value estimated at US $17.6 billion in 2018 (Safari et al., 2018).

Worryingly, the growth in demand for durian, and the subsequent expansion of planted areas, is not without its environmental and social impacts (Airriess, 2020; Thorogood et al., 2022). Reports have surfaced of deforestation for monoculture durian plantations to meet burgeoning demand from China (Mayberry, 2019), with one site resulting in conflict between Indigenous people and durian planters (Khoo & Idrus, 2025; The Star, 2018), and others leading to the destruction of important habitat for wildlife (Ellis-Petersen, 2018). Indiscriminate tree removal on hillsides to plant durian has also resulted in soil erosion, potentially contributing to worsening floods (MalaysiaKini, 2022). These incidents show that a holistic strategy for durian planting and expansion is required, with a sound understanding of ecological processes like natural pollination along with the habitats required to sustain these ecosystem services.

In Peninsular Malaysia, durian now accounts for more than 41% (or 70,000 hectares; Zakaria, 2020) of agricultural land. Many companies have developed durian investment schemes to finance production (Lum, 2022), while still relying on the hands-on knowledge and experience of farm managers and workers acquired through decades of durian cultivation (Wei, 2020). Yet despite the reliance of durian production on bat pollinators, pollinator conservation is rarely considered as part of durian-growing knowledge, (Mohd Noor, 2022). With

China's increasing durian imports in particular—an estimated US$7 billion in 2024—driving durian production in the country (Afifah and Tang, 2024; Ali et al., 2025; Ho et al., 2025; Khoo, 2024; Malay Mail, 2025; Nulimaimaiti, 2025), it is crucial to identify and understand knowledge gaps in promoting sustainable durian agriculture to ensure that the industry and people's livelihoods remain secure and resilient (Garibaldi et al., 2017).

In this study, we broadly assess Malaysian durian growers' perceptions and knowledge of farm wildlife, including durian pollinators. Specifically, we investigate: (1) durian grower attitudes and responses towards common wildlife species visiting their farms, with an emphasis on pollinating bats; (2) growers' ecological knowledge regarding durian and durian-planting; and (3) effectiveness of outreach materials in influencing growers' attitudes towards pollinating bats. We believe our findings can help empower durian growers as decision-makers, managers, and partners to develop and implement strategies for safeguarding durian pollination services. Ultimately, our study will contribute to informing the establishment of sustainable agroecosystems that are beneficial to both growers and wildlife over the long term (e.g., Garibaldi et al., 2017; Hevia et al., 2021).

## Materials and Methods

### Study Site

Peninsular Malaysia (3.9743° N, 102.4381° E; 131,732 km$^2$; Figure 1), also known as West Malaysia, is a geopolitical region consisting of 11 states, which together with the states of Sabah and Sarawak on the island of Borneo (East Malaysia), comprise the Federation of Malaysia. Peninsular Malaysia shares a land border with Thailand in the north, a maritime border with Singapore in the south, and maritime borders with Indonesia to the east and west (CIA, 2021). The climate is tropical and uniformly warm all year, with a mean annual temperature of 25.4°C and mean annual precipitation of 3085.5 mm (World Bank, 2022). There are two monsoon seasons: the Southwest Monsoon between April and September, and the Northeast Monsoon between October and March (Suhaila et al., 2010). Malaysia has a population that is classified into three main ethnic groups: Bumiputera which includes Malays and Indigenous minority groups (~70%), Chinese (~23%), Indians (~7%), and others (<1%) (Department of Statistics Malaysia, 2022).

Durian is planted throughout all 11 states of Peninsular Malaysia, occupying more than 70,000 ha (Zakaria, 2020) and generally experiences one main fruiting season between April and August, but crop yield and quality may vary depending on factors such as climate soil, irrigation, terrain, and altitude (Hariyono et al., 2013). The states of Pahang, Perak, and Johor are the top three main producer states, but Pahang, Kedah, Perak, and Negeri Sembilan have also recorded a significant increase in durian planted area in the past decades (Ahmad et al., 2020). Durian growers in Peninsular Malaysia are typically of Malay or Chinese ethnicity (Amekawa et al., 2017), and we found this to be the case through our snowball sampling as well, with the exception of an expatriate Caucasian American farm manager, whose owner-partner was Malaysian of Chinese ethnicity.

### Data Collection

We designed a questionnaire (Appendix I) with fixed-response questions and open-ended questions according to four main topics: (1) farm ownership, production, and management practices; (2) knowledge regarding durian and farm wildlife; (3) perceptions and attitudes toward farm wildlife and pollinators; and (4) socio-demographics. The questionnaire was written in Malay (Bahasa Malaysia), English, and Chinese. We pilot-tested the questionnaire during October-November 2019 on 14 durian growers, following which we redesigned the section on the before-and-after questions regarding perceptions and attitudes towards pollinators. Data obtained on durian production, management practices, farm wildlife, and grower socio-demographics were included from the pilot interviews, whereas the before-and-after perception data and income per acre were excluded. We considered growers as practising organic farming if they answered "yes" to "Is your farm organic?" (question 12), even though they may not have been certified organic by the Ministry of Agriculture, while growers who answered "yes" to "Do you think it's important to have bats visiting your farm"? (question 19) were scored as having knowledge of durian pollination ecology.

The questionnaire survey was conducted across Peninsular Malaysia via interviews between December 2019 and December 2021, with a hiatus from March-August 2020 due to the Covid-19 travel restrictions. Using the snowball sampling method (Bernard, 2006), we requested face-to-face interviews with growers opportunistically by leveraging a large network of durian grower contacts. We conducted the interviews at their farm or at a nearby location of their convenience throughout 10 states in Peninsular Malaysia (Figure 1(a). All interviews were conducted in person by two Malaysian female enumerators except for two interviews conducted over the phone; one enumerator conducted all the interviews while the other enumerator assisted with note-taking. Interviews were conducted in English, Malay, and Mandarin, except for two interviews that required a Hokkien translator (male, in his 60s). The duration of each interview was 20–60 minutes.

Each question and its answer options (where relevant) were read out aloud from the questionnaire by the enumerator to the grower, and recorded directly by the enumerator onto the questionnaire sheet. As part of the survey process, we also conducted outreach and simultaneously collected before-after data on the immediate impact of this outreach intervention by repeating questions regarding perceptions and attitudes towards pollinators. The outreach consisted


**Figure 1.** (Clockwise) (a) Survey Area in Peninsular Malaysia and Locations of Durian Growers Interviewed; (b) A Commercial Durian Farm; (c) Durian Fruit; (d) Conducting Outreach on Durian Pollination With a Durian Grower

of a short educational session where either an animation video available in English, Malay, and Mandarin (see Supplemental Materials) on durian pollination was played to the grower, or the natural pollination process was explained verbally using printed materials (e.g., brochures/infographics; see Supplemental Materials).

The questionnaire survey complies with the research ethics guidelines of Sunway University Malaysia. We obtained free, prior, and informed consent to participate from growers before each interview. To maintain their privacy, growers' identities were not recorded as part of the data collection.

We used Firth's reduced-bias logistic regression to examine the association between sociodemographic characteristics of growers (i.e., age, gender, ethnicity, and education level) and (1) organic farming practices and (2) knowledge of durian pollination ecology ($n$=56). We excluded three growers from our analysis: two did not provide information on their education and one was the only respondent belonging to an ethnicity category ('Other'). We reduced the number of categories of age (i.e., ≤40, 41–60, >60 years) and education level (i.e., primary, secondary, tertiary) to allow adequate sample sizes across all categories. In the analysis of organic farm management, there was quasi-complete separation of the response variable; all respondents aged ≤40 years did not practise organic farm management. Considering the quasi-complete separation in the organic management analysis as well as relatively small sample sizes in both analyses, we fitted Firth's reduced-bias logistic regression models implemented in the R package 'logistf' (Heinze et al., 2025) to obtain more reliable and less biased coefficient estimates (Firth, 1993; Heinze & Schemper, 2002). In both analyses, we conducted backward selection based on penalized likelihood ratio tests, with $p$-to-exit > 0.05.

Finally, we ran a chi-square test of independence to examine the association between organic farming practices and knowledge of durian pollination ecology among all growers ($n$=59).

## Results

We surveyed a total of 59 durian growers (9 females, 50 males; Table 1). The median age range was 51–60 years, and 99% were Malaysian citizens. Respondents had a median of 15 years of experience in the durian industry, and the age range of durian farms was 10–150 years old (median 35 years). Farm size ranged between 1–162 acres with a median of 5 acres (0.4–65.0 ha; median 2.02 ha) and a median of 100 trees in total, ranging between 12 and 11000 trees. Seventeen percent (n=10; Table 2) of the growers interviewed had MyGAP (Malaysian Good Agricultural Practices Scheme) certification, which is awarded annually by the Malaysian Department of Agriculture to farms that fulfil certain standards in sustainability, worker safety and welfare, and product quality. One grower (2%) interviewed had the MyOrganik certification which is similar to MyGAP but with stricter standards regarding pesticide and synthetic fertiliser usage. Our final Firth's logistic regression model revealed that grower age and ethnicity were significantly associated with organic farming practices (see Table i in Appendix II). Growers in the 41–60 year-old ($b$=3.37, $p$=0.001) and >61 year-old ($b$ = 3.15, $p$=0.011) age classes were significantly more likely to practise organic farming compared to younger growers (≤40 years old). Malay growers ($b$ = −2.16, $p$ = 0.002) were less likely to practice organic farming compared to Chinese growers. In addition, none of the respondents employed hand-pollination to enhance their durian fruit production, meaning that 100% of the growers we surveyed relied entirely on natural pollination to grow durian.

### *Attitudes and Responses Towards Farm Wildlife*

All respondents said that they had wildlife on their farm, with the top five most common wildlife species reported as Long-tailed Macaque *Macaca fascicularis* (80%), Plantain Squirrel *Callosciurus notatus* (75%), Wild Pig *Sus scrofa* (75%), bats (48%; not identified to species or family), and Dusky Langur *Trachypithecus obscurus* (28%; Figure 2; Table 3). Of these, species such as Long-tailed Macaque and Plantain Squirrel were reported to have deleterious effects on the farm, while species like Sun Bear *Helarctos malayanus* and Malayan Porcupine *Hystrix brachyura* were reported to be just passing through the farm. Two respondents (5%) said that other species such as Malayan Tiger *Panthera tigris* and Sun Bear had visited their farm based on signs (e.g., footprints and dung) although they had not directly observed them. Other species mentioned included hornbills and other bird species, but birds were reported as not having any significant impact on the durian trees.

Fifty-seven percent of respondents felt it was necessary to kill some of the farm wildlife, particularly the ones that caused the most destruction, namely squirrels which made holes in the fruit, macaques which would pluck and drop

**Table 1.** Socio-Demographic Profiles of Grower Interviewees (n = 59) and Their Farm Characteristics

| Respondent characteristics | | Count (%) |
|---|---|---|
| Gender | Male | 50 (85) |
| | Female | 9 (15) |
| Age (years) | <30 | 1 (2) |
| | 30-39 | 11 (19) |
| | 40-49 | 12 (20) |
| | 50-59 | 16 (27) |
| | 60-69 | 13 (22) |
| | >69 | 6 (10) |
| Ethnicity | Chinese | 33 (56) |
| | Malay | 25 (42) |
| | Other | 1 (2) |
| Highest education | Primary school | 8 (14) |
| | Secondary school | 29 (49) |
| | Diploma | 12 (20) |
| | Bachelor's degree | 5 (9) |
| | Master's degree | 3 (5) |
| | Rather not say | 2 (3) |
| Role | Farm and landowner | 45 (77) |
| | Farm owner leasing the land | 3 (5) |
| | Farm manager | 9 (15) |
| | Farm worker | 2 (3) |
| Experience in durian farming (years) | Average (min, median, max) | 20.8 (1.5, 15, 70) |
| Income per hectare of durian farm | Average in US $ (min, median, max) | 7600 (630, 3170, 37000) |

**Table 2.** Characteristics, Certification Status, and Management Practices of Farms Surveyed

| Farm characteristics | Median (min, max) |
|---|---|
| Age of farm (years) | 33 (10, 150) |
| Size of farm (acres) | 6 (1, 162) |
| No. of durian trees | 120 (12, 11000) |
| **Certification status** | **Count (%)** |
| MyGAP | 10 (17) |
| MyOrganik | 1 (2) |
| Others/unsure | 2 (3) |
| None | 46 (78) |
| **Management practices** | **Count (%)** |
| Managed organically[a] | 15 (25) |
| Not managed organically | 44 (75) |
| Practices intercropping | 40 (67) |
| Does not practice intercropping | 19 (33) |
| Practised/attempted hand-pollination[b] | 3 (5) |
| Does not practise hand-pollination | 56 (95) |
| Implements measures to attract pollinators | 5 (8.5) |

[a]Growers who said they employed organic farming practices (e.g., no use of synthetic fertilisers or pesticides) but did not apply for official MyOrganik certification from the Ministry of Agriculture.
[b]Growers did not employ hand-pollination as their main pollination strategy, but have attempted to hand-pollinate durian flowers, either as a regular addition to natural pollination or as an ad hoc attempt to increase fruit set and yield.

unripe fruits on the ground, and langurs which were described as "bulldozers" by Grower #17 based on the rate at which they consumed durian flowers. The majority of our respondents perceived Long-tailed Macaque, Plantain Squirrel, and Dusky Langur as being farm pests, and had a range of responses: some felt it was necessary to hire shooters or set traps to kill these animals, e.g., Grower #12: "*It is hard to control them and they destroy too many fruits*". However, some respondents would only set traps to catch and then release the animals far from their farm, or surrender the animals to the wildlife authorities, e.g., Grower #20: "*I could not bear to* [kill them]*, even though the damage by Long-tailed Macaques are the worst. I see it as a kind of 'tax' and I live with it.*"

## *Knowledge of Durian Pollination Ecology, and Attitudes Toward the Role of Bat Pollinators*

Based on our survey (Figure 3), 47% (n = 28) of respondents said that it was important for bats to visit their farms because bats pollinate durian flowers. A smaller proportion of respondents added that they thought bees (29%, n = 17) and other animals (e.g., civets, squirrels, macaques, etc.; 7%; n = 4) would also play a part in pollination, e.g. Grower #13: *"As long as the animal touches the flower, I would consider it a pollinator."* Three other respondents (7%) said that wind assisted in durian pollination, and that they had heard this advice from their durian grower network, and had attempted to increase pollination success by using leaf blowers or large fans to simulate windy conditions in their farm during the flowering season. However, one grower also disclosed that they had found this method to be ineffective and discontinued it the following year. When presented with a hypothetical situation of pollination failure, 8% (n = 5) said they would probably resort to hand-pollination, but also expressed that it may be too costly in terms of labour and time to be profitable. Ten percent (n = 6) of the remaining growers said hand-pollination would be impossible as the trees are too tall, and that "*no one in Malaysia would do this*" (Grower #12), and that they would likely have no alternative but to leave the trees alone or abandon farming. However, grower #40 shared that he was currently experimenting with pruning the tops of young durian trees in his farm so that the trees would be at a manageable and safer height for his workers to manage the fruits, and in the event of pollination failure, hand-pollination would be feasible.

Our final Firth's logistic regression model showed that only grower ethnicity showed a significant association with knowledge of durian pollination ecology (see Table i in Appendix II), with Malay growers ($b$=1.41, $p$=0.011) more likely to demonstrate a knowledge of durian pollination ecology than Chinese growers. The chi-square test did not reveal any statistically significant association between practising organic farming and knowledge of durian pollination ecology $X^2$ ($n$=59, $df$=1) = 1.295, $p$ = 0.26.

## *Impact of Outreach Intervention*

Out of the 22 respondents who did not think it was important (answered 'no' or 'unsure') for bats to visit their durian flowers, 59% (n = 13) indicated a change of attitude towards the importance of bats after the outreach engagement: either from answering 'no'/'unsure' to a 'yes' (n = 8), or from 'no' to 'unsure' (n = 5). Nevertheless, two growers elaborated on their uncertainty about the importance of bats: one said that he doubted if bats were pollinators because a fellow grower had dissected a bat and found durian floral parts in its gut, thus leading him to believe that bats were primarily consuming durian floral parts and therefore not acting as the principal and most effective pollinator. Another grower shared that he used to hunt flying foxes (*Pteropus* bats) and had never observed them in the act of pollination or perceived them as pollinators. In response to the before-and-after engagement questions regarding the importance of proximity to bat habitat (e.g., caves and forests) for durian productivity, none of the respondents changed their answers/preferences after the outreach. However, one respondent did point out that while his preferred characteristics remained unchanged, he did learn new knowledge about the connection between durian and bats.

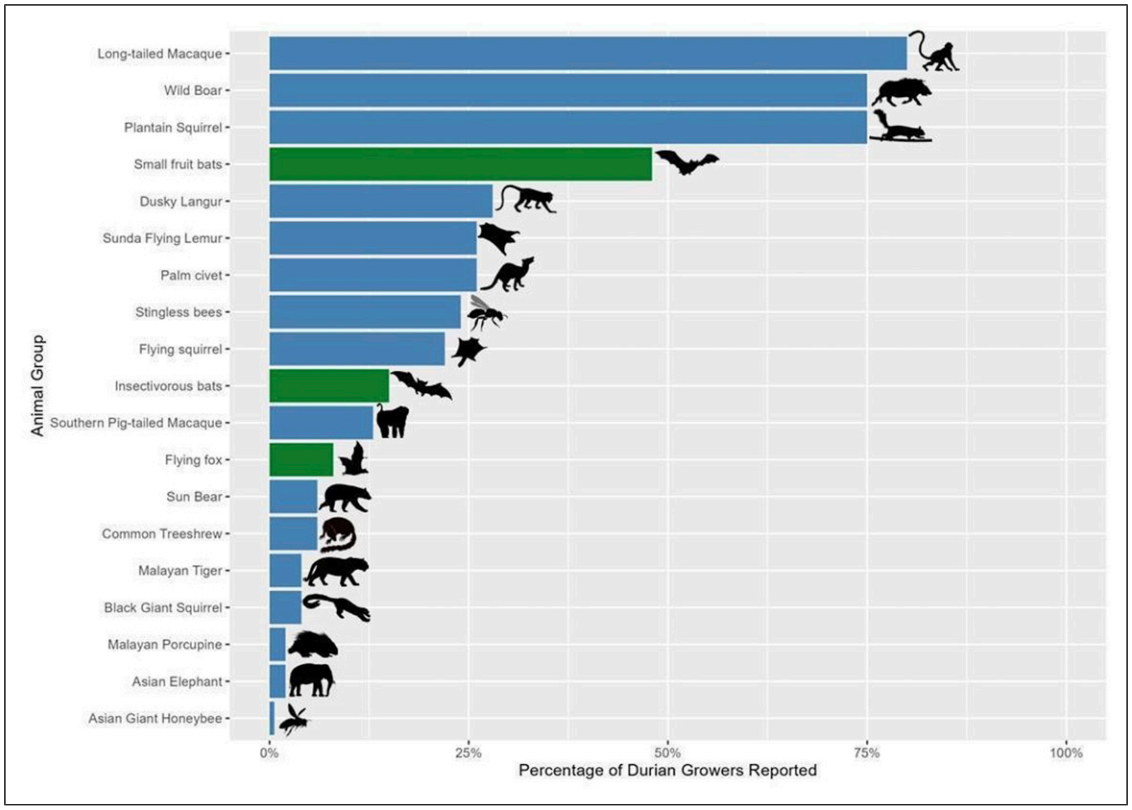


**Figure 2.** Wildlife in Durian Farms as Reported by Respondents

## Discussion

To our knowledge, this is the first in-depth study to comprehensively investigate durian grower knowledge and perceptions regarding bat pollinators. This is also the first attempt to survey a wide range of durian growers across a large spatial extent (i.e., across Peninsular Malaysia). Our findings show that the top five most common species of wildlife reported to visit durian farms across all 10 states that we surveyed in Peninsular Malaysia included small fruit bats.

Despite clear evidence of the key role bats hold as pollinators for durian (Aziz, Clements, McConkey, et al., 2017; Bumrungsri et al., 2009; Chaiyarat et al., 2019; Sheherazade et al., 2019), half (n = 23) of the growers surveyed were still unaware that bats are durian pollinators, and initially perceived bats to be of no importance or irrelevant with regards to their durian crop. Seven percent (n=3) of the growers also thought that bats were pests, but mainly with regards to other fruit crops such as dokong *Lansium parasiticum* and rambutan *Nephelium lappaceum*, rather than specifically to durian. While slightly over half of the growers agreed that bats are durian pollinators, it is unclear how important they regarded bats as the main and principal pollinators for durian, as a smaller percentage (35%) also stated that bees pollinate durian. For example, one grower (Grower #4) stated that bats were now a rare sight compared to two decades ago, and that he just "let natural pollinators take care of it", suggesting an assumption that other pollinating agents (e.g., bees, beetles, wind; see Results) would fill the niche of durian pollinator even if bat pollinators declined.

Our study did find that ethnic Malay growers were more likely to have knowledge of durian pollination ecology. This is likely due to the fact that many Malay growers have cultivated durian for generations as a traditional practice passed down through families, with some of those we surveyed only planting for personal consumption rather than for commercial exploitation. As such, there may be an element of Traditional Ecological Knowledge regarding the role of bats; e.g., one Malay grower from Terengganu shared that elders in his area used to say that when flying foxes were sighted, it was a sign that the year's durian harvest would be good (Figure 4; also see https://www.youtube.com/watch?v=98XRHusxk7M). In contrast, all the Chinese growers we surveyed planted durian for commercial purposes, with some of them, especially younger ones, being relative newcomers to the practice. The large-scale commercial operations of some Chinese growers aiming for a global market may also be an incentive for growers to obtain organic farming certification, as this may potentially be a selling point for more health-conscious consumers. However, the traditional practices of some Malay growers could also be considered a form of organic farming (e.g., no synthetic fertilisers or pesticides used), even if not indicated as such. Therefore, the cultural elements of durian farming warrant further investigation – particularly as

**Table 3.** Common Farm Wildlife, Their Reported Effects in Durian Farms, and Durian Growers' Responses to These (n = 59). The * Refers to Wildlife That Were Not Identified to Species and May Be Members of the Same Order, Family, or Genus

| Species | | IUCN red list status[a] | Peninsular Malaysia red list status[a] | Status under Malaysia's Wildlife Conservation Act 2010 [Act716])[b] | Fruit tree | % growers | Reported effects (if any) | Grower response |
|---|---|---|---|---|---|---|---|---|
| English name | Scientific name (where applicable) | | | | | | | |
| Long-tailed macaque | *Macaca fascicularis* | EN | N/A | Protected | Durian | 80 | Plucks unripe fruit and throws on the ground; feeds on ripe fruit | Trap, shoot |
| Southern pig-tailed macaque | *Macaca nemestrina* | EN | N/A | Protected | Durian | 13 | Plucks unripe fruit and throws on the ground; feeds on ripe fruit | Trap, shoot |
| Dusky langur | *Trachypithecus obscurus* | EN | NT | Protected | Durian | 28 | Feeds on flowers | Trap, shoot |
| Flying squirrel* | *Petaurista* sp. and *Ratufa* sp. | N/A | N/A | *Petaurista elegans*, *P. petaurista*, *Ratufa afinis* are Totally Protected | Durian | 22 | Feed on ripe fruit hanging in tree, urinates on fruit | Trap, shoot |
| Plantain squirrel | *Callosciurus notatus* | LC | N/A | Not protected | Durian | 75 | Feeds on ripe fruit hanging in tree, urinates on fruit | Trap, shoot |
| Black giant squirrel | *Ratufa bicolor* | NT | NT | Totally Protected | Durian | 4 | Feed on ripe fruit hanging in tree, urinates on fruit | Trap, shoot |
| Common treeshrew | *Tupaia glis* | LC | N/A | Totally Protected | Durian | 6 | Feed on ripe fruit hanging in tree | Trap |
| Wild pig | *Sus scrofa* | LC | N/A | Protected | Durian and other | 75 | Digs up soil and young trees; feeds on dropped ripe fruit | Shoot, scare with firecrackers, deploy guard dogs |
| Palm civet* | *Paradoxurus* sp. or *Paguma* sp. | N/A | N/A | Protected | N/A | 26 | Passing through | No action taken |
| Sunda colugo | *Galeopterus variegatus* | LC | NT | Totally Protected | Durian | 26 | Feeds on flowers | No action taken |

*(continued)*

**Table 3.** (continued)

| Species | | IUCN red list status[a] | Peninsular Malaysia red list status[a] | Status under Malaysia's Wildlife Conservation Act 2010 [Act716])[b] | Fruit tree | % growers | Reported effects (if any) | Grower response |
|---|---|---|---|---|---|---|---|---|
| English name | Scientific name (where applicable) | | | | | | | |
| Fruit bats* | (Family: Pteropodidae) | N/A | N/A | Various species both Protected and Totally Protected | Duku; dokong; rambutan | 48 | Feeds on ripe fruits | Put up nets |
| | | | | | Durian | 8 | Pollinates flowers | No action taken |
| Insectivorous bats* | Suborder: Microchiroptera | N/A | N/A | Various species both Protected and Totally Protected | N/A | 15 | Passing through; feeds on insects | No action taken |
| Malayan porcupine | *Hystrix brachyura* | LC | NT | Protected | Durian | 2 | Feeds on dropped ripe fruit | No action taken |
| Malayan tiger | *Panthera tigris jacksonii* | EN | CR | Totally protected | Durian | 4 | Feeds on dropped ripe fruit | No action taken |
| Sun bear | *Helarctos malayanus* | VU | VU | Totally Protected | N/A | 6 | Passing through in search of termite nests | No action taken |
| Stingless bees* | *Trigona* spp. | N/A | N/A | Not protected | Durian and other | 24 | Pollinates durian flowers | Welcome by growers, several growers keep stingless beehives in their farms |
| Asian giant honeybee | *Apis dorsata* | N/A | N/A | Not protected | Durian and other | 0.6 | Builds hive in durian trees during flowering season; pollinates flowers | Smoked out by farmworkers |
| Asian elephant | *Elephas maximas* | EN | VU | Totally Protected | N/A | 2 | Pulls or breaks tree branches | No action taken |

[a]CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC=Least Concern; N/A=Not assessed, not available or not applicable, e.g., multiple species grouped together.

[b]Offences involving Totally Protected species will result in higher penalties (e.g., maximum fine of RM500,000 Malaysian ringgit and/or 3 years' jail term), as compared to Protected Wildlife (e.g., maximum fine of 50,000 ringgit and/or 2 years' jail term). Totally Protected species are usually prioritised in policies on habitat protection. Protected species may be legally hunted with a permit, and include non-native species that are on the IUCN Red List and CITES Appendices.Note about the conservation status of *Pteropus* spp. in Malaysia: Two species occur in Malaysia, Large Flying Fox *Pteropus vampyrus*, listed as EN according to the IUCN Red List and EN on the Peninsular Malaysia Red List; and Island Flying Fox *P. hypomelanus*, listed as NT according to the IUCN Red List and EN on the Peninsular Malaysia Red List.

Indigenous minorities such as the Orang Asli were not covered by our survey.

Following our outreach intervention, 20% (n = 9) of durian growers reported a clear change in their perceptions towards bat pollinators, and were more likely to perceive bats as important visitors to their farms after the outreach. However, even among this 20%, two growers mentioned the caveat that they would only consider bats truly beneficial to their durian trees if these bats did not also consume their dokong and mango (*Mangifera indica*) fruits. Clearly, experiences and perceptions of fruit bats being crop raiders (Aziz et al., 2016 have a considerable psychological impact hindering

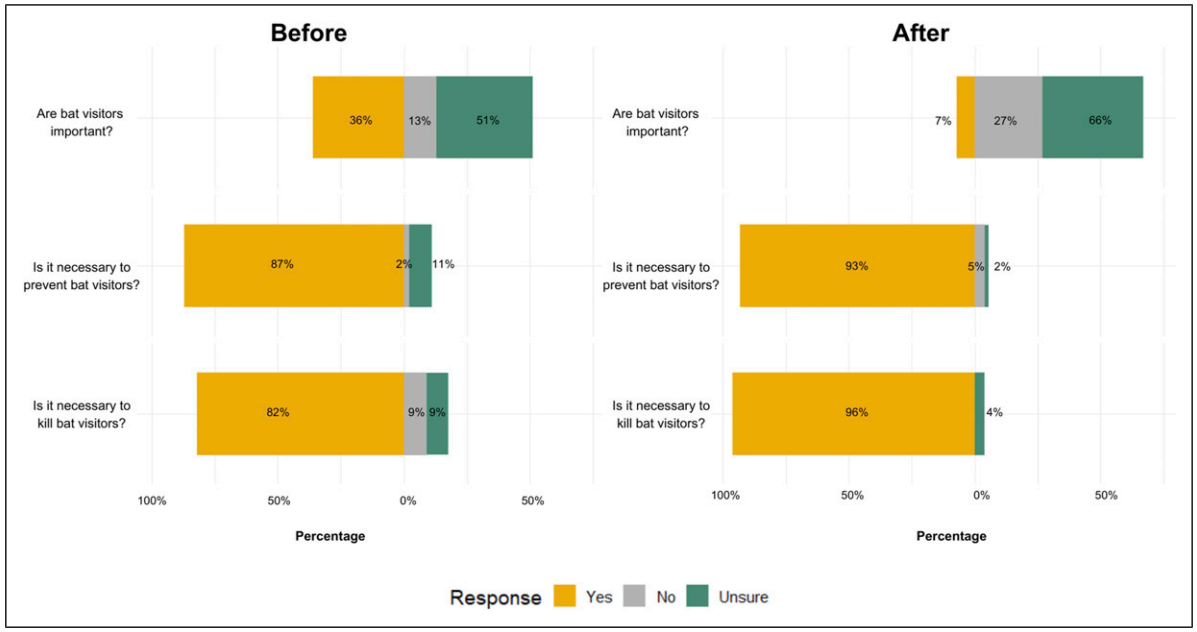


**Figure 3.** Grower Responses (n = 45) Before and After Outreach on Durian Pollination in Peninsular Malaysia

appreciation of their important pollinating roles, especially for frugi-nectarivorous bats such as *Rousettus* spp. And *Pteropus* spp. This is particularly significant as fruit bat pollinating activity is often unobserved due to its relatively unobtrusive nature, and bats are therefore often unacknowledged as pollinators (Aziz et al., 2016, Aziz, Clements, Giam, et al., 2017; Bumrungsri et al., 2009; Kung et al., 2015). As such, there is often a stronger perception of bats as fruit pests, leading to persecution and systematic culling in extreme cases (Florens and Baider, 2019; Mohd-Azlan et al., 2022; O'Shea et al., 2016). Cultural perceptions (Low, Hoong, et al., 2021) and media misrepresentation (Cerri et al., 2022; López-Baucells et al., 2023) also likely contribute to growers' preconceived notions of bats being exclusively destructive.

By contrast, bees, which are much less effective pollinators for durian (Aziz, Clements, McConkey, et al., 2017; Bumrungsri et al., 2009; Sheherazade et al., 2019; Start, 1974; Wayo et al., 2018), were occasionally misattributed as important durian pollinators by the durian growers. A similar

| ***Question: Do you think it is important to have bats visiting your farm?*** | | |
|---|---|---|
| ***Grower*** | ***Before outreach*** | ***After outreach*** |
| #12 | No, they don't do anything. There is no connection with bats to my durian farm. | Perhaps. There used to be flying foxes here in the 1960s but I haven't seen them since I was a child. |
| *#28* | Not really, sometimes they eat the dokong. | Yes, since they are pollinators. If they do not damage the dokong, then it's okay, otherwise it's a problem. |
| *#32* | No, they do not disturb anything. | Good to know that they are pollinators. And they also help to eat insects. |
| *#34* | No connection. | When I was a child, I was told a local belief about how the appearance of many flying foxes in the sky during the durian flowering season meant that the upcoming durian harvest would be a good one. |

**Figure 4.** Selected Responses of Durian Growers When Asked About the Importance of Bats, Before and After Conducting Outreach

case can be seen with cocoa growers in Ghana, who misattribute bees and ants as pollinators, instead of midges *Forcipomyia* spp., which are in fact the primary pollinators of cocoa (Umeh et al., 2022). This knowledge gap resulted in counter-productive agronomic practices, as insecticide application killed midges, and growers had to hand-pollinate to increase crop yield. This example, along with our findings, indicates that there are disproportionate perceptions of the importance of bee vs. non-bee pollinators, which can lead to negative consequences in terms of agricultural production.

### Attitudes and Responses Towards Farm Wildlife

The reported effects of the most common farm wildlife and grower responses to them indicate perceptions that are not only embedded strongly in day-to-day living experiences, but also linked to farming practices. Farm wildlife was almost always considered from a rational and utility-based approach (e.g., Kelemen et al., 2013), with one respondent who opposed killing wildlife even describing any loss of fruit as "nature's tax". There was also the anthropomorphic perception that Long-tailed Macaques were "naughty" and "wasteful" because they would pluck unripe fruit and toss it to the ground, whereas if the macaques had consumed the fruit, their takings might have seemed more justifiable, as it would have served a purpose.

Importantly, bats were not perceived as durian pests. This contrasts with the situation in Thailand, where durian growers set nets to prevent pollinating Cave Nectar Bats (*Eonycteris spelaea*) from visiting their flowering trees (Aziz et al., 2016; Chaiyarat et al., 2019). However, one respondent in our study did informally share an anecdote of a grower he knew who had set nets to prevent bats from accessing his durian flowers, but discontinued the practice once this respondent informed him of the bats' pollination importance (Han Sin Keng, pers. comm. 2021).

Instead, in our study, bats were only perceived as pests for other fruit trees such as dokong, rambutan, and mata kucing *Dimocarpus longan malesianus*, all of which fetch a lower market price compared to durian (Jabatan Pertanian Malaysia, 2018; Safari et al., 2018). According to Grower #29, dokong prices have been so low that he does not find it worth the time and effort needed to harvest the fruits for sale. While durian growers often intercrop their durian trees with other fruit trees, durian is usually the main source of revenue (People's Daily Online, 2023). Yet growers reported still putting up nets to trap (and ultimately kill) bats trying to access these other fruit trees, which could potentially pose a threat to durian-pollinating bats.

The loss of other fruits to frugivorous and frugi-nectarivorous bats may be outweighed by the profits and economic value of higher durian production. The presence of other fruit trees could even serve as an attractant to encourage more visits by frugi-nectarivorous bat pollinators –durian orchards that are not intensively managed are known to benefit from higher bat abundance and subsequently higher rates of natural pollination compared to monoculture orchards (Chaiyarat et al., 2019). Further, fruit damage is known to be reduced in mixed-tree farms compared to monoculture plantations; in southern Thailand, growers with mango monocultures regarded *Pteropus* spp. as pests whereas growers with mixed-fruit orchards did not (Aziz et al., 2016).

### Knowledge of Durian Pollination Ecology and Attitudes Toward the Role of Bat Pollinators

While half (51%) of the growers surveyed were aware of the importance of bat pollinators for durian, only five growers (8%) had an in-depth understanding of the ecological and landscape factors important to durian-growing, even giving examples of intercropping with suitable bat food plants, such as banana, dokong, and petai (bitter bean; *Parkia speciosa*) to attract bats, and planting a specific durian cultivar (D7) which was said to be the first to bloom and would thus attract bats to that specific farm first, gaining an advantage over other farms within the vicinity (Table 2). As such, the level of awareness of bats as durian pollinators in this study was higher than that of a durian-growing community on Tioman Island, Peninsular Malaysia (13%, n = 119, Aziz, Clements, Giam, et al., 2017). None of the growers interviewed practised hand-pollination as a regular management practice, due to logistical challenges and costs. This indicates that bat pollinators of durian in Peninsular Malaysia are playing an irreplaceable functional role. The failure to recognise the importance of bats as the primary natural pollinators of durian presents a problem. Areas with smaller bat populations due to eradication (Bumrungsri et al., 2009) are known to suffer from lower natural pollination rates of durian (e.g., Chanthaburi, Thailand, Chaiyarat et al., 2019; Wayo et al., 2018). Most durian growers in Peninsular Malaysia are yet to experience pollination failure, and are worryingly ignoring the importance of pollination ecology in favour of focusing disproportionately on crop management practices (e.g., irrigation, fertilisation, terrain, etc.). Even when the importance of pollinators is acknowledged, stingless bees are often mistakenly prioritised over bats (Fahimee et al., 2021; Norowi et al., 2010). Three of the growers said they maintained stingless bee colonies to help with pollination, but one elaborated that the stingless bees did not appear to be effective pollinators for his crop. Of the growers surveyed, 96% said they would probably give up durian farming if they had to resort to hand-pollination, due to the cost of labour or logistical impracticality. Given these views on the impracticability of hand-pollination, examples of pollination failure leading to crops requiring 100% hand-pollination and the slow decline of the apple industry in China, India, and Pakistan (Partap et al., 2000; Partap and Ya, 2012) should serve as a lesson to Malaysian growers.

This ignorance regarding bat pollination of durian in Malaysia stands in stark contrast to grower knowledge and perceptions towards insect pollinators in other regions (Busse et al., 2021; Hevia et al., 2021; Osterman et al., 2021). In a study

involving growers from 11 countries, grower knowledge of insect pollination was found to be directly connected to their on-farm experiences, whereby the pollinating taxa were observed, recognised, and valued by growers based on the abundance of these insects as crop flower visitors (Osterman et al., 2021). This could explain why many durian growers automatically assume bees to be of equal or even more importance than bats, as bees are often the most common, abundant, and noticeable visitors to durian flowers during the day (Aziz, Clements, Giam, et al., 2017; Bumrungsri et al., 2009).

Further, durian growers also lack knowledge of basic durian floral biology, such as flowers only blooming for one night, after which corollas and stamens are naturally shed by the tree (Bumrungsri et al., 2009). As reported from southern Thailand, observations of naturally dropped flower parts on the ground in the morning, or even direct observations of corollas and stamens falling due to bat visits in the evening, often lead growers to mistakenly assume that pollinating bats are pests that consume or damage durian flowers (Aziz et al., 2016; Chaiyarat et al., 2019).

### *Impact of Outreach Intervention*

While 28% of respondents indicated a change in attitude towards bats following our short outreach intervention, several respondents remained unconvinced regarding the role of bats as the principal and most effective pollinators of durian. These respondents further claimed they had not observed or witnessed bats pollinating their durian flowers, but also said they were usually only present on their farm during the day, not at night when durian pollination occurs. Further, bats generally feed in the upper levels of a tree, blend into the darkness, and the smaller pteropodids especially are quick and silent when feeding on nectar, rendering them largely unnoticeable to casual observers without the aid of thermal equipment (Aziz, Clements, McConkey, et al., 2017). Indeed, one grower (Grower #39) later communicated that following our outreach he started observing his durian trees at night and saw bats, including flying foxes, feeding on the flowers, despite previously reporting that he had never experienced bats visiting his farm. As such, most durian growers in Peninsular Malaysia are unlikely to observe bats in the act of pollination.

We asked growers what their ideal landscape characteristics for a durian farm might be (Table ii in Appendix II), and respondents expressed mixed sentiments about having farms in close proximity to forest (22%) and being surrounded by other durian farms (24%). The few who wanted proximity to forest cited reasons such as "*durian is a forest tree and so being near a forest would make durian happy*" (Grower #18). However, many respondents did not prefer this because they were afraid that the forest would act as a source of wildlife pests causing damage. This was also given as a reason for not wanting to be near other durian farms, as it was believed that a clustering of farms would attract more pests to come feed on the fruits. In contrast, respondents who preferred being surrounded by other durian farms said that more durian trees could help spread out the pest burden, rather than having all the pests descend on their farm alone.

Notably, none of the respondents changed their ideal characteristics for a durian farm after outreach was conducted. It is likely that durian growers prioritise the crucial elements of having a water body nearby, along with accessibility and ease of transportation, as being the most important criteria for durian-growing (e.g., Wong, 2024) rather than considering wider landscape connectivity and associated ecosystem services (Kelemen et al., 2013; Sritongchuay et al., 2022). In addition, the impact of bat habitat on durian productivity did not seem to matter to most of our respondents, indicating the perceived importance of farm proximity to bat pollinator roosting habitat was low or absent. Only one durian grower said that having a farm near a cave would be beneficial because the cave would act as a source for bat pollinators. This perception, while in the minority, is supported by scientific evidence that proximity to caves results in higher durian fruit production (Sritongchuay et al., 2016; Sritongchuay & Bumrungsri, 2016). Unfortunately, this important relationship remains unknown to most durian growers in our survey. As such, our survey results illustrate a stark contrast between growers' perceptions and scientists' findings regarding the importance and role of biodiversity in agricultural production (Maas et al., 2021).

We also observed that when growers were asked for the second time after outreach was conducted, more of them were likely to reflect on the role of bats, and recall when they last saw flying foxes in the area. However, the range of responses (Figure 4) indicates that a one-off outreach intervention is unlikely to be adequate for increasing awareness or catalysing behavioural change towards more bat-friendly farming practices.

### *Caveats and Study Limitations*

It is possible that our results were limited by our sampling approach, which failed to obtain a more diverse and representative sample of durian growers. As our sampling approach was based mainly on personal contacts (whether our own or those of durian growers we had already surveyed), the surveys we obtained may be biased towards growers who were already friendly towards us and held more positive attitudes towards biodiversity. As such, our sample may be underestimating growers who view bats more negatively or take more stringent action to either eradicate bats or prevent bats from accessing their durian trees. Respondents may also have been influenced by social desirability bias.

Our questionnaire design did not account for the widespread belief among growers that bees are the main pollinators for durian. In retrospect, we could have taken this into account and improved the survey by employing words such as "main", "primary", "principal", "most important", "most effective", or "irreplaceable" to accord greater importance to bats.

As our survey was designed and initially implemented before the start of the COVID-19 pandemic, our study was

also unable to account for any possible effects of the pandemic on our results. It is well known by now that public misperceptions of the alleged link between bats and the SARS-CoV-2 virus led to an intense backlash against bats and bat conservation, directly increasing negative perceptions and even physical persecution (Cerri et al., 2022; López-Baucells et al., 2023; Lu et al., 2021; Rocha et al., 2020). It is unclear how far this situation may have affected the respondents we surveyed after the start of the pandemic.

## Implications for Conservation

Our findings indicate a knowledge gap exists among durian growers in Peninsular Malaysia regarding the important mutualistic relationship between bats and durians. The need to increase awareness among growers and policymakers about the importance of bats as pollinators is crucial, as is the need to incorporate this ecosystem service as a key aspect of the durian supply chain (Crenna et al., 2017). Fruit bat conservation can and should be used to help shift local growers towards more nature-positive agriculture that increases yields without increased expansion (Balmford et al., 2025). While more outreach, education, and awareness-raising on the importance of bat pollination are urgently needed, greater effort is needed to conduct more persuasive deliveries and interventions (e.g., having the right messengers who are perceived as authoritative, trustworthy, and likeable; see Cialdini, 2001), especially because information alone is not enough to elicit behavioural change (Balmford et al., 2021; Bosone et al., 2022; Chess & Johnson, 2007; Petty and Krosnick, 1995; St. John et al., 2010). Hence, recruiting bat-friendly growers as allies should be a key strategy. Also, as ethnicity and age can play a role in influencing knowledge and farming practices, it is crucial to employ culturally appropriate delivery methods that communicate in different languages for different groups, particularly targeting younger and ethnic Chinese growers.

Much of the currently available information and messaging on pollinator conservation, particularly on social media, come mainly from temperate, Global North countries (e.g., Barkemeyer et al., 2013; Ratto et al., 2018). As these tend to focus disproportionately on bees, they may inadvertently contribute towards a poorer public understanding of tropical pollination ecology, which is more complex in its networks of both mutualistic and antagonistic interactions, frequently involving multiple pollinator taxa and plants that are highly dependent on vertebrate pollinators such as bats (i.e., chiropterophily). This bee-centric focus clearly impacts the beliefs and practices of local people and growers in tropical countries, sometimes to the detriment of local agronomic sustainability (e.g., beliefs that domestication of stingless bees in durian farms is an economically viable method of increasing fruit production rather than conserving bat populations in their natural habitats: see Norowi et al., 2010; Fahimee et al., 2021). As such, the predominant bee-centric narrative around pollinators (e.g., North American Pollinator Protection Campaign, EU Pollinator Information Hive) warrants more nuanced and strategic consideration when designing and planning global or regional pollinator conservation campaigns to ensure the inclusion of key vertebrate pollinators.

More importantly, there is a clear need for more locally contextualised and relevant outreach focused specifically on tropical pollination, particularly for Global South countries. Such outreach efforts need to highlight the importance of fruit bats and other non-bee pollinators, especially in regions where crops such as durian and cocoa rely on non-bee pollination for optimal fruit production. As our findings indicate, a one-off outreach intervention from one small local NGO was not a highly effective approach for changing perceptions towards bat pollinators. Repeated information is perceived as more truthful than novel information (Corneille et al., 2020), and considering the Mere Exposure Effect (Zajonc, 1968)—heightened recall and preference for familiar things —there is a need for reiteration and long-term messaging to increase salience (Mrkva and van Boven, 2020). This should ideally be executed within the context of a wider education and awareness campaign, leveraging on social influence and strategic messengers from different backgrounds and sectors to facilitate non-bee pollinator-friendly changes in agronomic practices (e.g., Culiberg & Elgaaied-Gambier, 2016; Keizer and Schultz, 2018). Awareness surveys on the importance of bat pollination should also be extended to include a wider range of stakeholders such as government personnel, conservation organisations, and durian consumers.

### *Future Directions*

Further research and empirical investigations are also urgently needed on the impact and extent of bats as potential pests of non-durian fruit trees, and whether prevention methods are negatively impacting bat pollinator populations. Perpetuated misinformation compounded by existing negative perceptions (Low, Hoong, et al., 2021; Rocha et al., 2020) could lead to persecution and mass culling events (Florens & Baider, 2019; O'Shea et al., 2016; Vincenot et al., 2015). As such, if crop damage by fruit bats is significant enough to warrant attention, then follow-up research is crucial to explore evidence-based non-lethal mitigation methods (Aziz et al., 2016).

More in-depth and precise valuation of bat pollination services will provide a clearer picture of the benefits bats bring to the durian industry in Peninsular Malaysia. Our findings estimate durian grower income per hectare in Peninsular Malaysia to have a range of US $600–30000, but these figures do not account for specific varieties grown and tree maturity, which would influence the number of fruits produced. Further research on the dependency ratio of specific durian cultivars on bat pollinators, and the subsequent effect on crop yield, will also shed more light on the degree of

dependency and subsequent long-term sustainability of Malaysia's durian industry on bat pollinators. One such insightful study in Sulawesi, Indonesia, valued bat pollination services at US $117 per hectare per fruiting season using a bioeconomic approach (Sheherazade et al., 2019). While valuation studies for managed pollinators (e.g., bee hives available for rent) exist, little is known about the value of wild pollinators and the services they provide (Baylis et al., 2021). As urbanisation and concomitant loss of pollinator habitat can impact pollination success and crop production in fruit farms (Sritongchuay, Hughes, Memmott et al., 2019, Sritongchuay, Hughes, & Bumrungsri, 2019, 2022), landscape connectivity between durian farms and bat pollinator habitats also needs to be better understood, including how proximity of farm to bat habitat influences both pollination success for durian (e.g., Sritongchuay et al., 2016), and fruit-raiding by bats. A cost-benefit analysis encompassing these aspects would shed some much-needed light on these opposing aspects and provide a more comprehensive view of the impact of bats in fruit farms.

There is also an urgent need for pollinator-friendly agricultural policy and pollinator-friendly farming guidelines. As hand-pollination is already necessary in Thailand to enhance fruit yield (O'Gara et al., 2004), there have been calls for durian orchards to be managed sustainably, using organic and eco-friendly practices that avoid the use of pesticides, and employ specific measures to conserve and increase wild bat pollinator populations (Chaiyarat et al., 2019); e.g., planting other bat-pollinated plants which will provide bats with food during non-durian season while also benefiting farmers (Stewart and Dudash, 2018). In relation to this, the cultural aspects of durian farming should be investigated; Traditional Ecological Knowledge and Indigenous durian cultivation practices could potentially provide insights and guidance for developing low-impact, nature-positive agriculture (Julis et al., 2025; Khoo, 2024), and these should be highlighted and promoted further with full and equitable Indigenous participation.

There are already existing policy recommendations for pollinator protection (Hipolito et al., 2021; IPBES, 2019; Martins, 2021), which include developing incentives to help growers benefit from pollination services. In Malaysia, even the most basic planting guidelines from the government stress the importance of planting at least three different cultivars to reduce disease risk (Airriess, 2020)—a practice that is also beneficial for pollination ecology.

Lastly, pollinators can only be maintained if pollinator sources and "green infrastructure"—connected habitat in which pollinators can thrive and move between roosting grounds and feeding sites—are protected (Dicks et al., 2016; Sritongchuay, Hughes, & Bumrungsri, 2019). Having a broader understanding of how land-use changes affect pollinator networks and communities will highlight how we can strategically safeguard these providers of pollination services. An example relevant to local durian growers is the roadmap for the conservation of flying foxes in Peninsular Malaysia (Aziz et al., 2019), which provides guidance on necessary research and conservation for long-term survival of this pollinator group within the Peninsular Malaysia context and landscape. While preliminary guidelines for bat-friendly farms (Rimba, 2018) have been developed, these should be further expanded on as necessary. Similar to longan fruit growers' demands in Thailand (Narjes & Lippert, 2016), what is ultimately needed to avoid the risk of a pollinator crisis is for durian growers to eventually organise, demand, and implement policies aimed at conserving wild bat pollinators. This will be instrumental in achieving both pollinator conservation and durian sustainability as a win-win solution.

## Conclusion

To our knowledge, our study is the first to have documented durian grower perceptions and responses to bats and other wildlife in their durian farms across Peninsular Malaysia. Our study has uncovered a large and severe knowledge gap about the importance of bat pollinators for durian, highlighting a crucial need for growers to incorporate pollination ecology and landscape factors into their farming practices to ensure the long-term security of pollination services for their crop. Our findings also reveal the need for better communication between growers, researchers, and policymakers to disseminate critical durian ecological knowledge and further the understanding of durian pollinators. Ultimately, we hope our survey results will help industry, policymakers, government agencies, and conservationists develop and implement pollinator- and biodiversity-friendly policies for the sustainable development of the durian industry in Southeast Asia.

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The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## Supplemental Material

Supplemental material for this article is available online.

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