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# ESTIMATING INSECT PEST CONSUMPTION BY THE ORIENTAL MAGPIE-ROBIN AND YELLOW-VENTED BULBUL IN OIL PALM PLANTATIONS FROM A FEEDING EXPERIMENT

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## ABSTRACT

*Insectivorous birds contribute to the provision of ecosystem services to humans in both human-dominated and natural ecosystems around the world. Natural predation of invertebrate populations is a prime example of one of the key ecosystem services provided by farmland birds in agricultural landscapes. Yet, it is unknown how many invertebrates are consumed by common farmland bird species such as Oriental Magpie-Robin (*Copsychus saularis*) and Yellow-vented Bulbul (*Pycnonotus goiavier*), which are abundant in oil palm plantations of Southeast Asia. Therefore, this study estimated the amount of insects consumed by these birds through a feeding experiment. From an assessment of 50 captured birds (25 individuals for each species), the average daily insect consumption of Oriental Magpie-Robin was estimated at 15.03 g/bird, which is slightly higher than Yellow-vented Bulbul (11.67 g/bird). These findings indicate that the potential of the two focal species to suppress insect populations might be limited by body weight and prey preferences. This study demonstrates the advantages of maintaining biodiversity, particularly farmland birds as biological control agents. Future estimates of pest insect consumption in oil palm plantations could potentially be based on the daily insect consumption by both bird species.*

**Keywords:** biodiversity, biological agent, birds, conservation, ecosystem services.

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## INTRODUCTION

Birds play a significant role as biological agents for controlling insect populations in both natural and human-modified landscapes (Díaz-Siefer et al., 2021; Garcia et al., 2020; Taylor et al., 2022). On a global scale, birds around the world are estimated to consume 400–500 million tonnes of invertebrates (e.g., beetles, crickets, grasshoppers) per year (Nyffeler et al., 2018). High in protein, 80% of bird species included insects as part of their diet in certain stages of their lifecycle (Mwansat et al., 2015). For

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some species, insects are the prime food resource for feeding nestlings as they provide adequate protein to support healthy growth (Capinera, 2010). Although there is a global estimate of insect consumption, little is known about insect eaten by birds and the amount of insect consumption in individual habitats, notably agroecosystems.

In agroecosystems, farmland birds provide various ecosystem services including insect pest suppression (Díaz-Siefer et al., 2021; Kamarudin et al., 2019; Milligan et al., 2016; Sow et al., 2020; Tela et al., 2021). It is estimated that 72%–89% of bird species found in oil palm plantations feed on insects (De Chenon & Susanto, 2006). In a study in Peninsular Malaysia, Yahya et al. (2023) shown the evidence of a positive correlation between the diversity of birds (both in terms of species richness and abundance) and the richness of insects in tropical farmlands, including oil palm plantations. According to their general ecological and feeding behaviour, some of the recorded bird species in agroecosystems reduce foliage and crop damages by suppressing insect and rodent pest populations resulting in an increase in crop yield (Díaz-Siefer et al., 2021; Yahya et al., 2024). In the case of oil palm cultivation, Koh (2008) highlighted the important role of insectivorous birds as natural pest control agents. However, previous studies have suggested that birds play a much smaller role as insect pest suppression agents compared to other taxa (e.g., arthropods) (Denan et al., 2019; 2023; Denmead et al., 2017; Nobilly et al., 2023). Nonetheless, Razak et al. (2020) found that oil palm smallholdings with high bird species richness and feeding guild diversity, but low bird abundance, produced higher yields, suggesting a significant role for birds as pest supressing agents in oil palm plantations.

Farmland birds are threatened by agriculture intensification, particularly by applying synthetic pesticides (Geiger et al., 2010). In industrial monoculture agroecosystems such as oil palm plantations, both chemical herbicides and insecticides are commonly used to control competing weeds and pest insects (Azhar et al., 2021; Razak et al., 2020; Tohiran et al., 2017, 2019; Wibawa et al., 2010). Prolonged application of such agrochemicals caused significant negative impacts on the ecosystems (Tohiran et al., 2019). For instance, heavy application of herbicides reduces understory vegetation complexity and structure (Nobilly et al., 2022), thus decimating one of the important habitats for biodiversity in oil palm agroecosystems (Ashton-Butt et al., 2018; Azhar et al., 2015). Understory vegetation provides valuable resources for farmland birds (i.e., nesting sites and food resources) including Oriental Magpie-Robin, *Copsychus saularis* (OMR) and Yellow-vented Bulbul, *Pycnonotus goiavier* (YVB) in oil palm plantations (Jambari et al., 2012).

OMR and YVB are common birds in oil palm plantations of Peninsular Malaysia, and they have been reported to consume insects including pest species in the plantations (Amit et al., 2015; Atiqah et al., 2019; Azhar et al., 2013; 2014; Azman et al., 2011; De Chenon & Susanto, 2006; Nursyamin et al., 2023; Tohiran *et at.*, 2019) (*Figure 1*). Both species were also recorded (often in high abundance) in oil palm plantations in other parts of Southeast Asia including Borneo (Amit et al., 2021; Gervais et al., 2012; Koh, 2008; Mohd-Azlan et al., 2019; Sheldon et al., 2010; Yudea and Santosa, 2019), Sumatra (De Chenon & Susanto, 2006), and the Philippines (Achondo et al., 2011; Cagod and Nuñeza, 2012). Compared to the introduced Barn Owl (*Tyto alba*), these understory resident passerine bird species are undervalued in terms of the ecosystem services they provide. To date, measures for promoting natural predation of pests in oil palm plantations are solely limited to Barn Owl (Atikah et al., 2020; Kamarudin et al., 2019; Yahya et al., 2016; 2020; Zainal-Abidin et al., 2021). For instance, providing nest boxes for Barn Owl has been commonly implemented in oil palm agroecosystems (Yahya et al., 2020).

(a)

(b)

*Figure 1. In Southeast Asia, (a) Oriental Magpie-Robin and (b) Yellow-vented Bulbul are common farmland birds in oil palm plantations.*

Oil palm stakeholders and growers have yet to consider the potential of farmland birds such as OMR and YVB to provide pest control services. Unlike the Barn Owl, exactly how many invertebrates are consumed by both OMR and YVB in oil palm plantations or other habitats (e.g., urban parks and forest edges) is not known. OMR exclusively feeds on insects (Collar et al., 2020), while YVB is a generalist that feeds on both plants and invertebrates, and it consumes 10%–35% of various invertebrates as its diet (Fishpool et al., 2020; Okosodo et al., 2016). Both local passerine species are likely to enhance natural pest control services in oil palm plantations as they are commonly seen in industrial palm plantations and smallholdings in Southeast Asia (Yahya et al., 2017, 2022, 2023). As changes in agricultural management may affect bird predation services by altering the resource base for natural enemies (Liere et al., 2017), there is an urgent need to understand pest insect control services provided by OMR and YVB in oil palm plantations.

This study aimed to assess the potential of two common farmland bird species (i.e., OMR and YVB) in suppressing insect populations in oil palm plantations via a feeding experiment. Mealworms (*Tenebrio molitor*) were used as substitutes for pest insects predated by the bird species. It was assumed that the captured birds would consume a similar amount of food insects as in the wild. Specifically, the objectives were to: 1) Estimate the amount of insect food intake by OMR and YVB; 2) compare the amount of insect food intake between OMR and YVB; and 3) examine the association between bird weight and insect food intake. To understand the potential pest control services by those bird species, two hypotheses were proposed. First, it was predicted that OMR consumes more insects than YVB. Second, it was predicted that insect consumption is positively related to body size. Findings from this study will improve the understanding of oil palm industry stakeholders regarding the conservation value of farmland birds, as well as their important roles in controlling insect populations in oil palm agroecosystems. This will help stakeholders to make more informed conservation decisions and improve their agricultural policies by incorporating land sharing or bird-friendly farming strategies.

## MATERIALS AND METHODS

### Study Area and Bird Trapping

The study was conducted in Lahad Datu District, Sabah, East Malaysia. Lahad Datu has a typical equatorial climate; hot and humid year-round with a daily mean temperature of 26.9°C and an average annual rainfall of 2,063 mm. Throughout the study, a total of 50 wild birds comprising OMR and YVB (25 birds for each species) were captured using mist-nets (6 x 3 m, 15 mm mesh-size) in oil palm smallholdings located at Kampung Kongsi (05°01′12″ N, 118°25′07″ E) and Kampung Bikang (05°00′56″ N, 118°27′11″ E). Ten mist-nets were deployed during each session to increase the chance of capturing focal species. Deployed mist-nets were checked frequently (every 20 min). Only adult OMR and YVB were kept for the feeding experiment. All bird trapping sessions were conducted between August and September 2021.

### Feeding Experiment

Prior to the experiment, birds were first weighed using a portable digital weighing scale on the day of capture. Each bird was individually kept in a cage (55 x 55 x 55 cm) inside a well-ventilated aviary throughout the experiment (10 consecutive days). Each cage was carefully placed inside the aviary to avoid direct exposure to sunlight. Only 10 captured birds were attended at a time. Birds captured were fed with fine food pellets and plain water was provided in separate containers for the night. To avoid acute stress on the birds, each occupied cage was covered with a cloth throughout the experiment. The feeding experiment was conducted the following morning at 06:00 by providing 30 g of live mealworms in a container. Mealworms were used for this experiment due to their morphological similarity to lepidopteran larvae.

After a 24 hr period, the leftover mealworms were weighed with a portable digital spoon scale. The leftover mealworms were replaced with a new 30 g of live mealworms, and this process was repeated for the next nine consecutive days. Water containers were cleaned and refilled daily. Prior to the release, all birds were weighed and tagged with a leg band before being released at the location where they were captured. The tag was to ensure no same individual bird was repeatedly used for the experiment. To safeguard animal welfare and avoid causing them unnecessary physical injuries, a qualified veterinary doctor monitored the trapping procedures and feeding experiment.

### Data Analysis

Generalised linear mixed models (GLMMs) that included both fixed and random effects were performed to assess the relationship between mealworms consumed, body weight, and bird species (Bolker et al., 2009; Schall, 1991). A normal distribution with an identity-link function was used for the models. A predictive model of the average consumed weight of mealworms was developed. The body weight of birds and species (i.e., OMR and YVB) were fitted as fixed effects.

Plot location was included in the model as a random factor (Bolker et al., 2009; Piepho et al., 2003). The final model was selected by sequentially adding explanatory variables to the initial model. The conventional and adjusted coefficients of regression, as well as the $r^2$ for the model, were reported. Paired t-tests were conducted to compare the body weight of each species before and after the feeding experiment. A one-way ANOVA was performed to test the effects of different birds and days on mealworm consumption. Post hoc Tukey's test was used to compare the means of mealworm consumption across different birds and days. All analyses were conducted in GenStat (VSN International, UK).

## RESULTS AND DISCUSSION

The results revealed that mealworm consumption was positively related to body weight (coefficient = 0.034, Wald = 13.82, $p$ < 0.001). Irrespective of species, birds with heavier body weight tend to consume more insect food in comparison to lighter birds. The body weights of OMR (back-transformed mean ± SD = 41.67 ± 6.46 g per bird, df = 24, t = 0.77, $p$ = 0.446) and YVB (back-transformed mean ± SD = 26.00 ± 5.10 g per bird, df = 24, t = 0.20, $p$ = 0.846) did not significantly change before and after the feeding experiment. It was observed that the mean weight of OMR was higher than that of YVB both prior to and after the feeding procedures (*Table 1*). In daily mealworm consumption, OMR (mean = 15.03 g per bird) was significantly greater (YVB, coefficient = –3.352, Wald = 4.07, $p$ = 0.044) than YVB (mean = 11.67 g per bird) (*Figure 2*). On a daily basis, OMR is likely to eat more insects than YVB in oil palm plantations. The statistical model explained 27.57% (adjusted $r^2$ = 24.49%) of the variation in mealworm consumption by both bird species. It was found that mealworm consumption by OMR and YVB varied significantly in different birds (OMR: Variance ratio = 7.22, $p$<0.001; YVB: Variance ratio = 1.86, $p$ = 0.011). Only insect consumption by OMR varied significantly on different days, but YVB did not (OMR: Variance ratio = 3.25, $p$ < 0.001; YVB: Variance ratio = 1.74, $p$ = 0.080). Post hoc test results indicate that mealworm consumption varied among birds and days (*Table 2* and *3*).

**TABLE 1. SUMMARY STATISTICS FOR MEASUREMENTS OF ORIENTAL MAGPIE-ROBIN AND YELLOW-VENTED BULBUL BODY WEIGHT BEFORE/AFTER THE FEEDING EXPERIMENT**

| Species | Value | Before feeding experiment (g) | After feeding experiment (g) |
|---|---|---|---|
| Oriental Magpie-Robin (n = 25) | Mean ± SD | 54.4 ± 7.3 | 53.4 ± 7.2 |
| | Median | 55 | 50 |
| | Minimum | 40 | 45 |
| | Maximum | 65 | 65 |
| Yellow-vented Bulbul (n = 25) | Mean ± SD | 37.6 ± 3.9 | 37.4 ± 3.9 |
| | Median | 40 | 35 |
| | Minimum | 30 | 30 |
| | Maximum | 45 | 45 |

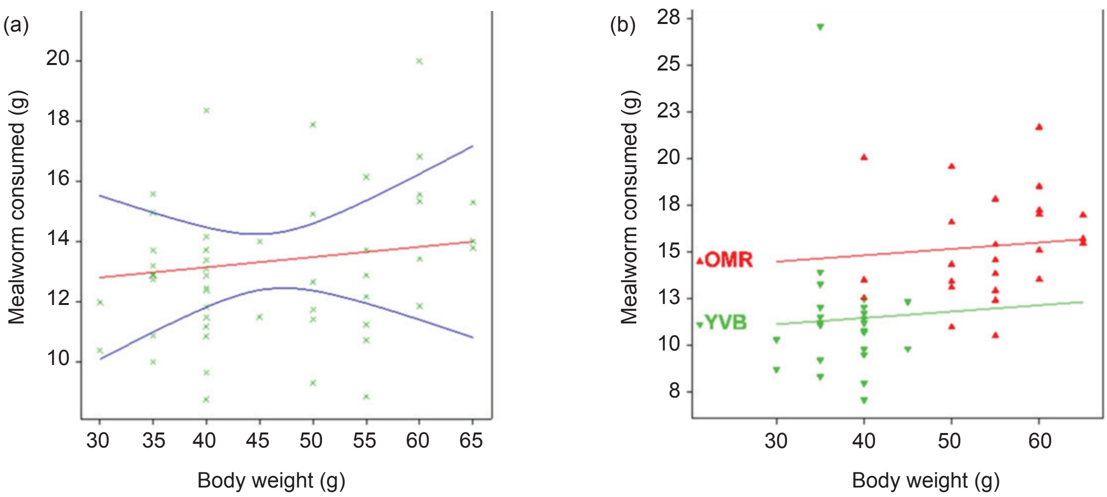


*Figure 2. (a) Scatter plot with a regression line (red) and 95% confidence intervals (blue) demonstrating a positive relationship between mealworm consumption and body weight in both bird species, and (b) scatter plot illustrating mealworm consumption by OMR and YVB, proportionate to body weight.*

**TABLE 2. TUKEY'S HONEST SIGNIFICANCE DIFFERENCE TEST RESULTS SHOWING THE COMPARISON OF MEALWORM CONSUMPTION IN DIFFERENT BIRDS. MEALWORM CONSUMPTION VARIED SIGNIFICANTLY BETWEEN CERTAIN INDIVIDUALS**

| Species | Bird | Mean (g) | Tukey |
|---|---|---|---|
| Oriental Magpie-Robin | OMR18 | 10.52 | a |
| | OMR8 | 10.98 | a |
| | OMR7 | 12.41 | ab |
| | OMR6 | 12.53 | ab |
| | OMR11 | 12.93 | ab |
| | OMR17 | 13.10 | abc |
| | OMR1 | 13.42 | abc |
| | OMR10 | 13.50 | abc |
| | OMR21 | 13.54 | abc |
| | OMR9 | 13.84 | abc |
| | OMR15 | 14.34 | abcd |
| | OMR13 | 14.56 | abcde |
| | OMR24 | 15.10 | abcde |
| | OMR14 | 15.39 | abcde |
| | OMR22 | 15.47 | abcde |
| | OMR20 | 15.70 | abcde |
| | OMR2 | 16.59 | bcdef |
| | OMR25 | 16.98 | bcdef |
| | OMR5 | 17.02 | bcdef |
| | OMR23 | 17.24 | bcdef |
| | OMR19 | 17.83 | bcdef |
| | OMR4 | 18.51 | cdef |
| | OMR16 | 19.57 | def |
| | OMR12 | 20.04 | ef |
| | OMR3 | 21.68 | f |
| Yellow-vented Bulbul | YVB22 | 7.08 | a |
| | YVB14 | 7.98 | a |
| | YVB15 | 8.33 | a |
| | YVB9 | 8.71 | a |
| | YVB11 | 9.21 | a |
| | YVB17 | 9.50 | a |
| | YVB20 | 9.80 | a |
| | YVB24 | 9.82 | a |
| | YVB12 | 10.31 | a |
| | YVB16 | 10.70 | a |
| | YVB8 | 10.78 | a |
| | YVB6 | 11.08 | a |
| | YVB1 | 11.19 | a |
| | YVB10 | 11.19 | a |
| | YVB5 | 11.22 | a |
| | YVB25 | 11.42 | a |
| | YVB3 | 11.52 | a |
| | YVB23 | 11.71 | a |
| | YVB18 | 12.03 | a |
| | YVB19 | 12.05 | a |

**TABLE 2. TUKEY'S HONEST SIGNIFICANCE DIFFERENCE TEST RESULTS SHOWING THE COMPARISON OF MEALWORM CONSUMPTION IN DIFFERENT BIRDS. MEALWORM CONSUMPTION VARIED SIGNIFICANTLY BETWEEN CERTAIN INDIVIDUALS (continued)**

| Species | Bird | Mean (g) | Tukey |
|---|---|---|---|
| | YVB2 | 12.33 | a |
| | YVB7 | 12.48 | a |
| | YVB4 | 13.28 | ab |
| | YVB21 | 13.92 | ab |
| | YVB13 | 27.07 | b |
| | YVB22 | 7.08 | a |
| | YVB14 | 7.98 | a |
| | YVB15 | 8.33 | a |

**TABLE 3. TUKEY'S HONEST SIGNIFICANCE DIFFERENCE TEST RESULTS SHOWING THE COMPARISON OF MEALWORM CONSUMPTION ON DIFFERENT DAYS. MEALWORM CONSUMPTION DIFFERED BETWEEN DAYS, BUT VARIED SIGNIFICANTLY IN SPECIFIC DAYS**

| Species | Bird | Mean (g) | Tukey |
|---|---|---|---|
| Oriental Magpie-Robin | Day10 | 12.67 | a |
| | Day9 | 13.84 | ab |
| | Day8 | 13.90 | ab |
| | Day4 | 15.25 | ab |
| | Day7 | 15.36 | ab |
| | Day6 | 15.44 | ab |
| | Day5 | 16.07 | ab |
| | Day1 | 16.57 | b |
| Yellow-vented Bulbul | Day1 | 9.35 | a |
| | Day10 | 9.48 | a |
| | Day8 | 10.31 | ab |
| | Day6 | 10.46 | ab |
| | Day9 | 10.69 | ab |
| | Day7 | 10.76 | ab |
| | Day2 | 11.34 | ab |
| | Day4 | 11.80 | ab |
| | Day3 | 12.29 | ab |
| | Day5 | 17.39 | b |

By estimating the daily insect consumption by both bird species from the feeding experiment, the findings highlight the importance of undervalued common farmland birds as potential providers for insect pest regulation in oil palm production landscapes. The prediction made in this study is considered conservative due to the tendency for both bird species to exhibit a greater consumption of different insects within oil palm plantations, as compared to the bird specimens obtained in the feeding experiment. The daily insect intake of both bird species might be used in the future to estimate pest insect control services in oil palm operations. In the future, the density of both bird species in oil palm plantations should be assessed to estimate insect consumption. Such data on bird density in oil palm fields is currently lacking since many published bird studies have focused on species diversity (Atiqah et al., 2019; Azhar et al., 2011, 2013, 2014; Azman et al., 2011; Tohiran et al., 2019; Yahya et al., 2017, 2022).

In general, it was found that OMR consumed a larger amount of mealworms than YVB. Such finding was expected, although considered as generalist and opportunist, small fruits and berries make up a large proportion of the adult YVB diet (Fishpool et al., 2020). YVB has also been observed to feed more on invertebrates than plants when feeding its chicks. Wee (2009) also noted that YVB feeds its chicks with invertebrates as its primary source of food. On the other hand, OMR feeds mainly on termites, ants and black soldier fly larvae

(Ashitha & Seedikkoya, 2020). Though OMR is considered insectivorous, it has also been observed feeding on geckos and other small lizards.

The results suggested that mealworm consumption varied between individuals. Some individual birds are likely to consume more insects compared to others. Although the ability of OMR and YVB to suppress insect populations may vary depending on the individuals, both species are likely to be valuable biological agents to control and suppress insect populations to a certain threshold given the immediate presence of both species in oil palm plantations, particularly in the study region. Both species are considered common and can be found in high abundance in Malaysia (Amit et al., 2021; Atiqah et al., 2019; Azhar et al., 2013, 2014; Mohd-Azlan et al., 2019; Yahya et al., 2017).

Mealworm consumption was associated with bird weight, with larger individuals consuming significantly more mealworms (*Figure 2a*). Our results also indicate that this relationship is proportionate to body weight for both OMR and YVB (*Figure 2b*). It is generally assumed that insectivorous birds consume half of their body weight per day to meet the daily energy demand (Railsback & Johnson, 2011). While it is likely that larger-bodied birds consume a greater amount of insect prey per day, oil palm is less favourable to most of the large-bodied insectivorous species (e.g., trogons, malkohas, drongos) which are commonly associated with closed habitats (e.g., lowland dipterocarp forests) (Billerman et al., 2022; Jeyarajasingam, 2012; Wells, 1999, 2010). Oil palm agriculture is commonly associated with various small to medium-bodied insectivorous birds (both diurnal and nocturnal birds) with various foraging specialisations (e.g., bark gleaning, foliage gleaning, sallying, terrestrial) (Azhar et al., 2013, 2014). For example, in Sarawak, Malaysia, Amit et al. (2021) found insectivorous birds constituted almost 50% of recorded bird species in oil palm plantations. These common insectivorous bird species are likely to consume a range of invertebrates including those which may cause damage to crops (e.g., herbivory insects).

There is a range of invertebrate species consumed in oil palm by insectivorous birds. Amit et al. (2015) reported that YVB's invertebrate food preferences mainly comprised of beetles (Coleoptera), followed by various other arthropod orders including true bugs (Hemiptera), flies and mosquitoes (Diptera), as well as wasps, bees and ants (Hymenoptera). Amit et al. (2015) also reported that dragonflies and damselflies (Odonata), grasshoppers and crickets (Orthoptera), termites and cockroaches (Blattodea), as well as butterflies and moths (Lepidoptera) were absent in stomach content analysis conducted on 45 individual YVB (Amit et al., 2015). As a generalist, YVB tends to consume insects, but dietary preferences may vary depending on life stages, as well as the availability of certain prey within their habitat.

The results suggested that YVB consumed a similar weight of mealworms throughout the experiment, indicating that predation pressure on arthropods provided by YVB is likely to be consistent in the wild. In other locations bulbul species have been found to have similar roles as in Fiji, the invasive bulbul species, Red-vented Bulbul (*Pycnonotus cafer*) has been identified as an effective insect control agent in agricultural landscapes (Thibault et al., 2018). In India, the Red-vented Bulbul has been shown to protect crops from the invasive cotton bollworm (*Helicoverpa armigera*). Contrary to the Red-vented Bulbul species, little information is known regarding the effectiveness of YVB in suppressing insect populations in agricultural landscapes.

It is acknowledged that the present study has several limitations concerning its experimental components. While this study involved assessing the daily consumption of insects by captured wild birds, the mealworm consumption data may not be completely representative of daily insect consumption in the wild. Nonetheless, this is the first study to provide baseline data on how much insects are devoured daily by typical farmland birds in oil palm plantations. Feeding behaviours may vary considerably between captive and natural environments due to the large energy expenditure needed to obtain food in the wild. In addition, the feeding behaviour of OMR and YVB may be influenced by various factors including insect diversity and abundance, habitat structure, breeding season, provisioning of nestlings, foraging strategy and territorial behaviour of a species (Hawa et al., 2016; Sethi & Bhatt, 2007; Singh et al., 2016; Wee, 2009), all of which cannot be accounted for by the experiment design. In addition, this study did not partition the estimated consumption data according to male or female birds as the sex of the YVB could not be morphologically determined. However, this study provides a good starting point for determining the important contribution of avian fauna, particularly OMR and YVB, to pest control ecosystem services (Nyffeler et al., 2018; Razak et al., 2020; Yahya et al., 2024).

The data suggests that associated biodiversity, particularly farmland birds and their pest control services can be crucial to maintaining high oil palm yields providing further evidence of the importance of undertaking land sharing or bird-friendly farming strategy. The implementation of land sharing strategy can benefit birds such as OMR and YVB by protecting their habitats and reducing the application of synthetic pesticides in oil palm landscapes. In addition to the benefits for the focal species, such strategies can also protect numerous animal species that inhabit or visit oil palm plantations. Land sharing therefore needs to be an integral part of oil palm certification schemes (e.g., Roundtable on Sustainable Palm Oil [RSPO] and Malaysian Sustainable Palm Oil [MSPO]) and Integrated Pest Management (IPM).

## CONCLUSION

In the future, the daily insect consumption by both bird species can be potentially used to estimate pest insect control services in oil palm plantations. The estimates presented in this paper emphasise the ecological and economic significance of common farmland birds in controlling insect populations, especially in tropical agricultural landscapes. The findings demonstrate the capabilities of common farmland bird species in suppressing insect populations might be limited by their food intake patterns which are influenced by various factors including species, body weight and prey preferences. The industry stakeholders should maintain both bird species' habitats inside oil palm plantations since they are potential biological control agents.

Minimising the use of agrochemicals and promoting natural processes (e.g., natural predation) are viable ways to improve sustainability in large-scale oil palm agroecosystems. Oil palm stakeholders, both smallholders and plantation companies, should consider associated biodiversity (i.e., farmland wildlife) as much as forest biodiversity in their conservation and landscape management. The conservation of beneficial birds such as OMR and YVB can be enhanced through land sharing or bird-friendly farming strategies in oil palm landscapes. Future work should investigate the role of associated biodiversity including farmland birds and other animal taxa, in oil palm production landscapes (i.e., smallholdings and industrial plantations) and their contribution to ecosystem services and disservices.

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