

# 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-Sieffer *et al.*, 2021; García *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 some species, insects are

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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-Sieffer *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-Sieffer *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 suppressing 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 al.*, 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 Nuñez, 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 (Atiqah *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).



Figure 1. In Southeast Asia, (a) (top) Oriental Magpie-Robin and (b) (bottom) 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 Kongsu (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, Hemel Hempstead, 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  $\pm$  SD = 41.67  $\pm$  6.46 g per bird, df = 24,  $t = 0.77$ ,  $p = 0.446$ ) and YVB (back-transformed mean  $\pm$  SD = 26.00  $\pm$  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 $\pm$ SD	54.4 $\pm$ 7.3	53.4 $\pm$ 7.2
	Median	55	50
	Minimum	40	45
	Maximum	65	65
Yellow-vented Bulbul (n = 25)	Mean $\pm$ SD	37.6 $\pm$ 3.9	37.4 $\pm$ 3.9
	Median	40	35
	Minimum	30	30
	Maximum	45	45

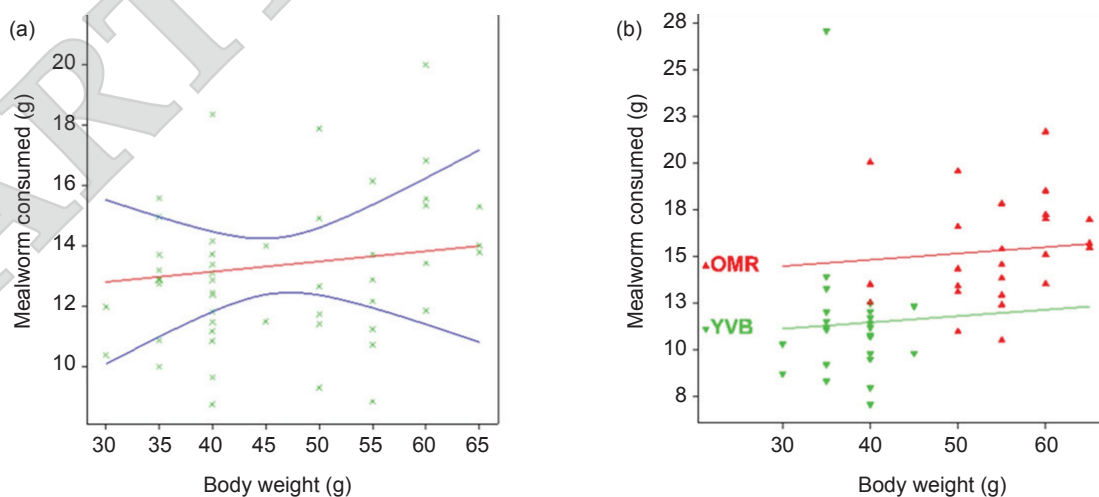


Figure 2. (a) Scatter plot with a regression line (red) and 95% confidence intervals (blue) demonstrating a positive relationship between mealworm consumption and body weight in both bird species, and (b) scatter plot illustrating mealworm consumption by OMR and YVB, proportionate to body weight.

**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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### REFERENCES

- Achondo, M. J. M. M., Casim, L., Bello, V. P., Tanalgo, K. C., Agduma, A. R., Bretaña, B. L. P., Mancao, L. S., Salem, J. G. S., & Supremo, J. P. (2011). Rapid assessment and feeding guilds of birds in selected rubber and oil palm plantations in North Cotabato. *Asian Journal of Biodiversity*, 2(1), 103–120.
- Amit, B., Tuen, A. A., & Kho, L. K. (2021). Bird species richness, abundance, and their feeding guild across oil palms development through mist-netting method in Betong, Sarawak. *Journal of Oil Palm Research*, 33(4), 617–628. <https://doi.org/10.21894/jopr.2021.0017>.
- Amit, B., Tuen, A. A., Haron, K., Harun, M. H., & Norman, K. (2015). The diet of yellow-vented bulbul (*pycnonotus goiavier*) in oil palm agroecosystems. *Journal of Oil Palm Research*, 27(4), 417–424.
- Ashitha, T., & Seedikkoya, K. (2020). Notes on food and feeding habits of Oriental Magpie-Robin (*Copsychus saularis*). *International Research Journal of Biological Sciences*, 9(3), 29–32.
- Ashton-Butt, A., Aryawan, A. a. K., Hood, A. S. C., Naim, M., Purnomo, D., Suhardi, N., Wahyuningsih, R., Willcock, S., Poppy, G. M., Caliman, J., Turner, E. C., Foster, W. A., Peh, K. S., & Snaddon, J. L. (2018). Understorey vegetation in oil palm plantations benefits soil biodiversity and decomposition rates. *Frontiers in Forests and Global Change*, 1. <https://doi.org/10.3389/ffgc.2018.00010>
- Atikah, S. N., Yahya, M. S., Puan, C. L., Zakaria, M., & Azhar, B. (2020). Can Forest-Associated nocturnal birds persist in oil palm agroecosystem? *Ornithological Science*, 18(2), 127–134. <https://doi.org/10.2326/osj.18.134>
- Atiqah, N., Yahya, M. S., Aisyah, S., Ashton-Butt, A., & Azhar, B. (2019). Birds associated with different tree species and structures in oil palm agroforestry landscapes in Malaysia. *Emu - Austral Ornithology*, 119(4), 397–401. <https://doi.org/10.1080/01584197.2019.1621680>
- Azhar, B., Lindenmayer, D. B., Wood, J., Fischer, J., Manning, A., McElhinny, C., & Zakaria, M. (2011). The conservation value of oil palm plantation estates, smallholdings and logged peat swamp forest for birds. *Forest Ecology and Management*, 262(12), 2306–2315. <https://doi.org/10.1016/j.foreco.2011.08.026>

- Azhar, B., Lindenmayer, D. B., Wood, J., Fischer, J., Manning, A., Mcelhinny, C., & Zakaria, M. (2013). The influence of agricultural system, stand structural complexity and landscape context on foraging birds in oil palm landscapes. *Ibis*, 155(2), 297–312. <https://doi.org/10.1111/ibi.12025>
- Azhar, B., Puan, C. L., Aziz, N., Sainuddin, M., Adila, N., Samsuddin, S., Asmah, S., Syafiq, M., Razak, S. A., Hafizuddin, A., Hawa, A., & Jamian, S. (2015). Effects of *in situ* habitat quality and landscape characteristics in the oil palm agricultural matrix on tropical understory birds, fruit bats and butterflies. *Biodiversity and Conservation*, 24(12), 3125–3144. <https://doi.org/10.1007/s10531-015-1005-6>
- Azhar, B., Puan, C. L., Zakaria, M., Hassan, N., & Arif, M. (2014). Effects of monoculture and polyculture practices in oil palm smallholdings on tropical farmland birds. *Basic and Applied Ecology*, 15(4), 336–346. <https://doi.org/10.1016/j.baae.2014.06.001>
- Azhar, B., Tohiran, K. A., Nobilly, F., Zulkifli, R., Syakir, M. I., Ishak, Z., Razi, N., Oon, A., Shahdan, A., & Maxwell, T. M. R. (2021). Time to revisit oil Palm-Livestock integration in the wake of United Nations Sustainable Development Goals (SDGs). *Frontiers in Sustainable Food Systems*, 5. <https://doi.org/10.3389/fsufs.2021.640285>
- Azman, N. M., Latip, N. S. A., Sah, S. A. M., Akil, M. A. M. M., Shafie, N. J., & Khairuddin, N. L. (2011). Avian diversity and feeding guilds in a secondary forest, an oil palm plantation, and a paddy field in riparian areas of the Kerian River Basin, Perak, Malaysia. *Tropical Life Sciences Research*, 22(2), 45–64.
- Billerman, S. M., Keeney, B. K., Rodewald, P. G., & Schulenberg, T. S. (Eds.). (2022). *Birds of the World*. Cornell Laboratory of Ornithology, Ithaca, NY, USA. Retrieved from <https://birdsoftheworld.org/bow/home> (accessed on XX).
- Bolker, B. M., Brooks, M. E., Clark, C. J., Geange, S. W., Poulsen, J. R., Stevens, M. H. H., & White, J. S. S. (2009). Generalized linear mixed models: a practical guide for ecology and evolution. *Trends in Ecology & Evolution*, 24(3), 127–135. <https://doi.org/10.1016/j.tree.2008.10.008>
- Cagod, B. M., & Nuñez, O. M. (2012). Avian species diversity in oil palm plantations of Agusan Del Sur and Compostela Valley, Philippines. *AES Bioflux*, 4(2), 85–105.
- Capinera, J. (2010). *Insects and wildlife: Arthropods and their relationships with wild vertebrate animals*. John Wiley & Sons Ltd., West Sussex, UK, 91 pp.
- Collar, N., Christie, D. A., & Kirwan, G. M. (2020). Oriental Magpie-Robin (*Copsychus saularis*), version 1.0. In Del Hoyo, J., Elliott, A., Sargatal, J., Christie, D. A., & De Juana, E. (Eds.), *Birds of the World*. Cornell Lab of Ornithology, Ithaca, NY, USA. <https://doi.org/10.2173/bow.magrob.01>
- De Chenon, R. D., & Susanto, A. (2006). Ecological observations on the diurnal birds in Indonesian oil palm plantations. *Journal of Oil Palm Research, (Special Issue)*, 122–143.
- Denan, N., Norhisham, A. R., Sanusi, R., Stone, J., & Azhar, B. (2023). Stand-level habitat characteristics and edge habitats drive biological pest control services in the understory of oil palm plantations. *Biological Control*, 183, 105261. <https://doi.org/10.1016/j.biocontrol.2023.105261>
- Denan, N., Zaki, W. M. W., Norhisham, A. R., Sanusi, R., Nasir, D. M., Nobilly, F., Ashton-Butt, A., Lechner, A. M., & Azhar, B. (2019). Predation of potential insect pests in oil palm plantations, rubber tree plantations, and fruit orchards. *Ecology and Evolution*, 10(2), 654–661. <https://doi.org/10.1002/ece3.5856>
- Denmead, L. H., Darras, K., Clough, Y., Diaz, P., Grass, I., Hoffmann, M. P., Nurdiansyah, F., Fardiansah, R., & Tscharnke, T. (2017). The role of ants, birds and bats for ecosystem functions and yield in oil palm plantations. *Ecology*, 98(7), 1945–1956. <https://doi.org/10.1002/ecy.1882>
- Díaz-Sieffer, P., Olmos-Moya, N., Fontúrbel, F. E., Lavandero, B., Pozo, R. A., & Celis-Diez, J. L. (2021). Bird-mediated effects of pest control services on crop productivity: A global synthesis. *Journal of Pest Science*, 95(2), 567–576. <https://doi.org/10.1007/s10340-021-01438-4>
- Fishpool, L., Tobias, J., & de Juana, E. (2020). Yellow-vented Bulbul (*Pycnonotus goiavier*), version 1.0. In Del Hoyo, J., Elliott, A., Sargatal, J., Christie, D. A., & De Juana, E. (Eds.), *Birds of the World*. Cornell Lab of Ornithology, Ithaca, NY, USA. <https://doi.org/10.2173/bow.yevbul.1.01>
- Garcia, K., Olimpi, E. M., Karp, D. S., & Gonthier, D. J. (2020). The good, the bad, and the risky: Can birds be incorporated as biological control agents into integrated pest management programs? *Journal of Integrated Pest Management*, 11(1), 1–11. <https://doi.org/10.1093/jipm/pmaa009>

- Geiger, F., Bengtsson, J., Berendse, F., Weisser, W. W., Emmerson, M., Morales, M. B., Ceryngier, P., Liira, J., Tschantke, T., Winqvist, C., Eggers, S., Bommarco, R., Pärt, T., Bretagnolle, V., Plantegenest, M., Clement, L. W., Dennis, C., Palmer, C., Oñate, J. J., . . . Inchausti, P. (2010). Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. *Basic and Applied Ecology*, *11*(2), 97–105. <https://doi.org/10.1016/j.baae.2009.12.001>
- Gervais, M., Bakewell, D., Azmi, R., & Zainal Abidin, A. A. (2012). Preliminary bird diversity study in oil palm plantation suggests positive effects of biodiversity enhancement: Technical communication. *Journal of Oil Palm and the Environment*, *3*(4), 30–37. <https://doi.org/10.5366/jope.2012.04>
- Hawa, A., Azhar, B., Top, M. M., & Zubaid, A. (2016). Depauperate avifauna in tropical peat swamp forests following logging and conversion to oil palm agriculture: Evidence from mist-netting data. *Wetlands*, *36*(5), 899–908. <https://doi.org/10.1007/s13157-016-0802-3>
- Jambari, A., Azhar, B., Ibrahim, N. L., Jamian, S., Hussin, A., Puan, C. L., Hafidzi, M. N., Yusof, E., & Zakaria, M. (2012). Avian biodiversity and conservation in Malaysian oil palm production areas. *Journal of Oil Palm Research*, *24*, 1277–1286.
- Jeyarajasingam, A. (2012). *A field guide to the birds of Peninsular Malaysia and Singapore*. Oxford University Press, Oxford. 67 pp.
- Kamarudin, N., Abu Seman, I., & Mohd Masri, M. M. (2019). Prospects in sustainable control of oil palm pests and diseases through the enhancement of ecosystem services – the way forward. *Journal of Oil Palm Research*, *31*(3), 381–393. <https://doi.org/10.21894/jopr.2019.0030>
- Koh, L. P. (2008). Birds defend oil palms from herbivorous insects. *Ecological Applications*, *18*(4), 821–825. <https://doi.org/10.1890/07-1650.1>
- Liere, H., Jha, S., & Philpott, S. M. (2017). Intersection between biodiversity conservation, agroecology, and ecosystem services. *Agroecology and Sustainable Food Systems*, *41*(7), 723–760. <https://doi.org/10.1080/21683565.2017.1330796>
- Milligan, M. C., Johnson, M. D., Garfinkel, M., Smith, C. J., & Njoroge, P. (2016). Quantifying pest control services by birds and ants in Kenyan coffee farms. *Biological Conservation*, *194*, 58–65. <https://doi.org/10.1016/j.biocon.2015.11.028>
- Mohd-Azlan, J., Fang, V. A. M., Kaicheen, S. S., Lok, L., & Lawes, M. J. (2019). The diversity of understorey birds in forest fragments and oil palm plantation, Sarawak, Borneo. *Journal of Oil Palm Research*, *31*(3), 437–447.
- Mwansat, G. S., Turshak, L. G., & Okolie, M. O. (2015). Insects as important delicacy for birds: Expanding our knowledge of insect food ecology of birds in the tropics. *Journal of International Scientific Publications*, *9*(1), 434–441.
- Nobilly, F., Atikah, S. N., Yahya, M. S., Jusoh, S., Cun, G. S., Norhisham, A. R., Tohiran, K. A., Zulkifli, R., & Azhar, B. (2022). Rotational cattle grazing improves understory vegetation biodiversity and structural complexity in oil palm plantations. *Weed Biology and Management*, *22*(1), 13–26. <https://doi.org/10.1111/wbm.12246>
- Nobilly, F., Atikah, S. N., Yahya, M. S., Jusoh, S., Maxwell, T. M. R., Norhisham, A. R., Tohiran, K. A., Zulkifli, R., & Azhar, B. (2023). Do silvopastoral management practices affect biological pest control in oil palm plantations? *BioControl*, *68*, 411–424. <https://doi.org/10.1007/s10526-023-10196-4>
- Nursyamin, Z., Yahya, M. S., Atikah, S. N., Tohiran, K. A., Norhisham, A. R., Othman, N. W., Lechner, A. M., & Azhar, B. (2023). Identifying indicator bird species for sustainable oil palm plantation certification. *Journal of Cleaner Production*, *415*, 137852. <https://doi.org/10.1016/j.jclepro.2023.137852>
- Nyffeler, M., Şekercioğlu, Ç. H., & Whelan, C. J. (2018). Insectivorous birds consume an estimated 400–500 million tons of prey annually. *The Science of Nature*, *105*(7–8), 47. <https://doi.org/10.1007/s00114-018-1571-z>
- Okosodo, E., Orimaye, J., & Obasogie, F. (2016). Food and Feeding Ecology of Common Bulbul (*Pycnonotus barbatus*) in Leventis Foundation Agricultural School Ilesa South Western Nigeria. *Greener Journal of Agricultural Sciences*, *6*(1), 10–16.
- Piepho, H. P., Büchse, A., & Emrich, K. (2003). A hitchhiker's guide to mixed models for randomized experiments. *Journal of Agronomy and Crop Science*, *189*(5), 310–322. <https://doi.org/10.1046/j.1439-037x.2003.00049.x>
- Railsback, S. F., & Johnson, M. D. (2011). Pattern-oriented modeling of bird foraging and pest

- control in coffee farms. *Ecological Modelling*, 222(18), 3305–3319. <https://doi.org/10.1016/j.ecolmodel.2011.07.009>
- Razak, S. A., Saadun, N., Azhar, B., & Lindenmayer, D. B. (2020). Smallholdings with high oil palm yield also support high bird species richness and diverse feeding guilds. *Environmental Research Letters*, 15(9), 094031. <https://doi.org/10.1088/1748-9326/aba2a5>
- Schall, R. (1991). Estimation in generalized linear models with random effects. *Biometrika*, 78(4), 719–727. <https://doi.org/10.1093/biomet/78.4.719>
- Sethi, V. K., & Bhatt, D. (2007). Provisioning of young by the Oriental Magpie-Robin (*Copsychus saularis*). *The Wilson Journal of Ornithology*, 119(3), 356–360. <https://doi.org/10.1676/06-105.1>
- Sheldon, F. H., Styring, A., & Hosner, P. A. (2010). Bird species richness in a Bornean exotic tree plantation: A long-term perspective. *Biological Conservation*, 143(2), 399–407. <https://doi.org/10.1016/j.biocon.2009.11.004>
- Singh, A., Bhatt, D., Sethi, V. K., & Dadwal, N. (2016). Nesting success of the oriental magpie robin *Copsychus saularis* in nest boxes and tree cavities. *Wildlife Biology*, 22(6), 277–283. <https://doi.org/10.2981/wlb.00233>
- Sow, A., Seye, D., Faye, E., Benoit, L., Galan, M., Haran, J., & Brévault, T. (2020). Birds and bats contribute to natural regulation of the millet head miner in tree-crop agroforestry systems. *Crop Protection*, 132, 105127. <https://doi.org/10.1016/j.cropro.2020.105127>
- Taylor, J. M., Smith, O. M., Edworthy, M., Kennedy, C. M., Latimer, C. E., Owen, J. P., Wilson-Rankin, E. E., & Snyder, W. E. (2022). Bird predation and landscape context shape arthropod communities on broccoli. *Ornithological Applications*, 124(2). <https://doi.org/10.1093/ornithapp/duac005>
- Tela, M., Cresswell, W., & Chapman, H. (2021). Pest-removal services provided by birds on subsistence farms in south-eastern Nigeria. *PLoS ONE*, 16(8), e0255638. <https://doi.org/10.1371/journal.pone.0255638>
- Thibault, M., Vidal, E., Potter, M. A., Dyer, E., & Brescia, F. (2018). The red-vented bulbul (*Pycnonotus cafer*): serious pest or understudied invader? *Biological Invasions*, 20(1), 121–136. <https://doi.org/10.1007/s10530-017-1521-2>
- Tohiran, K. A., Nobilly, F., Zulkifli, R., Ashton-Butt, A., & Azhar, B. (2019). Cattle-grazing in oil palm plantations sustainably controls understory vegetation. *Agriculture Ecosystems & Environment*, 278, 54–60. <https://doi.org/10.1016/j.agee.2019.03.021>
- Tohiran, K. A., Nobilly, F., Zulkifli, R., Maxwell, T., Moslim, R., & Azhar, B. (2017). Targeted cattle grazing as an alternative to herbicides for controlling weeds in bird-friendly oil palm plantations. *Agronomy for Sustainable Development*, 37(6), 1–11. <https://doi.org/10.1007/s13593-017-0471-5>
- Wee, Y. C. (2009). Observations on the behaviour of the Yellow-vented Bulbul, *Pycnonotus goiavier* (Scopoli) in two instances of failed nesting. *Nature in Singapore*, 2, 347–352.
- Wells, D. R. (1999). *The birds of the Thai-Malay Peninsula: Non-passerines (Vol. 1)*. Academic Press.
- Wells, D. R. (2010). *The birds of the Thai-Malay Peninsula: Passerines (Vol. 2)*. Bloomsbury Publishing.
- Wibawa, W., Mohayidin, M. G., Mohamad, R., Juraimi, A. S., & Omar, D. (2010). Efficacy and cost-effectiveness of three broad-spectrum herbicides to control weeds in immature oil palm plantation. *Pertanika Journal of Tropical Agricultural Science*, 33(2), 233–241.
- Yahya, M. S., Puan, C. L., Azhar, B., Atikah, S. N., & Ghazali, A. (2016). Nocturnal bird composition in relation to habitat heterogeneity in small scale oil palm agriculture in Malaysia. *Agriculture Ecosystems & Environment*, 233, 140–146. <https://doi.org/10.1016/j.agee.2016.09.003>
- Yahya, M. S., Syafiq, M., Ashton-Butt, A., Ghazali, A., Asmah, S., & Azhar, B. (2017). Switching from monoculture to polyculture farming benefits birds in oil palm production landscapes: Evidence from mist netting data. *Ecology and Evolution*, 7(16), 6314–6325. <https://doi.org/10.1002/ece3.3205>
- Yahya, M. S., Puan, C. L., Atikah, S. N., & Azhar, B. (2020). Density and diversity of nocturnal birds in oil palm smallholdings in Peninsular Malaysia. *Journal of Oil Palm Research*, 32(1), 57–63. <https://doi.org/10.21894/jopr.2020.0011>
- Yahya, M. S., Atikah, S. N., Mukri, I., Sanusi, R., Norhisham, A. R., & Azhar, B. (2022). Agroforestry orchards support greater avian biodiversity than monoculture oil palm and rubber tree plantations. *Forest Ecology*

and Management, 513, 120177. <https://doi.org/10.1016/j.foreco.2022.120177>

Yahya, M. S., Atikah, S. N., Mukri, I., Oon, A., Hawa, A., Sanusi, R., Norhisham, A. R., Lechner, A. M., & Azhar, B. (2023). Potential of agroforestry orchards as a conservation set-aside initiative in industrial rubber tree and oil palm plantations for avian biodiversity. *Biodiversity and Conservation*, 32(6), 2101–2125. <https://doi.org/10.1007/s10531-023-02594-y>

Yahya, M. S., Ibrahim, N. L., Kamarudin, N., Ahmad, S. N., Atikah, S. N., Sanusi, R., Norhisham, A. R., Masri, M. M. M., & Azhar, B. (2024). Higher avian biodiversity, increased shrub cover and proximity to continuous forest may reduce pest insect crop loss in small-scale oil palm farming. *Journal of*

*Applied Ecology*, 61(6), 1255–1268. <https://doi.org/10.1111/1365-2664.14632>

Yudea, C., & Santosa, Y. (2019). How does oil palm plantation impact bird species diversity? A case study from PKWE Estate, West Kalimantan. *IOP Conference Series: Earth and Environmental Science*, 336(1), 012026. <https://doi.org/10.1088/1755-1315/336/1/012026>

Zainal Abidin, C. M. R., Mohd Noor, H., Hamid, N. H., Ravindran, S., Puan, C. L., Kasim, A., & Salim, H. (2021). Comparison of effectiveness of introduced barn owls, *Tyto javanica javanica*, and rodenticide treatments on rat control in oil palm plantations. *Journal of Pest Science*, 95, 1009–1022. <https://doi.org/10.1007/s10340-021-01423-x>

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