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BIRD FUNCTIONAL GROUPS CAN REDUCE INSECT PESTS IN OIL PALM SMALLHOLDINGS IN RUPAT ISLAND, RIAU PROVINCE, INDONESIA

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ABSTRACT

Insect pests are one of the causes of yield reduction in oil palm. Birds from adjacent forest remnants can provide pest control services to address this problem. Insect pest control service by birds is available if the ecosystem is functioning with the presence of certain functional groups of birds. Our study aimed to examine bird functional groups that affect the number of insect pests. We assessed the herbivory rate using bird exclosure treatment. We classified birds according to foraging strategy, foraging strata, diet, and body mass traits. Our results showed that gleaning, sallying, omnivorous, and large body-size birds have a significant negative relationship with herbivory rates. However, there were no significant differences between treatment and control of herbivory rates. Thus, the pest control service by these bird groups is equal to ecosystem disservices from adjacent forest remnants.

Keywords: bird, ecosystem services, functional group, oil palm, pest control.

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INTRODUCTION

Oil palm plantation expansion is often accused of causing the deforestation of tropical rainforests (Carlson *et al*., 2012; Stibig *et al*., 2014). Yield gaps are often used as an argument to expand oil palm plantations that cause deforestation (Soliman *et al*., 2016). Pests are one of the causes of crop yield reduction. Leaf-eating insect pests can cause a 15%-50% yield reduction in case of complete defoliation. Severe Rhinoceros beetle (*Oryctes rhinoceros*) attacks in young plantations can lead to 20%-50% yield loss. Severe infestation of rat populations that reach >300 individuals per hectare can reduce oil production by about 5% in mature plantations (Woittiez *et al*., 2017).

Common pests in oil palm plantations include nettle caterpillar (*Setora nitens*) (Koh, 2008) and *Setothosea asigna* (Desmier de Chenon and Susanto, 2006), bagworm (Lepidoptera: Psychidae) (Basri *et al*., 1995; Kamarudin and Wahid, 2010) and rats (*Rattus rattus*) (Abidin *et al*., 2014). Caterpillars primarily feed on the leaflets (Koh, 2008; Murphy 2007; Sheil *et al*., 2009) while rats consume the male inflorescences (Chong *et al*., 2011; Silmi, 2013; Wood and Chung, 2003). In Malaysia, rats are also known to prey on the larva of oil palm pollinating weevil (*Elaeidobius kamerunicus*), which resides within the male inflorescences (Wood and Chung, 2003).

These pest problems, especially insect pests, can be solved by pest control services provided by birds from remnant forests adjacent to the oil palm plantation. Most of the previous studies in natural and agroecosystems have found that birds reduce the population densities of insects (Whelan *et al*., 2015). This service has been studied quantitatively by Denmead *et al*. (2017) and Koh (2008). They quantified insect pest control service by measuring the herbivory rate of the oil palm leaflets using bird exclosure treatment. Their studies revealed different results. Koh (2008), who conducted the study in an industrial oil palm plantation complex, showed that

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the herbivory rates in bird exclosure treatment were higher than the control group, while Denmead *et al.* (2017), who carried out the study in smallholdings, showed no significant difference. Thus, more studies are needed.

Insect pest control service by forest birds to the oil palm plantations, and ecosystem services in general, is available if the ecosystem functions. The ecosystem will function if bird species with specific functional characteristics or traits are present (van Bodegom and Price, 2015). On the other hand, certain traits in the ecosystem are affected by environmental conditions (Keddy, 1992; van Bodegom and Price, 2015). The study on trait-based bird functional groups associated with insect pest control services was conducted by Phillpott *et al*. (2009) in coffee and cacao plantations. Their research showed that bird species that forage in the understory and canopy, gleaners, omnivores, and tiny sizes were related to the reduction of insect pests. Another study by Luck *et al*. (2012) on apple plantations indicated that bird forage by hawking and sallying have a higher potential to reduce insect pests. Only a few studies on bird functional groups have been done in tropical agroecosystems (Sekercioglu, 2012). Denmead *et al*. (2017) and Koh (2008) studied the insect pest control services in the oil palm plantation but did not study the related bird traits. Understanding the bird traits related to insect pest control services in oil palm plantation is crucial to ensure that the oil palm plantations are managed properly. Therefore, this study investigated the bird functional groups that can potentially decrease the population of insect pests in smallholdings. With this understanding, we can formulate strategies to effectively manage the environmental conditions of smallholdings, ensuring the preservation and sustenance of the identified bird functional groups.

MATERIALS AND METHODS

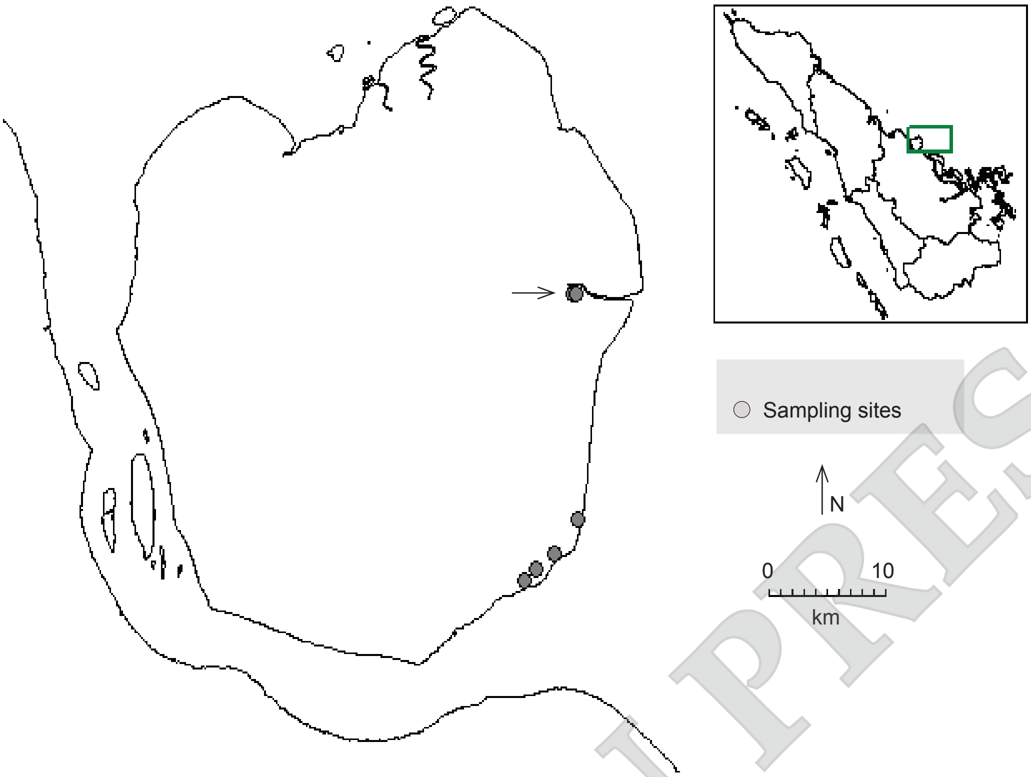
Our study was conducted in six oil palm smallholdings owned by different independent smallholders in Rupat Island, Riau Province, Sumatra, Indonesia, from 14 September to 14 October 2022. The area of each smallholding spans approximately 2 ha, with distance among them between 1.0 km and 17.0 km, except for two smallholdings which were separated by only 0.2 km, as depicted in *Figure 1*. Among the six smallholdings, only three retained adjacent forest remnants, specifically riparian and coastline mangrove forests. The width of these forest remnants averaged around 200 m.

Two bird exclosure treatments and two control groups were set at each smallholding, positioned at 200 m apart. The size of each exclosure was 100 x 100 x 120 cm (length x width x height) and featured a net cage with a mesh size of 2.5 x 2.5 cm. These cages were carefully placed over oil palm seedlings. The control group consisted of oil palm seedlings without protective net cages. The distance between the two treatment types was maintained at 10 m (*Figure 2*). All seedlings were obtained from the same nursery on Rupat Island and had similar height (approximately 1 m) and age (approximately 1 year old). Twenty undamaged leaflets were randomly chosen from each seedling, and their lamina bases were marked using a waterproof permanent marker. After 21 to 22 days, the marked leaflets were collected and photographed, adhering to the procedures outlined by Koh (2008).

Herbivory rates were measured based on the missing lamina areas using ImageJ (Rasband, 2018). The missing lamina area was quantified per leaflet per day the seedling remained at the sampling site. Since we wanted to look at the direct relationship between the missing lamina area and herbivory rate by insect pest species, we only recorded insect species that perched on the leaflet of the treatment or control seedlings. We did not record the overall insect pest species or count their abundance.

Bird observations were carried out from 06:00-08:00 hr and from 15:00-17:00 hr using point count method (Bibby *et al*., 1998). Each point count was carried out for 15 min and covered a radius of 50 m, with the bird exclosure treatment as the central point of reference. The distance between points was 200 m. The bird observation for each smallholding was replicated twice on different days and different orders of point. The number of individual bird species observed were recorded. In addition, the foraging strategies and foraging strata observed during surveys were documented.

The recorded bird species were then classified into functional groups based on four distinct traits: Foraging strategies, foraging strata, diet, and body size (*Table 1*). This classification of the bird functional group followed the traits used by Philpott *et al*. (2009). Based on observation, birds were classified into three foraging strategy groups: Gleaning, hawking, and sallying, following Remsen and Robinson's terminology (Remsen and Robinson, 1990). Bird species observed foraging on the ground or in the understorey were classified as understorey foragers, while those foraging in the mid or upper canopy were classified as canopy foragers. Birds displaying foraging behaviour across all strata or in aerial environments were categorised as all-strata foragers. Bird diets were classified into three: Insectivores, omnivores, and carnivores. Moreover, birds' body sizes were classified into four distinct body size groups: Tiny (< 15 g), small (15 to < 30 g), medium (30 to < 60 g), and large (60 to < 120 g). The diet and body size classifications were based on Birds of the World (2022).



Note: Sampling sites which were separated by only 0.2 km.

Figure 1. The location of smallholdings on Rupat Island, Riau Province, Indonesia.

Figure 2. (a) The control, and (b) the bird exclosure treatment; at one of the smallholdings.

The Wilcoxon-test was carried out to evaluate significant differences in herbivory rates between the bird exclosure treatment and the control group because the data did not follow normal distribution. Binomial Generalised Linear Mixed Model (GLMM) was used to determine the relationship between bird functional group and herbivory rates. We used binomial GLMM with the missing lamina area as the response variable. The fixed effect was the bird's individual number at each functional group, and the random effects were sampling sites and points. The response variable was the herbivory rates of the control treatment, aiming to assess whether bird access to seedlings led to a reduction in herbivory rates. The statistical analysis was done using R version 4.2.2. (R Core Team, 2022), using the Glmm package (Knudson, 2022).

TABLE 1. BIRD FUNCTIONAL CLASSIFICATION BASED ON FORAGING STRATEGY, FORAGING STRATA, DIET AND BODY SIZE TRAITS

Trait	Functional group
Foraging strategy	Gleaning
	Hawking
	Sallying
Foraging strata	Understorey
	Canopy
	All strata
Diet	Insectivore
	Omnivore
	Carnivore
Body size	Tiny (< 15 g)
	Small (15 to < 30 g)
	Medium (30 to < 60 g)
	Large (60 to < 120 g)

RESULTS AND DISCUSSION

We found a total of 10 bird species from all sampling sites with 71 individual birds. The most abundant bird functional group was insectivores. The most prevalent foraging strategy among these birds was hawking, and their preferred foraging stratum encompassed all strata. The dominant body size group among the recorded birds was tiny (*Table 2*). Similar to this study, Desmier de Chenon and Susanto (2006), in their study on oil palm plantation estates in North Sumatra, also reported the dominance of insectivores and tiny birds. However, their study revealed different dominant foraging strategies and strata, with gleaning and the understorey being prominent, respectively. Furthermore, they found that *Centropus bengalensis* and *Parus major* were consuming one of the essential defoliating pests *Setothosea asigna*. Interestingly, we did not find these two birds at our sampling sites, but we observed them in the remnant forest adjacent to the smallholdings. The height of the seedlings we used in our treatment and the condition of the smallholdings (the oil palm height ranged from 2 to 3 m and the understorey was not in a well-developed stage) may explain the dominance of all strata birds in our study. Older smallholdings with taller oil palm and well-developed understorey may attract more canopy and understorey birds.

We found a significant negative relationship between the abundance of gleaning (z = -2.04, *p*-value = 0.04), sallying (z = -2.25, *p*-value = 0.02), omnivorous (z = -3.84, *p*-value = 0.00) and large birds (z = -3.92, *p*-value = 0.00) with missing lamina areas, suggesting the reduction of herbivory rates (*Table 3, Figure 3*). However, the sampling sites and points as random effects showed significance to the response variable indicating that these factors affect the relationship between bird's functional groups and missing lamina areas (*Table 3*). Our finding suggested that an increase in the number of these bird functional groups corresponded to a reduction in herbivory on oil palm leaflets. Thus, gleaning, sallying, omnivorous, and large birds provide insect pest control within the oil palm smallholdings. Gleaning birds such as *Acridotheres javanicus* and sallying birds such as *Halcyon smyrnensis* picked food items from a substrate, such as the leaflet of oil palm, although the latter can also pick aerial prey. Moreover, all omnivorous birds at our sampling sites, *Pycnonotus goiavier* and *Acridotheres javanicus*, were gleaners, and most of sallying, *Halcyon smyrnensis* and *Todiramphus chloris*, were large birds (*Table 2*). This explains the negative relationship between the abundance of these bird groups and herbivory rate. On the other hand, most insectivorous birds (z = 6.79, *p*-value < 0.01) that occupy all strata (z = 3.55, *p*-value < 0.00) and use a hawking foraging strategy (z = 3.03, *p*-value < 0.01), which attacks prey items in continuous flight such as *Collocalia esculenta* (*Table 2*), showed positive relationship with herbivory rates (*Table 3*, *Figure 3*), indicating that they could not reduce insect pests on oil palm leaflets. It is worth noting that previous studies on ecosystem services in oil palm plantations, such as those conducted by Denmead *et al*. (2017), Gray and Lewis (2014) and Koh (2008), did not include an analysis of the relationship between bird functional groups and herbivory rates. Gleaning, sallying, omnivorous, and large birds used understorey, canopy, and all strata, therefore, heterogeneity of vegetation cover in remnant forests must be preserved (*Table 2*).

TABLE 2. FUNCTIONAL GROUP OF BIRD SPECIES FOUND AT THE SAMPLING SITES

Species	Individual number	Functional group			
		Foraging strategies	Foraging strata	Diet	Body size
Glossy Swiftlet (*Collocalia esculenta*)	42	Hawking	All strata	Insectivore	Tiny
White-throated Kingfisher (*Halcyon smyrnensis*)	3	Sallying	Understorey	Carnivore	Large
Collared Kingfisher (*Todiramphus chloris*)	1	Sallying	Understorey	Carnivore	Large
Blue-tailed Bee-eater (*Merops philippinus*)	2	Sallying	All strata	Insectivore	Medium
Pacific Swallow (*Hirundo tahitica*)	2	Hawking	All strata	Insectivore	Small
Yellow-vented Bulbul (*Pycnonotus goiavier*)	8	Gleaning	Canopy	Omnivore	Medium
Ashy Tailorbird (*Orthotomus ruficeps*)	4	Gleaning	All strata	Insectivore	Tiny
Yellow-bellied Prinia (*Prinia flaviventris*)	3	Gleaning	Understorey	Insectivore	Tiny
Malaysian Pied-Fantail (*Rhipidura javanica*)	3	Gleaning	Canopy	Insectivore	Small
Javan Myna (*Acridotheres javanicus*)	3	Gleaning	Understorey	Omnivore	Large
Total	**71**				

TABLE 3. RELATIONSHIP BETWEEN BIRD FUNCTIONAL GROUP AND HERBIVORY RATE OF CONTROL SEEDLINGS

Fixed effect			Random effect			Random effect		
	z	*p*-value		Z	*p*-value		z	*p*-value
Gleaning	**-2.04**	**0.04**	Site	1.60	0.06	Point	**2.16**	**0.02**
Hawking	**3.03**	**0.00**		**1.73**	**0.04**		**2.29**	**0.01**
Sallying	**-2.25**	**0.02**		**1.73**	**0.04**		**2.35**	**0.01**
Understorey	-1.44	0.15		**1.72**	**0.04**		**2.34**	**0.01**
Canopy	-0.97	0.33		**1.73**	**0.04**		**2.33**	**0.01**
All strata	**3.55**	**0.00**		**1.73**	**0.04**		**2.35**	**0.01**
Insectivore	**6.79**	**0.00**		**1.73**	**0.04**		**2.35**	**0.01**
Omnivore	**-3.84**	**0.00**		**1.73**	**0.04**		**2.35**	**0.01**
Carnivore	-1.55	0.12		**1.73**	**0.04**		**2.28**	**0.01**
Tiny	1.75	0.08		**1.73**	**0.04**		**2.31**	**0.01**
Small	-0.24	0.81		1.52	0.06		**2.35**	**0.01**
Medium	-1.21	0.23		**1.73**	**0.04**		**2.34**	**0.01**
Large	**-3.92**	**0.00**		**1.73**	**0.04**		**2.28**	**0.01**

Note: Significant z value (*p*-value < 0.05) appears in boldface.

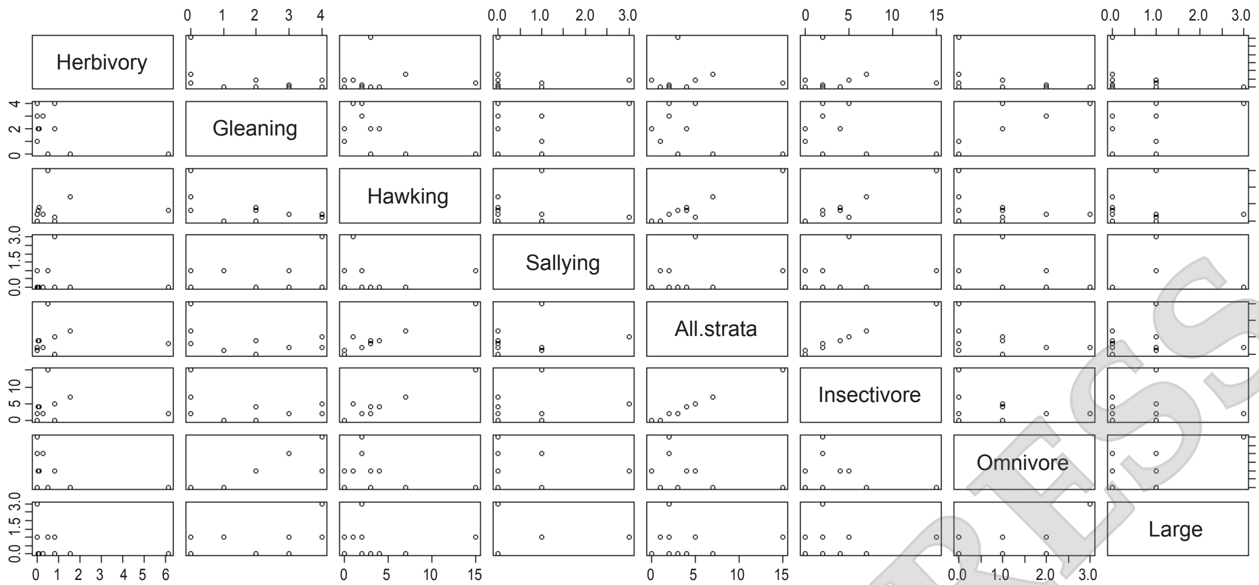


Figure 3. Relationship between herbivory rates and abundance of bird functional groups. Only significant relationships are shown.

During the survey, one seedling in bird exclosure treatment was heavily damaged by animals and one seedling in control was missing. Consequently, subsequent analyses of herbivory rates can only be done on 22 seedlings, 11 seedlings from each treatment. The difference between herbivory rates of bird exclosure treatment and control was not significant (W = 69, *p*-value = 0.60) (*Figure 4*). Our result was similar to the previous study carried out in oil palm smallholdings by Denmead *et al*. (2017), which also found no significant difference between herbivory rates in bird exclosure treatment and control groups, while Koh (2008) which conducted the study in industrial oil palm plantation found significant difference. Interestingly, the local farmers in our sampling sites reported that insect pests are not a significant problem in their plantations. These findings suggested that insect pest control service by gleaning, sallying, omnivorous, and large birds is equal to ecosystem disservices stemming from adjacent forest remnants, such as spill-over of insect pests (Edwards *et al*., 2014). Insect species with high dispersal ability and little or no response to forest edge can disperse from the forest to adjacent oil palm plantations. For example, certain butterfly species can disperse from forest remnants to oil palm plantations (Lucey and Hill, 2012). In this study, forest patches may be the source habitat of oil palm insect pests. We also found an indication that the understorey of the oil palm smallholding is also the source of insect pests. The herbivory rates of oil palm smallholding which had high understorey coverage, such as sampling unit 8, was higher than smallholding that had low coverage, such as sampling unit 11. However, we did not measure the understorey coverage. Further study is needed to examine this relationship.

CONCLUSION

Our study investigated the role of bird exclosure treatments in mitigating herbivory rates on oil palm seedlings in independent smallholdings. Although we initially observed a reduction in herbivory rates associated with gleaning, sallying, omnivorous, and large body size birds, our subsequent analysis did not reveal a statistically significant difference between the bird exclosure treatment and the control group.

These findings are consistent with previous research in similar oil palm smallholdings, which also failed to identify a significant impact of bird exclosure on herbivory rates. Moreover, local farmers reported that insect pests were not a significant concern in their smallholdings, suggesting that the ecosystem services provided by gleaning, sallying, omnivorous, and large birds may be comparable to any potential disservices originating from adjacent forest remnants.

The study highlights the complexity of ecological interactions in agricultural landscapes. While the presence of gleaning, sallying, omnivorous, and large body size birds may provide natural pest control benefits, other factors such as habitat connectivity and the specific pest species involved, can influence the effectiveness of this service. Further investigations into the dynamics of

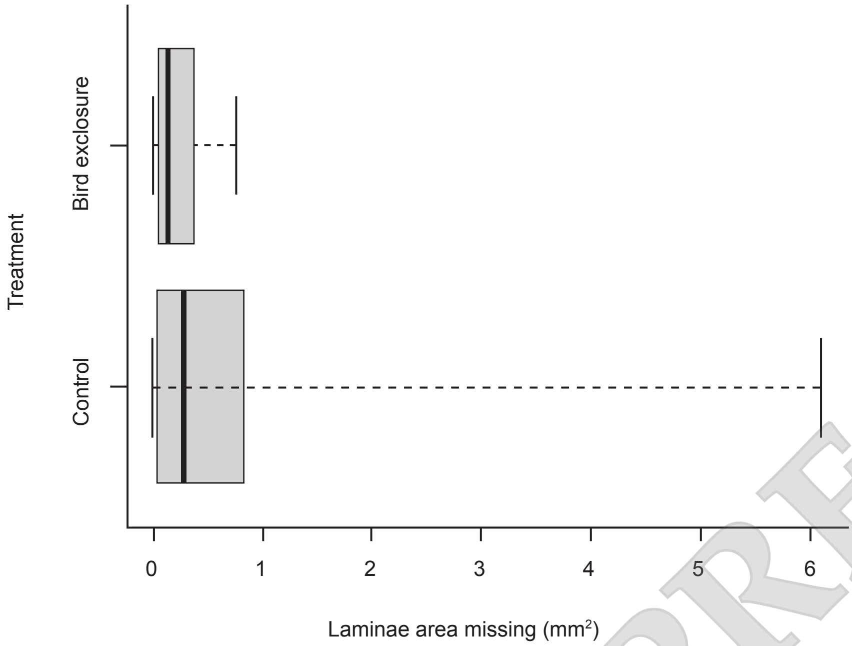


Figure 4. Herbivory rates of bird exclosure treatment and control groups.

bird-insect-plant interactions in different contexts are warranted to better understand and harness the potential of birds as agents of pest management in agricultural settings.

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