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AVIAN BIODIVERSITY AND CONSERVATION IN MALAYSIAN OIL PALM PRODUCTION AREAS

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ABSTRACT

Our study demonstrated the persistence of avian biodiversity in established oil palm production areas. Here, the empirical evidence on avian species richness reflects explicitly that oil palm production areas are not merely a 'green biological desert'. We investigated the relationships between bird species richness and different management regimes (plantations vs. *smallholdings) and vegetation characteristics in 30 oil palm areas in the states of Selangor, Perak, Negeri Sembilan and Pahang. We recorded 72 bird species, comprising approximately 32% forest-dependent, 19% migratory and 10% wetland species. Our study showed that plantations and smallholdings supported a similar total number of bird species richness (P = 0.709). However, we found that a greater height of the ground vegetation cover had a positive effect on total species richness (P < 0.001). Similarly, there was no significant difference between plantations and smallholdings with respect to the total number of migratory species (P = 0.322). This number also increased when ground vegetation cover was higher (P = 0.010). We recommend the following appropriate conservation measures that may enhance avian biodiversity in oil palm production areas: (1) implementation of tree planting projects that benefit wild birds, (2) integration of oil palm with livestock grazing to phase out dangerous agrochemicals that are harmful to wild birds, and (3) continued promotion of ground vegetation cover to increase habitat heterogeneity on a local scale. Potentially oil palm can move towards becoming a sustainable and profitable commodity if production areas can be managed for conservation outcomes.*

Keywords: avian biodiversity, conservation measures, oil palm, production areas, bird species richness.

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INTRODUCTION

Protecting biodiversity beyond that present in nature reserves is still a new conservation strategy, especially in developing countries (McNeely and Scherr, 2002; Sachs *et al*., 2010). Such a strategy is often linked to commercial agricultural areas in which some native fauna have been found to persist after land conversion (Krebs *et al*., 1999; Sekercioglu *et al*., 2007; Abrahamczyk *et al*., 2008; Fischer *et al*. 2008; Harvey *et al*., 2008; Perfecto and Vandermeer, 2008). It has been advocated that there is a need for better agricultural practices on farmlands that take into consideration the elements of biodiversity conservation. However, it remains questionable whether the idea of promoting oil palm (*Elaeis guineensis*) cultivation as being biodiversity-friendly can be accepted by consumers in the same way as is the case with other commodity crops (*e.g.* coffee and cacao) (Komar 2006; Fitzherbert *et al*., 2008; Rainforest Alliance Network, 2010). Industrial-scale expansion of oil palm has been

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associated with losses in tropical biodiversity, despite efforts (*e.g.* palm oil certification and biofuel policy) to transform the industry into a sustainable agribusiness (Fitzherbert *et al*., 2008; Danielsen *et al*., 2009; Koh *et al*., 2010).

Oil palm is currently one of the most dominant agricultural crops in some developing countries in the tropics (Donald, 2004; Wilcove and Koh, 2010). Malaysia and Indonesia are both the leading palm oil producers, contributing 80% of the world's palm oil production (Wilcove and Koh, 2010). In turn, the industry is of economic importance to these countries (Basiron, 2007; Tan *et al*., 2009). However, anti-palm oil campaigns have been carried out aggressively by international environmental NGO (*e.g*. Greenpeace and the Friends of the Earth), and these have undermined the substantial contribution of the industry to the local socio-economy over all these years (Lam *et al*., 2009; Koh *et al.,* 2010). In response to the strong protests, the Roundtable on Sustainable Palm Oil (RSPO) was formed to certify sustainable palm oil production (Corley, 2009; Laurance *et al*., 2010; Roundtable on Sustainable Palm Oil, 2010). The implementation of RSPO's principles and guidelines was still unable to convince the critics because there have been very few studies to support the certification scheme (Donald, 2004).

Participation by conservation biologists is urgently needed in the palm oil industry in order to prevent further biodiversity loss, and to educate palm oil stakeholders on the importance of biodiversity conservation (Groom *et al*., 2008). To date, only a small number of biodiversity studies have been carried out to quantify the conservation value of oil palm production areas, most of which having focused on the occurrence of forest-dependent species (Aratrakorn *et al*., 2006; Peh *et al*., 2006; Koh, 2008; Turner and Foster, 2009; Edwards *et al*., 2010) unlike those conducted in coffee and cacao plantations (Gallina *et al*., 1996; Greenberg *et al*., 1997; Carlo *et al*., 2004; Estrada *et al*., 2006; Bali *et al*., 2007; Dietsch *et al*., 2007; Philpott *et al*., 2008; Clough *et al*., 2009). There is even less scientific literature that gives emphasis to the means of maintaining and/or enhancing biodiversity conservation in oil palm production areas (Najera and Simonetti, 2010).

Our study aimed primarily at quantifying avian diversity with respect to management regime (*i.e.* smallholdings *vs.* monoculture plantations), and at examining the relationships between avian diversity and vegetation characteristics in oil palm oil production areas. We hypothesised that: (1) total bird species richness was significantly higher in smallholdings than in monoculture plantations, (2) smallholdings supported more migratory birds than plantations because of greater habitat heterogeneity in the former, (3) tall ground vegetation cover increased bird species richness as more habitats were created for wild birds, (4) ground vegetation cover was significantly lower in plantations than in smallholdings due to better weed management using agrochemicals in the former, and (5) undergrowth height was significantly higher in smallholdings than in plantations as smallholdings were not as intensively managed. We suggested that oil palm production areas may be of conservation importance, at least for avian species richness. The findings from this study will have great implications on the management practices in oil palm cultivation. We also recommended a number of appropriate measures to improve biodiversity conservation in oil palm production areas based on our findings and gleaned from published literature.

METHOD AND MATERIALS

Study Sites

We conducted bird and vegetation surveys from October 2009 to September 2010, covering a large portion of the oil palm production areas in Peninsular Malaysia (~39 478 ha and ~10 000 ha in plantations and smallholdings, respectively). We surveyed 11 plantations and 19 smallholdings in the states of Selangor, Perak, Negeri Sembilan and Pahang (located between N 3.718259, E 101.156087 and N 2.501173, E 101.909875). These 30 sites were at least 1 km apart. We defined plantations as oil palm cultivation areas that covered more than 50 ha each, and were managed by plantation companies, whereas a smallholding covered less than 50 ha and was owned by an individual. In addition, plantations were equipped with modern facilities and infrastructure, such as paved roads, perimeter fences, worker settlements and mills. Unlike the monoculture plantations, smallholdings were intercropped with other crops (*e.g*. durian, banana, coffee and cassava).

Bird Sampling

We used straight-line variable length transect sampling to survey birds (Anderson *et al*., 1979). We established 172 transects along the harvesting paths (74 and 98 transects located in plantations and smallholdings, respectively). The transect length ranged from 100 to 804 m. Three or four field observers (J Asrulsani, B Azhar, N L Ibrahim and J Syari) walked through the transects starting from 0700 to 1100 hr and resumed survey from 1530 to 1900 hr. We recorded data on all birds (species and relative abundance) that we heard or saw. Surveys were made on a clear day (without rain or heavy clouds). To ensure independent observations on the birds, transects were located at least 500 m apart. We identified bird species based on local field guides (Jeyarajasingam and Pearson, 1999; Robson, 2008) and a commercial audio DVD (Scharringa, 2005).

Vegetation Characteristics

We estimated the percentage of ground vegetation cover in a circle of 10-m radius on all the transects. We measured the height of ground vegetation, taking at least two measurements per transect. All measurements were averaged for every single transect (n = 172 sampling plots). In terms of floristic composition, ground vegetation cover comprised predominantly grasses (*e.g. Paspalum conjugatum* and *Centosteca lappacea*), broadleaves (*e.g. Asystasia intrusa* and *Mikania micrantha)*, ferns (*e.g. Nephrolepis biserrata* and *Dicnopteris linearis*) and woody shrubs (*e.g. Clidemia hirta, Lantana camara* and *Melastoma malabathricum*).

Statistical Methods

We computed avian biodiversity using three diversity indices: (1) Shannon-Weiner H, (2) Brillouin evenness, and (3) species richness. We implemented bootstrap diversity statistics and confidence intervals (100 permutations) to calculate better estimates. We applied an individual-based method to develop a collector curve plot. We performed all calculations in diversity using GenStat 12 (VSN International, Hemel Hempstead, United Kingdom).

Our study was a nested design which meant that the observation data could be grouped into similar sites. For avian diversity, we used the overall number of species (response variable) as a function of oil palm management regime (plantations or smallholdings), ground vegetation cover and height in all transects. We only took into account ground vegetation cover in the model development, and excluded undergrowth height due to significant multi-collinearity between these two predictor variables (Spearman's rank correlation = 0.59, $P < 0.001$), and we used the variable 'site' as a random effect. We repeated a similar modeling process for wetland and migratory species. We employed quasi-Poisson's distribution with a log-link function in our mixed models, and entered transect length (log-transformed) as an offset to standardise the number of bird species we encountered. We implemented all analyses in Generalised Linear Mixed Models (GLMM) (Schall, 1991) using GenStat 12. We used survey time (am *vs*. pm) as a fixed effect. We selected the final models by sequentially adding terms to fixed models. Similarly, we used GLMM to analyse both the vegetation characteristics in order to determine any differences with respect to management regime.

RESULTS AND DISCUSSION

We recorded a total of 3281 individual birds belonging to 72 bird species, which included 23 forest-dependent species, seven wetland species, and 14 migratory species (*Table 1*). Similar patterns

TABLE 1. SPECIES CHECKLIST FOR VARIOUS BIRDS DETECTED IN OIL PALM PRODUCTION AREAS

Species	Site detected	Status
Asian Brown Flycatcher, *Muscicapa dauurica*	Plantations and smallholdings	Migrant - Forest
Asian Glossy Starling, *Aplonis panayensis*	Smallholdings	Resident
Asian Koel, *Eudynamys scolopacea*	Plantations and smallholdings	Migrant
Asian Paradise-flycatcher, *Terpsiphone paradisi*	Smallholdings	Migrant - Forest
Ashy Tailorbird, *Orthotomus ruficeps*	Plantations and smallholdings	Resident
Barred Buttonquail, *Turnix suscitator*	Smallholdings	Resident
Black-headed Munia, *Lonchura malacca*	Plantations and smallholdings	Resident
Barn Owl, *Tyto alba*	Plantations	Resident
Baya Weaver, *Ploceus philippinus*	Plantations and smallholdings	Resident
Black-naped Oriole, *Oriolus chinensis*	Plantations and smallholdings	Migrant
Black-shouldered Kite, *Elanus caeruleus*	Plantations and smallholdings	Resident
Blue-throated Bee-eater, *Merops viridis*	Plantations and smallholdings	Migrant - Forest
Blue-eared Barbet, *Megalaima australis*	Plantations and smallholdings	Resident - Forest
Brown Shrike, *Lanius cristatus*	Smallholdings	Migrant
Brahminy Kite, *Haliastur indus*	Plantations	Resident
Buffy Fish Owl, *Ketupa ketupu*	Smallholdings	Resident
Changeable Hawk Eagle, *Spizaetus cirrhatus*	Plantations and smallholdings	Resident - Forest
Chinese Pond Heron, *Ardeola bacchus*	Smallholdings	Migrant - Wetland
Cinnamon Bittern, *Ixobrychus cinnamomeus*	Plantations	Migrant - Wetland

TABLE 1. SPECIES CHECKLIST FOR VARIOUS BIRDS DETECTED IN OIL PALM PRODUCTION AREAS (continued)

Species	Site detected	Status
Collared Kingfisher, *Todiramphus chloris*	Plantations and smallholdings	Migrant
Common Myna, *Acridotheres tristis*	Plantations and smallholdings	Resident
Common Tailorbird, *Orthotomus sutorius*	Plantations and smallholdings	Resident
Common Flameback, *Dinopium javanense*	Plantations and smallholdings	Resident
Coppersmith Barbet, *Megalaima haemacephala*	Smallholdings	Resident
Cream-vented Bulbul, *Pycnonotus simplex*	Smallholdings	Resident - Forest
Crested serpent Eagle, *Spilornis cheela*	Plantations and smallholdings	Resident - Forest
Dark-necked Tailorbird, *Orthotomus atrogularis*	Plantations and smallholdings	Resident - Forest
Dollarbird, *Eurystomus orientalis*	Plantations	Migrant - Forest
Dusky Eagle Owl, *Bubo coromandus*	Smallholdings	Resident - Forest
Greater Coucal, *Centropus sinensis*	Plantations and smallholdings	Resident
Green Imperial Pigeon, *Ducula aenea*	Smallholdings	Resident - Forest
Hill Myna, *Gracula religiosa*	Smallholdings	Resident - Forest
House Crow, *Corvus splendens*	Plantations and smallholdings	Resident
Javan Myna, *Acridotheres javanicus*	Plantations and smallholdings	Resident
Jungle Myna, *Acridotheres fuscus*	Plantations and smallholdings	Resident
Laced Woodpecker, *Picus vittatus*	Smallholdings	Resident
Large-tailed Nightjar, *Caprimulgus macrurus*	Smallholdings	Resident
Lesser Coucal, *Centropus bengalensis*	Plantations and smallholdings	Resident
Little Egret, *Egretta garzetta*	Smallholdings	Migrant - Wetland
Little heron, *Butorides striatus*	Plantations	Migrant - Wetland
Long-tailed Parakeet, *Psittacula longicauda*	Plantations and smallholdings	Resident - Forest
Olive-backed Sunbird, *Nectarinia jugularis*	Plantations and smallholdings	Resident
Olive-winged Bulbul, *Pycnonotus plumosus*	Plantations and smallholdings	Resident - Forest
Oriental Magpie Robin, *Copsychus saularis*	Plantations and smallholdings	Resident
Oriental Pied Hornbill, *Anthracoceros albirostris*	Smallholdings	Resident - Forest
Peaceful Dove, *Geopelia striata*	Plantations and smallholdings	Resident
Pied Fantail, *Rhipidura javanica*	Plantations and smallholdings	Resident
Pink-necked Green Pigeon, *Treron vernans*	Plantations and smallholdings	Resident - Forest
Plaintive Cuckoo, *Cacomantis merulinus*	Plantations	Resident
Purple Heron, *Ardea purpurea*	Plantations and smallholdings	Migrant - Wetland
Red-eyed Bulbul, *Pycnonotus brunneus*	Smallholdings	Resident - Forest
Red-wattled Lapwing, *Vanellus indicus*	Plantations and smallholdings	Resident - Wetland
Red Junglefowl, *Gallus gallus*	Plantations and smallholdings	Resident - Forest
Richard's Pipit, *Anthus richardi*	Plantation and Smallholdings	Migrant
Rhinoceros Hornbill, *Buceros rhinoceros*	Smallholdings	Resident - Forest
Rock Pigeon, *Columba livia*	Plantations	Resident
Rufescent Prinia, *Prinia rufescens*	Plantations	Resident
Rufous Woodpecker, *Celeus brachyurus*	Plantations	Resident - Forest
Spotted Dove, *Streptopelia chinensis*	Plantations and smallholdings	Resident
Spotted Wood Owl, *Strix seloputo*	Smallholdings	Resident - Forest
Scaly-breasted Munia, *Lonchura punctulata*	Plantations and smallholdings	Resident
Slender-billed Crow, *Corvus enca*	Plantations and smallholdings	Resident
Stork-billed Kingfisher, *Halcyon capensis*	Smallholdings	Resident - Forest
Streak-eared Bulbul, *Pycnonotus blanfordi*	Plantations	Resident
Striped Tit Babbler, *Macronous gularis*	Smallholdings	Resident - Forest
White-brested Waterhen, *Amaurornis phoenicurus*	Plantations and smallholdings	Resident - Wetland
White-headed Munia, *Lonchura maja*	Plantations and smallholdings	Resident
White-rumped Munia, *Lonchura striata*	Smallholdings	Resident
White-throated Kingfisher, *Halcyon smyrnensis*	Plantations and smallholdings	Resident
White-vented Myna, *Acridotheres grandis*	Smallholdings	Resident
Yellow-bellied Prinia, *Prinia flaviventris*	Plantations and smallholdings	Resident
Yellow-vented Bulbul, *Pycnonotus goiavier*	Plantations and smallholdings	Resident

Note: resident birds refer to local species which bred in our study sites.

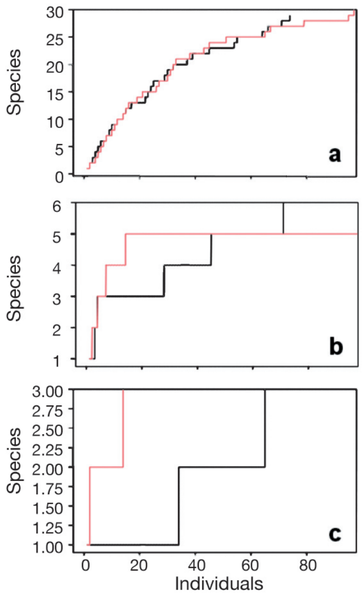


Figure 1. Species accumulation curves depicting (a) total species richness, (b) total migratory species, and (c) total wetland species in oil palm plantations (black) and smallholdings (red).

of avian biodiversity occurred in both oil palm plantations and smallholdings (*Figure 1*). However, estimated values of species richness from the bootstrapping method were higher than the observed values (*Table 2*).

We detected similar bird species richness as compared to other studies conducted in primary or secondary tropical rainforests (ranging between 42 and 157 species) (Wong, 1986; Kang and Lee, 1993; Peh *et al*., 2005; 2010). The true value for species richness in oil palm production areas was estimated at ~98 species, which was an increase of 36% over the observed value (*Table 2*). This implies that oil palm production areas can complement, but not substitute, the role of protected areas in terms of biodiversity conservation. Similarly, a study on birds in rubber (*Hevea brasiliensis*) plantations (Yorke, 1984) recorded a total of 84 bird species, but the study was done over a three-year period. Fewer wetland species were detected in rubber plantations as compared with our study. This could be attributed to the absence of aquatic habitats or water bodies in rubber plantations.

It should be stressed that we recorded six forest-dependent species (*Table 1*) despite oil palm production areas being almost monoculture with only a single crop species planted. For example, we detected the Rhinoceros Hornbill (*Buceros rhinoceros*) in smallholdings (*Figure 2*). We observed this forest species roosting on mature oil palm in large numbers (70 individuals per flock) on almost every visit to the same site, and they eventually flew away to a nearby logged peat swamp forest the next morning. We believe that the hornbills roosted on mature oil palm because not many native trees were left in the logged peat swamp forest. Other species recorded were the Oriental Pied Hornbill (*Anthracoceros albirostris*), the Asian Paradise Flycatcher (*Terpsiphone paradisi*) and the Dusky Eagle Owl (*Bubo coromandus*). Different bird species may utilise oil palm production areas according to their respective biological requirements (*e.g.* foraging, roosting and breeding) (Manning *et al*., 2004), despite oil palm production areas being less complex in terms of species diversity than native tropical rainforests (*Figure 3*).

We found that the total richness in smallholdings and plantations was not significantly different ($F = 0.14$, $P = 0.709$), but ground vegetation cover had a positive effect on total species richness (coefficient = 0.0048, $F = 15.94$, $P < 0.01$). Nonetheless, diversity indices showed that smallholdings supported higher avian biodiversity as compared with plantations (*Table 2*).

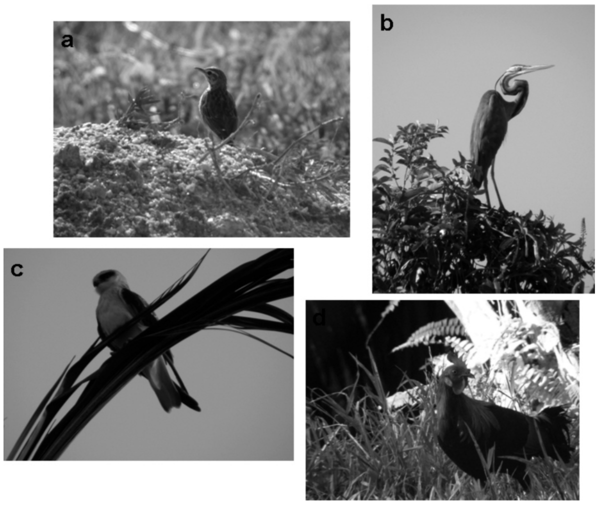
In contrast, the richness of wetland species was estimated to be higher in plantations than in smallholdings, although the value of the Shannon-Weiner index was slightly lower in this case (*Table 2*). This result may be attributed to the presence

TABLE 2. AVIAN BIODIVERSITY IN OIL PALM PRODUCTION AREAS AS DEFINED BY CONVENTIONAL DIVERSITY INDICES

Diversity index	Plantations	Smallholdings	Total	Bootstrap estimate ± S.E.	95% bootstrap CI
Total species richness					
Shannon-Weiner H	4.26	4.53	4.52	4.49 ± 0.01	4.47, 4.51
Brillouin evenness	0.94	0.99	0.99	0.98 ± 0.00	0.97, 0.98
Species richness	98.00	98.00	98.00	97.96 ± 0.20	97.00, 98.00
Total migratory species					
Shannon-Weiner H	3.88	3.96	4.28	3.99 ± 0.05	3.88, 4.09
Brillouin evenness	0.92	0.99	0.97	0.96 ± 0.01	0.95, 0.97
Species richness	79.00	58.00	83.00	65.32 ± 2.95	60.00, 70.00
Total wetland species					
Shannon-Weiner H	1.97	2.03	2.69	2.28 ± 0.16	1.96, 2.58
Brillouin evenness	0.88	1.00	0.99	0.96 ± 0.03	0.89, 1.00
Species richness	32.00	8.00	16.00	11.20 ± 1.46	8.00, 14.00

Note: photographs by Badrul Azhar.

Figure 2. Utilisation of oil palm oil production areas by charismatic forest species reflects the conservation value of these production areas. Rhinoceros Hornbills were roosting on a mature oil palm in a smallholding at dusk (a), but daily foraging occurred in a nearby logged peat swamp (b).



Note: photographs by Badrul Azhar.

*Figure 3. Various bird groups which inhabited oil palm production areas included (a) common open area birds (*e.g. *Richard's Pipit), (b) wetland birds (*e.g. *Purple Heron), (c) birds of prey (*e.g. *Black-shouldered Kite), and (d) game birds (*e.g. *Red Junglefowl).*

of some aquatic habitats in plantations (*e.g.* flood-controlled drains and ponds). These wetland birds comprised the Purple Heron (*Ardea purpurea*) and the Chinese Pond Heron (*Ardeola bacchus*) that frequently foraged or bred in oil palm production areas, particularly in areas dominated by young palms (< 10 years).

Plantations and smallholdings recorded similar values for total migratory species (F = 1.03, P = 0.322). Greater height of the ground vegetation cover increased the total number of migratory species (F = 6.88, P = 0.010). Migrants such as the Asian Brown Flycatcher (*Muscicapa dauurica*), the Brown Shrike (*Lanius cristatus*) and the Chinese Pond Heron (*Ardeola bacchus*) rested and foraged in oil palm production areas. We only detected a small number of migratory species, possibly because our sampling efforts were limited to a small number of field days per month and of sites. We did not record species that were reported to be common visitors to oil palm production areas such as the Black Baza (*Aviceda leuphotes*), the Forest Wagtail (*Dendronanthus indicus*) and the Arctic Warbler (*Phylloscopus borealis*) (Jeyarajasingam and Pearson, 1999).

We had expected avian biodiversity (*e.g.* total species richness) in smallholdings to be much higher than in plantations. However, our study showed that the management regime may not have had an influence on avian biodiversity. This may imply that certain measures to enhance biodiversity in oil palm plantations may still be inadequate or may not be successfully applied throughout oil palm production areas. For example, wildlife or forest corridors are known to be useful to conserve biodiversity, but the implementation of such an approach may be limited. This is because the opportunities to create such corridors are constrained by land availability or other technical issues (*e.g.* jurisdiction over forest protection and expertise in conservation biology) faced by palm oil stakeholders.

Most previous studies on biodiversity in oil palm plantations had concentrated on forest-dependent species without taking into account the presence of wetland or migratory birds. Although oil palm production areas are no substitute for the tropical rainforest in terms of biodiversity (Fitzherbert *et al.*, 2008; Danielsen *et al.*, 2009), the importance of agricultural areas dominated by oil palm cultivation should not be ignored as some forest-dependent, wetland and migratory species may use the existing habitats in oil palm production areas (*e.g.* undergrowth, mature oil palm, epiphytes, scattered shrubs and aquatic habitats). Similarly, some studies have recognised that migratory birds used coffee plantations as transit points during the winter season in the Northern Hemisphere (Greenberg *et al.*, 1997; Reitsma *et al.*, 2001).

Our study also demonstrated that management regime had no significant effect on ground vegetation cover (mean ± S.E. = 42.78 ± 1.49, F = 0.34, P = 0.567) and undergrowth height (mean ± S.E. = 41.04 ± 2.52, F = 0.17, P = 0.681). These results imply that the vegetation structure in both regimes may have been subjected to certain standard practices (*e.g.* similar application of agrochemicals or harvesting system).

From our observations, fewer bird species visited plantations that had recently been sprayed with pesticide or herbicide. Bare ground along the harvesting paths may be unattractive to bird species because some species such as the Red Junglefowl (*Gallus gallus*) may require undergrowth that provides concealment from predators. In addition, arthropods that may act as food for birds may be more abundant in association with thick ground vegetation cover within the planted plots. A study has showed that the Red Junglefowl in oil palm plantations consumed more arthropods than any other animal food source (Arshad *et al*., 2000). Nearly 83% of the species recorded in this study were insectivorous, carnivorous or omnivorous birds which may play an important ecological role in controlling arthropod populations, including insect pests (de Chenon and Susanto, 2006). On the other hand, specialised frugivorous birds were rarely detected in oil palm production areas. This may be attributed to the absence of native fruit trees (*e.g. Ficus* spp.) that can supply food to such birds.

Our results were conservative as we visited each of the study sites only once or twice. At any one site, we used different transects rather than repeating the previous ones to increase spatial replicates. A longer study period, preferably over more than five years, may have resulted in the detection of more bird species in oil palm production areas. However, our results are still statistically robust because we surveyed a large portion of the oil palm production areas.

Note: photographs by Badrul Azhar.

*Figure 4. Appropriate measures to enhance biodiversity conservation in oil palm production areas: (a) tree planting for the benefit of wildlife, (b) cattle grazing employed as a biological control method for weedy plants that can reduce the use of hazardous agrochemicals which may harm both wildlife and humans, (c) maintaining clean aquatic habitats (*e.g. *drains), and (d) promoting local heterogeneity within planted plots by retaining some ground vegetation cover and epiphytes.*

Recommendations on Conservation

Our results show explicitly that oil palm production areas were not completely a 'green biological desert' as previously thought, but that the production areas also need to be managed wisely for biodiversity conservation. There is an urgent need to increase the scientific understanding of the biodiversity value of oil palm production areas as well as to find the best approaches to maintain or enhance this biodiversity. Oil palm research should incorporate biodiversity studies as one of its backbone components because the associated environmental issues, including climate change and biodiversity crisis, have become major topics in land conversion. Such studies on biodiversity should not be limited to a small number of short-term studies because oil palm cultivation is currently expanding rapidly into other humid tropical regions.

We suggest six general recommendations which could help in enhancing avian biodiversity in oil palm production areas. These recommendations are based partly on our own results, extensive field experience and references to the relevant literature (*Figure 4*): (1) extensive implementation of tree planting projects in commercial plantations to provide birds with additional habitats and food sources (Manning *et al*., 2006; Cunningham *et al*., 2008). Planting native trees (*e.g. Ficus* spp.) can be carried out on unproductive land or along the roadsides; (2) phasing out the application of dangerous agrochemicals (*e.g.* pesticides and herbicides) (McNeely and Scherr, 2002; Wilson *et al*., 2009). To control weedy plants and to supplement crop growth with organic manure, integrating oil palm cultivation with rotational livestock grazing (*e.g.* cattle, sheep and goats) should be encouraged (Kirby *et al*., 1997; Hart, 2006). Moderate grazing can maintain local heterogeneity to benefit resident or migratory birds (Rook *et al*., 2004; Martin and McIntye, 2007); (3) ensuring good water quality in aquatic habitats; (4) promotion of ground vegetation cover to increase habitat heterogeneity on a local scale (Benton *et al.*, 2003; Fischer *et al*., 2006; Lindenmayer *et al*., 2006); (5) enforcement of a ban on wildlife hunting within oil palm production areas. Security officers or auxiliary police hired by plantation companies should be trained to deal with poachers. At the same time, they should be exposed to local wildlife or forestry laws, and (6) fostering close collaboration with local research institutions (*e.g.* public universities) to conduct long-term monitoring which can produce stronger empirical results and more useful recommendations. This approach may also benefit local researchers in terms of capacity building in conducting quality research.

Wild birds do not recognise human-perceived boundaries (*e.g.* between protected areas and agricultural areas). Some birds will inhabit or forage in oil palm landscapes. Therefore, palm oil stakeholders should promote biodiversity studies and conservation work in oil palm production areas in order to better protect wild birds. For instance, existing oil palm production areas managed as buffer zones for protected areas have unexplored conservation potential that can be implemented with careful planning and monitoring.

CONCLUSION

Our study demonstrates that oil palm production areas hold conservation value based on the recorded avian biodiversity although these areas have fewer forest bird species. Our results show explicitly that plantations and smallholdings support not only resident species, but also wetland and migratory species. Our findings challenge the common negative perception that has suggested oil palm production lands are completely devoid of biodiversity and thus should be excluded from any conservation strategy. With proper management practices that aim for conservation outcomes, it is possible that oil palm cultivation can move towards a sustainable status similar to that of other commodities (*e.g.* coffee and cacao). Biodiversity studies in oil palm production areas should be promoted and supported financially by all interested stakeholders. Local research institutions with their professional expertise are important in this regard because they can play a major role in long-term monitoring. Greater conservation outcomes together with scientific evidence from such long-term studies may more effectively defend the sustainability of oil palm production.

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