Pertanika J. Trop. Agric. Sci. 41 (4): 1669-1683 (2018)

TROPICAL AGRICULTURAL SCIENCE

Journal homepage: http://www.pertanika.upm.edu.my/

The Rice-Growing Cycle Influences Diversity and Species Assemblages of Birds in the Paddy Field Ecosystem in East Peninsular Malaysia

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ABSTRACT

The paddy field ecosystem is an important habitat for water birds, as well as some migratory species due to the abundance of food resources. We want to determine which factors influence bird species abundance, diversity, and composition in different paddy field sites with different rice growing stages. Rapid assessments of birds were conducted in three paddy fields located on the east coast of Peninsular Malaysia: Pahang (Pekan), Terengganu (Besut) and Kelantan (Melor). The survey method involved point count sampling. From the survey, Pekan recorded 1,141 individuals from 17 species, Melor with 992 individuals from 11 species, and Besut, with 348 individuals from eight species. The Ardeidae family was the most dominant, at 71%, at all study areas, followed by the Rallidae (21.43%), Columbidae (14.29%) and Halcyonidae (14.29%). The species richness and assemblages were found to correlate with the rice-growing cycle, where the post-harvest (land preparation) and seedling (vegetative) stages were associated with the highest species incidence, as demonstrated in Pekan and Melor, due to these sites being inundated or flooded. Species abundance was statistically significant for different feeding guild groups based on Welch's $F(4, 4.095) = 68.027$, $p<0.05$. Carnivorous birds were most common during the post-harvest and seedling stage, in contrast to insectivorous/granivorous birds, which were most common during the flowering stage. This study could aid in pest management in relation to bird communities in the paddy field ecosystem through the application of biological control practices instead of chemicals, without compromising rice yield.

Keywords: Birds, bird pest, feeding guild, paddy field, rice growing cycle

ARTICLE INFO

Article history:
Received: 14 February 2018
Accepted: 26 June 2018
Published: 14 November 2018

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ISSN: 1511-3701
e-ISSN 2231-8542

INTRODUCTION

Paddy, which is the world's most widely cultivated crop cover about 1.55 million km^2 of earth's land surface (Donald, 2004). Until the year 2016, world rice (*Oryza sativa*), production has reached 741 million tonnes from only 568 million tonnes, 20 years ago (Food and Agriculture Organization [FAO], 2018). Rice is a staple food of Malaysia, and it has become the main gastronomic resource there. Thus, rice growing has become a major agricultural activity in Malaysia. Rice growing is particularly intense around the north coast of Peninsular Malaysia due to its topographical aspects, specifically being less mountainous and having more fertile soil.

Donald (2004) stated that most wetlands had been converted into paddy fields to increase rice production. In addition, many forested areas have been converted for agricultural uses, such as oil palm stands, rubber plantations and paddy fields (Aratrakorn, Thunhikorn, & Donald, 2006). This conversion leads to habitat loss for many organisms that have inhabited these forests for thousands of years, including birds. The number of bird species in wetland rice fields less than that in forested areas (Wood et al., 2010) because paddy fields are poorer breeding sites for resident birds (Fanslow, 2006). Birds are important and diverse consumers in the paddy ecosystem, residing in either the secondary or top trophic level. Birds, as compared to arthropods, and aquatic organism, are more often thought as pests in the paddy fields (Elphick, 2008). According to Zakaria and Rajpar (2013), water birds rely entirely on wetlands to perform their daily activities, such as nesting, foraging, loafing and moulting, while terrestrial birds visit wetland areas for shelter and food and also to forage. Paddy fields serve as a unique wetland landscape that creates feeding and nursery grounds for birds (Mojiol, Hassan, Maluda, & Immit, 2008), especially water birds, raptors, and sparrows. The presence of such animals in the paddy field environment is mainly due to human activities, such as ploughing, planting and seasonal flooding in that such activities attract many kinds of bird species for foraging and resting (Stafford, Kaminski, & Reinecke, 2010). Sightings of small prey near the water surface lure birds to feed (Acosta et al., 2010). In addition to birds, other organisms inhabiting paddy field landscape, includes weedy plants, plankton, various types of bacteria, aquatic insects, mice and water snakes (Lu, Watanabe, & Kimura, 2002). The interaction of these organisms creates a balanced ecosystem, thus making paddy fields a good habitat for many species (Deb, 2009).

According to Wells (1999), the abundance of birds in paddy fields is also influenced by bird migration during the migratory season, which occurs from September to March. Paddy fields cater a large number of migratory water birds as well as raptors (King, Elphick, Guadagnin, Taft, & Amano, 2010) due to the large number of food resources available, such as crustaceans, molluscs and polychaetes (Stafford et al., 2010). However, most paddy fields are now affected by development and reclamation (Munira et al., 2014). Therefore, it is necessary to manage the habitat sustainably because birds play many roles in the ecosystem, such as acting as predators, pollinators, scavengers, seed dispersers, seed predators and ecosystem engineers (Whelan, Wenny, & Marquis, 2008). For instance, the Asian open bill (*Anastomus oscitans*), a vagrant stork species in Peninsular Malaysia, has been using paddy fields for feeding and roosting grounds. It was also found to be a biological control agent for the golden apple snail (*Pomacea caniculata*), a common pest in the paddy field landscape (Zainul-Abidin, Mohd-Taib, & Md-Nor, 2017).

Studies of bird diversity and assemblages in paddy fields have been restricted to the west coast of Peninsular Malaysia (Munira et al., 2014; Shah et al., 2008). Not many studies explore factors that shape the abundance and diversity of birds on the east coast of Peninsular Malaysia. The aim of the study was to document the diversity and assemblages of bird species in different paddy field sites in east Peninsular Malaysia, as well as how these correlate with the rice-growing cycle. Several paddy fields in various rice-growing stages were chosen on the east coast of Peninsular Malaysia. We hypothesized that the ecological traits of birds, such as feeding guild, would correspond to the rice-growing stage. This information is vital for conservation efforts targeting birds in the paddy fields, particularly those that become natural biological control agents for certain pests. Specific practices can also be implemented to control bird pest species in the paddy fields and thus enhance rice yield.

MATERIALS AND METHODS

Study Site

The study was conducted in three states on the east coast of Peninsular Malaysia: Pahang (Pekan) (03°01.587' N, 102°36.343' E), Terengganu (Besut) (05°93.542' N, 102°34.376' E) and Kelantan (Melor) (05°70.824' N, 102°53.403' E) (Figure 1).

The study was conducted between September and November of 2015, alternating from site to site. Observation was made for a week at each site in each month, and repeated for the subsequent months. At the time of sampling, Melor, Besut and Pekan were in the seedling (vegetative), flowering (reproductive) and post-harvesting (land preparation) stages, respectively (International Rice Research Institute [IRRI], 2017). The vegetative stage refers to the germination to panicle initiation. At this stage, farmers plant rice seeds in flooded plots. These inundated plots are very important because they also allow fishes and amphibians to be seen and eaten by predators such as raptors. The reproductive stage refers to everything from panicle initiation to flowering. In this stage, the paddy plots are dense with paddy plants, thus limiting food detection by predators. The land preparation stage refers to the ploughing activity that takes place prior to the transplanting stage, after the harvesting season. At this stage, ploughing activity was

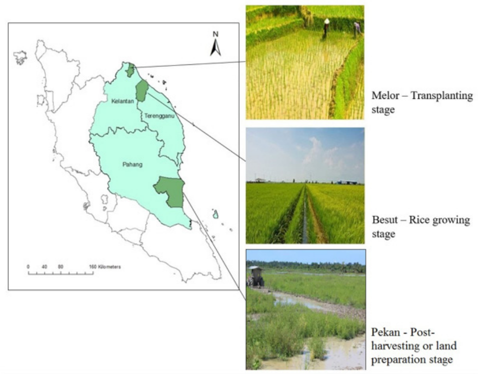

Figure 1. Location of the study sites on the east coast of Peninsular Malaysia and their respective rice growing phases

been performed to fertilise the soil prior to the seedling stage. Such activities also cause aquatic insects and fishes to move freely and thus be seen by predators.

Sampling

Birds were observed by performing point count method, with the aid of 10x42 binoculars. A total of 20 points were randomly chosen in respective paddy plots. At each point, observation was conducted for 10 minutes. Two observers were involved in the survey (FSMT and HAK). The data recorded were species abundance. Migratory species were also census as it indicates the role of paddy field ecosystem to harbour migratory species. The observation began at 0700 hour until 1900 hour, with 45 minutes time interval and 15 minutes breaks to avoid continuous data collection. Only birds observed within 30 meters distance from both sides of the points were counted, and points selected were at least 200 meters apart to avoid double counting (Gregory, Gibbons, & Donald, 2004). We tried to avoid double counting by using a careful observation especially on flying birds over the census area. However, same individual birds recorded at subsequent points will be treated as different individuals. Each species is identified as a member of a specific feeding guild, following Zakaria and Rajpar (2010).

Data Analysis

To compare species compositions between habitats, we used a Euclidean distance matrix to determine the degree of similarity in terms of species composition between various sites. Principal component analysis (PCA) was conducted to determine the species assemblages inhabiting various paddy sites by visualizing the similarities or differences between factors involved. The index for PC1 explains the most variation in the data. Both analyses were performed using MVSP (Multivariate Statistical Package), Version 3.13b. A one-way ANOVA was conducted to determine whether species abundance differed for groups with different rice-growing stages and feeding guilds. These data were analysed using SPSS, Version 23.

RESULTS

The Ardeidae family was the most common family overall, at 35.71% across all study areas. This family is followed by the Rallidae, at 21.43% with 94 individuals from three species, as well as the Columbidae and Halcyonidae, which were both represented at a rate of 14.29%, with two species and 120 and 44 individuals, respectively. Other

Table 1

Euclidean distance matrix for species distribution in various paddy field sites

	Pekan	Besut	Melor
Pekan	0		
Besut	334.657	0	
Melor	204.203	356.679	0

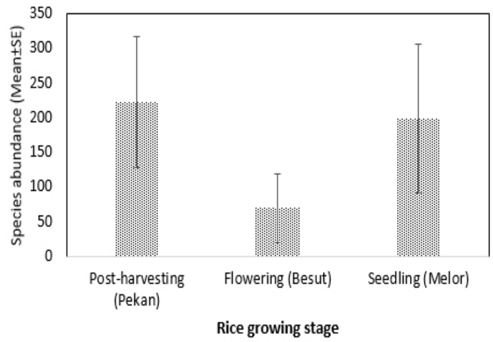

Figure 2. Mean ± SE of species abundance in various rice-growing stages

families were represented by only one species each. Among all of the species recorded across the three study sites, Pekan shows the highest species richness, with 17 species from 12 families. The species commonly found in Pekan were the great egret (*Ardea alba*), cattle egret (*Bubulcus ibis*), jungle myna (*Acridotheres fuscus*), Eurasian tree sparrow (*Passer montanus*), Pacific swallow (*Hirundo tahitica*) and little egret (*Egretta garzetta*). In comparison, Melor recorded a fairly high number of species, 12, and the most common were similar to species found in Pekan. The lowest number of species was found in Besut, with only eight species, which were dominated by the jungle myna and Eurasian tree sparrow. The species assemblages in Besut stand very much in contrast to those of Pekan and Melor because of the absence of any water birds (Ardeidae). A Euclidean distance matrix shows a high similarity between Pekan and Melor, with Euclidean distance 204.2 (Table 1). Besut shows a low similarity to both Pekan and Melor, with distances of 334.7 and 356.7, respectively.

The post-harvesting and seedling stages show a similarly high abundance of birds, as illustrated in Figure 2. A one-way ANOVA was conducted to determine whether the species abundance was different according to rice-growing stages. The data were normally distributed for each group, as assessed via Shapiro-Wilk test ($p>0.05$). There was homogeneity of variances, as assessed by Levene's test for the equality of variance ($p=0.189$). However, there were no significant differences in species abundance among different rice-growing stages, $F(2, 12) = 0.889$, $p=0.436$. Species abundance was highest in the post-harvest stage in Pekan (222.4±94.56), followed by the seedling stage in Melor (198.4±106.95). The lowest species abundance was seen at the flowering stage in Besut (69.6±49.04). Species abundance differed significantly between post-harvesting (Pekan) and flowering stage (Besut) ($p<0.05$).

Based on the PCA analysis (Figure 3), the four species with the highest scores in PC1 were the Great egret, Cattle egret, Jungle myna, and Eurasian tree sparrow. PC1, with

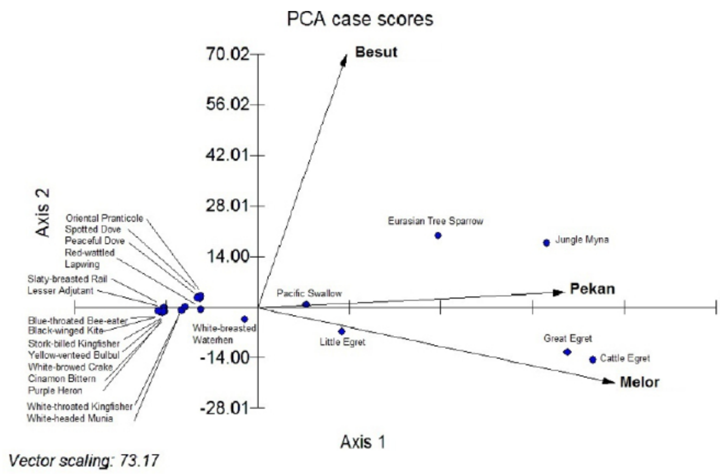

Figure 3. Scree plot of PCA loading abundance for each species and for various paddy field sites

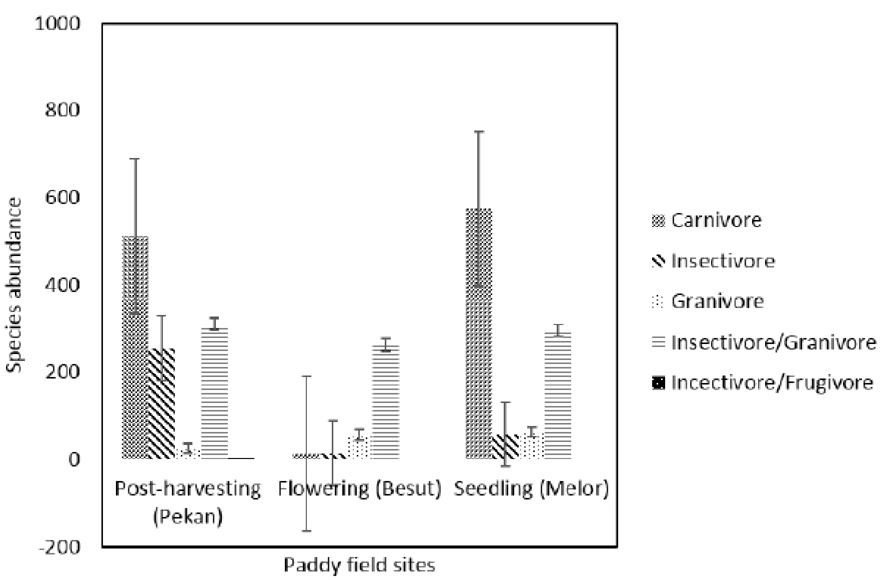

Figure 4. Species abundance for birds of various feeding guilds by rice-growing stage

its eigenvalue percentage 83.2%, could be explained by the high flood level during the post-harvesting and seedling stages, whereby PC2, with a percentage of 9.5% could be explained by the flowering, or reproductive, stage. The positive PCA loading for both axes, which represent the jungle myna and Eurasian tree sparrow, shows an abundance of these species during high flood levels as well as the flowering stage. This is proven with the high abundance of these species in all rice-growing stages, specifically the species assemblages in Besut during the flowering stage. The Pacific swallow shows a direction parallel with that of Pekan, confirming that this species was restricted to Pekan and was thus represented during the high flood levels in the post-harvest stage. The positive loading for PC1 and negative loading for PC2, on the other hand, represent the great egret, cattle egret and little egret. These species were highly abundant during the high flood levels, especially during the post-harvest and seedling stages in Pekan and Melor. The negative loading for PC1 and the positive loading for PC2 represent several species, such as the spotted dove (*Spilopelia chinensis)*, peaceful dove (*Geopelia placida)* and oriental pranticole (*Glareola maldivarum),* which explain these species were present at the site with low flood levels during the flowering stage. The weak negative PCA loading for the white-breasted waterhen (*Amaurornis pheonicurus)* indicates that this species is affected by neither flood level nor flowering stage. Nevertheless, it was only found in fairly high abundance in Pekan and Melor. The remaining species generally had negative PCA loadings for PC1 and loadings of 0 at PC2, which indicates that they were less influenced by flood level and flowering stage. These species were generally from different feeding guilds and were present only during the post-harvesting stage in Pekan, for instance, the white-throated kingfisher (*Halcyon smyrnensis)*, purple heron (*Ardea purpurea)*, yellow-vented bulbul (*Pycnonotus goiavier)* and cinnamon bittern (*Ixobrychus cinnamomeus)*.

Based on feeding guild, birds were categorized into five groups: carnivore, insectivore, granivore, insectivore/granivore (I/G) and insectivore/frugivore (I/F). A one-way Welch ANOVA was conducted to determine whether species abundance differed by feeding guild in various rice-growing stages (Figure 4). Data were normally distributed for each group, as assessed by Shapiro-Wilk test ($p>0.05$). The assumption of the homogeneity of variances was violated, as assessed by Levene's test of the homogeneity of variances ($p=0.001$). Species abundance was statistically significant for various feeding guild groups, Welch's $F(4, 4.095) = 68.027$, $p<0.05$. Species abundance was highest in carnivores (367.33±177.6), followed by I/G (289.67±14.5) and insectivores (109.67±74.2) and was lowest in granivores and I/F with (48.67±11.5) and (2±1.75), respectively. The abundance of the carnivore feeding guild was high during both the seedling and post-harvest stages, but this guild type was not present during the flowering stage. These species refer to birds from the Ardeidae family, particularly the great egret, cattle egret, and little egret, which are highly abundant during both the seedling and post-harvesting stages. The I/G feeding guild was about equally distributed across the various rice growing stage, though it was somewhat more common during the flowering stage. Insectivores were significantly more common in the post-harvest stage as compared to the seedling and flowering stages.

DISCUSSION

Bird Assemblages in Various Rice-growing Stages

The study has shown that the Pekan paddy field has the highest species richness and diversity of birds, followed by Melor and, finally, Besut. Apart from that, species assemblages also differed in relation to rice-growing stages, which was itself influenced by landscape matrix type. This result is in parallel with other research projects on birds in paddy fields (Munira et al. 2014; Paliwal & Bhandarkar 2014). The paddy field ecosystem provides abundant food sources. Thus, the presence of diverse food types in different parts of the rice-growing cycle also significantly affect species assemblages.

Based on this study, Pekan and Melor sites had greater abundances of water bird species, mainly the carnivorous feeding guild, such as the great egret, little egret and cattle egret. Water birds from the Ardeidae family were the most dominant species in the rice field, particularly during the inundated periods of the seedling and post-harvest phases. Pekan, which was undergoing ploughing activities in the land preparation period, attracted many carnivorous birds because these activities allow for the openness of plots. Thus, prey such as aquatic insects, small vertebrates, fishes, tadpoles, snakes and rodents can be easily seen and caught by predators (Stafford et al., 2010). This is a benefit to carnivorous birds because they have many food resources (Paliwal & Bhandarkar, 2014). In addition, Pekan also recorded other water birds species, such as the lesser adjutant, purple heron, and cinnamon bittern, in lower numbers. Lourenço (2006) demonstrated that the abundance of carnivorous birds increased with the increase in numbers of prey, such as shrews, snakes and rats. The noise and territorial behaviours of shrews cause them to be vulnerable to these predators (Munira et al., 2014). These carnivore species can become good biological control agents for pest populations, particularly rats and snails.

Insectivorous bird species are also categorized as beneficial species in paddy fields due to their ability to control insect pests. Insectivorous birds can be found in paddy fields due to the abundance of insects during all rice-growing stages, as shown in the similar distributions of insectivorous species across all paddy field sites. Herbivorous insects from the Homoptera, Orthoptera, Hymenoptera, Lepidoptera, Hemiptera and Coleoptera families constitute the main pests in paddy fields, particularly the sap-feeders (Norela, Anizan, Ismail, & Maimon, 2013). Insects choose to breed and complete their lifecycles in paddy fields because they like moist conditions and dense foliage (Chettri, Deb, Sharma, & Jackson, 2005). Thus, the abundant insects in the paddy fields attract insectivorous bird species. Therefore, the presence of insectivorous species such as the house sparrow and myna (Rajashekara & Venkatesha, 2014), which were found abundantly in all paddy field sites, could potentially control these insect pests. In this study, the abundance of insectivorous birds is correlated with the abundance of insects in various rice-growing stages. According to Norela et al. (2013), insect populations decreased in tandem with the rice-growing stages in that they peaked during the early vegetative stage but declined at the end of the maturation stage of the paddy. Therefore, this supports this study's finding that there was an increase in the abundance of insectivorous birds, particularly the Pacific swallow and blue-tailed bee-eater, which were only present during the post-harvest stage, as well as the Oriental pratincole, which was present during both the post-harvesting and seedling stages. This is due to the abundance of insects during the post-harvesting stages. These species, on the other hand, were generally absent or declined during the flowering stage.

Compared to carnivorous and insectivorous species, granivorous species are commonly found in high abundance due to their efficient reproductive capacity in agricultural habitats (Dhindsa & Saini, 1994), thus contributing to economic losses in a variety of agricultural sectors. In paddy fields, prior to the harvesting season, the rice ripens, thus attracting granivorous species (Maeda, 2001) such as the white-headed munia, spotted dove and peaceful dove. The flowering stage in Besut in particular recorded a high number of granivorous and insectivore/granivore species due to the emergence of rice buds and seeds. These species are thought of as pests in the paddy field environment because they reduce the rice yield (Sridhara, Subramanyam, & Krishnamoorthy, 1983). Sridhara et al. (1983) also found a similar pattern of maximum species density among granivorous and insectivorous species during the ripening stage in Bangalore, India, due to low abundance of predators during the breeding season. Breeding activities among grain eaters involve the shifting of their diet from grain to insects to feed their nestlings (Mathew, Narendran, & Zacharias, 1980; Simwat, 1977), thus increasing the abundance of these species during the flowering stage. Several methods have been implemented to control for these pests in paddy fields, including the use of physical and chemical techniques (Dhindsa & Saini, 1994). The use of pesticides, however, has indiscriminately killed some endangered birds (Dhindsa, 1986). Therefore, precautions should be taken when using this method. The black-winged kite species, a raptor found in Besut, on the other hand, could control smaller pest birds, particularly granivorous birds (Sridhara et al., 1983).

Conservation of Birds in Paddy Fields Ecosystem

Paddy fields serve as a great habitat and nursery grounds for birds (Mojiol et al., 2008). There is plenty of food available in the paddy fields such as grains, paddy seeds, insects, fishes, tadpoles, snakes, and even small mammals such as rats. The lesser adjutant, a species categorised as vulnerable in the IUCN Red data list was present in the Pekan site, as were other migrant species namely the Oriental pratincole, and blue-tailed bee-eater (*Merops philippinus)*. Migration could influence the species richness of paddy fields because migrant birds need food and shelter to survive weather fluctuations (Wells, 1999) and there is a large number of food resources in paddy fields (King et al., 2010) such as crustaceans, mollusc and polychaetes (Stafford et al., 2010). However, the number of migrants species found in this study was very low compared to that found in paddy field in northwestern Peninsular Malaysia by Munira et al. (2014) who recorded migratory waders from the Scolopacidae family. The west coast region contained more wetland, shoreline, marshes, mangrove and agriculture than the east coast of Peninsular Malaysia (Zainul-Abidin et al., 2017), thus explaining the remarkably low diversity of birds in this study. Furthermore, the west coast region is also an important pathway for waterbird species as they travel through Peninsular Malaysia (Li, Yeap, & Kumar, 2007).

Pesticides have been widely used in the agricultural industry including rice production, which subsequently reduces biodiversity in the ecosystem (Samharinto, Abadi, Rahardjo, & Halim, 2012; Wood et al., 2010). This, in turn, shrinks the food web in the rice fields via the elimination of organism at various trophic levels such as raptors and other predators, thus resulting in population built-ups of insect, rodent and bird pest species (Dhindsa & Saini, 1994). Very few raptor species were found during the survey which indicates an insufficient use of natural biological control agents in these paddy fields. Plantations of trees surrounding the rice fields for perching and roosting are also essential in promoting certain populations of birds in the paddy field particularly raptors, insectivorous and frugivorous species which could help control pests in the paddy field.

CONCLUSIONS

Due to our relatively small sample size (sampling did not cover the whole rice growing stages in different paddy field sites), future study should incorporate bird survey in a complete cycle of rice growing stages, in different paddy field sites. Nevertheless, this study provided some valuable insight, that paddy fields in the east coast of Peninsular Malaysia contain many carnivorous and insectivorous species that could serve as good biological control agents against pest. Understanding the bird assemblages in different rice growing cycle could enlighten farmers on when best to control for bird pest in particular. More studies must be carried out to investigate how biological control application particularly among bird communities can enhance the effectiveness of pest control in rice fields without compromising rice yield.

ACKNOWLEDGEMENT

We would like to thank the owners of the paddy field sites for permitting this study to be carried out, as well as the local communities and rice farmers for their cooperation during the study. This research is funded by Tradewind Corporation Berhad grant ST-2014-004.

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APPENDIX

List of bird species and their relative abundance in each study sites

Family	Common Name	Taxa	Pahang	Terengganu	Kelantan	Residency status	Protection status	Guild type
Ciconiidae	Lesser adjutant	*Leptoptilos javanicus*	7 (0.6)	0 (0.0)	0 (0.0)	R	V	C
Ardeidae	Purple heron	*Ardea purpurea*	6 (0.5)	0 (0.0)	0 (0.0)	R&M	LC	C
	Cinnamon bittern	*Ixobrychus cinnamomeus*	5 (0.4)	0 (0.0)	0 (0.0)	R&M	LC	C
	Great egret	*Ardea alba*	194 (17.0)	0 (0.0)	218 (22.0)	R&M	LC	C
	Little egret	*Egretta garzetta*	79 (6.9)	0 (0.0)	105 (10.6)	R&M	LC	C
	Cattle egret	*Bubulcus ibis*	182 (16.0)	0 (0.0)	252 (25.4)	R&M	LC	C
Accipitridae	Black-winged kite	*Elanus caeruleus*	0 (0.0)	1 (0.3)	0 (0.0)	R	LC	C
Rallidae	White-breasted waterhen	*Amaurornis pheonicurus*	45 (3.9)	0 (0.0)	43 (4.3)	R&M	LC	I
	White-browed crake	*Amaurornis cinerea*	0 (0.0)	0 (0.0)	2 (0.2)	R	LC	I
	Slaty-breasted rail	*Gallirallus striatus*	0 (0.0)	0 (0.0)	4 (0.4)	R	LC	I
Charariidae	Red-wattled lapwings	*Vanellus indicus*	47 (4.1)	0 (0.0)	0 (0.0)	R	LC	C
Glareolidae	Oriental pranticole	*Glareola maldivarum*	42 (3.7)	15 (4.3)	0 (0.0)	R&M	LC	I

APPENDIX *(Continue)*

Columbidae	Eastern spotted dove	Spilopelia chinensis	0 (0.0)	30 (8.6)	33 (3.3)	R	LC	G
	Peaceful dove	*Geopelia placida*	0 (0.0)	27 (7.8)	30 (3.0)	R	LC	G
Halcyonidae	White-throated kingfisher	*Halcyon smyrnensis*	17 (1.5)	8 (2.3)	9 (0.9)	R	LC	C
	Stork-billed kingfisher	*Pelargopsis capensis*	5 (0.4)	5 (1.4)	0 (0.0)	R	LC	C
Meropidae	Blue-tailed bee eater	*Merops philippinus*	7 (0.6)	0 (0.0)	0 (0.0)	R&M	LC	I
Hirundinidae	Pacific swallow	*Hirundo tahitica*	162 (14.2)	0 (0.0)	0 (0.0)	R	LC	I
Pycnonotidae	Yellow-vented bulbul	*Pycnonotus goiavier*	6 (0.5)	0 (0.0)	0 (0.0)	R	LC	I/F
Sturnidae	Jungle myna	*Acridotheres fuscus*	164 (14.4)	138 (40.0)	190 (19.2)	R	LC	I/G
Passeridae	Eurasian tree sparrow	*Passer montanus*	147 (12.9)	124 (35.6)	106 (10.7)	R	LC	I/G
Estrildidae	White-headed munia	*Lonchura maja*	26 (2.3)	0 (0.0)	0 (0.0)	R	LC	G
Total (Individual)			1141	348	993			

Note: Residensy status: R=resident, R&M=resident and migrant, Protection status: V=vulnerable, LC=least concern, Feeding guild: C=carnivorous, I=insectivorous, I/F=Insectivorous and frugivorous, G=granivorous, I/G=insectivorous and granivorous.