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FEEDING ECOLOGY OF BIRDS IN SELECTED MICROHABITAT IN PULAU TINGGI, JOHOR, MALAYSIA

NORMAISHARAH MOKHTER[1,2], MUHAMMAD ARIFUDDIN AKHSAN[2], MUHAMMAD ASRAF AMRAN[2], TZE JIEN LEE[1,2], MD-ZAIRI ZAINAL[3], MUHAMMAD ABU BAKAR ABDUL-LATIFF[1,2] AND NOR ATIQAH NORAZLIMI[1,2]*

[1]Environmental Management and Conservation Research Unit (eNCORe), Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn Malaysia (Pagoh Campus), 84600 Muar, Johor, Malaysia. [2]Department of Technology and Natural Resources, Faculty of Applied Sciences and Technology Universiti Tun Hussein Onn Malaysia (Pagoh Campus), 84600 Muar, Johor, Malaysia. [3]Shaz Resort Pulau Tinggi Sdn. Bhd., Lot 44, Kampung Penaga, Pulau Tinggi, 86800 Mersing, Johor, Malaysia.

**Corresponding author: atiqah@uthm.edu.my*
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Abstract: Understanding the feeding ecologies of birds is a crucial part of conservation purposes. Scholars interpreted terrestrial birds in many journals, yet studies on waterbirds, primarily shorebirds were poorly understood along the Peninsular Malaysia coastal line. Most researchers only record species presence and very few studies were previously conducted on feeding ecologies. Therefore, this study aims to investigate the feeding ecology of the birds in a selected microhabitat in Pulau Tinggi from March until August 2019. The study used mist-netting and direct observation techniques with a video camera and binoculars. A total of 39 species of birds comprising 24 families were censused. Seven feeding guilds were successfully identified. Carnivores dominated the highest species composition with 28%, followed by insectivores at 21%, frugivores and omnivores at 15% each, carnivore-insectivores and frugivore-insectivores at 10% each, and granivorous with 5%. From the analysis, we found no significant difference between the feeding guild and birds' location of birds' feeding preferences in forest and coastal zones ($z= -1.1$, $p= 0.31$). Understanding the feeding ecology of the birds in a specific ecosystem is vital to understand how the birds exploit their resources and utilize the environment to avoid competition and thus sustain in that ecosystem.

Keywords: Island birds, feeding ecology, feeding guild, beak morphology.

Introduction

The island provides an extensive range of microhabitats for birds, from terrestrial to the shorelines. Terrestrial and shorelines support different bird groups depending on their habitat's niche for daily activities. Waterbirds are bird species that entirely depend on wetlands for various activities, including foraging, nesting, loafing and moulting. In comparison, terrestrial birds refer to bird species that do not rely on the wetland habitats but may utilize the wetland areas for searching for food, shelter and loaf (Rajpar & Zakaria, 2010).

Lowland dipterocarp forest accounts for a massive scale in Malaysia, where this forest is rich in biodiversity compared to other forest types (Whitmore, 1985). With different strata offered by lowland forests, birds utilize different strata to minimize competition for resources, nesting sites and territories. Different niches from different strata levels separate bird species in spaces, times and diets (Mansor & Ramli, 2017). Wells (1976) divided birds inhabiting lowland forest strata into three main groups: The top, middle and undergrowth. The top canopy is dominated by hornbill, barbet and pigeon species, mainly consuming fruits and insects. While the middle level is where species like trogons, woodpeckers and bulbul can be found and lastly, at the lowest level of the forest lived by pittas, thrushes, babblers and pheasants.

Scholars interpreted terrestrial birds in many journals, yet studies on waterbirds, primarily shorebirds were poorly understood along the Peninsular Malaysia coastal line. Most researchers only record species presence (Sodhi *et al.,* 1999; Rosli *et al.,* 2008; Yeok *et al.,* 2016; Hamza *et al.,* 2016; Hamza *et al*., 2018; Hamza & Ho, 2019; Hamza *et al*., 2019) rather than detailing on ecological studies including feeding ecology. Only a few studies previously related to feeding ecologies (Riak, 2004; Lomolji, 2011; Norazlimi & Ramli, 2015).

Studies associated with bird communities are grouped to avoid conflict in comparing too large communities with different compositions, called guilds (Gardali *et al.,* 2006). The researcher could produce a more precise conclusion if species are categorized into a guild, habitat type and foraging style (Kus & Beck, 2001). Analysis of the guild is essential in providing information about each guild's response to a particular habitat change. Birds can be distinguished based on eight types of feeding guilds. They are carnivore (CR), insectivore (IN), frugivore (FR), nectarivore (NEC), omnivore (OM), granivore (GR), carnivore-insectivore (Car-Ins) and frugivore-insectivore (Fru-Ins) (Myers, 2009; Phillipps & Phillips, 2014).

This study will help to understand the feeding ecology of birds in terrestrials and shorebirds in the study area of Pulau Tinggi, Mersing, Johor. These include determining the relationship between feeding guilds and habitat preferences and the level of vertical strata where each guild dominates or is usually seen.

Materials and Methods

Study Area

Tanjung Balang, a Malay village in Pulau Tinggi, has been selected as our sampling site in this survey (Figure 1). Pulau Tinggi (13.5 km^2) is the largest island in the southern Seribuat Archipelago in the coastal waters of Pahang and Johor states. Pulau Tinggi and Pulau Sibu are the only Islands that accommodate artisanal

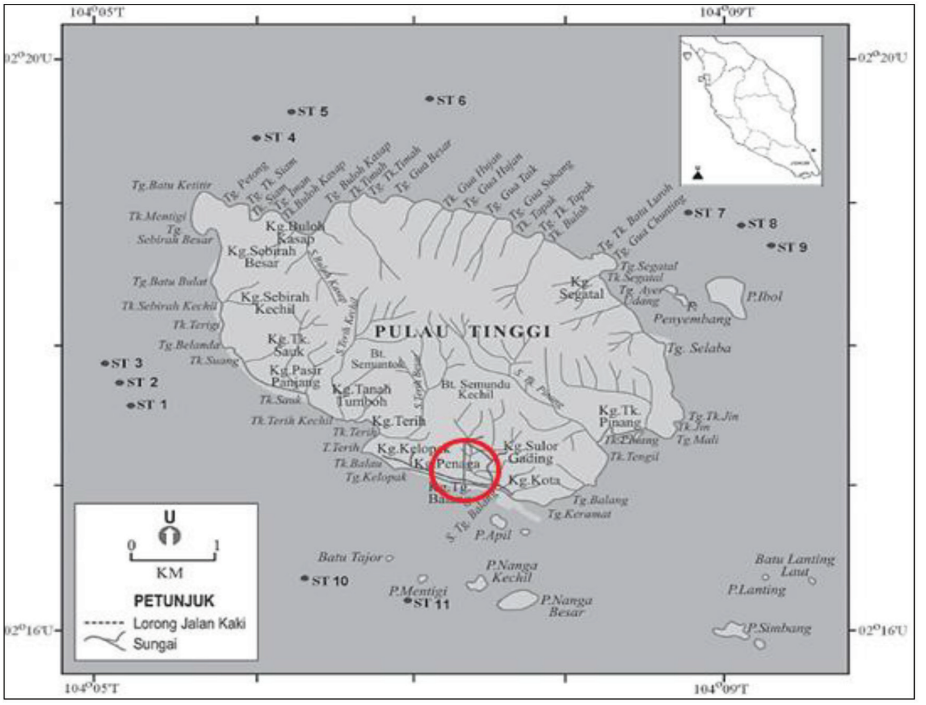

Figure 1: Location of the study area in Pulau Tinggi (location in red circle)
Source: Faiz *et al*. (2007)

fishing communities besides supporting resorts and marine parks. The rest of the Islands within this region are generally smaller in size besides steep in height, making them inadequate to support human settlement (Hamza *et al.,* 2019). In addition, compared to other islands in this archipelago dominated mainly by rocky outcrops, Pulau Tinggi served with a bigger dipterocarp forest land, thus, accommodating primarily terrestrial birds besides shorebirds. Therefore, this study covered both terrestrial and shorebirds in total. These two forests and coastal zone were further divided into smaller microhabitats: Primary forest, secondary forest, waterfall, forest edge, pond, coastal line and human settlement/resort area.

Procedures

Mist Netting

A total of five mist nets were deployed randomly along 2.7 km trails in each zone for each month from March to August 2019. Mist nets were operated from 0700 to 1800 hours and regularly inspected every two hours. Given a total of 50 days of sampling effort for each site and each mist net GPS reading was recorded. All captured birds were identified by species using a field guide to the Peninsular Malaysia and Singapore birds by Jeyarajasingam and Pearson (2012). Caught birds were morphologically measured (Head bill, Bill length, Bill depth, Tarsus, Wing length, Wingspan, Total Length and Tail Length), weighed and ringed with an aluminium tag before releasing back.

Feeding Ecology

The feeding behaviours of birds were studied from Jun to August 2019 by direct observation technique. Birds were observed using binoculars (12x42 magnifications), a field scope (30x50 magnification) and a video recorder to see their food intakes. Observation will occur during bird active time in the morning from 0700 to 1000 hours and in the evening from 1600 to 1800 hours.

Feeding Guild

Birds censured by mist-netting and direct observation were grouped into eight feeding guilds (Table 1), referring to information from Myers (2009) and Phillipps and Phillipps (2014).

Observation Sites

Seven sites representing different microhabitats were selected as the observation sites. They included a waterfall, primary, secondary, forest edge, pond, orchard, human settlement and coastal line (Figure 2). Guild composition in each site was identified based on observation and mist net data collection throughout the sampling period.

Table 1: The definition of avian guild

Feeding Guild	Definition
Insectivore	Insect feeders
Nectarivore	Nectar of flowers feeders
Frugivore	Fruits feeders
Carnivore	Small mammals, birds and fish feeders
Granivore	Grain or seeds feeders
Frugivore-Insectivore (Fru-Ins)	Primarily fruit feeders but shift to insects when fruits are scarce
Carnivore-Insectivore (Car-Ins)	Primarily small mammals, birds and fish feeders but shift to insects when the formers are low
Omnivore	Plant and animal feeders

Figure 2: Map showing microhabitats selected as observation sites

Frequency Visitor for Each Level of Vertical Strata

In this study, we also recorded the level of vertical strata where the birds were sighted. For forest birds, the level was classified according to Peh *et al*. (2006) as in Table 2. For waterbirds, we classified them into bottom feeders (BF) and birds that plunge (P) into the water's surface to catch their prey.

Statistical Analysis

All data sets were organized in excel before being further analyzed through statistical testing. Paleontological Statistics (PAST) (Hammer, Harper & Ryan, 2007) and SPSS (2019) statistical software were used to analyze all data. All data sets were tested with Shapiro-Wilks' W test for normality. In all cases, a = 0.05 was used. Spearman Rank Correlation was used to analyze the correlation between beak length and prey size for the birds observed. In addition, a Paired-sample t-test was used to examine the significance of bird guild compared to forest and coastal zone.

Results and Discussion

Pulau Tinggi, located in the Seribuat Archipelago of Johor State was a vegetated Island supporting terrestrial and waterbirds. The open sea along the east coast of Peninsular Malaysia harbours rich fisheries production, thus, playing as an important feeding ground for waterbirds.

Guild Composition

39 bird species from 24 families were censused through mist-netting and direct observation during our sampling period in Tanjung Balang Village at Pulau Tinggi, Mersing, Johor. Carnivores recorded the highest species composition of 28%, followed by Insectivores at 21%, Frugivore and Omnivore at 13% each, Car-Ins and Fru-Ins at 10% each and lastly, Granivores at only 5% (Figure 2).

As shown in Table 3, carnivores mostly come from raptors (Accipitridae) and water birds group, including the family of Kingfisher (Alcedinidae), Egret and Heron (Ardeidae) and Terns (Laridae). On the other hand, the remaining avian guilds are dominated by terrestrial birds, including families of Cuckoo (Cuculidae),

Drongo (Dicruridae), Monarch (Monarchidae), Dove and pigeon (Columbidae), Dollarbird (Coraciidae), Sunbird (Nectariniidae), Robin and Shama (Muscicapidae), Munia (Estrildidae), Crow (Corvidae) and Flowerpecker (Dicaeidae). Table 3 shows the summary of birds censused throughout the survey.

Table 3: Birds censused throughout the sampling period in the sampling site with guild grouping and level where birds were encountered

Family	Scientific Name	Common Name	Guild	Level
Accipitridae	*Haliastur indus*	Brahminy Kite	Cr	C
	Haliaeetus leucogaster	White-bellied Sea- Eagle	Cr	C
	Nisaetus cirrhatus	Changeable Hawk Eagle	Cr	C
Alcedinidae	*Halcyon smyrnensis*	White-throated Kingfisher	Cr	P
	Alcedo meninting	Blue-eared kingfisher	Cr	P
	Alcedo athhis	Common Kingfisher	Cr	P
	Todiramphus chloris	Collared Kingfisher	Cr	P
Apodidae	*Apus nipalensis*	House Swift	In	P
Ardeidae	*Egretta sacra*	Pacific Reef-heron	Cr	BF
	Butorides striata	Little/striated heron	Cr	BF
Columbidae	*Chalcopaps indica*	Asian Emerald Dove	Fr	S,G
	Ducula aenea	Green Imperial-pigeon	Fr	C
	Streptopelia chinensis	Spotted Dove	Fr	S,G
Coraciidae	*Eurystomus orientalis*	Dollarbird	In	C
Corvidae	*Corvus enca*	Slender-billed Crow	Om	G
Cuculidae	*Hierococcyx fugax*	Malaysian Hawk-Cuckoo	In	M
Dicaeidae	*Dicaeum cruentatum*	Scarlet-backed Flowerpecker	Fr	S
Dicruridae	*Dicrurus remifer*	Lesser Racquet-tailed Drongo	In	M
Estrildidae	*Lonchura punctulata*	Scaly-breasted Munia	Gr	S,G
Hirundinidae	*Hirundo Tahitica*	Pacific Swallow	In	P
Laniidae	*Lanius cristatus*	Brown Shrike	Car-Ins	M
Laridae	*Sterna hirundo*	Common Tern	Cr	P
Monarchidae	*Hypothymis azurea*	Black-naped Monarch	In	S
Muscicapidae	*Copsychus saularis*	Oriental Magpie Robin	Car-Ins	S
	Luscinia cyane	Siberian Blue Robin	Cr	S
	Copsychus malabaricus	White-rumped Shama	In	S
Nectariniidae	*Anthreptes malacensis*	Brown-throated Sunbird	Fru-Ins, Nec	S,M
	Cinnyris jugularis	Olive-backed Sunbird	Fru-Ins, Nec	S,M
Oriolidae	*Oriolus chinensis*	Blacked-naped Oriole	Om	C
Passeridae	*Passer montanus*	Eurasian Tree Sparrow	Gr	S,G

Pellorneidae	*Trichastoma rostratum*	White-chested Babbler	Car-Ins	S
Phylloscopidae	*Phylloscopus borealis*	Arctic Warbler	In	S
Pycnonotidae	*Pycnonotus plumosus*	Olive-winged Bulbul	Fru-Ins	S
	Pycnonotus goiavier	Yellow-vented Bulbul	Fru	S
Scolopacidae	*Tringa glareola*	Wood Sandpiper	Car-Ins	BF
	Actitis hypoleucos	Common Sandpiper	Om	BF
Sturnidae	*Acridotheres tristis*	Common Myna	Om	G,S
	Gracula religiosa	Common Hill Myna	Om	C
	Aplonis panayensis	Asian Glossy Starling	Fru-Ins	G,S

*Keynote: Cr=Carnivore, In=Insectivore, Fr=Frugivore, Om=Omnivore, Car-Ins=Carnivore-Insectivore, Fru-Ins=Frugivore-Insectivore, Nec=Nectarivore, Gr=Granivore, C=Canopy, S=Shrub, G-Ground, M=Middle, P=Plunge, BF=Bottom Feeder

Revising on past studies on birds in small islands around Peninsular Malaysia, Pulau Tioman is highlighted with the highest species records compared to the other islands due to several factors including larger island size (100 km^2), long-term studies duration with extensive documentation by researchers where records were made since 1966 till 1998 by Medway (1966), Lee *et al.* (1977), Wells (1986; 1990a,b), Bransbury (1993), Anonymous (1995), Csorba *et al.* (1997) and Sodhi *et al.* (1999). Generally, all birds censused in Pulau Tinggi were found in Pulau Tioman except Blue-eared Kingfisher (*Alcedo meninting*), Slender-billed Crow (*Corvus enca*), Lesser Racquet-tailed Drongo (*Dicrurus remifer*), Scaly-breasted Munia (*Lonchura punctulata*), Common Tern (*Sterna hirundo*), Siberian Blue Robin (*Luscinia cyane*), Eurasian Tree Sparrow (*Passer montanus*), Yellow-vented Bulbul (*Pycnonotus goiavier*) and Common Sandpiper (*Actitis hypoleucos*). While Pulau Bidong, Terengganu by Hamza *et al*. (2018) and three islands (Pulau Perak, Jarak and Lalang) along streets of Malacca by Ramli *et al.* (2008) support lower numbers of bird species as they were smaller in size compared to Pulau Tinggi and Pulau Tioman with records 26 and 31 species of birds each. Meanwhile, Pulau Bidong and Malacca street's island shared a few similar species with Pulau Tinggi, including House Swift (*Apus nipalensis*), Oriental Dollarbird (*Eurystomus orientalis*), Pacific Swallow (*Hirundo Tahitica*), Olive-backed Sunbird (*Cinnyris jugularis*), Black-naped Oriole (*Oriolus chinensis*) and Asian Glossy Starling (*Aplonis panayensis*) with additional shared species in Bidong Island namely Collared Kingfisher (*Todiramphus chloris*), Pacific Reef-egret (*Egretta sacra*), Brown-throated Sunbird (*Anthreptes malacensis*), Arctic Warbler (*Phylloscopus borealis*) and Common Sandpiper (*Actitis hypoleucos*) and Malacca streets Islands namely Brahminy Kite (*Haliastur indus*), Little Heron (*Butorides striata*), Spotted Dove (*Streptopelia chinensis*) and Oriental Magpie Robin (*Copsychus saularis*). These similar species that occurred in the Malaysian Islands indicated that the island does play an important role in supporting the survival of birds similar to the continental ecosystem (Gilbert *et al*., 2018).

The highest capture by mist-netting is Fru-Ins groups, with 150 individuals, followed by insectivores, frugivores, car-ins, carnivores, omnivores and granivores (Figure 3). Even though Carnivores were recorded with the highest species number (Figure 2), Carnivore species in this study were bigger than forage in an open area at a higher level and thus, could not be censused by mist-netting. Mist-netting is optimal in capturing small birds that were hardly seen by observation (for example, passerine) that usually forage at the understorey and ground level (Ramli *et al.,* 2009). Following this, researchers generated ideas to capture birds that fly at a higher level by using a taller pole, deploying a mist net on a canopy walkway

(Rahman, 2002) and even climbing tree trunks up to 40 cm in diameter (Moffett & Lowman, 1995) to catch birds on canopy level. However, more workforce was needed to conduct this method. Nevertheless, direct observation will be more time-efficient, and less workforce is required to record big birds and those flying at the canopy level or in an open area.

Microhabitat Selection by Feeding Guild

Vegetation structure is vital in determining bird communities that occur in the habitat. In this study, the coastal zone covers huge microhabitats, including coastal lines, human settlements, ponds, fruit orchards and forest edges. In contrast, the forest zone covers three microhabitats, namely primary and secondary forest and waterfall ecosystems. From Table 4, The coastal line was populated with the highest capture of Fru-Ins birds, dominated by Asian Glossy Starling (*Aplonis panayensis*) species, with 73 individuals captured. At the same time, the remaining species under this guild captured in the coastal zone were the Brown-throated Sunbird (*Anthreptes malacensis*), Olive-backed Sunbird (*Cinnyris jugularis*) and Olive-winged Bulbul (*Pycnonotus plumosus*). In the forest zone, Insectivore and Fru-Ins ranked with the highest capture. White-rumped Shama (*Copsychus malabaricus*) and White-chested Babbler (*Trichastoma rostratum*) were two insectivore species that dominated this zone while Fru-Ins was the Olive-winged Bulbul (*Pycnonotus plumosus*). However, a t-test comparing both individuals for each guild capture in this two-zone gave no significant difference with a score

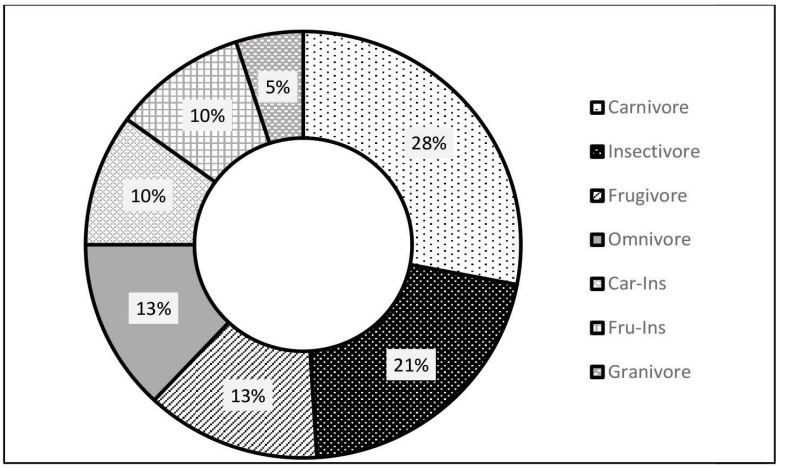

Figure 3: Percentage of avian feeding guild in sampling site

Table 4: Number of individuals for each guild censused through mist-netting

Guild	Forest	Coast
Carnivore	1	8
Insectivore	28	14
Frugivore	6	15
Omnivore	0	5
Granivore	0	4
Car-Ins	10	10
Fru-Ins	27	125

(z=-1.1, p=0.31). Probably, this is because some species could not be counted simply by using mist-netting, so individual numbers varied greatly between these areas.

The Avian guild's distribution was influenced by vegetation variation in the area (Pearmen, 2002). From Figure 4, human settlement supports a variety of avian guilds as it is structurally complex, offering diverse feeding niches for the avian community. Omnivore species, including Common Myna (*Acridotheres tristis*) and Slender-billed Crow (*Corvus enca*) were abundant here as they exhibit a broad range of food items. Fruits and flowering trees planted by the locals, along with the human settlement and fruit orchards, attract insects, thus, luring their prey among Fru-Ins and Insectivore birds. In addition, Granivore species were also found here, which are the Spotted Dove (*Streptopelia chinensis*), Scaly-breasted Munia (*Lonchura punctulata*) and Eurasian Tree Sparrow (*Passer montanus*). Granivore was well adapted to anthropogenic human activities as they have always seen in human plantations such as paddy fields (Azman *et al.,* 2011; Azman *et al.,* 2012). As mentioned above, the coastal line is dominated by Carnivore species that feed on fish and crustaceans in the sea. The pond ecosystem provides additional food sources for carnivore birds, where here Sandpipers and Little heron (*Butorides striata*) were found to forage for worms and fish. Common kingfisher (*Alcedo atthis*) was also captured in this pond area. As it goes to the forest edge, birds' compositions started to change gradually from Carnivore species into Fru-Ins and Insectivore guild, highlighting similar composition with forest birds indicating assemblage of coastal and forest zone.

The high density of trees in the forest with a greater basal area is suitable for insect communities (Chettri *et al*., 2005). A better moist condition and dense foliage will be an additional point for insects' presence in the habitat (Erwin, 2001). Following that, the forest ecosystem attracts more Insectivores and Fru-Ins guild into the area (Figure 5). Fru-Ins birds from groups of bulbuls were adaptable to the seasonal availability of fruits where they will consume insects during fruit scarcity. Thus, this family is always referred to as colonizing species in the forest (Zakaria *et al*., 2005). Secondary forests recorded higher individual capture with various guild compositions than primary forests. As Miller *et al.* (2004) reported, the secondary forest was structurally complex and could offer more niches by having higher levels of plants and insect diversity. Around the waterfall area, Blue-eared Kingfisher (*Alcedo meninting*) was sighted preying on river shrimp besides high numbers of Black-naped Monarch (*Hypothymis azurea*) were preying on the aquatic insect. Insectivores occurred in a wide range of habitats in Pulau Tinggi. As a result obtained by del Rio

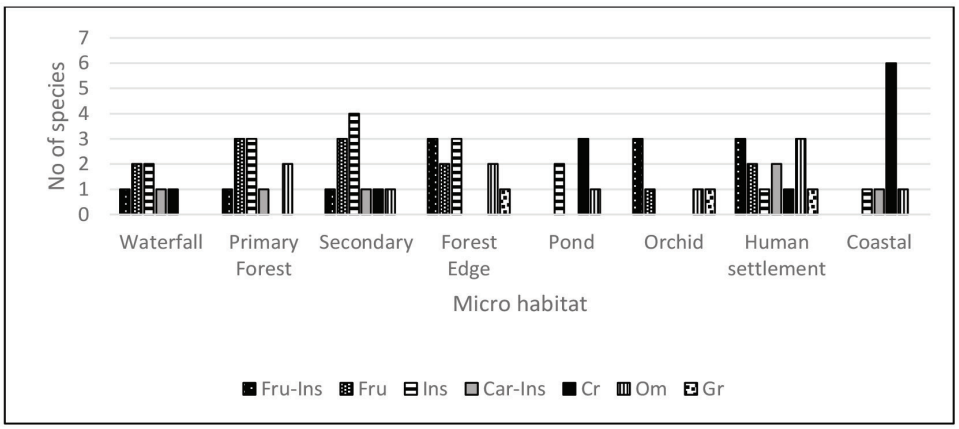

Figure 4: Species presence for each feeding guild in every microhabitat in Pulau Tinggi

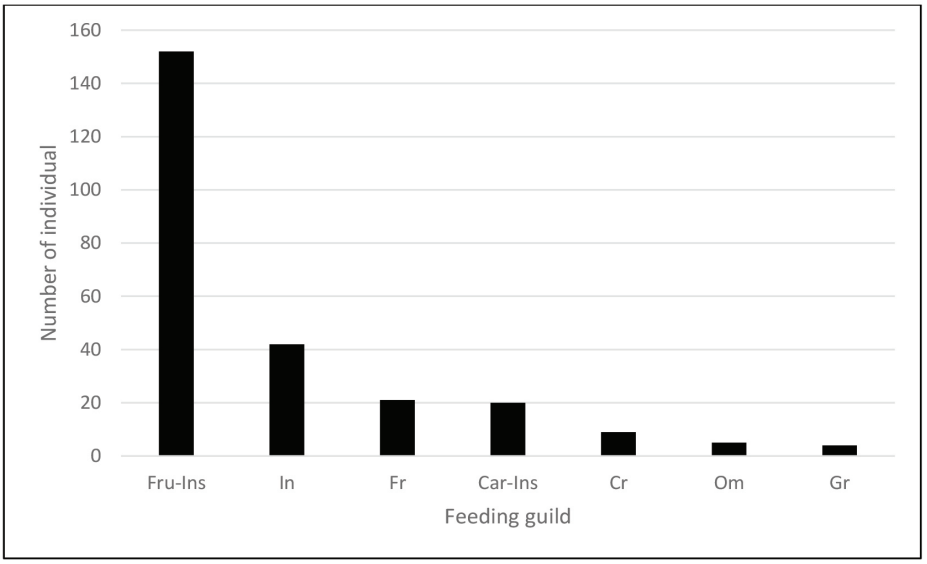

Figure 5: Total individual censused through mist-netting separated by avian feeding guild

(2001), Azman *et al.* (2011), Pineda-Diez *et al.* (2012), Ding *et al.* (2015) and Rathod *et al.* (2015) where this avian guild was also found in secondary forests, oil palm plantations, tropical land-bridge island to the coastal area.

The Inhabitant in Each Level of Vertical Strata

Figure 6 explains that in terrestrial, carnivore birds dominate canopy levels. The middle level was frequently visited with Insectivore and Fru-Ins groups. The shrub was the most preferred level inhabited by different avian groups, where Fru-Ins and Frugivore were the highest in species numbers. In contrast, the ground level is utilized by species from groups of Omnivores, Granivores, Frugivores and one species of Fru-Ins. Babblers and Black-naped monarchs were the most dominant insectivores frequently spotted around the shrubs and ground level of the forest because Babblers preferred to forage on the forest floor (lower vegetation strata) (Anthal & Sahi, 2013; Mansor *et al.,* 2015; Styring *et al.,* 2016) including probing on dead leaves on the ground (Mansor *et al.,* 2015) besides observed hopping from branch to branch in the dense vegetation of shrub. Pang *et al.* (2017) ran a survey on birds that utilized different forest levels by deploying eight stack nets to identify guild composition at each level. The result showed that birds were highly captured at the shelves of 1-3 using space from the forest floor to 1.8 m above the ground was most preferred and utilized by birds. At this level, birds were provided with protection from predators, food resources and other services such as perching and nesting sites (Tuen & Brown, 1996).

In contrast, lower numbers of birds were captured on a higher level, which indicates less utilization of a relatively straightforward area. The canopy level utilized by carnivore species as the foliage and branches served them with an appropriate perching place to rest and build the nest (Pang *et al.,* 2017). Besides, Hill Myna (*Gracula religiosa*) and Green Imperial-pigeon (*Ducula aenea*) frequently flew at the canopy level. This space is suitable for accommodating fast flyers such as dove and broadbill (Phillipps & Phillipps, 2014).

In the coastal zone, carnivores from the family of raptors, tern and kingfishers catch prey of fish by plunging onto the water's surface. While Bottom feeders, namely egrets, sandpipers and herons have a larger diet scale that consumes not only fish but also crustaceans, bivalves and worms.

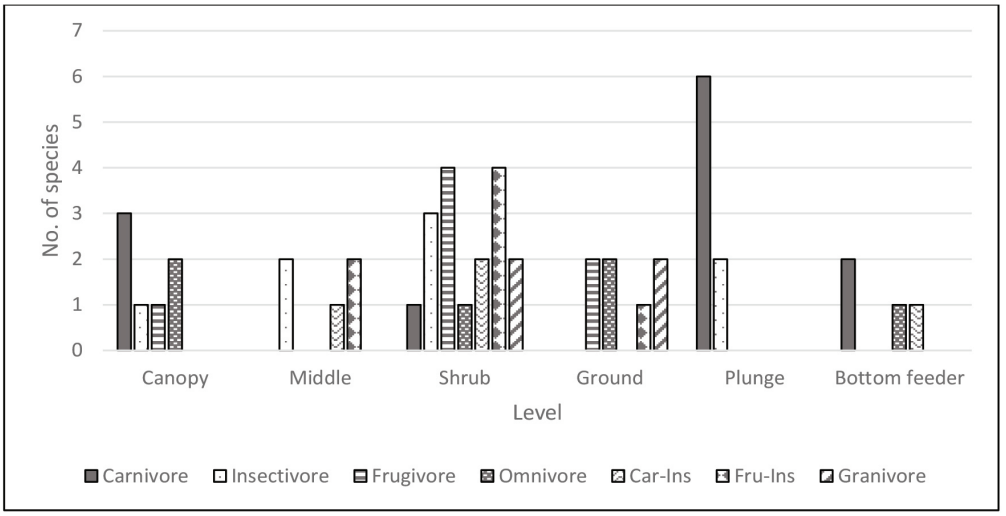

Figure 6: Level of vertical strata where avian guild frequently sighted

Conclusion

In conclusion, the composition of birds within a habitat is adversely affected by the food availability offered within the area. Terrestrial birds, particularly forest species, utilized different strata of the forest level based on their ecological benefits. Clustering avian into feeding guilds helps to see species utilization in each habitat instead of describing them one by one. This clustering allows researchers to see any shifting when the area is experiencing changes. More studies on the feeding ecology of birds help highlight the importance of conserving and preserving the natural habitats of birds for their longevity of survival by ensuring the consistency of food resource presence.

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