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Assessment of Bird Diversity and Abundance in Three Land Use Change in Bukit Mor Ex-Mining Site, Muar, Johor

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Abstract

Malaysia has a number of ex-mining sites. Ex-mining areas, often seen as symbols of environmental degradation, hold a remarkable potential for transformation into thriving ecosystems. These landscapes can become vital habitats for both migratory and resident bird species through natural vegetation regrowth. Several research has been conducted to survey the avian diversity in the ex-mining sites of Malaysia. However, little is known about these locations' potential as substitute habitats for birds, especially in the Muar district of Johor. A study was conducted in the ex-mining site of Bukit Mor, Muar, Johor from July to October 2024 to assess the bird diversity and its abundance in the area where the objectives were to provide a checklist of avian diversity in Bukit Mor ex-mining site, Muar, Johor, and to compare the diversity of avian in selected land-use changes in Bukit Mor ex-mining site, Muar, Johor. The point count method with the help of a camera, binocular, and sound recording application was utilized to survey the bird diversity and abundance in the sampling area which consists of 3 land-use changes namely, Secondary Forest (Area A), Fruit Plantation (Area B), and Oil Palm Plantation (Area C). A total of 61 species of birds were observed from 37 families, where 31 were observed in Area A, 36 in Area B, and 30 in Area C. The results of the diversity indices in each microhabitat were high which shows that each microhabitat has high bird diversity. The Kruskal-Wallis test shows that there are no statistically significant differences in median bird species counts across the three land-use changes, which might imply that the land-use changes were very close to one another, thus the birds can fly and move to each microhabitat with no difficulty. Besides, the Species Accumulation Curve shows that the line in the graph has not reached an asymptote yet, indicating that there should be more species to be discovered in the area. Conclusively, the study showed that reclaimed ex-mining sites are suitable for birds to live, and the area has the potential to be a spot for avitourism.

1. Introduction

Malaysia is a small country in Southeast Asia, which is rich in natural resources including minerals, forests, marine resources and many more, which contribute significantly to the nation's economic growth [1]. Despite its small size, Malaysia possesses a wide variety of resources including minerals and ores [1]. Historically, the country was a global champion in tin production in the 19th century [2]. However, in 1985, there was a tin crisis occurred marking a significant reduction in tin price by up to 50% and over 300 tin mines stopped their operations [2][3]

Many mining sites are abandoned by miners due to the sites no longer serving their original productive functions [4]. Successions of plants often happen in abandoned mining sites as there are little to no disturbance happening in the area. As the vegetation grows, the number of species in the area will increase including bird species. Thus, the longer the vegetation is on the reclamation site, the higher the number of avian species that will use the site [5]. Birds are one of the best indicators to an environment as they have close relationships with one or more habitats, making them specialists or generalists [6][7].

Although the potential of ex-mining sites as an alternative habitat for avian species is high, the ex-mining sites in Johor, especially in the Muar district, remain understudied. If the ex-mining sites are studied, the data obtained can be utilized so that the ex-mining sites can be altered into site for avitourism. Thus, the study seeks to investigate the diversity and abundance of avian species in the Bukit Mor ex-mining site in Muar, Johor. The objectives of this study are to provide a checklist of avian diversity in Bukit Mor ex-mining site, Muar, Johor and to compare the diversity of avian in selected land-use changes in Bukit Mor ex-mining site, Muar, Johor.

2. Materials and Methods

2.1 Study site

The research was conducted on the ex-mining site of Bukit Mor, Muar, Johor with the coordinates of 1°59'42.2"N 102°42'20.2"E as shown in Fig. 1. The ex-mining site comprises three distinctively different land-use changes, which are a secondary forest area (Site A), a fruit plantation area (Site B), and an oil palm plantation area (Site C). Besides, the ex-mining site also has a large water body, which is an open area, that attracts many avian species around it.

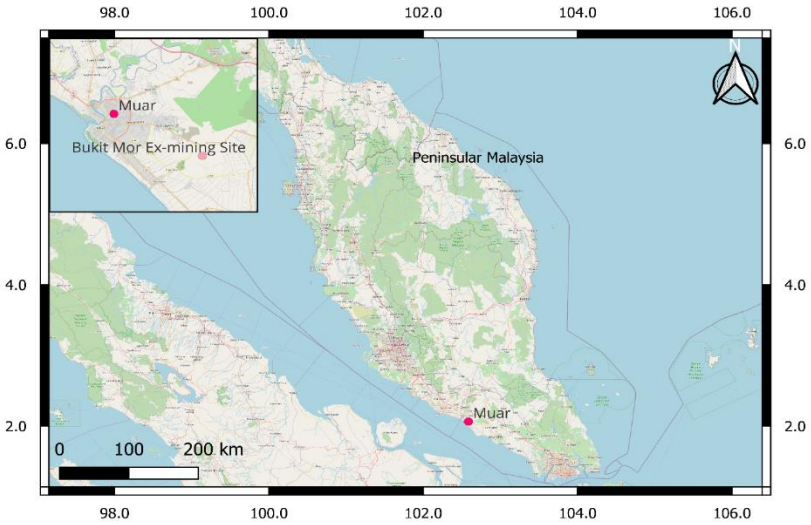

Fig. 1 The location of the ex-mining site of Bukit Mor, Muar, Johor

2.2 Methodology

The point count method was used to assess the avian diversity throughout the land-use changes which were Secondary Forest site, Fruit Plantation site, and Oil Palm Plantation site in the Bukit Mor ex-mining site from July to October 2024. A bird survey was conducted in the morning from 7.00 am to 11.00 am and in the evening from 3.00 pm to 7.00 pm. Binoculars and a mirrorless camera were used to observe and record the avian species in the area. The birds were identified using the guidebook [8] or with online databases such as eBird (https://ebird.org/region/MY) and Birding in Malaysia (https://www.birdinginmalaysia.com/).

Diversity indices such as species richness, Shannon-Wiener Index, and Simpson's Diversity Index were then calculated based on the bird data in all land-use changes. Species accumulation curves were constructed to assess sampling completeness. In addition, a comparative analysis of the avian diversity in each microhabitat was analysed statistically using an Kruskal-Wallis test.

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3. Results and Discussion

3.1 Checklist of Overall Avian Species in Bukit Mor, Muar, Johor

Throughout the sampling, 61 avian species were recorded as shown in Table 1. Generally, 37 families of birds were observed, with 48 resident species, 9 resident migrant species, and 4 migrant species. Meanwhile, 57 species are listed in IUCN status as Least Concern, 3 as Near Threatened and 1 as Vulnerable [9]. Notable rare species in the site include the Gray-headed Fish-eagle (*Ichthyophaga ichthyaetus*) Cinnamon-headed Green-pigeon (*Treron fulvicollis*), White-chested Babbler (*Pellorneum rostratum*), and Javan Myna (*Acridotheres javanicus*) which are listed as globally threatened species according to the IUCN redlist. In terms of family composition, Cisticolidae has the highest number of observed species (5 species) followed by the families Ardeidae and Columbidae each with 4 species as seen in Fig. 2.

Table 1 List of bird species in the sampling area

No.	Family	Scientific Name	Common Name	Local Name	Distribution Status	IUCN Status
1	Accipitridae	*Haliastur indus*	Brahminy Kite	Helang Merah	Resident	Least Concern
2		*Ichthyophaga ichthyaetus*	Gray-headed Fish-eagle	Helang Kanguk Besar	Resident	Near Threatened
3	Acrocephalidae	*Acrocephalus orientalis*	Oriental Reed Warbler	Cekup Paya Besar	Migrant	Least Concern
4	Aegithinidae	*Aegithina tiphia*	Common Iora	Burung Kunyit Kecil	Resident	Least Concern
5	Alcedinidae	*Halcyon smyrnensis*	White-throated Kingfisher	Pekaka Dada Putih	Resident	Least Concern
6	Anatidae	*Dendrocygna javanica*	Lesser Whistling Duck	Belibis	Resident	Least Concern
7	Ardeidae	*Ardea purpurea*	Purple Heron	Pucung Serandau	Resident Migrant	Least Concern
8		*Butorides striata*	Striated Heron	Pucung Keladi	Resident Migrant	Least Concern
9		*Ardea cinerea*	Grey Heron	Pucung Seriap	Resident	Least Concern
10		*Ixobrychus sinensis*	Yellow Bittern	Pucung Kuning	Resident Migrant	Least Concern
11	Campephagidae	*Lalage nigra*	Pied Triller	Rembah Kening Putih	Resident	Least Concern
12	Caprimulgidae	*Caprimulgus affinis*	Savanna Nightjar	Tukang Savana	Resident	Least Concern
13	Charadriidae	*Vanellus indicus*	Red-wattled Lapwing	Rapang Minta Duit	Resident	Least Concern
14	Cisticolidae	*Orthotomus sutorius*	Common Tailorbird	Perenjak Pisang	Resident	Least Concern
15		*Orthotomus sericeus*	Rufous-tailed Tailorbird	Perenjak Ekor Merah	Resident	Least Concern
16		*Orthotomus atrogularis*	Dark-necked Tailorbird	Perenjak Leher Hitam	Resident	Least Concern
17		*Prinia flaviventris*	Yellow-bellied Prinia	Perenjak Kuning	Resident	Least Concern
18		*Orthotomus ruficeps*	Ashy Tailorbird	Perenjak Kelabu	Resident	Least Concern

19	Columbidae	*Treron vernans*	Pink-necked Green Pigeon	Punai Gading	Resident	Least Concern
20		*Geopelia striata*	Zebra Dove	Merbuk	Resident	Least Concern
21		*Streptopelia chinensis*	Spotted Dove	Tekukur	Resident	Least Concern
22		*Treron fulvicollis*	Cinnamon-headed Green-pigeon	Punai Bakau	Resident	Near Threatened
23	Coraciidae	*Eurystomus orientalis*	Oriental Dollarbird	Tiong Batu	Resident Migrant	Least Concern
24	Cuculidae	*Centropus bengalensis*	Lesser Coucal	Bubut Kecil	Resident	Least Concern
25		*Cacomantis merulinus*	Plaintive cuckoo	Burung Mati Anak	Resident	Least Concern
26		*Eudynamys scolopaceus*	Asian Koel	Burung Tuwu	Resident Migrant	Least Concern
27	Dicaeidae	*Dicaeum cruentatum*	Scarlet-backed Flowerpecker	Sepah Puteri Merah	Resident	Least Concern
28	Estrildidae	*Lonchura punctulata*	Scaly-breasted Munia	Pipit Pinang	Resident	Least Concern
29	Eurylaimidae	*Cymbirhynchus macrohynchos*	Black-and-red Broadbill	Burung Rakit	Resident	Least Concern
30	Falconidae	*Microhierax fringillarius*	Black-thighed Falconet	Helang Belalang	Resident	Least Concern
31	Hirundinidae	*Hirundo tahitica*	Pacific Swallow	Layang-layang Pasifik	Resident	Least Concern
32	Laniidae	*Lanius cristatus*	Brown Shrike	Tirjup Coklat	Migrant	Least Concern
33		*Lanius schach*	Long-tailed Shrike	Tirjup Ekor Panjang	Resident	Least Concern
34	Locustellidae	*Helopsaltes certhiola*	Pallas's Grasshopper Warbler	Cekup Belakang Perang	Migrant	Least Concern
35	Meropidae	*Merops viridis*	Blue-throated Bee-eater	Beberek Leher Biru	Resident Migrant	Least Concern
36	Monarchidae	*Hypothymis azurea*	Black-naped Monarch	Kelicap Ranting	Resident	Least Concern
37	Muscicapidae	*Copsychus malabaricus*	White-rumped Shama	Murai Rimba	Resident	Least Concern
38		*Cyornis rufigastra*	Mangrove Blue Flycatcher	Sambar Biru Bakau	Resident	Least Concern
39		*Copsychus saularis*	Oriental Magpie-Robin	Murai Kampung	Resident	Least Concern
40	Nectariniidae	*Anthreptes malacensis*	Brown-throated Sunbird	Kelicap Mayang Kelapa	Resident	Least Concern
41		*Arachnothera crassirostris*	Thick-billed Spiderhunter	Kelicap Jantung Paruh Tebal	Resident	Least Concern

42		*Cinnyris jugularis*	Olive-backed Sunbird	Kelicap Bukit	Resident	Least Concern
43	Oriolidae	*Oriolus chinensis*	Black-naped Oriole	Burung Kunyit Besar	Resident Migrant	Least Concern
44	Passeridae	*Passer montanus*	Eurasian Tree Sparrow	Ciak Rumah	Resident	Least Concern
45	Pellorneidae	*Pellorneum rostratum*	White-chested Babbler	Rimba Dada Putih	Resident	Near Threatened
46	Phasianidae	*Gallus gallus*	Red Junglefowl	Ayam Hutan	Resident	Least Concern
47	Phylloscopidae	*Phylloscopus inornatus*	Yellow-browed Warbler	Cekup Daun Paruh Pendek	Migrant	Least Concern
48	Picidae	*Micropternus brachyurus*	Rufous Woodpecker	Belatok Biji Nangka	Resident	Least Concern
49	Ploceidae	*Ploceus philippinus*	Baya Weaver	Burung Tempua	Resident	Least Concern
50		*Pycnonotus goiavier*	Yellow-vented Bulbul	Merbah Kapur	Resident	Least Concern
51	Pycnonotidae	*Pycnonotus plumosus*	Olive-winged Bulbul	Merbah Belukar	Resident	Least Concern
52		*Pycnonotus simplex*	Cream-vented Bulbul	Merbah Mata Putih	Resident	Least Concern
53		*Amaurornis phoenicurus*	White-breasted Waterhen	Ruak-ruak	Resident Migrant	Least Concern
54	Rallidae	*Porphyrio poliocephalus*	Gray-headed Swamphen	Panglin Biasa	Resident	Least Concern
55		*Zapornia fusca*	Ruddy-breasted Crake	Sinta Belacan	Resident Migrant	Least Concern
56	Rhipiduridae	*Rhipidura javanica*	Malaysian Pied-Fantail	Murai Gila	Resident	Least Concern
57		*Acridotheres javanicus*	Javan Myna	Tiong Jambul Jawa	Resident	Vulnerable
58	Sturnidae	*Aplonis panayensis*	Asian Glossy Starling	Perling Mata Merah	Resident	Least Concern
59		*Acridotheres fuscus*	Jungle Myna	Tiong Sawah	Resident	Least Concern
60	Timaliidae	*Mixornis gularis*	Pin-striped Tit-Babbler	Rimba Berjalur	Resident	Least Concern
61	Zostesopidae	*Zosterops simplex*	Swinhoe's White-eye	Kelicap Kacamata Biasa	Resident	Least Concern

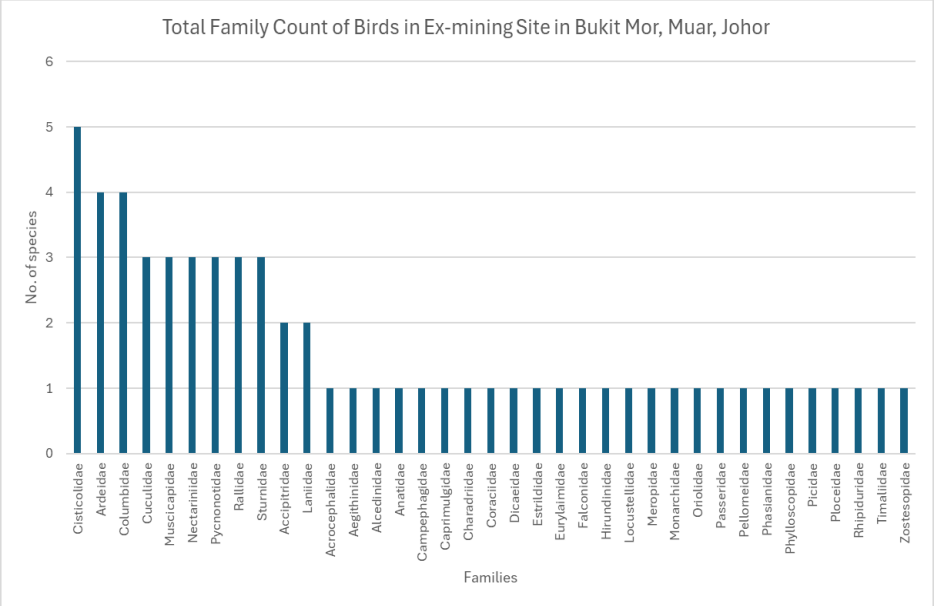

Fig. 2 Composition of avian families in the ex-mining sites of Bukit Mor, Muar, Johor

The birds from the Family Cisticolidae have a diet comprised mainly of insects, and plant materials such as berries and seeds [10]. Hence, with the high number of insects observed in the ex-mining sites in Bukit Mor, Muar, Johor, the area should be suitable for the Cisticolas to thrive. On the other hand, the Ardeidae are tree-nesting birds [11]. The high number of trees in the ex-mining area makes it the ideal habitat for the Ardeidae. Besides, the research on the Purple Heron (Ardea purpurea), shows that the main diet of the species is fish, reptiles and amphibians which are 30%, 30% and 28% respectively [12]. Given that the ex-mining area has a large body of water, the area should have a lot of fish, reptiles, and amphibians for the herons to feed on. Next, although the Columbidae's primary diet consists of grains and frugivores, they also occasionally consume insects, worms, snails, lizards, leaves, buds, and flowers [13]. Fruits are plucked from trees, and seeds are picked up from the ground and consumed whole. The ex-mining sites in Bukit Mor were observed to have abundant insects, as well as several fruiting plants like bananas, the area has a high food source for the Columbidae thus, the high availability of food sources allows the Columbidae to live in this area.

Fig. 3 shows the Species Accumulation Curve constructed for this study. The red line represents the cumulative number of species observed as the sampling effort increases, while the blue lines represent the 95% confidence intervals, which show the variability in the species richness estimates. The red line started with a steep slope, showing the rapid discovery of new species. However, as the sample number increases, the curve starts to flatten, indicating that there is a slower rate of new species discovery, but the line is still going. This shows that the line has not reached the asymptote yet, thus, there should be more species to be discovered in the ex-mining site of Bukit Mor, Muar, Johor. Therefore, a longer sampling period should be implemented in the area so that the remaining undiscovered species can be discovered.

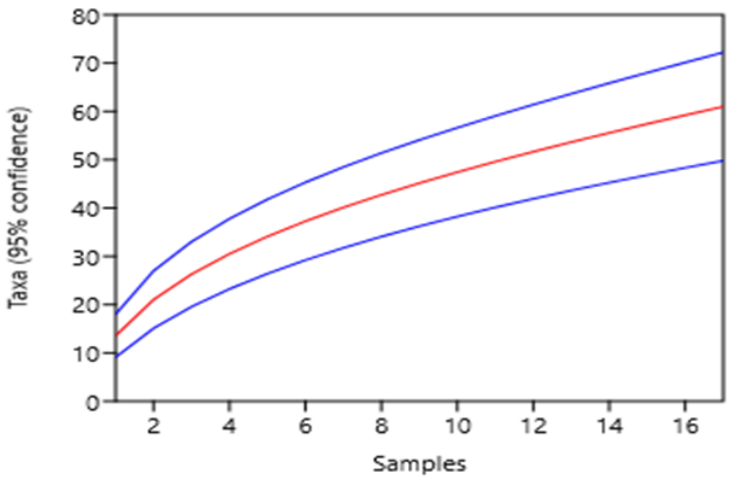

Fig. 3 Species Accumulation Curve

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3.2 Comparative Analysis of Avian Species in Selected Land-use changes

Of 61 avian species recorded, 31 were found in the Secondary Forest area, 36 in Fruit Plantation area and 30 in Oil Palm Plantation area. The diversity and evenness of birds in the ex-mining site are high due to the high value of Simpson's Diversity Index, Shannon Index, and Shannon Evenness as presented in Table 2. The high value of the indices shows that the diversity and evenness of birds in the land-use changes are high. Besides, the result from the Kruskal-Wallis test from Fig 5 shows that the tests imply that the region has little to no effect on bird counts, thus, the bird counts in all the land-use changes are similar. This might be because all three land-use changes are very near to one another. This allows the birds to fly and move from one area to another, resulting in the following data.

Table 2 Summary of the calculation of the diversity indices for avian species in all land-use changes in the ex-mining site of Bukit Mor, Muar, Johor.

Area	Species Richness, S	Simpson's Diversity Index, 1-D	Shannon Index, H'	Shannon Evenness, E
Secondary Forest	31	0.92446	2.8263	0.82303
Fruit Plantation	36	0.95116	3.1685	0.88419
Oil Palm Plantation	30	0.94189	2.9919	0.87967

Yellow-vented Bulbul (*Pycnonotus goiaver*) is the most abundant species recorded in this study (44 individuals) which can be found in all land-use changes. This is because it is a generalist species that feeds on various foods, such as nectar, flowers, insects, and fruits [14] [15] [16] [17]. Besides, there are also site-dependent species Oriental Dollarbird (*Eurystomus orientalis*) which can be found only in Secondary Forest area (Site A), Purple Heron (*Ardea purpurea*) in Fruit Plantation area (Site B) and Savanna Nightjar (*Caprimulgus affinis*) in Oil Palm Plantation area (Site C).

Oriental Dollarbird preferred areas with a mixture of small or large patches of trees or forest and a mixture of open land [18]. Since Site A is a small patch of secondary forest, the area is ideal for the Oriental Dollarbird to live in. Furthermore, the Purple Heron was observed in Area B and at a high number of individuals showing that the area has a high food supply for the species. The Purple Heron consumes a wide range of food in the aquatic environment such as fish, frogs, and snakes [19]. This is supported by the presence of a large pond near Area B, which has plenty of resources for the bird species. In addition, Savanna Nightjar only can be found on Site C. Most of the nightjar species are nocturnal, and prefer to rest on the ground, thus, with its camouflage ability, it can perfectly hide itself in the grassy area of Site C, protecting itself from predators [20].

The study areas have high diversity and evenness. This can be proven from the value of the indices obtained as stated in Table 2. All sites have high scores on Simpson's and Shannon Index which is near to 1 indicating the area supports diverse avian species. In terms of species evenness, all sites show almost the same score on the Shannon evenness Index, showing uniformity in the species composition.

From the result of the normality test (Fig 4), the Shapiro-Wilk Test (W) for Secondary Forest, Fruit Plantation, and Oil Palm Plantation are 0.6376, 0.7466, and 0.7206 respectively which are closer to 1, which is below the threshold for normality, which suggests that the data indicates non-normality. Not only that, the p-values for all three land-use changes in the Bukit Mor ex-mining site are extremely small, thus confirming rejection for normality. The Anderson-Darling Test (A) for all land-use changes are high which are 5.061, 3.016, and 3.073 respectively for Secondary Forest, Fruit Plantation, and Oil Palm Plantation, suggesting that there is a strong deviation from normality.

Furthermore, the Lilliefors Test (L) shows that the L-statistics for Secondary Forest, Fruit Plantation and Oil Palm Plantation are 0.3592, 0.2377, and 0.2535 respectively with p-values less than 0.0001. As the Lilliefors Test for all three land-use changes in the Bukit Mor ex-mining site are more than 0.0001, normality is rejected. Besides, Monte Carlo stimulations also consistently yield p-values which are close to 0.0001, further validating non-normality. Finally, the Jarque-Bera Test (JB) shows that the values for Secondary Forest, Fruit Plantation, and Oil Palm Plantation are 16.81, 30.68, and 24,6 respectively, which are very high, which are more than the associated p-values of 0.005, thus again reject normality.

These normality test confirms that the land-use changes in the Bukit Mor ex-mining site strongly indicate non-normality. Thus, non-parametric method, the Kruskal-Wallis test should be utilized to compare the distribution of birds from the three land-use changes of Bukit Mor ex-mining site, Muar, Johor.

	Secondary Forest	Fruit Plantation	Oil Palm Plantation
N	31	36	30
Shapiro-Wilk W	0.6376	0.7466	0.7206
p(normal)	1.575E-07	1.661E-06	3.154E-06
Anderson-Darling A	5.061	3.016	3.073
p(normal)	7.898E-13	9.793E-08	6.508E-08
p(Monte Carlo)	0.0001	0.0001	0.0001
Lilliefors L	0.3592	0.2377	0.2535
p(normal)	0.0001	0.0001	0.0001
p(Monte Carlo)	0.0001	0.0001	0.0002
Jarque-Bera JB	16.81	30.68	24.6
p(normal)	0.0002243	2.178E-07	4.561E-06
p(Monte Carlo)	0.0054	0.0012	0.002

Fig. 4 Result of Normality Test using PAST software

From the results of Kruskal-Wallis test in Fig. 5, the null hypothesis (H_0) of the test is the median bird species counts across the Secondary Forest, Fruit Plantation, and Oil Palm Plantation are equal. Since the p value is 0.5574 which is higher than 0.05, the null hypothesis is not rejected. This means that there is no statistically significant difference in the median number of bird species among the three land-use changes in Bukit Mor ex-mining site. Next, to further confirm the results of the Kruskal-Wallis, a post-hoc test for the Kruskal-Wallis will be used which is the Dunn's test (see Fig. 6).

Kruskal-Wallis test for equal medians

H (*chi2*):	0.9876
H_C (tie corrected):	1.169
p (same):	0.5574

There is no significant difference between sample medians

Fig. 5 Result of Kurskal-Wallis test using PAST software

From the results of Dunn's Test in Fig. 6, in the pairwise comparison between Secondary Forest and Fruit Plantation, the p-value is 0.2799. Since the p-value is greater than α=0.05, there is no significant difference in bird species counts between these two land-use changes. Next, in the comparison between Secondary Forest and Oil Palm Plantation, the p-value is 0.6012 which is also greater than α=0.05, which means that there is no significant difference in bird species counts between these two groups. Finally, with the comparison between Fruit Plantation and Oil Palm Plantation, the p-value is 0.5965, which is also greater than α=0.05. Hence, there is no significant difference in bird species counts between these two land-use changes as well.

In general, the pairwise comparisons above have reinforced the conclusion from the Kruskal-Wallis test. There are no statistically significant differences in median bird species counts across the three land-use changes, namely the Secondary Forest area, Fruit Plantation area, and Oil Palm Plantation area in Bukit Mor ex-mining sites. This might be due to all three land-use changes in the Bukit Mor ex-mining site are remarkably close to one another. Since the birds have the ability to fly, they can move to the land-use changes easily.

	Secondary Forest	Fruit Plantation	Oil Palm Plantati
Secondary Forest		0.2799	0.6012
Fruit Plantation	0.2799		0.5965
Oil Palm Plantati	0.6012	0.5965	

Fig. 6 Result of Dunn's test using PAST software

Bukit Mor ex-mining site was compared to other avitourism site in Malaysia to determine whether the site is suitable for avitourism activities or not. Therefore, the site was compared to two avitourism sites, which were the Kuala Selangor Nature Park and Panti Bird Sanctuary.

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Table 3 Comparison between Bukit Mor ex-mining site and avitourism site in Malaysia

	Number of Species	Number of Individuals	Number of Migrant Species	Number of Globally Threatened Species
Bukit Mor ex-mining site	61	346	4	4
Kuala Selangor Nature Park	162	100,000	30	7
Panti Bird Sanctuary	274	-	-	20

When Bukit Mor ex-mining site is compared with Kuala Selangor Nature Park, a popular site for avitourism in Malaysia, it shows that the Kuala Selangor Nature Park have more species at more than 150 species according to the website of Kuala Selangor at (https://www.kuala-selangor.com/kuala-selangor-attraction/kuala-selangor-nature-park.html), compared to the Bukit Mor ex-mining site at 61 species. Besides, the Kuala Selangor Nature Park has an estimated number of 100,000 individuals in the area compared to Bukit Mor ex-mining site at 346 individuals at the time of monitoring.

Not only that, the Kuala Selangor Nature Park, has about 30 species of migrant birds which passes through the area during their annual migration while Bukit Mor ex-mining site only have 4 migrant species. Furthermore, Kuala Selangor Nature Park have 7 globally threatened species while Bukit Mor ex-mining site have 4 globally threatened species. Conclusively, the Kuala Selangor Nature Park have way more bird species compared to Bukit Mor ex-mining site as well as more migrant species, individuals, and number of globally threatened species.

When comparing the Bukit Mor ex-mining site and Panti Bird Sanctuary, it shows that the Panti Bird Sanctuary has more species compared to the Bukit Mor ex-mining site which is at 274 species compared to 61 species. However, there is no estimated number of individuals of bird and number of migrant species in the Panti Bird Sanctuary. Therefore, these two comparisons cannot be compared. Next, Panti Bird Sanctuary has 20 globally threatened species compared to Bukit Mor ex-mining site which is only at 4.

From the comparisons of Bukit Mor ex-mining site with two avitourism sites in Malaysia, it shows that the species obtained in the study area might not be sufficient to be a site for avitourism for now. However, from the result of species accumulation curve, it shows that not every species in the area is observed. Therefore, prolong research in the Bukit Mor ex-mining site will increase the number of species in the Bukit Mor ex-mining site, which might change the current result drastically.

The results of this study show that ex-mining sites hold immense potential to support avian biodiversity. A total of 61 avian species were recorded at the Bukit Mor ex-mining site in Muar, Johor, between July and October 2024, during a relatively short observation period. It indicates that the site already provides a suitable habitat for avian species, even without any formal restoration efforts being conducted. These mining sites, once the mining activity has been terminated and no longer produces ore, should not be abandoned. Steps should be taken to change the use and rehabilitate these areas. Post-mining includes systematic and continuous activities by which ecological and societal functions are restored after mining [21]. For example, in Indonesia, mining companies are obliged to rehabilitate the post-mining lands to accelerate natural succession and shorten recovery times, thus restoring these areas to near-original conditions [22].

Malaysia is suggested to follow this good practice from Indonesia to maximize the ecological and economic potential of post-mining landscapes. Some restoration techniques work well and can be taken for Malaysia's ex-mining sites. For example, the use of *Pongamia pinnata*, a species from the legume family, helped in rehabilitating a mining site in Central Kalimantan [23]. Over four years, biodiversity had increased, with additions including five avian species added in the third year, alongside new butterfly, moth, and spider species. This demonstrates the success of those practices in enhancing biodiversity and ecological productivity. The establishment of similar strategies in Malaysia may not only restore these sites but also attract a broader range of bird species, hence turning those areas into hubs for avitourism.

4. Conclusion

In conclusion, the ex-mining site of Bukit Mor, Muar, Johor has high species diversity and abundance which is evidenced by the record of 61 species of birds where 57 species were listed as Least Concern, 3 species as Near Threatened and 1 species as Vulnerable in the IUCN Redlist in this study. This richness can be attributed to the availability of different food sources, such as arthropods, nectar, and fruits. The Kruskal-Wallis test proved that there is no statistically significant difference in the median number of birds species among three land-use changes

in Bukit Mor ex-mining site, indicating that there is no difference in the number of bird species in all three land-use changes. The species accumulation curve indicates that some species have not been recorded yet, which sheds light on the possibility that future studies, by mist-netting, nocturnal avian surveys, and extending the sampling effort, would find more species, which might make the site qualify to be an avitourism area in near future. This emphasizes the potential of such sites for serving as surrogate habitats for bird species. To fulfill this potential, the restoration of abandoned mining sites should be prioritized, ensuring that natural succession is allowed to take its course and maintain biodiversity. Additionally, legislative steps should be taken to insist that mining companies rehabilitate post-mining landscapes; this will hasten ecological recovery and ensure that such areas are restored to close-to-natural conditions. By implementing these strategies, Malaysia can transform ex-mining sites into valuable ecological and functional landscapes.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm their contributions to the paper as follows: **study conception and design:** Lee Chun Wai; **data collection:** Lee Chun Wai; **analysis and interpretation of results:** Lee Chun Wai, Nor Atiqah Norazlimi, Ilham-Norhakim Mohd Lokman; **draft manuscript preparation:** Lee Chun Wai, Nor Atiqah Norazlimi. All authors reviewed the results and approved the final version of the manuscript.

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