

Spatio-Temporal Analysis of Threatened Bird Species in Perak, Malaysia Using Citizen Science Data

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Abstract – Birds are recognized as important indicators of the current state of the environment, mainly as they are sensitive to habitat change. There is little research that spatially analyses the threatened bird hotspots and their relationship with land use and land cover changes, particularly in Malaysia. This study aims to spatially analyze the pattern of threatened birds in Perak, Malaysia using seven years of temporal data from the Citizen Science database. Spatial analysis tools, such as the Average Nearest neighbour analysis and high/low clustering (Getis-Ord General G), were used to analyze the distribution and spatial concentration of the data, followed by the Pearson correlation to determine the relationship between bird occurrence with land-use types. The results showed that the hotspot location of threatened birds for seven years was in Taiping City, while the coldspot was in the mangrove area of Kuala Gula. The study discovered a pattern of water birds commonly spotted in mangrove areas (i.e., Milky Stork and Lesser Adjutant) within the Taiping Lake Garden. The correlation analysis results indicated that shorter distances to green areas and longer distances to urban areas can influence the number of threatened birds spotted. Such findings can assist relevant authorities in the effort to protect and preserve threatened and endangered bird species by promoting a green landscape design and wildlife conservation within a city.

Keywords – *Spatial Analysis, IUCN endangered birds, Land use Land Cover Changes, Citizen Science Data*

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1.0 Introduction

The bird population is significant to ensure the sustainability of biodiversity in Malaysia. Hence, maintaining the bird population stands as an invaluable factor for ecologists in evaluating the health of habitats, particularly since they are sensitive to habitat change and are easy to monitor. Urbanization is one of the most extreme kinds of land-use change (Simkin et al., 2022) and its detrimental effects on biodiversity in Malaysia have been thoroughly investigated (Azari et al., 2022; Darren et al., 2021; Lechner et al., 2021; Samat et al., 2020). However, scarce research has been undertaken to identify the bird species that are most influenced by the impacts and the extent to which habitat disturbance has affected biodiversity (Li et al., 2021). Several bird species in Malaysia have been listed by the International Union for Conservation of Nature (IUCN) as endangered (e.g., Milky Stork) and vulnerable (e.g., Rhinoceros Hornbill) in the red list assessment, which is in the threatened species category (Ahmat et al., 2022; Suis et al., 2019; Ismail & Rahman, 2016). Birds are good bio-indicators in studying the effects of forest disturbance and habitat structure on species composition (Fontúrbel et al., 2021; Simamora et al., 2021; Canterbury et al., 2000; Mekonen, 2017; Kang et al., 2015). The ecological niches of tropical birds are incredibly diverse and relatively well understood. Birds are also easier to spot than other animal species due to their frequently loud vocalizations and striking colouring (Tantipisanuh & Gale, 2018). However, spatial bias has been highlighted by Stojanovic et al., (2020) in the recovery of the threatened species, particularly in the conservation intervention during migration and winter.

Mohd Taib et al. (2016) have investigated the tropical bird population in fragmented forests for 30 years and found that land-use development is the main factor contributing to the massive decline of bird species. The land cover change primarily drives bird community and species dynamics through ecological processes occurring at both local and landscape scales (Vickery et al., 2014). Moreover, land uses have intensive agricultural irrigation practices, leading to the over-exploitation of groundwater and surface water resources while dramatically decreasing the free water available to wildlife, especially bird communities (Zamora-Marín et al., 2021).

Crowdsourcing and Citizen Science have been a common platform for gathering data by non-professional citizens to supplement data in various scientific studies (Haklay et al., 2021) such as in disaster management (Muhamad Hakimi et al., 2023) and tree management (Idris et al., 2022). Citizen Science in collecting bird census has been well established; the longest run of such a program is in the Christmas Bird Count where currently in its 123th year (Audubon, 2023). In

Malaysia, eBird Malaysia hosted by the Cornell Lab of Ornithology (eBird, 2023) has centralized the birdwatching data observation and is able to gather a lot of birding data contributed by voluntary bird watchers in Malaysia. Such data are valuable to support further analysis to understand the changes in the current ecosystem and the impact on biodiversity including the biology and ecology of birds. Economic development and land use changes have arguably contributed to the loss of habitat; hence Ali et al. (2019) suggest the need for temporal birding data and land use land cover data over an extended period to compare and identify significant changes, hence the trends in bird abundance and distribution through time, the impacts of monitoring and conservation actions and evaluate the effectiveness of management responses can be conducted (Legge et al., 2018).

Therefore, this study aims to analyze the pattern of threatened birds in Perak, Malaysia, and the relationship between their occurrence with the land use types of the study area. The following section describes the methodology used in this study, which includes a brief description of the study areas and subjects, the general flow of methods, as well as a description of the data and analysis procedures. It is followed by a description of the results and discussion, along with the conclusions and recommendations.

2.0 Methodology

2.1 Study Areas

Taiping and Kuala Gula are important locations to study threatened bird species due to their significance as biodiversity hotspots in Malaysia. Taiping (4°51'N 100°44'E) is a town located in the Larut, Matang, and Selama Districts of Perak, Malaysia. It is situated approximately 48 km to the northwest of Ipoh, Perak and 78 km to the southeast of George Town, Penang. Taiping is known for being the wettest town in Peninsular Malaysia, even during the driest month of June where it still receives 159 mm | 6.3 inches of rainfall. The city's annual rainfall is about 3,000, which is significantly higher than the Peninsular's average of 2,000 mm – 2,500 mm (Climate-data.org, 2023). Its unusual rainfall has led to a fertile collection of flora and century-old rain trees in the Taiping Lake Gardens. Additionally, Taiping is situated near the Bukit Larut (Maxwell Hill) hill station, which is a protected area known for its rich biodiversity that harbours diverse bird species, including many threatened and endemic ones. Its proximity to Bukit Larut makes Taiping an excellent location for studying these bird species and understanding their ecology and conservation needs.

Meanwhile, Kuala Gula (4.9344° N, 100.4608° E) is a fishing village located on the northern coast of Perak, approximately 50 km to the northwest of Taiping Town. It is part of the Matang Mangrove Forest Reserve, which consists of mangrove forests and muddy coastal areas that provide vital habitats for more than 60 species of waterbirds (e.g., egrets, herons, storks, rails, shorebirds, terns, and gulls) as well as some raptors and kingfishers that are wetland dependent. Furthermore, the globally endangered Milky Stork is the emblematic species of Kuala Gula, along with the vulnerable species of Lesser Adjutant Storks (Waterbird Conservation Centre). Such location is important for migratory birds since it is a rest stop on their long-distance journeys. Many of these migratory bird species are endangered, making Kuala Gula an important place for monitoring and conserving their populations. This site is known as a bird lover's paradise because of the Kuala Gula Bird Sanctuary, where thousands of migrating birds roost in the mangrove swamps between August and December. It is home to no less than 62 of the 192 bird species that travel here from other countries to rest and feed (Azhari & Hassan, 2021).

Another worthwhile destination for bird watchers is Kuala Sepetang, which is a seaside town close to Kuala Gula. It is located approximately 72 km to the northwest of Ipoh City. Tourists and bird watchers have the option of renting boats from the local fishing community fishing town to see the rare Milky Stork, waterbirds, and shorebirds along the mudflats (Tourism Malaysia, 2015).

Pondok Tanjung Forest Reserve, a lowland forest area located about 24 km north of Taiping, is another Important Bird Area (IBA) in Malaysia (Tourism Malaysia, 2015). It is one of the last remaining swamp forests in northern Peninsular Malaysia. The area has three major habitat types: peat swamp, seasonally flooded freshwater swamp, and hill dipterocarp woods. Pondok Tanjong is a critical IBA candidate as the peat swamp forest provides refuge for habitat specialists and rare species (BirdLife International, 2023). This important bird region has been home to more than 140 bird species, including the Blue-rumped Parrot, Black Hornbill, Red-throated Barbet, and Black-throated Babbler.

2.2 General Flow of Methodology

This study employed the spatiotemporal analysis to determine the threatened bird species in Perak. It focused on eight threatened bird species. The data on endangered bird populations from 2015 to 2021 were extracted from eBird (<https://ebird.org/home>). Meanwhile, the data on land-use was extracted from Sentinel-2 of the USGS website to analyze its influence over the bird patterns of the study area. The Nearest Neighbour and Getis Ord methods were used to analyze the bird population spatially while the Pearson correlation was utilized to investigate the relationship between the number of birds occurrence and the land-use type. Figure 1 shows the research framework of this study.

2.3 Subject Data - Bird Species

Four hundred fifty-three (453) count data of bird locations from eBird (<https://ebird.org/home>) were collected and normalized by year based on the date of bird found in the study area. This study focused on eight threatened bird species that were sighted in the location from 2015 to 2021, as shown in Table 1 below.

Table 1. Status of threatened bird species (Source: <https://www.mybis.gov.my/one/>)

Common name	Scientific name	Status	Count
Fluffy-backed Tit Babbler	<i>Macronus ptilosus</i>	Near Threatened (NT)	25
Green Iora	<i>Aegithina virdissima</i>	Near Threatened (NT)	64
Javan Myna	<i>Acridotheres javanicus</i>	Vulnerable (VU)	79
Lesser Adjutant	<i>Leptoptilos javanicus</i>	Vulnerable (VU)	51
Milky Stork	<i>Mycteria cinerea</i>	Endangered (EN)	83
Rhinoceros Hornbill	<i>Buceros rhinoceros</i>	Vulnerable (VU)	76
Rufous-collared Kingfisher	<i>Actenoides concretus</i>	Near Threatened (NT)	36
Rufous-crowned Babbler	<i>Malacopteron magnum</i>	Near Threatened (NT)	11

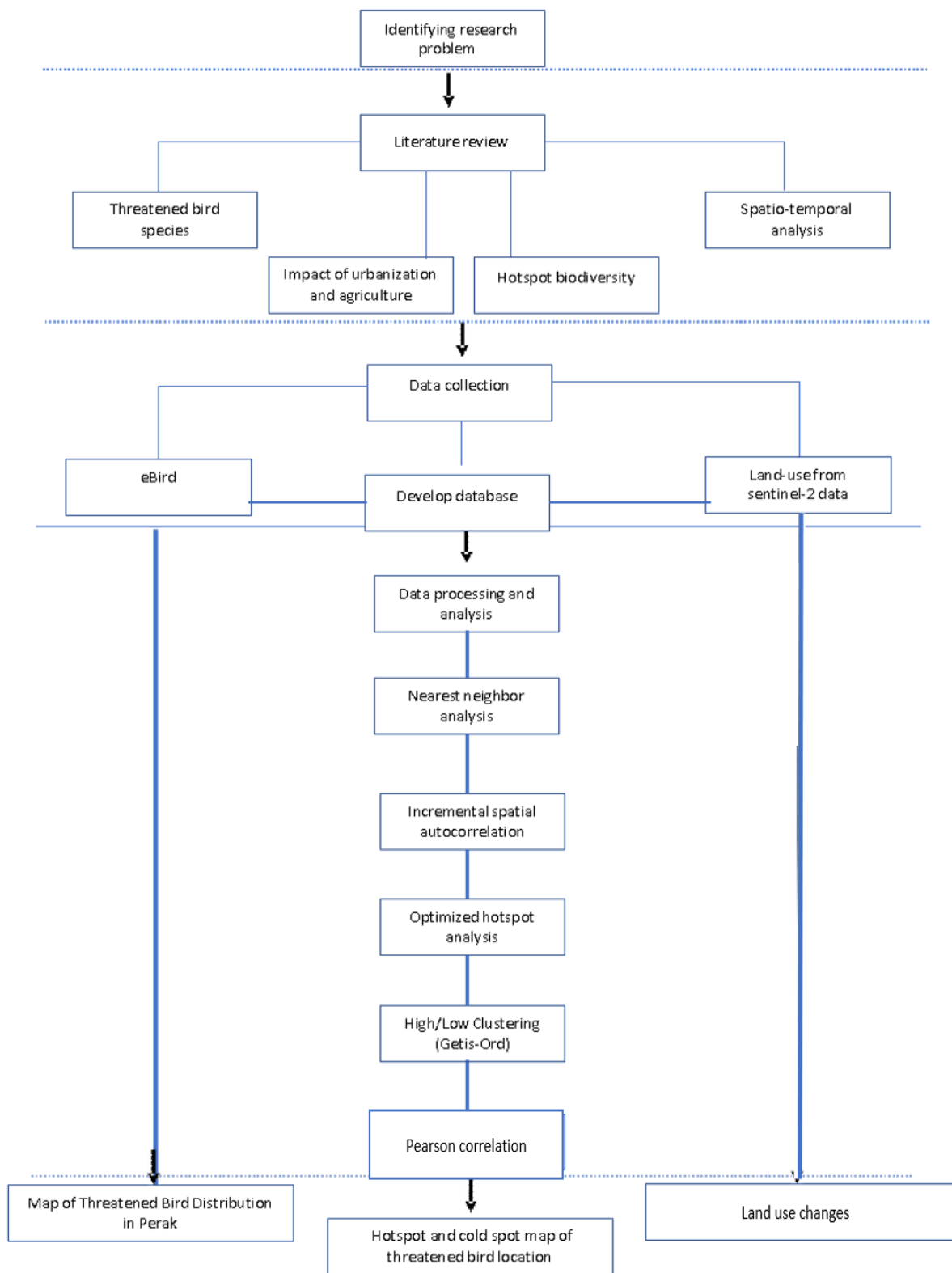


Figure 1. Research framework

There were four bird species under the near threatened (NT) status, three species under the vulnerable (VU) status, and one species under the endangered (EN) status. These statuses were aligned with the official Red Listing Authority for birds for the IUCN Red List by following The IUCN Red List Categories and Criteria (Birdlife International, 2023). Near Threatened (NT) refers to a species that does not meet the criteria for Critically Endangered, Endangered, or Vulnerable but has the potential to be qualified soon. Whereas, Vulnerable (VU) and Endangered (EN) refer to species that are considered to have a high risk of extinction.

In this study, two species were deemed prevalent in swamps and wetlands. First, *Mycteria cinerea*, or Milky Stork, is a large bird often found in mangrove swamps and mudflats that feeds on crabs and mudskippers. Such species is endangered due to habitat loss, land degradation, poaching, and water pollution. Second, *Leptoptilos javanicus* (*L. javanicus*), or Lesser Adjutant, is a huge stork that can be identified by its naked head and yellowish-orange neck. Such species is limited to mangrove habitats and is considered vulnerable due to bird hunting activity and habitat loss (Tan et al., 2020).

Several other species were commonly found in the forests. For instance, Rhinoceros Hornbill is a giant bird in the Asia rainforest and can be seen from lowlands to 1,300 m above sea level. This species is becoming extinct due to the loss of nesting habitats and poaching activities. *Acridotheres javanicus* (Javan Myna), also known as Tiong Jambul Jawa, is a medium-sized myna that is threatened due to bird poaching activities. *Macronus ptilosus*, or Fluffy-backed Babbler, is a small bird that is 17 cm in length and can be commonly found in Brunei, Malaysia, Sumatra, and Thailand forests. Its population is decreasing due to illegal logging and forest degradation. Meanwhile, Rufous-crowned Babbler, locally known as Rimba Tua Besar or Kekicau Ubun Merah, is a common species in the forest of Peninsular Malaysia, Sumatra, and Borneo. It lives at low elevations and hills up to 500 m. The species is decreasing due to habitat loss. Finally, *Aegithina viridissima*, or Green Iora, can be found in Brunei, Indonesia, Malaysia, Myanmar, Singapore, and Thailand. Its habitats are lowland and mangrove forests; however, the species is threatened due to habitat degradation (Tan et al., 2020).

2.4 Land-Use and Landcover from Sentinel-2 Data

Sentinel-2 provides high-resolution satellite data for land cover/use monitoring, climate change monitoring, and catastrophe monitoring to supplement other satellite programmes, such as Landsat.

This study used the image satellites of Sentinel-2 data from 2015 to 2021 to observe the change in land-use within the Kuala Gula and Taiping areas. Before image classification, the cloud masking process removed the cloud of the raster images. It was followed by an ISO unsupervised classification where the raster band was divided into five classes: forest, urban, waterbody, agriculture, and green area. The area of every feature was later calculated.

2.5 Data Pre-Processing

The data pre-processing involved extracting land-use and birding data from 2015 to 2021 using the unsupervised classification method in ArcGIS. The eight types of threatened bird species were removed and dissolved by year to overlay with the land-use data by year. The coordinate of this data was transformed in WGS 1984 UTM Zone 47 N.

Table 2. Data of eBird before editing by year

FID	Shape *	COMMON_NAM	SCIENTIFIC	LOCALITY	LATITUDE	LONGITUDE	Date	Year
0	Multipoint	Fluffy-backed Tit-Babbler	Macronus ptilosus	Kamunting (North) ex-mining lands, Perak	4.909138	100.715472	8/5/2021	2021
1	Multipoint	Fluffy-backed Tit-Babbler	Macronus ptilosus	Pondok Tanjung Forest Reserve	5.059091	100.723278	25/8/2018	2018
2	Multipoint	Fluffy-backed Tit-Babbler	Macronus ptilosus	Pondok Tanjung Forest Reserve	5.059091	100.723278	12/7/2020	2020
3	Multipoint	Fluffy-backed Tit-Babbler	Macronus ptilosus	Pondok Tanjung Forest Reserve	5.059091	100.723278	10/10/2020	2020
4	Multipoint	Fluffy-backed Tit-Babbler	Macronus ptilosus	Pondok Tanjung Forest Reserve	5.059091	100.723278	24/10/2020	2020
5	Multipoint	Fluffy-backed Tit-Babbler	Macronus ptilosus	Pondok Tanjung Forest Reserve	5.088631	100.719652	18/5/2019	2019
6	Multipoint	Fluffy-backed Tit-Babbler	Macronus ptilosus	Pondok Tanjung Forest Reserve (Redang Panjang access),	5.083833	100.78075	20/5/2012	2012
7	Multipoint	Fluffy-backed Tit-Babbler	Macronus ptilosus	Pondok Tanjung Forest Reserve (Redang Panjang access),	5.083833	100.78075	6/11/2020	2020
8	Multipoint	Fluffy-backed Tit-Babbler	Macronus ptilosus	Pondok Tanjung Forest Reserve (Redang Panjang access),	5.083833	100.78075	4/4/2021	2021
9	Multipoint	Fluffy-backed Tit-Babbler	Macronus ptilosus	Pondok Tanjung Forest Reserve	5.06046	100.723027	18/5/2019	2019
10	Multipoint	Fluffy-backed Tit-Babbler	Macronus ptilosus	Pondok Tanjung Forest Reserve	5.06046	100.723027	30/6/2019	2019
11	Multipoint	Fluffy-backed Tit-Babbler	Macronus ptilosus	Pondok Tanjung Forest Reserve	5.06046	100.723027	13/7/2019	2019
12	Multipoint	Fluffy-backed Tit-Babbler	Macronus ptilosus	Pondok Tanjung Forest Reserve	5.06046	100.723027	24/8/2019	2019

Table 3. Data of eBird after editing by the year 2016

GLOBAL_UNI	LAST_EDITE	TAXONOMIC	CATEGORY	TAXON_CONC	COMMON_NAM	LOCALITY	SCIENTIFIC	Year
:CornellLabOfOrnithology	49:33.5	9269	species	avibase-0D3D9303	Rhinoceros Hornbill	Bukit Larut	Buceros rhinoceros	2016
:CornellLabOfOrnithology	29:39.0	9269	species	avibase-0D3D9303	Rhinoceros Hornbill	Bukit Larut	Buceros rhinoceros	2016
:CornellLabOfOrnithology	56:36.0	6959	species	avibase-74907154	Lesser Adjutant	Kuala Gula Bird Sanctuary	Leptoptilos javanicus	2016
:CornellLabOfOrnithology	56:35.9	6959	species	avibase-74907154	Lesser Adjutant	Kuala Gula Bird Sanctuary	Leptoptilos javanicus	2016
:CornellLabOfOrnithology	32:00.9	6959	species	avibase-74907154	Lesser Adjutant	Kuala Gula Bird Sanctuary	Leptoptilos javanicus	2016
:CornellLabOfOrnithology	56:30.4	26952	species	avibase-D70B61EE	Javan Myna	Kuala Gula Bird Sanctuary	Acridotheres javanicus	2016
:CornellLabOfOrnithology	31/8/2017 11:34	6959	species	avibase-74907154	Lesser Adjutant	Kuala Sepetang, Taiping	Leptoptilos javanicus	2016
:CornellLabOfOrnithology	16/3/2020 0:33	6959	species	avibase-74907154	Lesser Adjutant	Kuala Sepetang, Taiping	Leptoptilos javanicus	2016
:CornellLabOfOrnithology	31/8/2017 11:34	9715	species	avibase-4A150CE8	Rufous-collared Kingfisher	MY-Perak-Taiping	Actenoides concretus	2016

2.6 Methods Used in Spatial Pattern Analysis

The number of threatened birds at the spotted locations was analyzed for their spatial pattern using the average nearest neighbour analysis, incremental spatial autocorrelation, and high/low clustering analysis to see the pattern of bird occurrence. Meanwhile, Pearson correlation was used to analyze the correlation between the number of bird occurrences with the spotted locations in four land-use types - urban, forest, agriculture, and green area. In the correlation analysis, the location of the

birds spotted was the dependent variable while the independent variables were the distance to forest, green, agriculture, and urban area.

Nearest neighbour analysis was performed using spatial statistical tools in ArcGIS version 10.8 to analyze the bird population pattern. This analysis calculated the mean of the nearest distance between all points and their nearest neighbours. A shorter mean indicates that the pattern is more clustered than a scattered pattern, whereas a random pattern mean is larger than a clustered pattern but shorter than a scattered pattern (Buyong, 2007). This tool determined the linear distance between two or more nearby sites that had been specified. The threatened birds (number of birds being spotted) were inserted in the input feature class option. Euclidean distance, where selected, indicated that the length of the line segment connecting the two points (locations) would be measured before performing the analysis. The output of the nearest neighbour analysis would determine if the distribution of bird patterns was clustered, random, or regular (see ArcGIS Pro, 2023a for the equation used to calculate the average nearest neighbour ratio).

Meanwhile, the high/low clustering (using Getis-Ord General G) was used in this study to measure the concentration of high or low values. Results from the inferential statistic were interpreted within the context of the null hypothesis: there is no spatial clustering of feature values where the values are spatially random (ArcGIS Pro, 2023b). This study used the high/low clustering (Getis-Ord General G) tool in ArcGIS version 10.8. The locations of threatened birds were set as the input feature class and the number of birds from 2015 to 2021 was inserted as the input field. The high/low clustering tool returned four values: Observed General G, Expected General G, z-score, and p-value. The Getis-Ord G_i^* Stats tool (ArcGIS Pro, 2023c) was then used to visualize the concentration locations and their extent. The output of this analysis answered the questions ‘Where are the locations of birds clustered (whether hot spots or cold spots)?’ and ‘Where are the bird threatened occurrences most dense?’.

The near analysis tool in ArcGIS was used to measure the distance between the input features. This tool can calculate distance and additional proximity information between the input and the closest element in another layer or feature class (ArcGIS Pro, 2023d). The length (distance) from each bird location to each feature variable - distance to forest, green area, agriculture, and urban - were measured and the output was represented as explanatory variables. These data were then used in the correlation analysis to measure the relationship between the frequency of bird occurrence and the land-use types.

Pearson correlation, also known as Pearson's correlation coefficient (r), is a widely used method for determining a linear relationship between two variables. It assesses the magnitude and direction of the linear relationship between these variables. The correlation coefficient ranges from -1 to 1, with (a) +1 indicating perfect positive linear correlation, which means that as one variable increases, the other increases proportionally; (b) -1 indicating perfect negative linear correlation, which means that as one variable increases, the other decreases proportionally; and (c) a value close to 0 indicating little to no linear correlation between the variables. It should be noted, however, that Pearson's correlation coefficient only captures linear correlations and it may not adequately depict their association if the variables' relationship is non-linear (Turney, 2023).

3.0 Results and Discussions

The data of this study was analyzed using the average nearest neighbour analysis, high/low clustering analysis, and Pearson correlation. The spatial pattern of threatened bird occurrence (see Figures 2 and 3) demonstrated cluster distribution. The p-values from both analyses were statistically significant ($p < 0.001$), hence rejecting the null hypothesis that the occurrence of threatened birds spotted in both areas (Taiping and Kuala Gula, Perak) are randomly distributed. In other words, the spotted locations are clustered and the spatial distribution is highly clustered, as shown in Figure 3.

3.1 Distribution of Threatened Birds in Perak

This study observed the pattern of threatened bird population trends in Taiping and Kuala Gula along with the influencing factors. The data showed that there were 27 birds in 2015, 9 birds in 2016, 38 birds in 2017, 85 birds in 2019, the highest count of 115 birds in 2020, and 86 birds in 2021 (see Figure 4). The highest and least species were Javan Mayna and Lesser Adjutant, respectively. The Javan Mayna species was spotted dominantly near the Taiping Lake Garden Perak, followed by the coastal areas - Kuala Gula, Kuala Sepetang, Kuala Kurau, and Pondok Tanjung Forest Reserve. Meanwhile, Lesser Adjutant was the least threatened species in the study area, mainly in Kuala Gula and Kuala Sepetang.

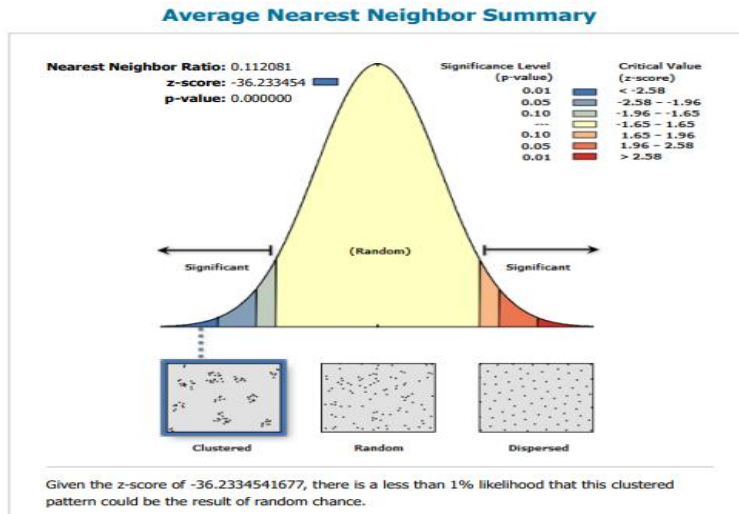


Figure 2. The clustered pattern of average nearest neighbour analysis

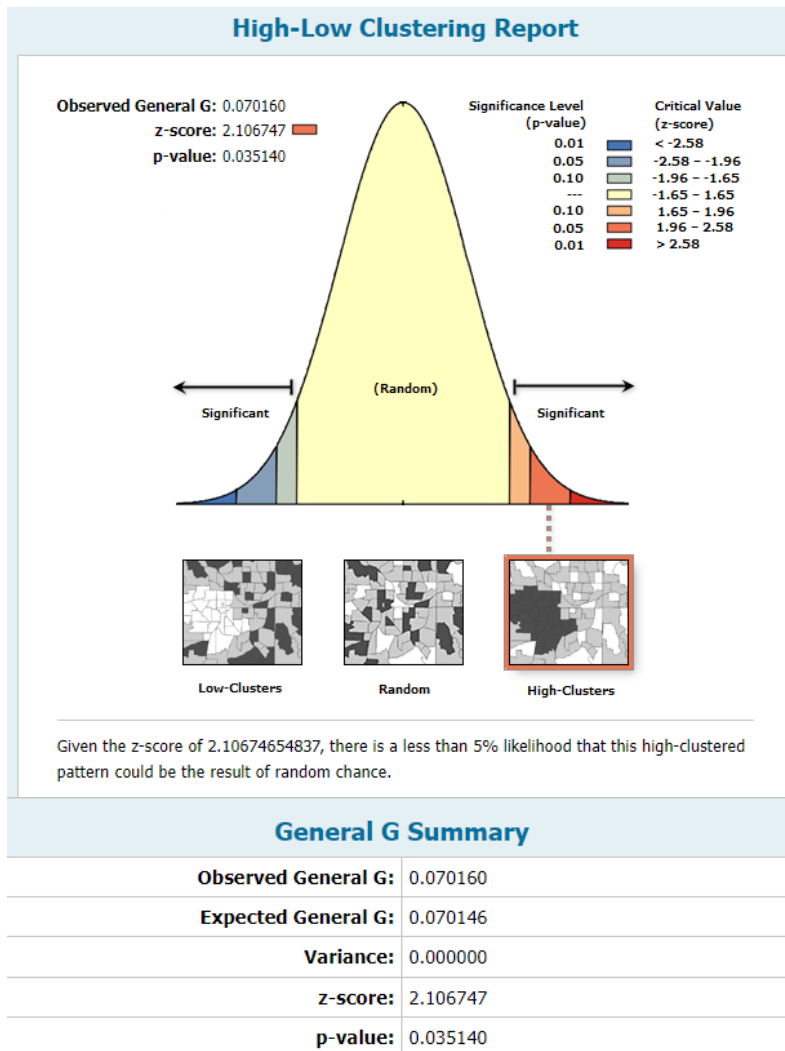


Figure 3. The high-low clustering report summary

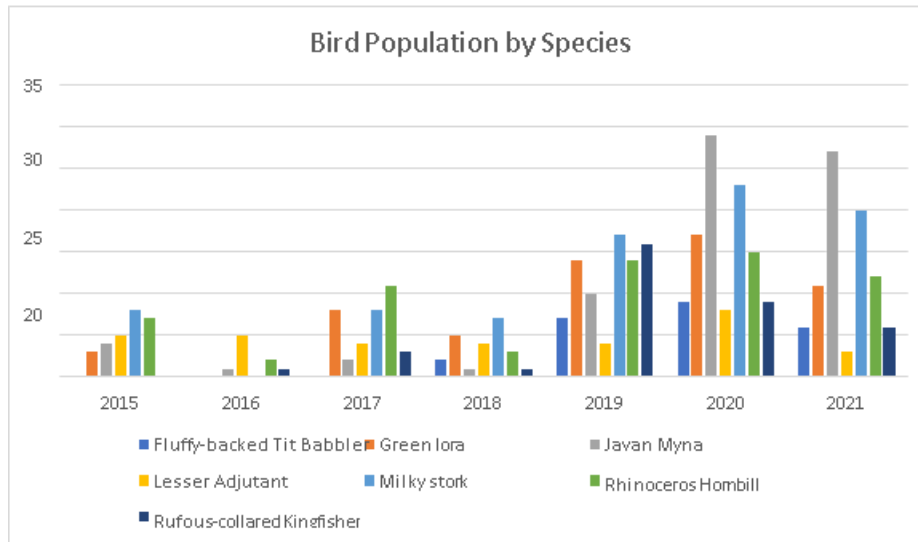


Figure 4. The bird population by species from 2015 to 2021

Figure 5 shows a decreasing pattern of bird observations in 2021. It mainly owed to the COVID-19 pandemic in 2020 where all bird-watching events and festivals in Malaysia were either cancelled or conducted via digital or online mediums (Bird Watching Asia, 2021). Moreover, bird-watching activities were only allowed for locals at the National Parks, which opened in mid-June 2020 (Bird Watching Asia, 2021).

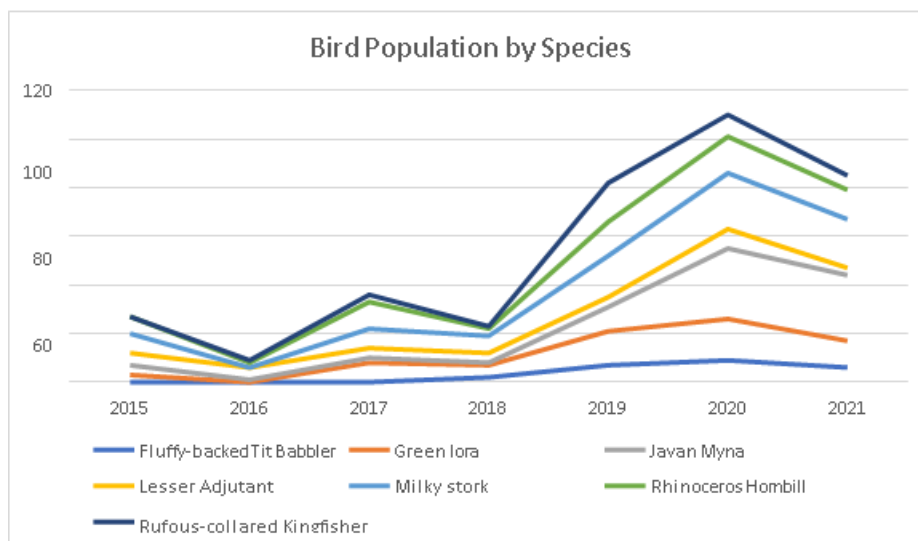


Figure 5. A significant decline in bird-watching activity was observed in 2021 due to COVID-19

Distribution of Threatened Bird Species in Perak

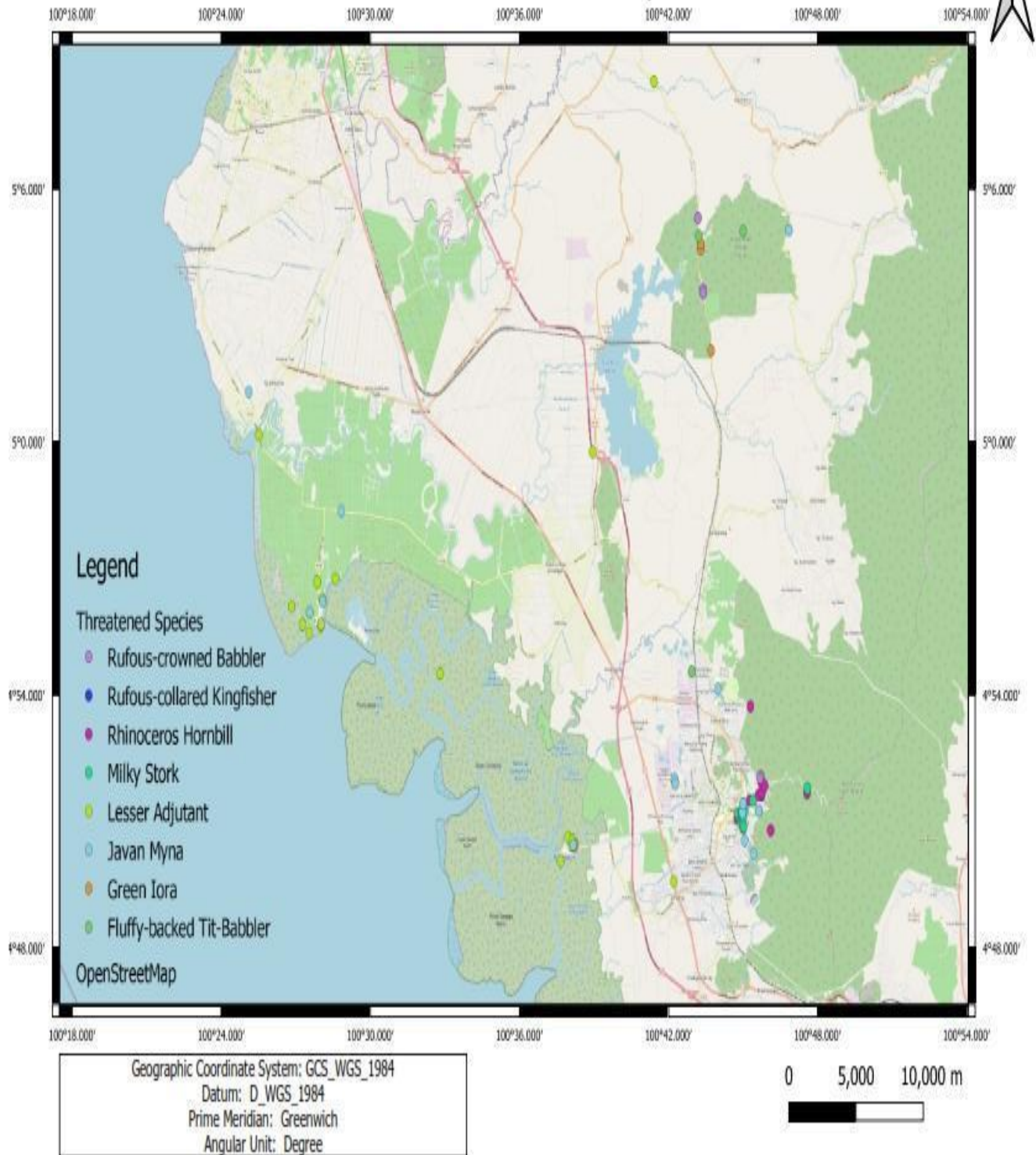


Figure 6. The distribution map of threatened bird species in Perak

3.2 The Influence of Land-Use on Birds Pattern for 2015 to 2021

The locations of the birds were overlaid with land-use maps for the year 2015 to 2021. Threatened birds were recorded across four areas in Perak: (1) Kuala Gula and Kuala Sepetang (in the west of Perak) near the coastal and water bodies; (2) Taiping Lake Garden (southern Perak); (3) within the green area and wetlands in Pondok Tanjung (northern Perak); and (4) the swamp reserve forest. The data in 2015 and 2016 showed that most birds were mainly spotted near the green and agricultural areas in Kuala Gula and Taiping Lake Garden (see Figures 7 and 8). Both the Rufous-crowned Babbler and Fluffy-backed Tit Babbler species were only spotted in the Pondok Tanjung Forest Reserve (Figures 9 and 10). In contrast, the Rufous-collared Kingfisher was found near Pondok Tanjung and Taiping Lake Garden (see Figure 11). Finally, Rhinoceros Hornbills, Javan Myna, and Milky Storks were popularly spotted near the Taiping Lake Garden from 2019 to 2021 (see Figures 12 and 13).

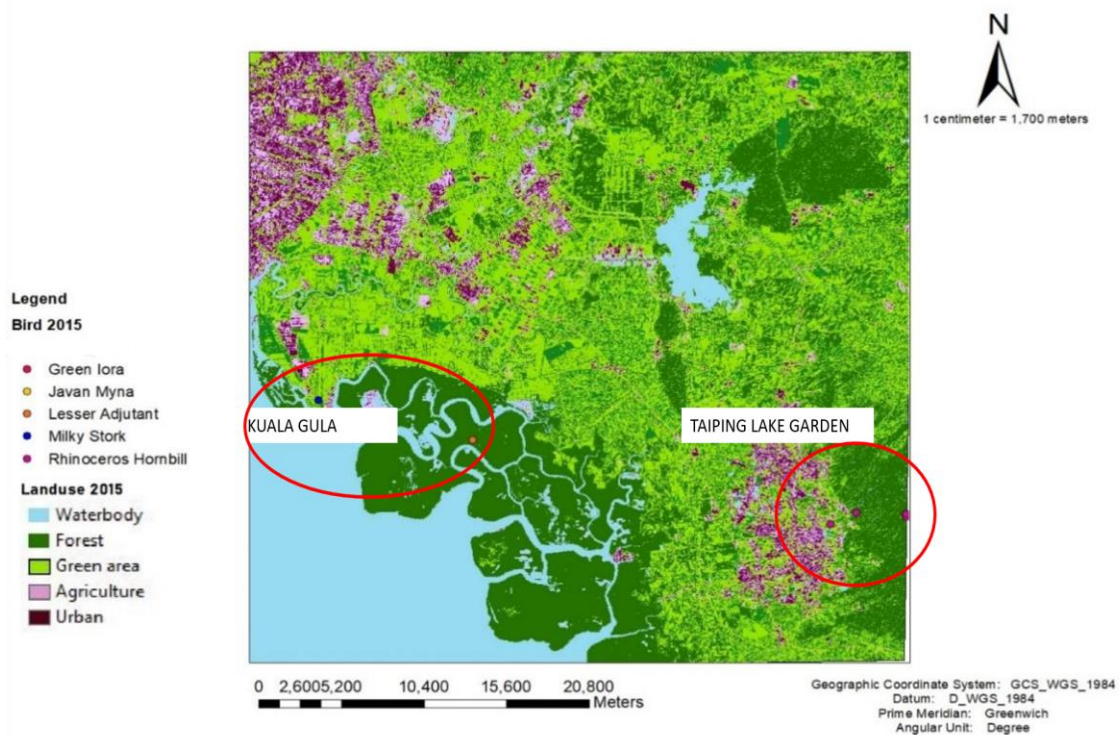


Figure 7. The overlay of land-use and threatened bird species locations in 2015

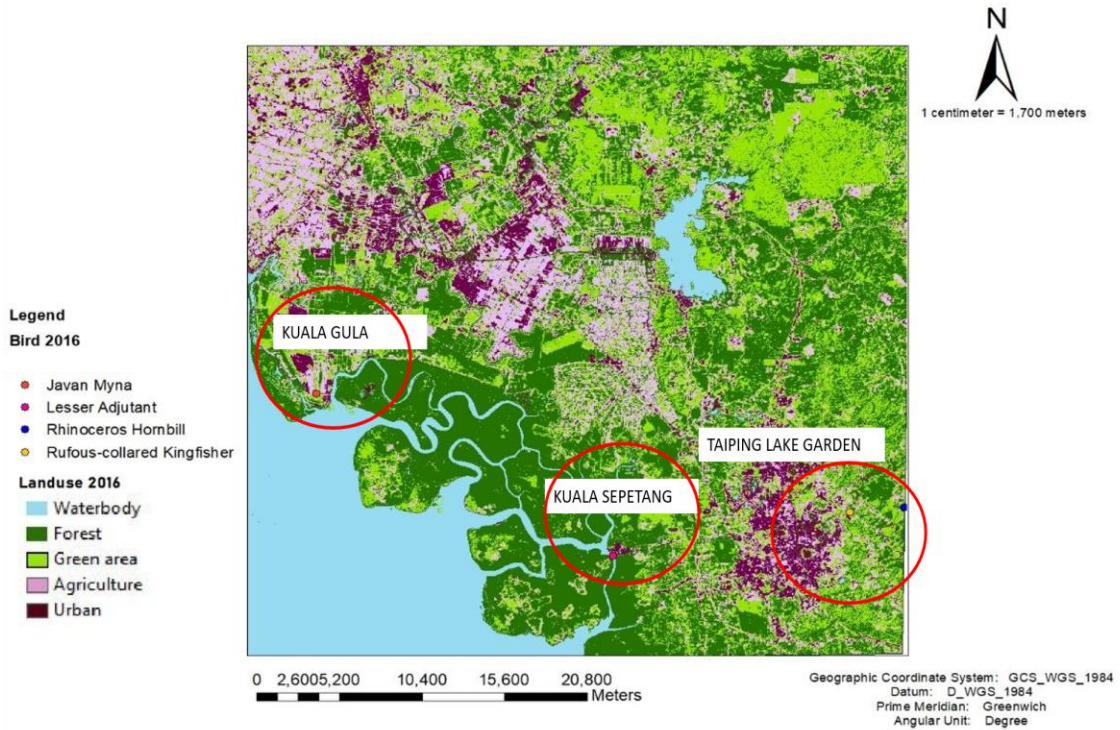


Figure 8. The overlay of land-use and threatened bird species locations in 2016

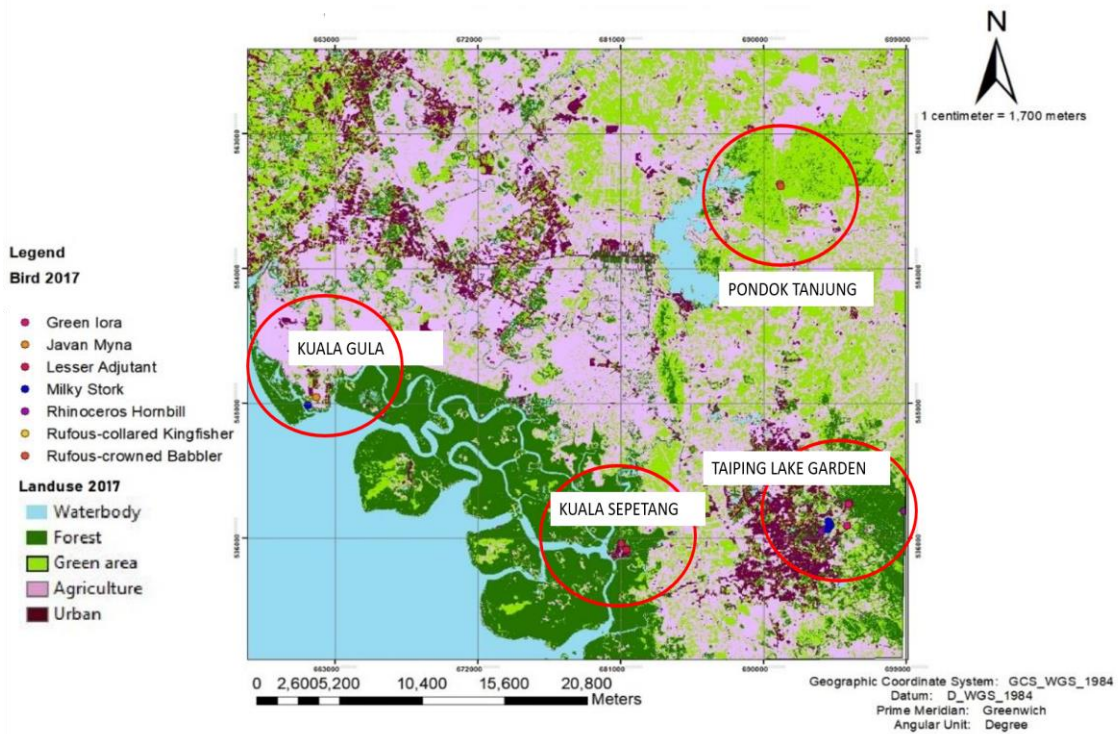


Figure 9. The overlay of land-use and threatened bird species locations in 2017

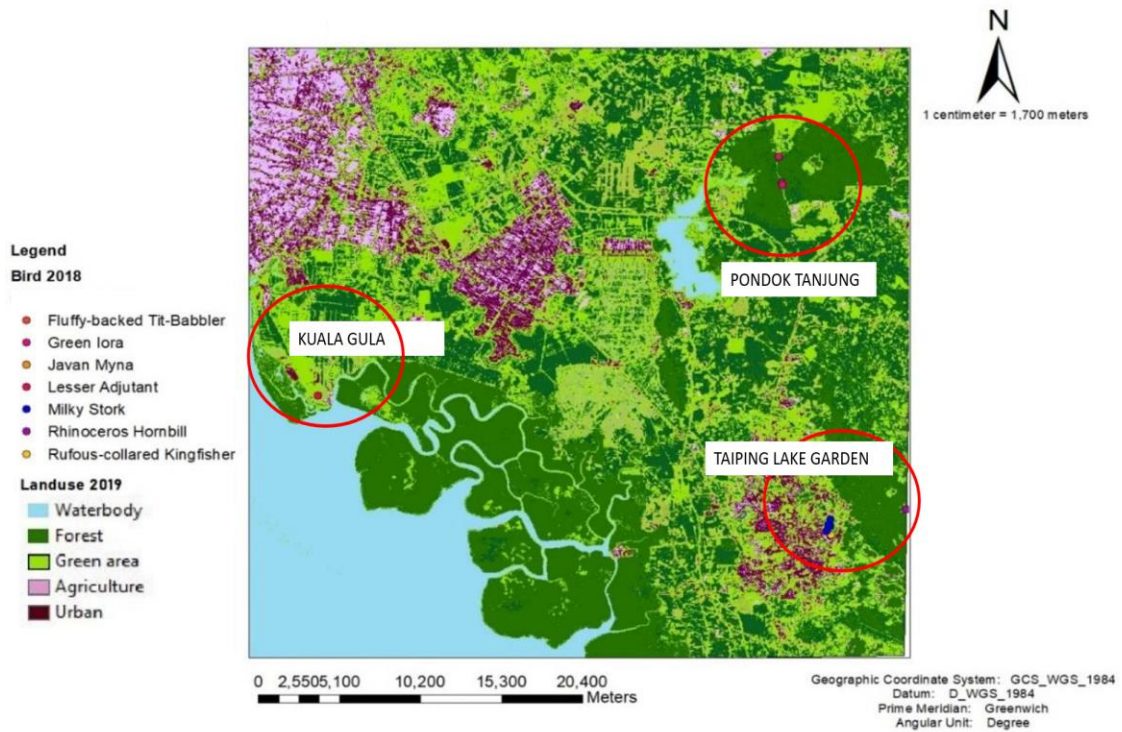


Figure 10. The overlay of land-use and threatened bird species locations in 2018

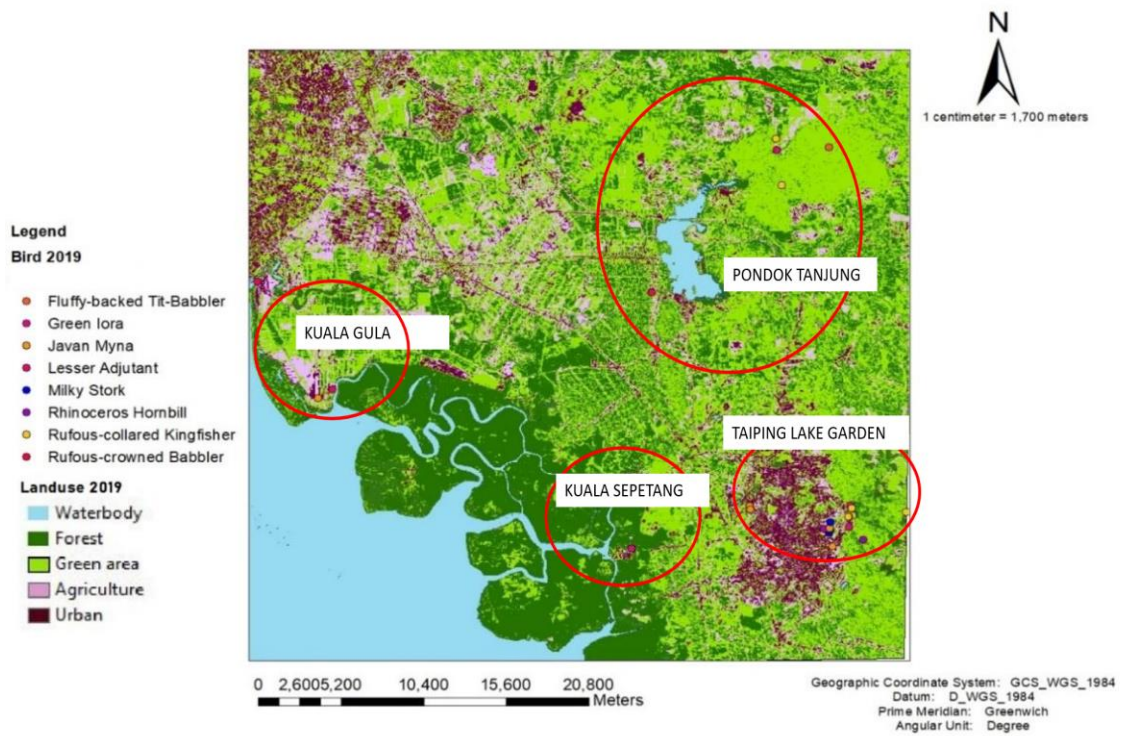


Figure 11. The overlay of land-use and threatened bird species locations in 2019

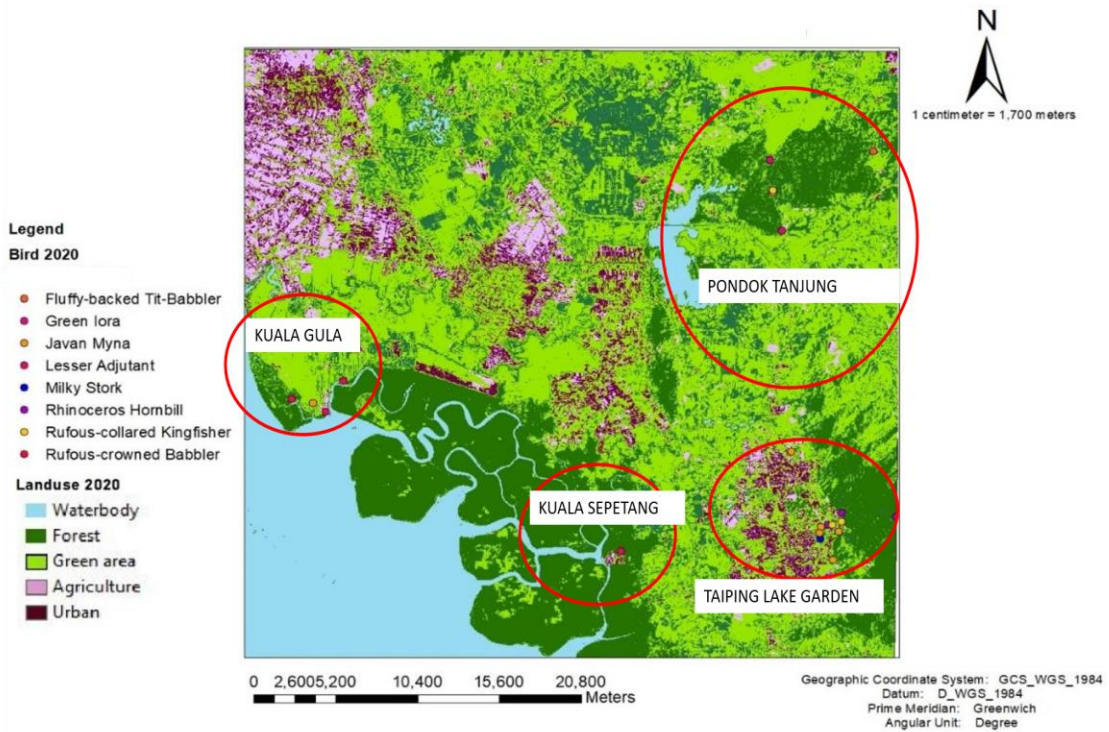


Figure 12. The overlay of land-use and threatened bird species locations in 2020

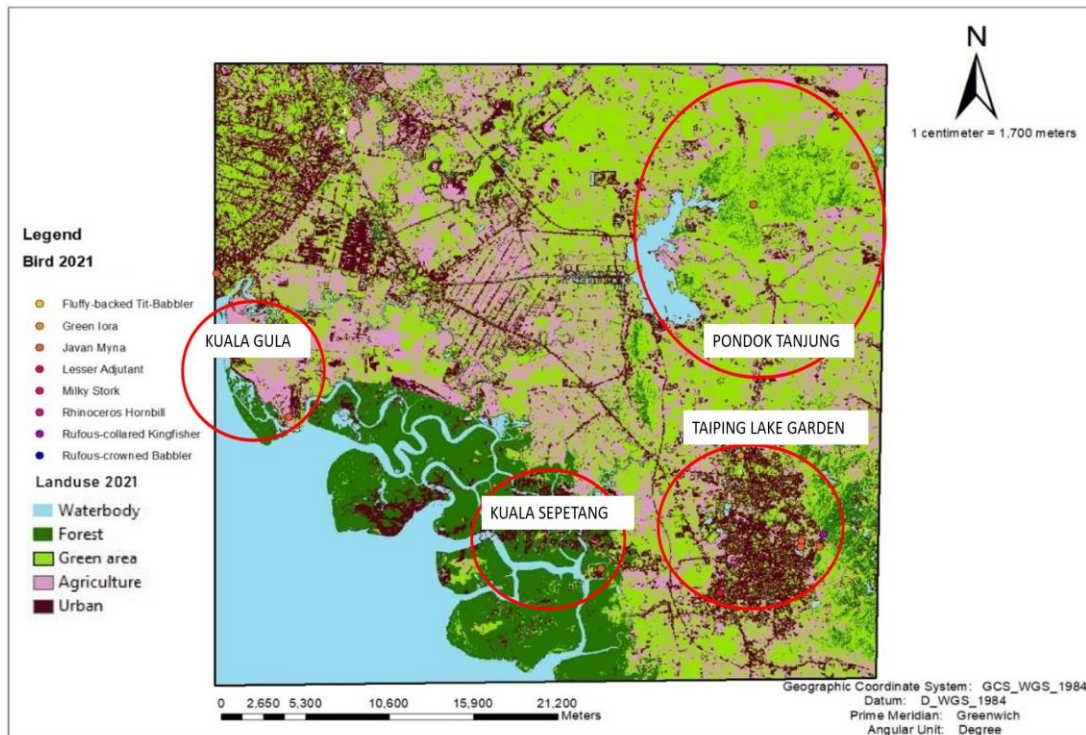
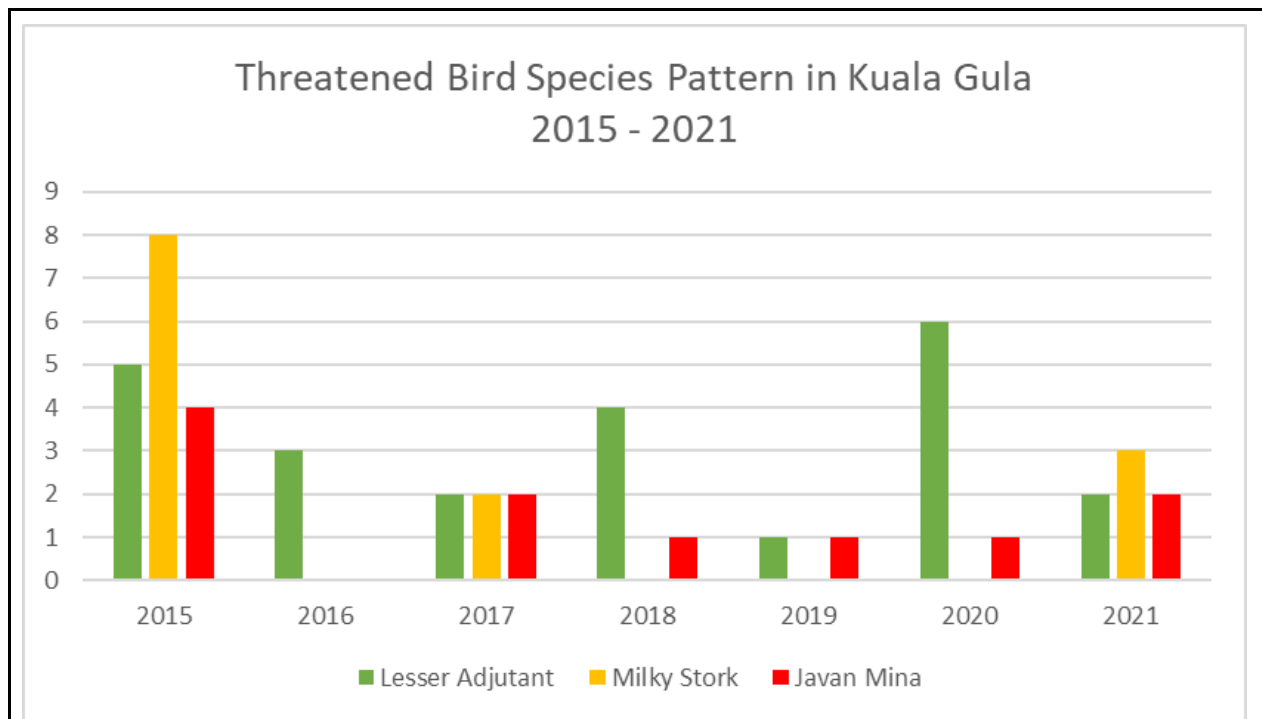


Figure 13. The overlay of land-use and threatened bird species locations in 2021

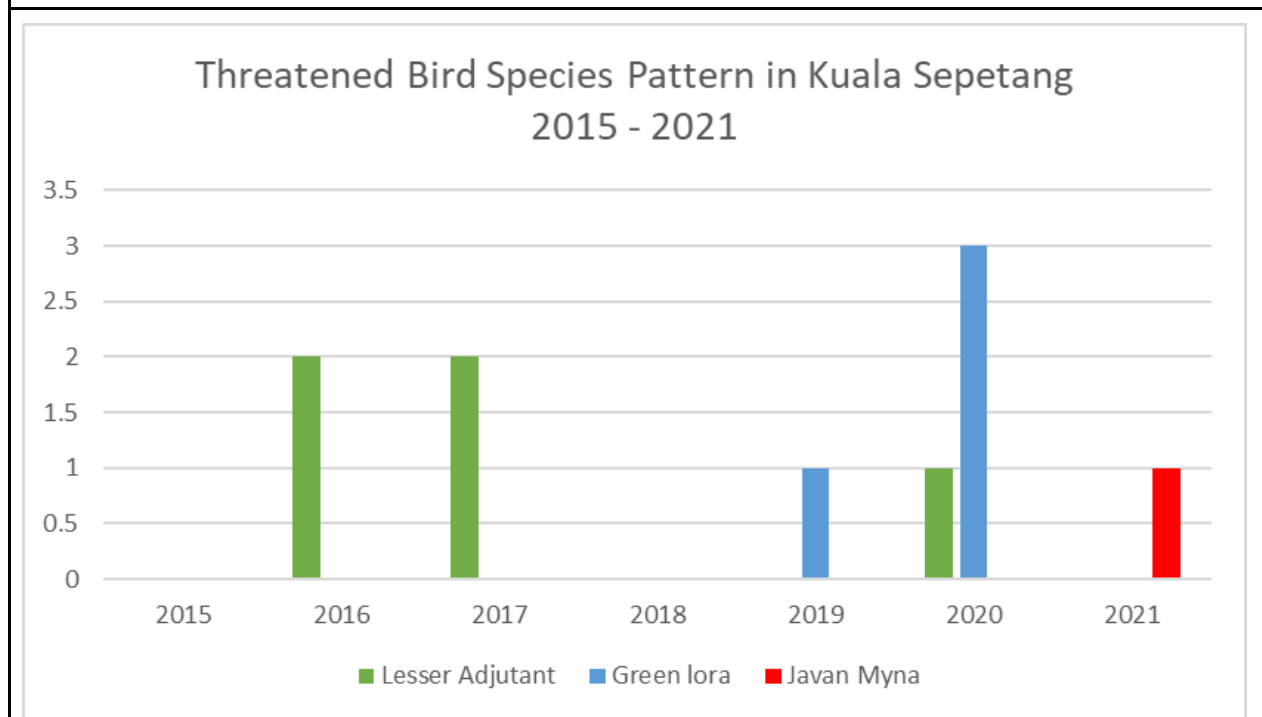
The vulnerable Milky Storks species was dominantly spotted near Kuala Gula in 2015; however, it was later spotted near the Taiping Lake Garden from 2017 to 2021 (see Figure 14(d)). The Lesser Adjutant species was dominantly spotted in the wetlands near Kuala Gula and Kuala Sepetang, but the number later decreased in the latter area (see Figures 14(a) and 14(b)). Such species is often found in wetlands, shallow marshes, fields, and swamps (Bird Watching Asia, 2021); however, it was surprisingly spotted near the Taiping Lake Garden in 2019 and 2021. This might be due to its excellent ecosystem where the three main lakes, ponds, and islands provide a suitable habitat and food sources for urban wildlife and migratory birds to land near this area (Malay Mail 2021; Ariffin et al., 2019).

Javan Myna is an abundant species commonly spotted in cities, open parks, and forest edges in Malaysia yet is vulnerable in other countries such as Indonesia (Tan et al., 2020). It was spotted almost every year in Kuala Gula before increasingly being spotted near the urban areas of the Taiping Lake Garden and the forest area near Pondok Tanjung between 2019 to 2021. Pondok Tanjung is the largest swamp reserve forest in northern Peninsular Malaysia (BirdLife International, 2023).

Green Iora was mainly spotted near the Taiping Lake Garden and Pondok Tanjung, with a few were found in Kuala Sepetang particularly in 2019 and 2020. Kuala Sepetang is a coastal town near the Matang mangrove swamp forest. It offers a natural wetland that is famous for coastal migratory waterbirds and migrant forest birds (Rainforest Journal, 2014).

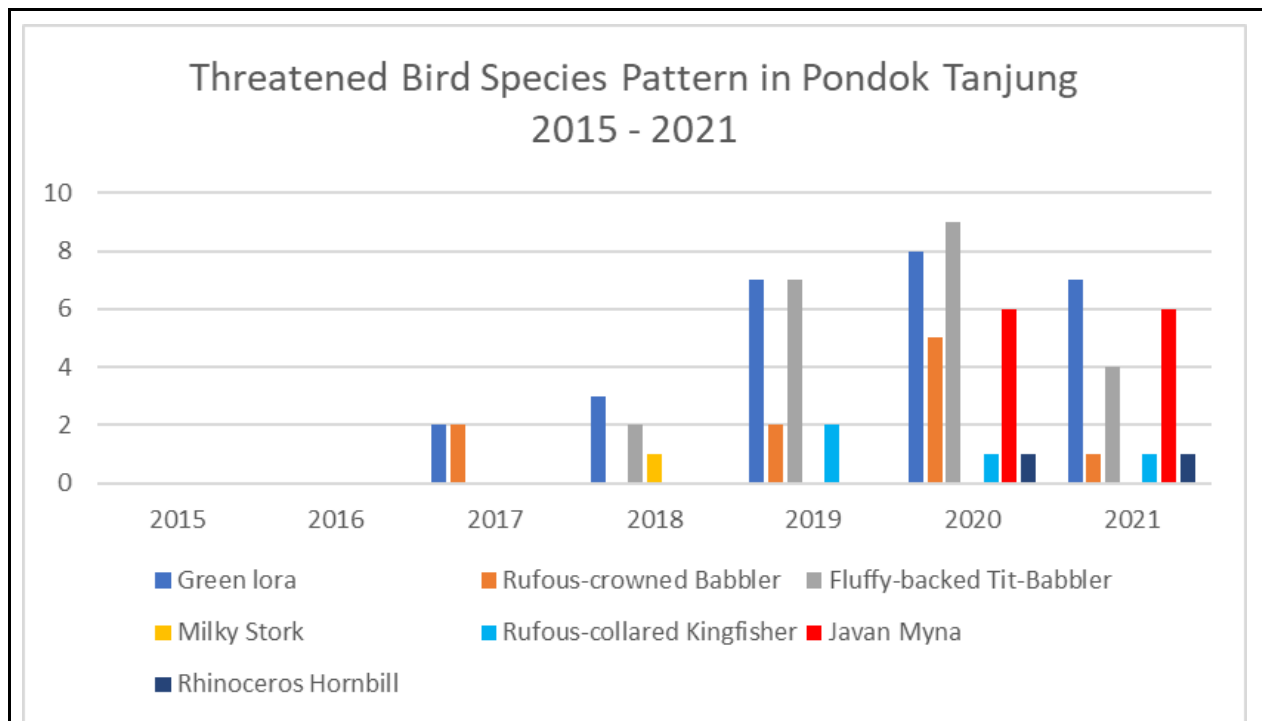


(a) Kuala Gula

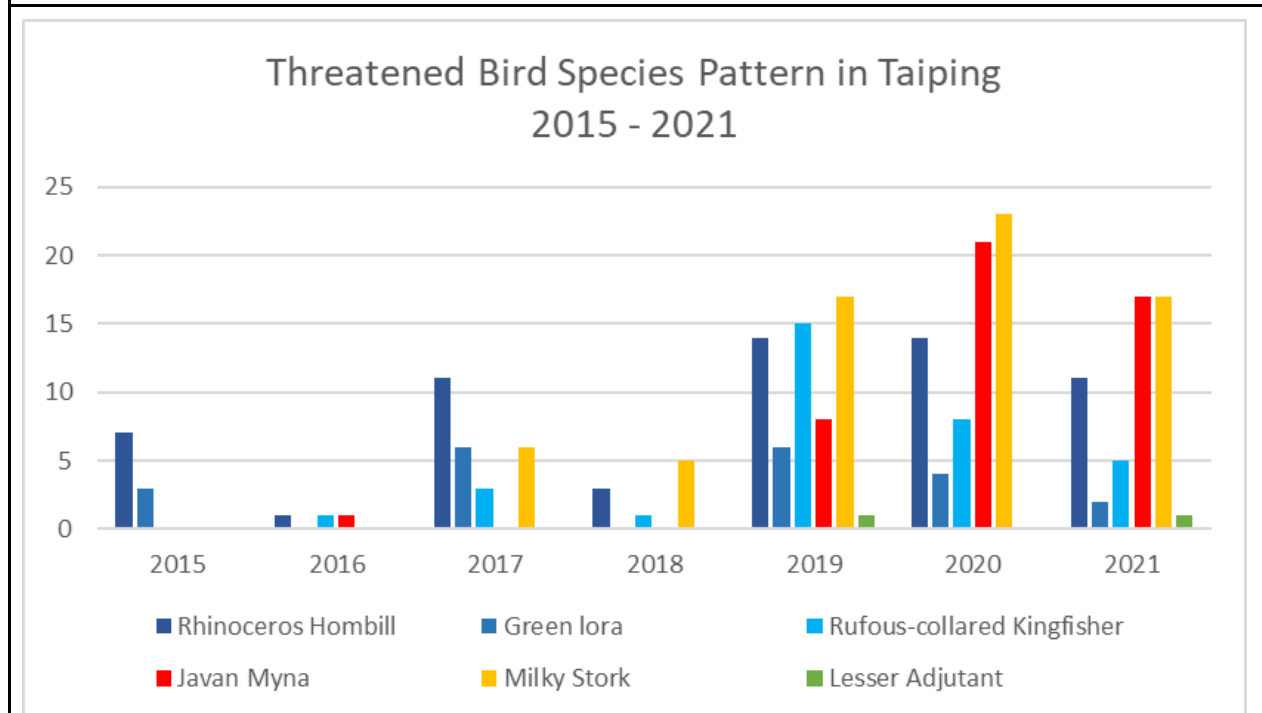


(b) Kuala Sepetang

Figure 14. The bird species patterns according to locations for 2015-2021. (a) Kuala Gula, (b) Kuala Sepetang



(c) Pondok Tanjung



(d) Taiping

Figure 14. The bird species patterns according to locations for 2015-2021. (c) Pondok Tanjung, and (d) Taiping Lake Garden

Figure 15 shows that the land-use area significantly changed from 2015 to 2021 with increased agriculture and urban areas. However, starting in 2019, the agricultural area significantly decreased while the urban area grew constantly. Significant changes in land-use patterns were observed with the decrease of green and forest in the study area. However, the increasing size of the urban regions in Taiping did not significantly affect the bird species patterns. Conversely, rare and threatened birds have been increasingly spotted and nested in that area (The Star, 2021). This probably owes to the preservation of the green area near the Taiping Lake Garden, which is surrounded by artificial man-made lakes and green spaces. The analysis also showed that most of the spotted bird's distance was near the green, forest, and agricultural areas.

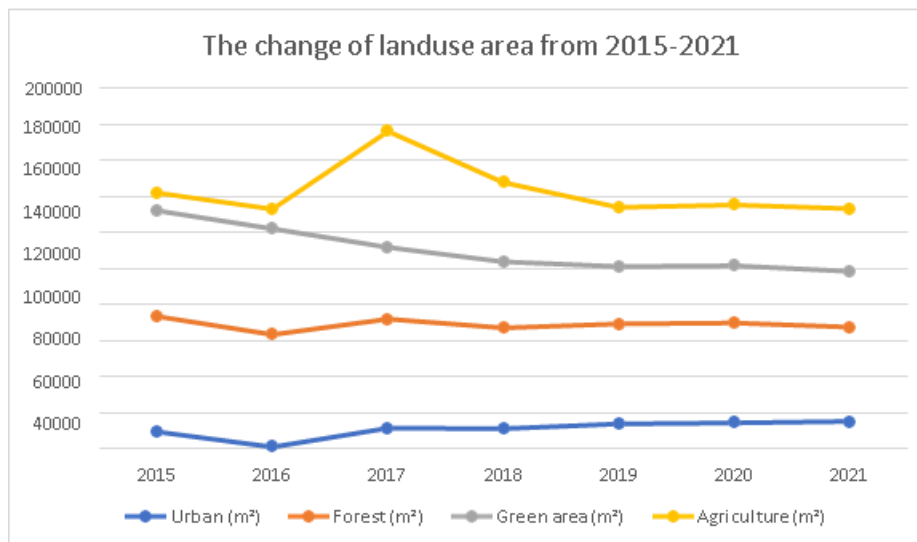


Figure 15. The difference in land-use area from 2015 to 2021

Table 4. The difference between urban, forest, green, and agriculture areas from 2015 to 2021

Year	Urban (m ²)	Forest (m ²)	Green area (m ²)	Agriculture (m ²)
2015	9463.24	63988.96	58626.40	9841.36
2016	1054.24	62374.66	58623.40	10892.46
2017	11491.24	60504.56	39694.60	64379.36
2018	11210.84	55910.16	36643.84	43938.84
2019	13909.76	55434.88	31718.92	32848.48
2020	14397.04	55423.80	31708.84	33709.40
2021	15240.25	52346.20	30800.95	34805.90

3.3 The Relationship Between Land-Use Type and Birds' Occurrence

The correlation analysis results in Figures 16 and 17 show significant relationships between the number of spotted birds in urban and green areas ($p < 0.05$) with the R^2 values of 0.611 and 0.593, respectively. This indicates that the number of birds spotted in this study is highly correlated with the land-use types.

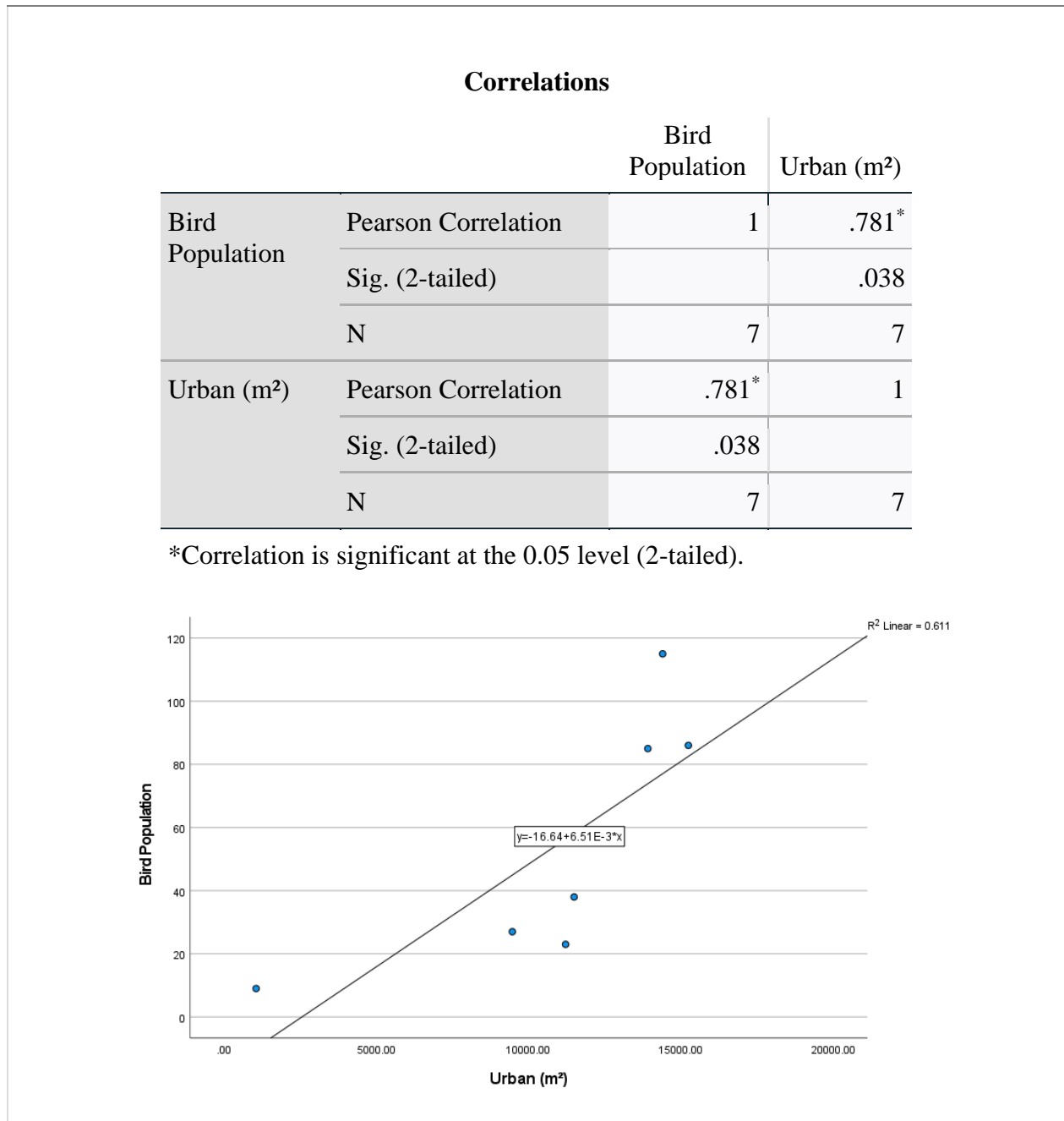


Figure 16. The correlation between the number of spotted birds and the distance to urban area

Correlations

		<i>Bird Population</i>	<i>Green Area (m²)</i>
<i>Bird Population</i>	<i>Pearson Correlation</i>	1	-.770*
	<i>Sig. (2-tailed)</i>		.043
	<i>N</i>	7	7
<i>Green Area (m²)</i>	<i>Pearson Correlation</i>	-.770*	1
	<i>Sig. (2-tailed)</i>	.043	
	<i>N</i>	7	7

*Correlation is significant at the 0.05 level (2-tailed).

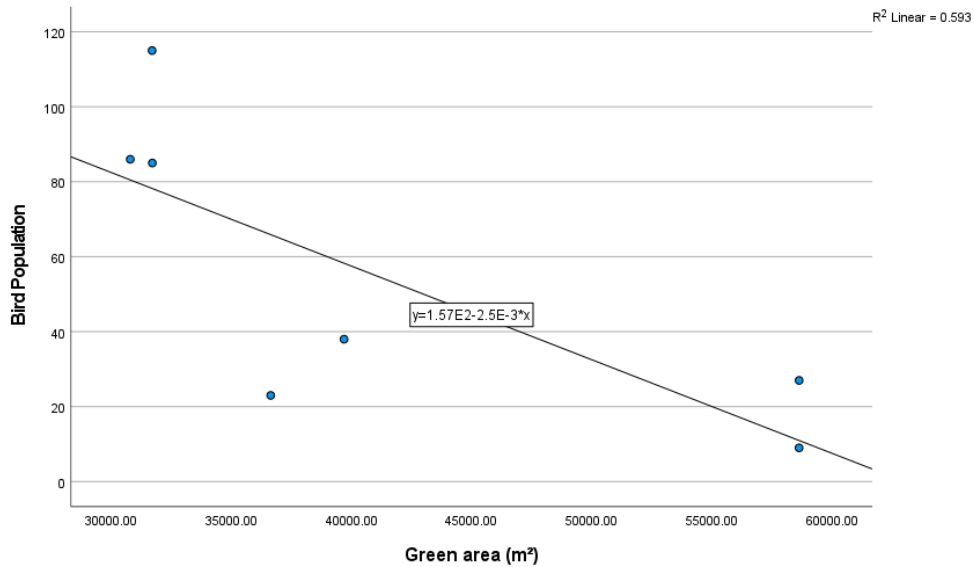


Figure 17. The correlation between the number of spotted birds and the distance to the green area

The positive correlation in Figure 16 suggests that the more birds being spotted, the longer the distance between the subjects. Whereas, the negative correlation in Figure 17 indicates that higher number of birds being spotted resulted in shorter distance to the green area. In other words, the distance to urban and green areas may influence the number of birds spotted. Meanwhile, an insignificant correlation ($p > 0.05$) was found between the number of spotted birds in the forest and

agriculture areas, with the R^2 values of 0.527 and 0.037, respectively. This contradicts the findings by Ali et al. (2019) who reported a significant relationship between the number of birds and the distance to a forest area. It might be due to the fact that the data used in this study (i.e., the number of birds being spotted) had two distinct habitats - wetlands and forests; hence, separate analyses could be done according to the species richness and their typical habitats.

3.4 The Hotspot Analysis of Threatened Birds from 2015 to 2021

Cluster pattern analysis was conducted to identify the hot and cold spots of threatened birds. Figure 18 shows that the distance from every point was near, leading to the clustered pattern. The Getis-Ord G_i^* stats revealed that the p-value was statistically significant and the z-score was positive. This rejected the null hypothesis, in which there is no spatial clustering of feature values where the values are spatially random.

A site can be considered a hotspot if a higher-than-average occurrence of the event being analyzed is found in a cluster, whereas a cold spot is a site with less-than-average bird count. Higher average with similar surrounding areas often indicates a 'hotter' hotspot (Geospatiality, 2016). In this study, high z-score and low p-value for a feature indicated a significant hotspot. As shown in Figure 18, the G_i^* -score was < 3.26249 , where high values' spatial distribution was more spatially concentrated and the assigned hotspot area was in Taiping. A low negative z-score and a small p-value indicated a significant cold spot. Additionally, the G_i^* -score was > -10.784 and it assigned a coldspot area in Kuala Gula, Perak.

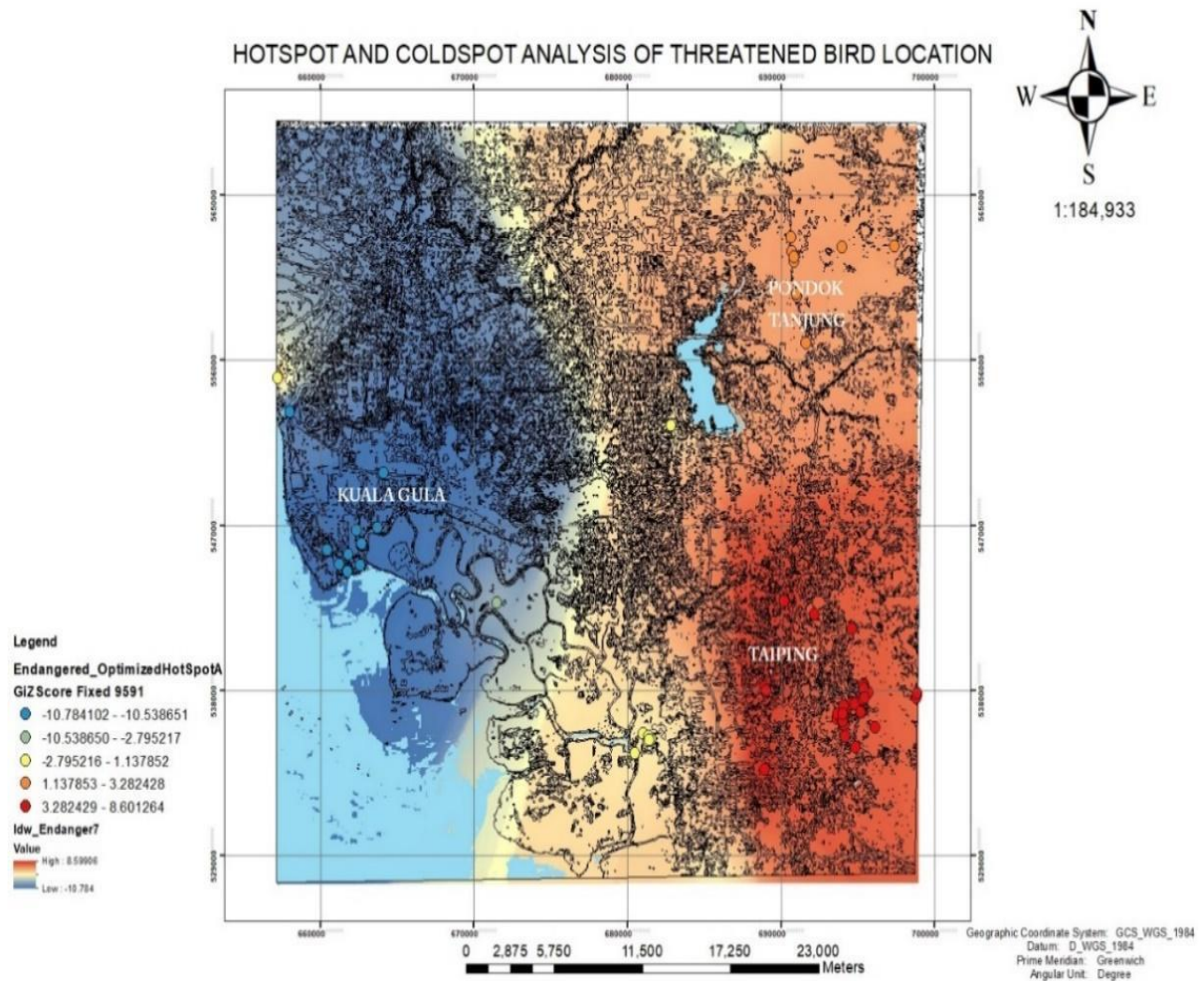


Figure 18. The hotspot and coldspot map of threatened bird locations

3.5 Discussion

This study investigated the occurrence of bird species classified as threatened according to the IUCN Red List Category and Criteria in Perak, Malaysia, namely Milky Storks (endangered status), Javan Mayna, Lesser Adjutant, and Rhinoceros Hornbill (vulnerable status), as well as Fluffy-backed Tit Babbler, Green Iora, Rufous-collared Kingfisher, and Rufous-crowned Babbler (near threatened status). Following the data extracted from the Citizen Science database (eBird) for 2016 to 2021, this study found that these species were distributed across four locations in Perak: the Taiping Lake Garden (close to the Taiping City), Pondok Tanjung Reserve Forest (northern Perak), Kuala Gula, and Kuala Sepetang (western Perak near the coastal area). The findings were further

confirmed by the correlation analysis, which revealed a negative relationship between the number of species and distance to green areas and a positive relationship with urban areas. This suggests that the bird tends to land near the green area compared to the urban area.

The coastal mangrove in Southeast Asia has been propounded as a typical habitat for two Stork species: Milky Storks (endangered status) and Lesser Adjutant (vulnerable status). These species were commonly spotted in Kuala Gula and Kuala Sepetang before 2017 but later emerged increasingly in man-made lakes at the Taiping Lake Garden near the Taiping green city. According to Rahman et al. (2020), the reintroduction of captive-bred Milky Storks by Zoo Negara in 2013 and 2014 has improved its population in Kuala Gula Sanctuary Park. Although this species is well-adapted to the ecosystem in such area due to the rich food sources mainly from the intense shrimp farming activities, it is currently facing the issues of water quality as well as insecticides and heavy metals pollution from nearby industries that are absorbed into freshwater species, ultimately affecting their primary food sources (Tolohah et al., 2023). Myna, which is classified as a vulnerable species, has also been spotted within the Taiping Lake Garden and Pondok Tanjung from 2019 onwards. The species is commonly spotted every year in the Kuala Gula mangrove area.

Several other species were also investigated in this study, including forest birds such as Rufous-crowned Babbler and Fluffy-backed Tit Babbler that were only spotted in Pondok Tanjung Reserve Forest as well as Rhinoceros Hornbills and Rufous-collared Kingfisher that were found near the Taiping Lake Garden and Pondok Tanjung Reserve Forest. Results from the clustering analysis revealed that the hotspot (dominant) location of the threatened birds investigated in this study was near the Taiping Lake Garden. In contrast, the coldspot (less dominant) location was in Kuala Gula. Pondok Tanjung was the second hotspot (orange-coloured) as shown in Figure 18. This indicates that although it is located in suburban areas, the ecosystem in Taiping Lake Garden can attract more bird species, including rare and threatened species. This owes to the local council's effort to preserve a large green area (64 hectares) whilst offering suitable habitat and food sources for the local and migratory birds that are on the verge of extinction as a result of climate change and habitat loss due to land degradation and human activities such as poaching. This aligns with Ali et al. (2019) who highlighted the role of green urbanism in attracting more birds into a city after forest loss due to the availability of open and green spaces that are allocated for sustainable and liveable cities by the council and developers.

4.0 Conclusion

This study explored the distribution of eight bird species classified as threatened in Perak, Malaysia as well as the relationship between species occurrence and the distance to land-use types. The data was obtained from the Citizen Science database (eBirds) and analyzed using spatial analysis. It was found that the number of bird occurrences and distance to green areas were negatively correlated, whereas such relationship was positively correlated with the distance to urban area. These birds were mostly spotted within proximity to the green area. Results from the high/low Clustering (Getis-Ord General G statistic) further revealed that the green area in the Taiping city located near the lake garden was assigned as the hotspot for the bird's occurrence, while Kuala Gula was found as the coldspot. The increasing number of birds spotted in Taiping is believed to be prompted by the ecosystem in Taiping Lake Garden, which is surrounded by man-made lakes and rich heritage trees that attract more forest and waterbirds. Kuala Gula was assigned as a cold spot due to the less threatened birds found there. Significant changes in land-use patterns were also observed with the decrease of green and forest within the study area from 2016 to 2021. However, the urbanization in Taiping city does not affect the birds' occurrence as more threatened birds have emerged in the area, particularly as the biodiversity and ecosystem have been well-preserved and maintained by the authorities and communities. However, the need for conservation in the coldspot area (i.e., Kuala Gula) is important to safeguard the Milky Stork and Lesser Adjutant population since their habitats are in mangrove forests.

Nevertheless, there are several limitations to this study. The Citizen Science data used in this study may be biased to certain randomly observed species and locations accessible by volunteers. The increasing number of threatened birds, such as Milky Storks and Lesser Adjutants, in the Taiping Lake Garden might be due to the volunteers' restricted accessibility to the area during the COVID-19 pandemic, particularly for the 2020 and 2021 datasets. Besides, the land-use data extracted from Sentinel-2 contained cloud masks in certain areas, hence imposing difficulty to accurately calculate the size of land-use changes. Future analysis is recommended by focusing on separate species - water and forest species - and including more temporal birding data from various sources to make predictions of threatened birds' patterns robustly.

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