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Spatial Distribution of Malaysian Storks Determined Based on Citizen Science (eBird) Data

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ABSTRACT

Waterbird populations are rapidly declining worldwide, including in many countries in Southeast Asia. Massive land use changes in Peninsular Malaysia are a major threat to biodiversity due to habitat loss and alteration, affecting the populations of many waterbird species. This study was conducted to determine the spatial distribution of three stork species, the Asian Openbill *Anastomus oscitans*, Painted Stork *Mycteria leucocephala* and Milky Stork *Mycteria cinerea*, in Peninsular Malaysia using the citizen science database, eBird. About 86,881 occurrences of the Asian Openbill, 2,391 occurrences of the Painted Stork and 242 occurrences of the Milky Stork were identified in the eBird database throughout Peninsular Malaysia between 2019 and 2021, suggesting major differences in occurrence size between the three species. Map generated from ArcGIS and a statistically significant difference in the population distribution of the three stork species across Peninsular Malaysia indicate habitat segregation. The populations of these stork species should be carefully monitored and managed to avoid imbalance with other waterbird populations.

Keywords: Citizen science data, distribution, Peninsular Malaysia, storks, waterbirds

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INTRODUCTION

Malaysia supports diverse ecosystems, including tropical rainforests and aquatic ecosystems with estuaries and mangrove forests, and is one of the world's megadiverse countries rich in flora and fauna. However, land use changes and anthropogenic activities in Peninsular Malaysia threaten the country's biodiversity (Darren et al.,

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2021; Rahman et al., 2014), and many waterbird species are affected due to habitat loss and limited food resources in coastal and freshwater areas. Waterbird populations are severely declining worldwide, especially in Southeast Asia, because of anthropogenic activities, such as habitat destruction, pollution, hunting, and recreation, which intensify the effects of disturbance on certain waterbird species (Robinson & Cranswick, 2003).

Twenty species of stork (family Ciconiidae) have been identified worldwide, of which four are considered endangered (IUCN, 2022). Of the 11 stork species in tropical Asia, three found in Southeast Asia are endangered: the Greater Adjutant, *Leptoptilos dubius*; Storm's Stork, *Ciconia stormi*; and Milky Stork, *Mycteria cinerea* (BirdLife International, 2016). The Milky Stork's Malay name is "Botak Upeh," is native species to Malaysia and has an estimated 5,500 individuals surviving worldwide (BirdLife International, 2022). In Peninsular Malaysia, the wild population of Milky Storks are restricted to Matang Mangrove Forest Reserve near Kuala Gula, Perak, since the mangrove forest is the most suitable habitat for these species to survive (Ismail & Rahman, 2012). This species was part of a captive breeding and release programme in Zoo Negara, located in Peninsular Malaysia, between 1998 and 2004 to restore the population in the wild (Ismail et al., 2011). In 2005, Zoo Negara in Hulu Kelang, Selangor, became a successful sanctuary for about one hundred individuals of Milky Storks that lived and bred in captivity (Ismail & Rahman, 2012). Unfortunately, their wild population faces major threats from hazardous chemicals such as heavy metals ingested via food and water (Rahman et al., 2017; Rahman et al., 2014), habitat destruction, poaching by humans, high rates of predation and disturbance caused by anthropogenic activities (Ismail & Rahman, 2012).

The Asian Openbill (*Anastomus oscitans*) has recently been recognised as a native waterbird of Peninsular Malaysia and is commonly known as "Botak Asia" or "Upeh Paruh Sepit" by local bird guides. The migration of this species from southern Thailand to Peninsular Malaysia began during the dry season in early 2013 and was a major cause of its presence in Peninsular Malaysia (Chuah, 2013; Low et al., 2013; Tan & Murali, 2013). The population of Asian Openbill in Malaysia is considered to be in decline. However, the species is not listed as endangered as its populations in other countries, such as Nepal, Pakistan and India, are still at a high level (Abidin et al., 2017).

The Painted Stork's Malay name is "Botak Padi" (*Mycteria leucocephala*), a vagrant species in Peninsular Malaysia, may be classified as the most abundant of Asian storks (Zakaria & Nor, 2019). Previously, the Painted Stork was an introduced species brought to Malaysia (Zoo Negara) in 1965 from Sri Lanka. Then, after a few years in captivity, this species was let loose outside Zoo Negara, able to survive and spread rapidly in the lakes and ponds all over Selangor and Kuala Lumpur (Zakaria & Nor, 2019). However, its numbers have been declining for years in South Asia and Southeast Asia, and it was classified as Near Threatened in 2004 (IUCN, 2021) due to several factors, including deforestation, water pollution, wetland drainage and hunting (Koli et al., 2013).

This study determined the spatial distribution sizes of the Asian Openbill, Painted Stork and Milky Stork in Peninsular Malaysia using eBird, the citizen science database. Their similar habitat preferences, particularly for freshwater areas, raise the question of how these three stork species are spatially distributed in Peninsular Malaysia. eBird, which provides over 140 million accurate records contributed by 150,000 different researchers from around the world (Callaghan & Gawlik, 2015), is an important resource for obtaining comprehensive information on the presence of stork species in Peninsular Malaysia because data have been recorded for many locations throughout the country.

MATERIALS AND METHODS

Study Area

Malaysia consists of two regions, Peninsular Malaysia and Malaysian Borneo (East Malaysia). This study covered all states of Peninsular Malaysia, which is 131,598 km^2 in area and comprises 11 of the 13 states and two of the three federal territories (i.e., Wilayah Persekutuan Kuala Lumpur and Wilayah Persekutuan Putrajaya) of Malaysia (Figure 1). Peninsular Malaysia extends from southern Thailand to Singapore. It is surrounded by the sea and separated from Sumatra in the west by the Straits of Malacca and East Malaysia by the South China Sea.

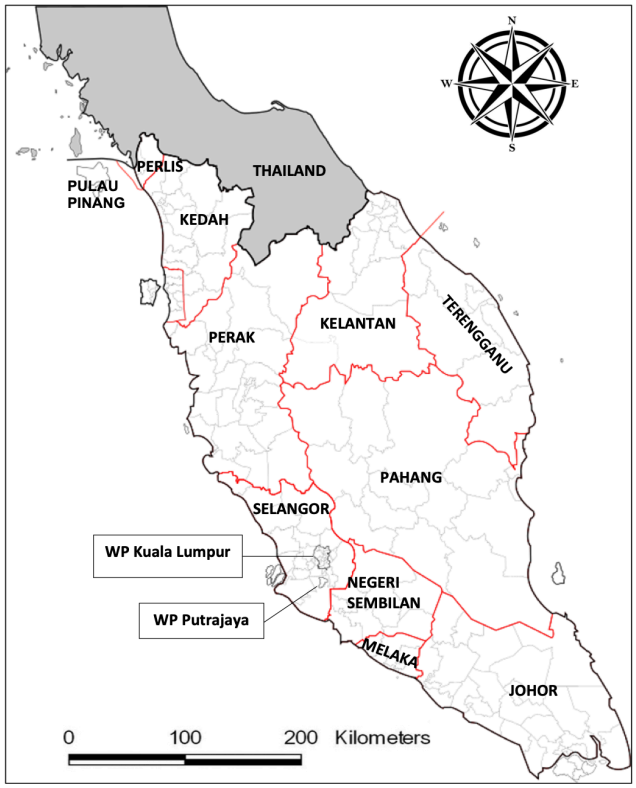

Figure 1. The map of Peninsular Malaysia

eBird Data

Data were obtained from the eBird website, which provides specific information to identify the occurrences and estimate the distribution patterns of the three species of stork in Peninsular Malaysia. eBird, whose citizen science data have been used by scientific researchers worldwide, provides data for over 180,000 locations across the landscape, easily accessible at any time. Data were downloaded from eBird to identify the distributions and to compare the abundance

and distribution sizes of the Asian Openbill, Painted Stork and Milky Stork in all states in Peninsular Malaysia. The data set received from eBird included validated observation dates, observer identification, exact locations, coordinates, and observation counts. Only 'complete' checklists were included in this study after the downloaded data were vetted. A species checklist was defined as 'complete' if the 'stationary', 'travelling', or 'exhaustive' protocol was followed (Sullivan et al., 2014). Checklists with 'group identifiers' were excluded from the study since they duplicated data. The data for the abundances of the three stork species were collected from January 2019 to March 2021. They were grouped according to the 10 states of Peninsular Malaysia and the two federals' territories. According to the data obtained, the study area included states and territories extending from the north to the south of Peninsular Malaysia in the direction of the west coast: Johor (MY-01), Kedah (MY- 02), Kelantan (MY-03), Melaka (MY-04), Negeri Sembilan (MY-05), Pahang (MY- 06), Pulau Pinang (MY-07), Perak (MY-08), Perlis (MY-09), Selangor (MY-10), Terengganu (MY-11), Wilayah Persekutuan Kuala Lumpur (MY-14), and Wilayah Persekutuan Putrajaya (MY-16).

Data Analyses

Data for the distribution of the three selected species of stork were analysed using ArcGIS Desktop 10.8 to address estimated position error (ESRI, Redlands, CA, USA) to ensure that the occurrences were within 100 m of the border of Peninsular Malaysia (Arazmi et al., 2022). The Kernel Density Tool was used to determine the density and distribution pattern of the three stork species in Peninsular Malaysia. The kernels were analysed using a UTM Zone 48N projection at 1 km resolution. The Arc Toolbox was used to generate a map of the occurrence of each species, map the overlaps of the occurrences, and identify which areas received bird visits throughout the study period. Kernel output was stretched using a histogram equaliser and resampled with the bilinear interpolation technique to enhance the appearance and smoothness of the raster data.

The data were normally distributed (determined using quantile–quantile plots and the Shapiro–Wilk test). According to states, the Kruskal-Wallis test was used to compare the distribution of the occurrences of the three stork species across Peninsular Malaysia. All analyses were performed using Minitab 19 software.

RESULTS

A total of 86,881 occurrences of the Asian Openbill, 2,391 occurrences of the Painted Stork and 242 occurrences of the Milky Stork were identified across Peninsular Malaysia between 2019 and 2020 (Figure 2). The Asian Openbill was present in 10 states and one federal territory. The largest number of records of Asian Openbills was for Melaka, with 32,784 occurrences, while the smallest number was for Wilayah Persekutuan Kuala

Lumpur, with 250 occurrences (Figure 3). Painted Storks were recorded in five states and federal territories, with the highest number in Selangor, 2,013 occurrences and the lowest in Seremban and Pahang, with one and two occurrences, respectively (Figure 3). The highest number of Milky Storks was recorded in Perak, with 211 occurrences (Figure 3). Meanwhile, for Terengganu, zero individual was recorded for all three species of storks (Figure 2).

The distributions of the three stork species in Peninsular Malaysia differed significantly (Kruskal–Wallis test: $H = 6.893$, $p = 0.027$). The three species showed habitat segregation

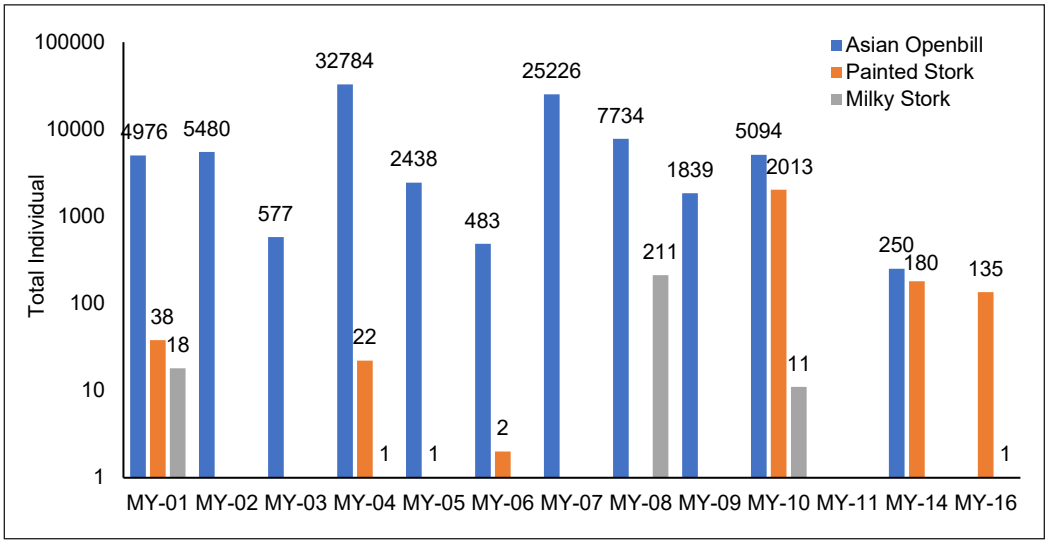

Figure 2. An abundance of Asian Openbill, Painted Storks and Milky Stork recorded in Peninsular Malaysia from January 2019 until March 2021

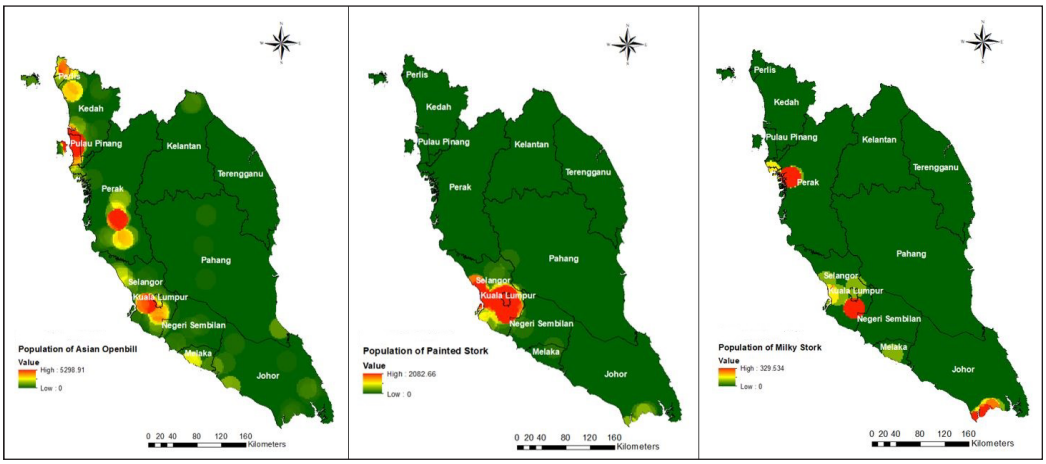

Figure 3. Distribution of Asian Openbill, Painted Stork and Milky Stork in Peninsular Malaysia between 2019 and 2021

across Peninsular Malaysia, with the Asian Openbill distributed from the northwest to the southwest, the Painted Stork concentrated in the central west, and the Milky Stork with three isolated populations in the northwest, the central east and the south (Figure 4).

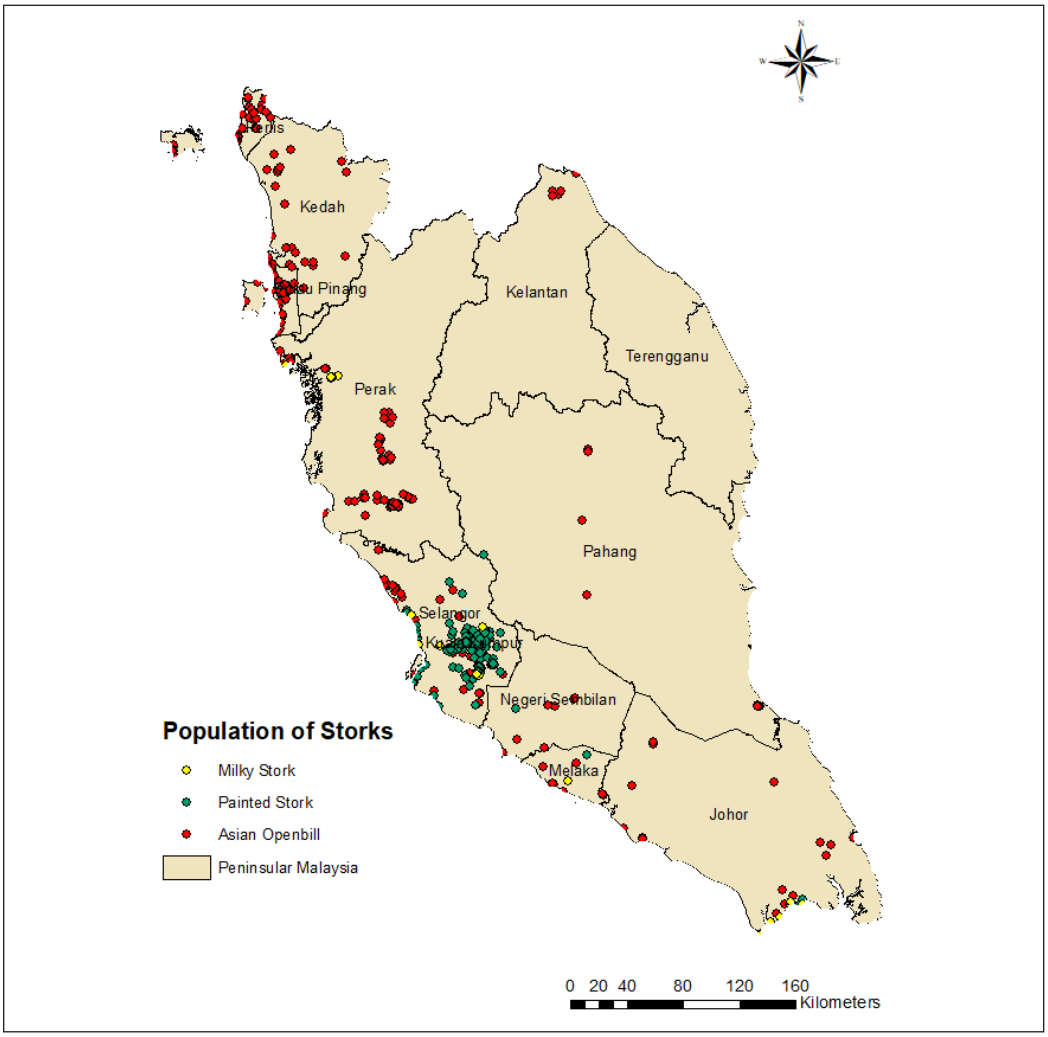

Figure 4. Habitat overlapping by Asian Openbill, Painted Stork and Milky Stork in Peninsular Malaysia between 2019 and 2021

DISCUSSION

This study shows that the Asian Openbill has a larger observation number in Peninsular Malaysia than the other two stork species. It indicates its success in dispersing from southern Thailand to the north and south of Peninsular Malaysia. Infestation of paddy fields by the invasive golden apple snail (*Pomacea canaliculata*), particularly at the early stages of rice cultivation, promotes its spread and population success but pressures its breeding

colonies, causing this species to migrate further to potential new sites. The population of this species greatly increased, particularly during the floods of 2011 in central Thailand, and depleted the snail population, which led to a food shortage and forced some colonies to abandon their original sites. About 522,112 hectares of actively cultivated rice fields in Peninsular Malaysia have facilitated the southward migration of the species (Jabatan Pertanian Semenanjung Malaysia, 2021). All areas in Peninsular Malaysia with records of Asian Openbills are mostly covered with shallowly flooded rice fields, where the conditions are moist and conducive to foraging by this species.

The high concentration of Painted Storks in Selangor, including Kuala Lumpur and Putrajaya, is related to Zoo Negara's captive breeding and release programme in 1965 (Koli et al., 2013). After 40 years, this species has bred, and its population rapidly increased in Selangor and surrounding areas, but it has not spread tremendously across other states. This species preferred migrating and building new colonies nearby wetland areas such as Putrajaya Wetland and other main lakes in Shah Alam and the Saujana Golf Resort (Zakaria & Nor, 2019). Painted Storks are mostly concentrated on the west coast of Peninsular Malaysia and nearby areas with large freshwater bodies, such as artificial lakes for recreational activities and wetland areas (e.g., the Putrajaya Wetland).

The Milky Stork has the smallest observation numbers of the three stork species, with only 242 occurrences across Peninsular Malaysia, which confirms the Endangered conservation status rank of this species (IUCN, 2021). The larger Milky Stork occurrence recorded in Perak may be due to the conservation programme of captive breeding and re-introduction implemented in the Kuala Gula Bird Sanctuary. About 50 Milky Storks were released in Kuala Gula between 2007 and 2014 (Ismail & Rahman, 2016). The large mangrove area in the Matang Mangrove Forest in Perak provides a release site and makes it possible to aid the survival of this species. This species shows high habitat specificity in mangrove areas. However, the west coast of Peninsular Malaysia is likely to have experienced pollution from heavy metals, insecticides, organochlorine mixtures, and other harmful pollutants categorised as toxins that may be absorbed into gastropods and fish, which are the main food sources of the Milky Stork (Ismail et al., 2011; Rahman et al., 2014; Samsi et al., 2017). Continuous consumption of contaminated prey will likely harm the birds and lead to low population numbers in Peninsular Malaysia.

In general, the three stork species were simultaneously present in three states, Selangor, Melaka and Johor, throughout 2019 and 2020. However, this overlap was highly concentrated in Selangor due to Zoo Negara's captive breeding programmes for the Painted Stork and the Milky Stork. However, they were re-introduced at different times in different areas: the Painted Stork in the Zoo Negara area in 1965 and the Milky Stork in Kuala Selangor Nature Park (KSNP) in 1998 and 2003 (Ismail & Rahman, 2016; Zakaria & Nor, 2019). The Zoo Negara area was selected as the release site for the Painted Stork because

of the presence of many artificial freshwater lakes and urban parks with large trees, which made it a more suitable breeding habitat. KSNP was selected as the early release site of the Milky Stork because it is close to Zoo Negara and has a mangrove habitat. At the same time, the Asian Openbill migrated across western Peninsular Malaysia, where they visited the paddy fields in Sekinchan and Sabak Bernam in Selangor state (Ali et al., 2020). These sites highlight the presence of the three stork species in the same region but at different localities and demonstrate their different habitat preferences—the Painted Stork prefers artificial freshwater lakes. In contrast, the Milky Stork favours mangrove habitat and the Asian Openbill paddy fields. Habitat segregation could reduce the competition rates by decreasing the number of niche overlaps between the related and trophically similar species (Mansor et al., 2015). However, in some regions, they overlap; thus, identifying their diets in the same habitat is crucial (Figure 4). Competition between the stork species might be avoided by dietary segregation, which could be revealed by a differential selection of major prey types (Mansor et al., 2020).

CONCLUSION

We conclude that the distribution of Malaysian storks relies significantly on the availability of their preferred habitats. The maintenance of urban lakes with suitable trees supports Painted Storks; the protection of mangrove habitat supports Milky Storks; and paddy fields sustain the Asian Openbill. However, paddy fields should be controlled and well managed to avoid large-scale natural habitat loss and overpopulation by the Asian Openbill, which could disrupt other native birds that also consume small aquatic animals. Citizen science data has become reliable for the public and researchers to measure, analyse, manage, conserve, and preserve wildlife and its habitat. Our spatial distribution model can be integrated with appropriate parameters in future studies to predict the species' potential distribution corresponding to land use changes. Additionally, further study is required to obtain detailed information about the diets of storks and other sympatric waterbird species.

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