Population trends of passage and wintering barn swallows (*Hirundo Rustica*) in Peninsular Malaysia

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Abstract. In Peninsular Malaysia, passage and wintering Barn Swallows (*Hirundo rustica*) often congregate at nocturnal roosts in towns. As a Holarctic migratory species, it is at risk of population collapse. Despite extensive research, little is known about this species in its wintering grounds, especially in the tropics. This study aimed to determine how climate change influences the population growth of this species across a geographical area over a decade, from 2009 to 2019. A species distribution model was constructed using data obtained from the eBird database – a citizen science project – of records from diverse locations. We used the Kernel Density tool in ArcGIS to describe Barn Swallow density and expansion pattern across Peninsular Malaysia. We demonstrate that the Barn Swallow’s population has fallen by about 27.1% over the last decade. In 2009, the species was dispersed in two distinct areas: Perlis to Pulau Pinang; and the Pahang region bordering Selangor and Negeri Sembilan; in addition, some individuals chose to winter in south-eastern Johor. Within ten years, the flock has descended from Perlis to the north-east corner of Perak, while the vast wintering area in Pahang has decreased and stretched down to Melaka and Johor. The differences in Barn Swallow numbers and distribution patterns observed in this study could be a result of climate and land use changes which have caused this species to spread to parts of other wintering regions, altering the arrival and departure times of migration, thereby interfering with its breeding season.

Keywords: climate change, land-use, roosting site, swallows, wintering region

Track Name: Human, Social, Economic and Environmental Sustainability.

1. Introduction

Climatic variations can significantly affect the availability of plant and other resources for animals, resulting in population changes [1]. There is substantial evidence that the ongoing biodiversity crisis is being exacerbated primarily by human-induced global change, most notably in climate and land use [2,3]. The loss of biodiversity is one of the most severe risks to life on Earth [4]. The current species extinction rates are around a thousand times higher than the natural background rate, and the trend is moving upwards [5,6].

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Birds are significant markers of overall biodiversity [7–9]. They are particularly vulnerable to climate change [10] and habitat disturbance [11]; this is especially the case for tropical species [12,13]. They are also widely used as umbrella species, as their conservation is intended to protect a vast number of naturally co-occurring species [14,15].

The Barn Swallow (*Hirundo rustica*) is a popular and ubiquitous species often observed in human settlements [16]. It is one of 83 species in the Hirundinidae, the bird family of swallows and martins (hirundines; [17]). There are six Barn Swallow subspecies: *H. r. savignii* breeding in North Africa; *H. r. transitiva* breeding primarily in the Middle East; *H. r. rustica* breeding in Europe; *H. r. tytleri* breeding in Siberia and Mongolia; *H. r. erythrogaster* breeding in North America [18]; and *H. r. gutturalis*, with a breeding range from the eastern Himalayas to northeast Russia (Siberia), China, the Korean Peninsula, and Japan [19], spending the winter in Thailand and the Malay Peninsula [20].

This study aimed to investigate the impact of climate change on the distribution and abundance of the Barn Swallow in Peninsular Malaysia between 2009 and 2019. We used data from eBird, a citizen science initiative for which data are collected by observers of all skill levels, from novices to experienced ornithologists [21]. Data from eBird have been widely used for species distribution modelling and in many recent studies (e.g., [20]). However, to our knowledge, these data have not been used to date to simulate long-term patterns in species abundance, particularly of migratory bird species, in Peninsular Malaysia. We hypothesised that the Barn Swallow numbers decrease as the pace of land use and climate change increases. This knowledge is critical for developing an adequate mitigation strategy to conserve and preserve the populations of this migratory species.

2. Methods

2.1 Study area

With a total area of 132,265 km², Peninsular Malaysia is divided into four distinct economic growth zones: Perlis, Kedah, Penang, and Perak are in the north; Selangor, Federal Territory of Kuala Lumpur, and Federal Territory of Putrajaya are in the west; Negeri Sembilan, Melaka, and Johor are in the south; and Kelantan, Terengganu, and Pahang are in the east. The climate of Malaysia is tropical, with hot and humid weather throughout the year. Previously dominated by tropical forests, today, this region is covered with a combination of agricultural land, woodland, wetlands, and urban–suburban–rural areas. Consequently, the loss of habitat due to deforestation, which eventually leads to climate change, has long been linked to the decline in migratory bird species, such as the Barn Swallow, in Peninsular Malaysia.
2.2 eBird dataset

We estimated the distribution and range extension of the Barn Swallow using the eBird citizen science database. The dataset from eBird, which contains all checklists entered in 2009 and 2019, was obtained from the eBird website. The eBird primary dataset comprises all validated observations, including dates, observers, locations, coordinates, and observation counts. To prevent bias, we removed incomplete checklists since they did not appropriately sample the population. Checklists related to ‘group identifier’ were also eliminated since they were redundant checklists. We included comprehensive species checklists if the ‘stationary’, ‘travelling’, or ‘exhaustive’ protocols were followed [21]. For the selected years, annual data were evaluated and sorted. We examined species abundance and population size to evaluate how the distribution pattern has changed across Peninsular Malaysia.
2.3 Data analysis
The data collected spanned two separate years, 2009 and 2019, with a 10-year gap. The data were normally distributed, confirmed by inspection of quantile-quantile plots and the Shapiro–Wilk test. A t-test was used for data analysis [23] with the PAST programme (Paleontological Statistics, 2.17). Barn Swallow distribution data for 2009 and 2019 were then analysed with ArcGIS 10.7; the occurrences were set within 100 metres of the border of Peninsular Malaysia. Distributions outside the study area were omitted. Species distributions were derived based on both specified years (2009 and 2019). The Kernel Density tool was used to determine Barn Swallow density and differences in the expansion pattern across Peninsular Malaysia over the ten-year period. Kernels were determined using a Kertau RSO projection at 1-km resolution, with a 1-km search radius to prevent unnecessarily large bandwidth computed from the cell filled by points. The kernel output was stretched with a histogram equaliser and re-sampled with bilinear interpolation to improve the appearance and smoothness of the raster data.

3. Results
The eBird data yielded 26,010 numbers of swallows in 2009 (mean ± standard deviation; 2000.77 ± 1923.25) and 18,965 in 2019 (1458.85 ± 509.70) and demonstrated a 27.1% decrease in swallow abundance between the beginning and the end of the ten-year period ($t = 0.27$, $p = 0.79$) (Table 1). Swallow numbers rose in all states except Negeri Sembilan, where they dropped by over 97.7% over the ten years (Fig. 2). The pattern of distribution revealed that the Barn Swallow observation decreased in western and eastern Peninsular Malaysia in the ten-year period (Fig. 3). Based on the data for 2009 and 2019, Negeri Sembilan and Perak were the most popular wintering spots in Peninsular Malaysia, with the highest Barn Swallow individual counts, respectively. The swallow populations in the east coast of Peninsular Malaysia have also grown slowly, particularly in Kelantan, where just ten observations were reported for 2019 in the eBird database. Based on the derived kernel values, Selangor and Pahang supported the highest density of Barn Swallow roosting spots in 2009. However, by 2019, the roosting spots had dwindled and begun to spread further north to Penang and south to Malacca.

| States                        | 2009 | 2019 |
|-------------------------------|------|------|
| Johore                        | 74   | 4558 |
| Kedah                         | 104  | 829  |
| Kelantan                      | 0    | 10   |
| Kuala Lumpur Federal Territory| 0    | 96   |
| Malacca                       | 0    | 198  |
| Negeri Sembilan               | 25077| 577  |
| Pahang                        | 378  | 1244 |
| Penang                        | 159  | 3779 |
| Perak                         | 151  | 5261 |
| Perlis                        | 23   | 1267 |
| Putrajaya Federal Territory   | 0    | 20   |
| Selangor                      | 44   | 1113 |
| Terengganu                    | 0    | 13   |

Table 1. Abundance of Barn Swallows recorded throughout Peninsular Malaysia in the years 2009 and 2019.
**Figure 2.** Occurrence of Barn Swallow in Peninsular Malaysia in 2009 and 2019.

**Figure 3.** Spatial abundance of Barn Swallows observed throughout Peninsular Malaysia in the years 2009 and 2019. Maps were generated using ArcGIS v. 10.7.
4. Discussion

According to the eBird data for Peninsular Malaysia, Barn Swallow observations followed a rising pattern. One likely explanation is that more people began recording their sightings on eBird. Over 500,000 users have accessed eBird since its inception, and over 21 million bird records have been collected through more than 1.6 million checklist submissions. eBird has received data from over 35,000 unique users for more than 180,000 sites from the western hemisphere and New Zealand. Since eBird accepts ‘historical’ data, 13% of the checklists predate the November 2002 debut of eBird. Participation has increased steadily since that time [21].

However, as the number of observations has grown, the number of individual birds recorded has decreased. This was most noticeable for Negeri Sembilan, where individual records of Barn Swallows have declined by about 97.7% in the last ten years. Habitat loss is one possible factor for this decrease. Climate change has a substantial impact on habitat loss. Because of rising temperatures, flooding, and desertification, the habitats of migrating birds are at risk of changing and disappearing. According to Global Forest Watch [24], Jempol, the largest district in Negeri Sembilan, has lost 98,300 hectares (ha) of tree cover between 2001 and 2020 – a 75% loss in cover since 2000 and 36.1 megatonnes (Mt) of carbon dioxide equivalents (CO₂e) in emissions released into the atmosphere per year. During the same period, Jelebu, the second largest district in Negeri Sembilan, lost 33,300 ha of tree cover, comparable to a 26% loss in cover since 2000 and 18.4 Mt of CO₂e in emissions. Furthermore, between 2001 and 2020, Kuala Pilah district lost 21,200 ha of tree cover, a 24% reduction since 2000 and 13.9 Mt of CO₂e in emissions.

Extensive habitat loss in the tropics will continue to intensify the impact of climate change on tropical birds, particularly endemic and range-restricted species [25,26]. Coastal wetlands are an example of a habitat that migrating birds use for nesting and feeding. Regrettably, tropical coastal habitats are rapidly disappearing and are highly vulnerable to climate change and rising sea levels [27]. The loss of these coastal habitats should be of considerable concern since they provide vital ecological functions and services, such as protection against tsunami damage [28]. In addition, migrant species such as the Barn Swallow use these locations for food and rest during their journey; they can replenish their energy reserves and recuperate at these spots before continuing their arduous migrations. Unfortunately, sea-level rise caused by climate change will inundate these coastal wetlands, obliterating the habitats of birds and other animals. Without these rest stops, migrating birds’ energy reserves deplete, and they struggle to complete their journeys [29].

The Barn Swallow’s distribution pattern suggests that the population has migrated away from northern and eastern Peninsular Malaysia in response to habitat loss. Birds and other fauna are adjusting their ranges in reaction to climate change, with bird species moving poleward or to higher altitudes in tropical highlands [30]. The magnitude of such movements is projected to increase in the future; for example, several European birds are anticipated to experience range boundary movements of over 1,000 km [31]. However, landscapes fragmented or rendered unsuitable owing to human land use may impede birds’ capacity to relocate to new, climatically acceptable habitats. Furthermore, many hotspots of bird species richness are currently found in protected areas, from which birds may migrate to unprotected areas due to climatic shifts [32].

In addition, habitat loss affects temperature fluctuations. Temperature records for Malaysia reveals a rising trend. At the same time, climate modelling employing 14 global climate models (GCMs) indicates that Malaysia might suffer temperature changes ranging from 0.7 to 2.6 °C and precipitation variation ranging from -30% to 30% [33]. These changes affect the migration routes and annual migration rhythms of many migratory birds, as the majority of these species alter their routes, reduce their journeys, or cancel them in response to changing temperatures [34].

Increasing food scarcity on wintering grounds due to decreased rainfall may impair the non-breeding performance of migrating birds and delay their departure to breeding grounds [35]. Changes in tropical wintering habitats also harm migrants’ subsequent performance on their breeding grounds. Female American Redstarts (Setophaga ruticilla) wintering in high-quality habitat produce a higher number of offspring and fledge them earlier than females wintering in low-quality habitat [36]. Certain migratory
birds that cannot match their migratory time to climate change-induced phenological changes already suffer negative consequences [37,38]. Birds that have evolved in areas with unpredictable weather are likely to cope better with climate change [39]. Unpredictable conditions affect nomadic birds, which can migrate great distances in response to droughts, floods, and other adverse weather events.

Climate change directly causes further degradation of natural resources, infrastructure, environment, and human health. In addition, some types of indirect damage are expected to be significant [40]. Climate change is likely to significantly impact bird reproduction and the entire annual cycle [41]. Numerous bird species, including swallows that migrate to higher elevations or latitudes, travel considerable distances to their nesting grounds [34]. Their migration to summertime grounds is almost certainly governed primarily by photoperiod and endogenous clocks [42]. Short- and medium-distance migrants, on the other hand, can adapt to climate change more quickly, whereas long-distance migrants, such as the Barn Swallow, are disadvantaged [43]. Their migration patterns are typically more rigid, and they have difficulty adjusting to temperature changes, thus, they are more vulnerable to climate change than other birds.

In addition, mild winter temperatures help local birds to survive and thrive. As a result, they begin to make use of long-distance migrants' food supplies and breeding grounds. Long-distance migrants may find that many resident birds already occupy their breeding grounds [34] and face increased competition for space as well as food. Although there is a risk of mismatch between migrant species and their breeding grounds, it is also possible that after their arrival at the breeding grounds, the degree of snow cover and food availability of the destination fluctuates significantly over time. As a result, they could be better at responding to changes in weather and climate than other species.

5. Conclusion

Malaysia's tropical forests are diverse, and the impact of climate change on their biodiversity is a significant issue. While species composition is projected to be affected at the landscape scale by climate change, its significant variation at the local scale is expected due to soil and topographic factors. While some bird species have adapted to these changes, others have not, resulting in their extinction. The climate change we are witnessing today is different: human-induced global warming is accelerating, and many bird species are finding it increasingly difficult to adapt to the resulting shifts in climate. This study determined how climate change influences Barn Swallow numbers across an area over a decade from 2009 to 2019 and show that its community has shifted its preferred wintering region to survive. In addition, their abundance has also reduced drastically within the decade.

However, if climate change were the only new threat to birds, it is reasonable to expect that many species would adjust to the new conditions and survive, given current population and genetic variability, as well as the fact that their earlier generation survived previous climate transitions. [44]. Nevertheless, other human-made obstacles, such as habitat disruption in Negeri Sembilan, either individually or in combination, can affect the lives of birds. Birds that inhabit the harshest environments on Earth (deserts, high altitudes, and high latitudes) are already approaching the limits of their stress tolerance [34] and may be unable to deal with new difficulties. Numerous species that are already in decline due to various circumstances may be unable to cope with a multiplicity of future problems [45].

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