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REVIEW PAPER

Habitat Complexity Influencing Avian Community Structure, Conservation Management and its Implications in Malaysia

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ABSTRACT

In this review, we explore the understanding of habitat complexity influencing the bird community with a special focus on Malaysia's recent case studies. Malaysia is one of the mega-diverse countries because it is gifted with the beauty of biodiversity. However, biodiversity resources are greatly affected by human activities such as mining operations, agricultural expansion, timber extraction, and hunting activity. In bird ecological research, habitat complexity is crucial because it affects biodiversity overall within species interactions and resource availability by evaluating environmental features including floristic composition and habitat heterogeneity. The positive relationship between habitat complexity and species diversity has been extensively documented. Complex habitats provide a variety of resources and niches, allowing different species to coexist. However, the advanced research methodologies, long-term monitoring, and a more nuanced understanding of the specific ecological processes influencing bird populations should be well emphasized. This review intends to fill in the gaps by critically analyzing potential conservation management strategies that might be adopted to increase habitat connectivity and minimize the negative effects of habitat loss on bird community structures in Malaysia.

Keywords: Bird diversity, conservation management, habitat complexity

INTRODUCTION

This paper review provided an overview of previous research on the definition of habitat complexity, the relationship between habitat complexity with species diversity and its effect on species diversity. This review next went over the analysis of 20 chosen papers from 2012 – 2022 about the habitat complexity of avian community structure in Malaysia. In addition, various topics have been covered in understanding habitat attributes used to measure habitat complexity and its impacts on bird diversity, the recent studies, gaps and future needs in the study of bird ecology as well as the potential conservation efforts and their implication to the conservation of bird populations in Malaysia.

For decades, researchers have been enthralled by various avian groups found in Malaysia, subsequently developing a profound understanding of the complex interactions between birds and their surroundings. Malaysia has the privilege to research the effect of habitat complexity in determining the distribution of bird communities as it is one of the mega-diversity countries in the world. Data from the Avibase (2022) database shows that Malaysia has 852 bird species belonging to 101 families, of which 18 are endemic species, 76 species are globally threatened and 17 are introduced species while Malaysia Nature Society (2022) issued the latest number with 814 bird species. Moreover, biodiversity resources are greatly affected by human activities such as mining operations, agricultural expansion, timber extraction, and the hunting of wild animals (Scanes, 2018, Atikah *et al.*, 2021). In Peninsular Malaysia, most pristine lowland dipterocarp forests have been exploited or harvested for timber business and development on commercial

crops and plantation areas (Atikah *et al.*, 2021). All these activities have surely reduced the diversity of the fauna to the extent that reflects the degree of habitat disturbance.

The spatiotemporal distribution of several important environmental resources influences the abundance of bird species. Moreover, the richness and diversity of bird species in terrestrial landscapes are directly correlated with habitat structure and floristic features; larger regions typically have a wider variety of habitats that different bird species can occupy (Mohd-Azlan *et al.*, 2015). Studies have demonstrated a connection between distinct bird species and various habitats. Birds are utilized as surrogates for determining the effects of habitat alteration because of their quick reaction to changing environments, which makes them ideal indicators of habitat quality, productivity, and stability (Vallecillo *et al.*, 2016). Hence, they are considered the most sensitive ecological indicators of the health of an ecosystem.

Understanding how various factors impact biodiversity is becoming more critical considering rapid ongoing global trends. It is essential to have a thorough knowledge of the relationships between habitat and fauna to manage the animal habitat, restore ecosystems, and support conservation practices (Morelli *et al*., 2013; Stirnemann *et al*., 2015). According to Stirnemann *et al.* (2015), most of the researches only focused on the correlations between the distribution and richness of species to the habitat offered by the physical structure of vegetation focusing on the quantity (e.g., cover area) rather than the complexity of habitat.

In conclusion, for successful conservation and management methods in Malaysia, it is critical to comprehend the impact of habitat complexity and variety on bird populations. Recent research has emphasized the significance of habitat variability in fostering robust bird groups and the beneficial association between habitat complexity and avian diversity (Stirnemann *et al.*, 2015). Malaysia may work to protect and restore various habitats by incorporating these findings into conservation planning, assuring the long-term survival of its outstanding bird species.

Definition of Habitat Complexity

In ecology, habitat complexity does not have a single definition of complexity - probably, there will never be one (Loke and Chisholm, 2022). Some researchers like Loke and Chisholm (2022), Carvalho and Barros (2017), Loke *et al.* (2015), Stein and Kreft (2015), Kovalenko *et al.* (2012) and Tokeshi and Arakaki (2012) have chosen their own preferred definition because of this ambiguity or have resorted to intuition. Furthermore, Kovalenko *et al*. (2012) stated that understanding how habitat complexity affects species distributions and trophic interactions is constrained by the ambiguity surrounding the terminologies used to define it, the metrics used to assess it, and the scales at which it is measured. The idea of habitat complexity indicates the coexistence of several "kinds" of elements that comprise a habitat – encompassing the presence of physical, structural and compositional features (Tokeshi and Arakaki, 2012; Loke *et al.*, 2015; Loke and Chisholm, 2022). Carvalho and Barros (2017) indicated "habitat complexity" as a measure of the absolute abundance of physical or structural components in a certain area – even in marine ecosystems. In addition, Carvalho and Barros (2017) conceptualized habitat complexity as a multidimensional measure that relates to a range of quantitative traits (such as the size, density and number of various structural elements) and qualitative traits (such as the composition or spatial arrangement of structural elements) of habitat attributes that may interact and have an impact on ecosystems at different levels. Moreover, Stein and Kreft (2015) proposed "habitat complexity" refers to vegetation including habitat structure and physical components – a multidimensional measure that incorporates a variety of factors such as landscape structure, spatial heterogeneity and resource distribution.

There are many approaches to measure or quantify the complexity of natural habitats so we can better understand how habitat complexity study was studied. Tokeshi and Araki (2012) emphasized that fractal geometry has been used to characterize habitat complexity by providing the hierarchical organization, spatial arrangement, and ecological processes occurring within the habitats. The multidimensional measure should be considered by including physical, chemical, and biological components while measuring the complexity of the habitat (Kovalenko *et al.*, 2012; Carvalho and Barros, 2017). Other than that, other methods mentioned

to quantify the habitat complexity – structural, functional, and landscape heterogeneity measurement (Stein and Kreft, 2015; Loke and Chisholm, 2022) while Loke *et al.* (2015) added feature artificial structure to enhance habitat complexity.

To conclude, habitat complexity can be defined as the existence of various components while considering the structural, physical and arrangement features (i.e., resources availability, soil type, vegetation, elevation, and climatic condition) within a habitat which can be influenced by fractal patterns to be quantified using several measures. Moreover, habitat complexity plays an important role in supporting biodiversity, the process of ecology, and conservation efforts because it can promote species richness and abundance as well as whole ecosystem health by providing more resources, niches, and microhabitats.

Relationship between Habitat Complexity and Species Diversity

The link between spatial environmental complexity and species diversity is a prominent topic in the field of ecology, evolution, and biogeography. Habitat complexity can arise from a variety of factors, such as structural heterogeneity, topographical variability, and the presence of biotic factors such as other species and their interactions. Since then, many studies have examined how environmental heterogeneity affects a wide range of taxonomic groups in many terrestrial and aquatic systems.

The habitat-heterogeneity theory, first put forth by MacArthur and MacArthur (1961), contends that a rise in the variety of habitats might result in a rise in species diversity. They explained when habitats are large enough to support various populations, then habitat variation may benefit diversity in some ways. The relationship between habitat complexity and species diversity has frequently been attributed to the surface area effect - ecosystems with greater levels of complexity typically create more favourable conditions for supporting higher species diversity (Kovalenko *et al*., 2012; St. Pierre and Kovalenko, 2014). Besides, Tokeshi & Arakaki (2012) added that a greater range of habitable area sizes might be available to species with a wider range of body sizes, hence promoting the richness of species, while Stein & Kreft (2015) suggested the idea that habitat complexity in abiotic or biotic environments expands the amount of available niche space, which permits more species to coexist. For example, greater vegetation density in a forest canopy can provide a range of microhabitats for insects, birds, and mammals, leading to greater species richness and diversity (Ghadiri *et al.*, 2012). Similarly, coral reefs with more complex structures, such as branching or tabular corals, tend to support higher biodiversity than simpler reef structures (Komyakova *et al.*, 2018).

Recent studies have also shown that habitat complexity can be influenced by the functional diversity of species in ecosystems. Functional diversity is the various ecological roles performed by different species including nutrient cycling, predation even pollination. Greater habitat complexity can enhance the diversity of functional traits in a community (Pease *et al.*, 2012; Schmera *et al.*, 2017), leading to greater functional redundancy and resilience in the face of disturbances such as climate change or habitat loss. For instance, a recent study by Coutinho *et al.* (2021) discovered that habitat complexity in the form of diverse microhabitats increased the functional diversity of bee colonies in agroecosystems. The study showed that bee species with different functional characteristics such as body size and foraging habits, were more likely to occur in agroecosystems with greater habitat complexity - which improved the functional diversity and stability of the bee community.

Even though there is a usually positive relationship between habitat complexity and species diversity, there are also some circumstances where increased complexity of habitat may not necessarily be advantageous to higher diversity. For example, in some cases as Fletcher *et al.* (2018) and Regolin *et al.* (2020), habitat fragmentation can increase the edge habitat and lead to higher habitat complexity, but this may not necessarily affect higher species diversity. Likewise, the effectiveness of habitat complexity in supporting diverse communities may be reduced by the presence of invasive species (Schirmel *et al.*, 2016) or other biotic stressors (Mayor-Pinto *et al.*, 2016; Michel *et al.*, 2016).

In conclusion, habitat complexity is

important in maintaining species diversity in ecosystems. Greater habitat complexity provides a wider range of resources and niches for organisms, which can increase species richness, functional diversity, and resilience to disturbances. Recent studies have shown that habitat complexity can also influence the functional diversity of communities (Pease *et al.*, 2012; Schmera *et al.*, 2017; Countiho *et al.*, 2021), highlighting the importance of preserving and restoring complex habitats to maintain biodiversity in the face of global environmental change.

Effect of Habitat Complexity on Species Diversity

A major factor in the loss of biodiversity worldwide is habitat destruction. Given the correlation between habitat complexity and biological richness, destruction involving structural simplification usually accounts for a significant portion of this loss. Numerous studies that evaluate the complexity of habitats only concentrate on the existence or absence of complex structures or a particular part of the complexity, most frequently the density of structural parts (St. Pierre & Kovalenko, 2014; Stirnemann *et al*., 2015). They added even though the mechanisms underlying this benefit are not fully understood, possible explanations include increased niches because of increased microhabitat availability, higher productivity, and a sampling effect linked to a larger surface area needs to be emphasized. Thus, Hanz *et al.* (2019) stated a study of the morphological diversity of species groups concluded that in more complex habitats, both group niche area and individual species niche constriction increase, which agrees with the bigger niche space hypothesis.

The environment contains a greater variety of habitats and microhabitats often lead to habitat complexity. Higher species diversity is the outcome of the variety of habitats because they produce niches and resources that may be used by various species for shelter, food resources or even nesting sites. For instance, the complexity of the habitat in a forest ecosystem can be reflected in the diversity of tree species, tree diameters, canopy cover, understory vegetation, fallen logs, and standing dead trees. Research by Regnery *et al.* (2013) focused on tree microhabitats in the forest and showed tree cavities and cracks on a tree can support important microhabitats for cavity-nesting bird and bat species. Paillet *et al.* (2018) commended that tree cavities found in forest can be important for cavity-nesting birds and bats while cracks and loose barks were particularly relevant for saproxylic beetles. This structural variety allows various species to fill distinct niches within the microhabitats in the forest, supporting a greater variety of species. Besides, abundant resources allow more species to live within the same macrohabitat. When the heterogeneity of habitat occurs, it can provide more different resources to occupy different species so it can reduce competition and promote species diversity too. For example, in a coral reef environment, different species of coral-associated fishes can be found inhabiting different coral species. Wehrberger and Herler (2014) concluded that corals reef can be settled with different types of coral species with a variety of structural complexity such as body size or crevices size that may be occupied by different species of fish based on their body sizes; compared to fish living in less complex reef corals, those linked with more complex microhabitats had distinct body morphologies of fishes.

However, it is believed that the presence of habitat complexity does not promise high species diversity in an area due to other environmental factors such as global warming and anthropogenic disturbance which causing habitat loss, especially the fragile microhabitats. Coral reefs are an example of a complex environment that may be extremely sensitive and fragile to many anthropogenic influences. For instance, coral bleaching episodes brought on by climate change may result in coral cover loss and a consequent drop in reef complexity (Graham, 2014; Pratchett *et al.*, 2018). Fish that depend on coral for refuge and feeding is frequently affected by coral bleaching due to the loss of structural complexity and habitat availability. Reduced fish numbers and variations in species richness can result from the loss of preferred habitats, with certain specialised fish species that depend on coral being particularly vulnerable (Graham, 2014; Pratchett *et al.*, 2018). While Novoa *et al.* (2021) stated structurally temperate forest habitat served partitioning niches to cater different types of birds with specific refuge, foraging and nesting needs can be destroyed by fire disturbance that naturally occurred by lightning and all the others were unintended

ignition by humans. They added after the fire episodes, the vegetation height and plant species abundance deteriorated respectively leading to a decline in overall bird diversity. Besides, environmental factors such as elevation cannot ensure the presence of habitat complexity supports high species diversity. As elevation increases, the habitat becomes less complex – foliage height and vegetation patches decreased can lead to the decline of bird diversity since fewer niches and food source availability as elevation is getting higher (Sam *et al.*, 2019).

MATERIALS AND METHODS

In this review article, the available literature by topic was searched using the Google Scholar databases from 2012 to 2022 and Preferred Reporting Items for Systematic Reviews (PRISMA) was performed to identify publications studying habitat complexity influencing bird community structure in Malaysia. We limited our search to peer-reviewed, articles in English, excluded reviews and grey literature (e.g., theses, technical reports, institutional dossiers) and used the combination of keywords to examine (i) correlations between habitat complexity, bird diversity and its conservation implications and (ii) habitat attributes used to measure habitat complexity that influencing bird community structure. The following keyword combinations were used for the search: "habitat complexity" AND "conservation" AND "bird diversity". An initial search resulted in 822 articles, which were limited to 20 articles after filtering with additional keywords such as “Malaysia” and “point counts”. Then the 20 chosen articles have been analyzed using Critical Thinking method to point out the main findings, sampling area, methods used, strengths and limitations of the studies into table (refer Supplementary Material: Table S1).

Habitat Complexity on Avian Community Structure in Malaysia

Measuring Habitat Complexity and its Impacts on Avian Community Structure

Successful conservation and management strategies depend on having a thorough understanding of the intricate interactions that exist between birds and their habitat. Because it affects the availability of resources, interactions between species, and biodiversity, habitat complexity is crucial in influencing the composition of bird groups. We shall examine the ideas of habitat complexity and its significance in studies of avian ecology. With the use of information collected from several studies carried out in Malaysia (refer to Supplementary Material, Table S1), different habitat characteristics are used to gauge habitat complexity. The subject matter will be supported by the cited publications, which offer insightful illustrations and proof.

Habitat attribute is defined as any living or non-living feature of the environment such as vegetation types, availability of food sources, temperature, moisture levels and shelter that provides resources necessary for a species in a particular habitat. Researchers have developed several variables to measure habitat complexity and evaluate its impacts on bird community structure. The floristic structure is one of the essential characteristics used to determine habitat complexity. In a selectively logged hill dipterocarp forest, Atikah *et al*. (2021) investigated the impact of vegetation structure on bird biodiversity. They found a significant correlation between bird species richness and abundance with habitat complexity, as measured by variables such as canopy cover, tree density, tree height and understory density. For instance, certain bird species may favour areas with dense undergrowth for nesting, while others may thrive in open canopy spaces for aerial foraging. In addition, microclimate factors are another characteristic to measure habitat complexity. For example, Rajpar and Zakaria (2015) delved into the relationship between bird populations and microclimate conditions such as temperature, humidity and wind patterns in shrub and open area in Selangor, Malaysia. Additionally, specific habitat variables, including the availability of perching sites, nesting materials, and foraging opportunities, play a pivotal role in shaping bird communities through their study. They suggested the diversity of birds can be positively impacted by adding bird-friendly elements to open spaces, such as creating artificial perching spots or keeping a range of plant species in shrub environments. Besides, Shafie *et al.* (2022) found different feeding guilds provide valuable insights into the trophic dynamics of the ecosystem, indicating the availability and diversity of food resources within the habitat. Differences in tree density,

canopy cover, understory vegetation, elevation gradients, the presence of microhabitats such as fallen logs, seasonal variability and biotic interactions could influence the diversity and abundance of bird species (Shafie *et al.*, 2022). Thus, a more complex habitat structure can provide a greater variety of niches, supporting a diverse community of birds with distinct habitat preferences.

Maintaining different bird populations and fostering environmental stability depends on habitat complexity. A habitat's inclusion of different structural components and vegetation offers birds a variety of resources, such as nesting spaces, feeding opportunities, and protection from predators. Atiqah *et al.* (2019) shed light on the intricate interplay between birds and tree species within oil palm agroforestry landscapes. They indicated the presence of different tree species provides a range of resources such as fruits, insects, and nesting sites, catering to the diverse dietary and nesting preferences of various bird species. Moreover, the vertical and horizontal heterogeneity in tree structures, including tall emergent trees, mid-story canopy layers, and a well-developed understory, offers birds a diverse array of perching, nesting, and foraging options (Atiqah *et al.*, 2019). Hence, conservation strategies that prioritize maintaining a rich diversity of tree species and structures within oil palm agroforestry landscapes can thus contribute significantly to bird conservation. As well, Razak *et al.* (2020) also showed that smallholdings with high oil palm productivity fostered significant avian species diversity and various feeding habits, demonstrating the beneficial association between habitat complexity and bird populations. High oil palm yield may indicate favourable conditions, such as adequate vegetation structure, sufficient food resources, and a relatively stable environment (Razak *et al.*, 2020). Next, Azhar *et al*. (2014) revealed that monoculture practices, characterized by the cultivation of a single crop of oil palm, can have distinct impacts on bird communities compared to polyculture practices involving the cultivation of multiple crops like bananas, coconuts, tapiocas, corns and sugar canes. Monoculture landscapes may limit the availability of diverse resources for birds, leading to a decrease in species richness. They added that polyculture practices, on the other hand, offer a more heterogeneous environment, providing a broader spectrum of resources crucial for supporting a diverse bird community. Integrating such findings into agricultural practices can help strike a balance between human needs and the preservation of avian biodiversity (Azhar *et al.*, 2014).

Numerous studies conducted in Malaysia have emphasised the beneficial effects of habitat complexity and variety on the composition of bird communities. Atikah *et al.* (2021) found that enhanced vegetation structure in hill dipterocarp forests with selective logging had a favourable impact on bird biodiversity. Furthermore, Shafie *et al.* (2022) noted that changes in habitat complexity in Terengganu's lowland dipterocarp woods resulted in variances in bird species distribution and abundance. Moreover, research has shown how critical habitat complexity is in supplying nutrients to bird populations. According to Razak *et al.* (2020), increased habitat diversity in agricultural settings can provide birds with better foraging possibilities by supporting a vast range of bird species and varied dietary guilds. Although there are typically favourable benefits of habitat complexity and variability in bird community composition in Malaysia, there are also adverse consequences related to ecosystem destruction and fragmentation. The destruction of habitat, which is a result of anthropogenic practices like deforestation and agricultural activities, is harmful to bird groups. Ismail *et al*. (2012) found less variety in the avifauna in the man-made Putrajaya wetlands, which are flanked by urban and farming areas. Similarly, Azman *et al.* (2019) showed that although supporting bird diversity, paddy fields in Peninsular Malaysia had fewer species than undisturbed native habitats. Birds' access to adequate nesting locations, food supplies, and secure shelter is limited by habitat degradation and dissipation which harms species diversity and population levels. Furthermore, modifications in the complexity of the ecosystem might affect bird populations by changing the microclimate. Rajpar and Zakaria (2015) showed that open-area and shrub areas exhibited distinctive microclimate features, affecting bird numbers and species diversity. Bird numbers, nesting success, and the capacity to locate food and shelter are all impacted by changes in daily temperature, humidity, and plant structure brought on by habitat changes. These results underline how crucial it is to preserve habitat complexity and reduce habitat

loss to guarantee the long-term survival of bird groups in Malaysia.

To sum up, habitat complexity demonstrated a vital role in shaping bird community structures. Various habitat attributes such as floristic structure, microclimate conditions, and specific habitat variables significantly influence bird species richness, abundance, and distribution since they can provide essential resources for nesting, feeding, and protection within the habitat. conservation initiatives should concentrate on protecting and rebuilding habitats with various structures and compositions to lessen the detrimental impacts of habitat loss and fragmentation on bird populations. To preserve robust and healthy bird populations in Malaysia, it is vital to promote habitat connectivity, safeguard crucial areas for avian biodiversity, and apply sustainable land utilization practices.

Recent Studies, Gaps, and needs on Avian Ecology in Malaysia

The bird population in Malaysia is remarkably diverse and is important to ecological research. The composition, number, and ecological roles of bird populations have been extensively studied in a variety of ecosystems in Malaysia. These findings highlight how crucial it is to preserve and comprehend bird groups to manage and conserve the environment. The selected 20 papers from 2012 to 2022 showed a variety of studies on bird ecology that focused on habitat complexity. Table S1 shows the ideas of critical thinking within the chosen papers.

It has been discovered that differences in vegetation systems have a major influence on the diversity and composition of bird communities (Amir *et al.*, 2015; Atikah *et al*., 2021). They highlighted the need for an understanding of avian responses to diverse environments considering not only land use but also specific structural elements within habitats. The link between bird richness and climatic attributes (temperature, humidity and wind patterns) and habitat factors (perching sites, nesting materials and foraging opportunities) has also been investigated, indicating the various impacts that various environments have on avian community structure (Rajpar & Zakaria, 2015).

But some research gaps must be studied. For instance, further research is needed to comprehend the impact of habitat complexity in altered landscapes like agricultural ecosystems (Kadir *et al.*, 2021; Atiqah *et al.*, 2019; Azhar *et al.*, 2024). Furthermore, little is known about how populations of nocturnal bird species react to habitat complexity (Yahya *et al.*, 2020). Further research is required to fully understand how habitat complexity affects bird populations specifically in fragile microhabitats like mangrove environments (Amir *et al*., 2015; Mohd-Azlan *et al.*, 2015).

Understanding the spatial dynamics of bird populations is crucial for effective habitat management and conservation, especially in landscapes undergoing rapid changes. Future studies could focus on incorporating more precise environmental variables, considering seasonal fluctuations and microclimatic conditions that may influence bird behaviour, breeding success and overall population dynamics by employing advanced modelling techniques and monitoring technologies to improve, predict and mitigate an effective conservation management strategy for bird populations (Rajpar and Zakaria, 2015; Martins *et al.*, 2021).

In summary, studies in the future should concentrate on longer observations to determine conservation measures and investigate spatio-temporal dynamics to narrow these gaps. The effect of habitat complexity on bird community structure across various habitats and land-use types must also be fully understood by requiring a multi-faceted approach, including advanced research methodologies, long-term monitoring, and a more nuanced understanding of the specific ecological processes influencing bird populations. Addressing these gaps will not only contribute to academic knowledge but will also enhance the effectiveness of conservation initiatives, ensuring the sustained health of avian communities in the face of environmental changes and anthropogenic pressures.

Prospective Conservation Management and its Conservation Implications

Future strategies that take habitat complexity and varieties into account are required for the conservation control of bird populations in Malaysia. By promoting a mix of local plant species, adopting varied crop structures and polyculture approaches to agricultural

landscapes can mimic natural habitats and then provide more suitable homes for avian species such as granivorous, fructivorous and insectivorous species (Azhar *et al.*, 2014; Atiqah *et al.*, 2019). Next, technology improvements provide conservationists with useful tools. Important information on habitat features, shifts in the landscape, and species dispersion may be obtained via remote sensing, GIS, and satellite imaging (Amir *et al.*, 2015; Atikah *et al.*, 2021; Martins *et al.*, 2021). Besides, Martins *et al.* (2021) and Azhar *et al.* (2014) added that sophisticated statistical techniques and occupancy modelling enhance and provide a robust framework for assessing habitat preferences, population trends, and the impact of environmental variables on bird species also aiding in evidence-based conservation decision-making. Moreover, conservation players or shareholders may acquire accurate knowledge of habitat complexity and prioritize conservation actions by fusing these technologies with field studies. Additionally, community involvement and citizen science programmes or online open crowd-source communities such as eBird, Inaturalist and BirdNet are essential for bird conservation (Puan *et al.*, 2019; Razak *et al.*, 2020). Other than that, the feeling of ownership and mutual accountability for habitat rehabilitation initiatives is fostered by engaging local people in bird population observation and monitoring as well as awareness-raising through educational programmes (Ismail *et al.*, 2012).

Marini *et al.* (2019) underlined the concept of species-habitat networks that emphasizes the interconnectedness of complexity of habitats with bird diversity and highlighted the need for a holistic approach to landscape management. They suggested establishing and preserving ecological corridors that link habitats that can facilitate the movement of bird species so it can enhance genetic diversity, reduces fragmentation, and provide birds with access to various resources throughout their life cycles. While Fraixedas *et al.* (2020) asked to strengthen a comprehensive bird monitoring program among scientists, conservationists, and citizen scientists to track bird populations, identify trends, and assess the impact of habitat management strategies because the continuous monitoring allows for adaptive conservation practices that respond to changing conditions and emerging threats.

In conclusion, ecological connection conservation, technology improvements, and local involvement are crucial for the management of bird conservation in Malaysia. Malaysia may increase habitat complexity and variability, eventually protecting its bird species, by embracing polyculture cropping, recovering ecological corridors, using technology for surveillance and empirical studies, and involving local people. By putting these strategies into practice, Malaysia may increase habitat variability and complexity, both of which have a favourable impact on the structure of bird communities and promote the long-term preservation of its avian biodiversity.

CONCLUSION

The complexity of the habitat is important in avian ecology study because it influences resource availability and interactions among species as well as biodiversity as a whole. By analyzing environmental characteristics like floristic composition and habitat heterogeneity, researchers may learn more about the interactions between birds and their surroundings. Future studies should focus on longer-term observations of the impact of habitat complexity on bird community structure across a range of habitats and land-use types to identify conservation priorities and fill in knowledge gaps. Moreover, a study into the functional relationships between bird species and their habitats, as well as the application of research findings in conservation contexts, will lead to an improvement in conservation and management techniques. Adopting sustainable land management practices, restoring ecological connectedness, utilizing technology improvements in monitoring and research, and encouraging citizen science and community involvement are potential strategies for managing bird conservation in Malaysia. Malaysia can work towards successful habitat management and the preservation of its abundant bird species by putting these future strategies into practice.

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