Review Article

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Winged Wonders and Lush Landscapes: Exploring the Harmony between Birds and Forests

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Abstract

Birds are essential bio- or eco-engineers that play a vital role in regulating nature, and their interactions with other environmental aspects can be complex and varied. Forests and birds are intricately intertwined. Through their mutual interaction, they create a harmonious living system that supports both parties. Forest birds play a crucial role in maintaining the balance of nature by dispersing seeds, pollinating flowers, and controlling insect populations. In addition to housing and food, forests offer bird's places to nest, wintering grounds, and thermal refuges. The diversity and distribution of forest birds are critical indicators of forest health and ecosystem function. However, factors such as climate change, habitat loss and fragmentation, and human activities profoundly impact the distribution and abundance of forest birds. Addressing these issues and taking action to mitigate their effects is essential. The forest ecosystem and its avian inhabitants can be protected by restoring degraded habitats, putting conservation practices into place, and promoting sustainable forestry practices.

Keywords: Birds, Bird Diversity, Forest, Winged Wonders

Background

Birds exist in all continents (except Antarctica), countries, and habitats. They are global, widespread, and adaptable species. According to the global abundance estimate report, approximately 50 billion individual birds live today [1]. More than 11,000 bird species exist worldwide, each with a distinct appearance, mannerisms, and geographic range [2]. Some birds have evolved to live in the harshest environments on Earth, while others have developed the ability to fly long distances to find more hospitable conditions [3]. In this instance, agree that most highland forest birds are typically sedentary [4]. They rarely relocate to another highland and prefer to remain in one place. On the other hand, Birds are naturally mobile and likely to live in habitats where they can find the resources they need to survive and reproduce [5, 6].

Forests cover a third of the Earth's land surface, but this area is dwindling. Deforestation caused us to lose 420 million hectares of forest between 1990 and 2020, an area nearly twice the size of France [7]. Thomas Crowther and his team used data from 429,775 ground-sourced measurements to create a global tree density map, published in the journal Nature in 2015. The study found approximately 3.04 trillion trees in the world, but this number is declining. Over 15 billion trees are cut down each year, meaning the global number of trees has fallen by almost half since the start of human civilization [8].

Forests have immense economic, cultural, and ecological significance in the lives of humans and other living things. For instance, UNESCO's World Heritage forests are a significant asset in the fight against climate change. They absorb approximately 190 million metric tons of CO_2 from the atmosphere annually, significantly contributing to global efforts to reduce greenhouse gas emissions [9]. Russia, Brazil, the United States, Canada, China, Australia, and the Democratic Republic of the Congo are the countries with the largest forest areas on Earth. Each country has forests covering more than 100 million hectares, which are essential for preserving the entire planet's biodiversity and controlling the climate [10]. Forests covering an area of 424 million hectares (nearly 10% of the world's forest) have been set aside to protect biodiversity worldwide [11]. This report indicates how conservation efforts are being challenged around the world.

Birds and forests are inextricably linked. Birds rely on forests for food, shelter, and nesting sites [12, 13]. Forests, in turn, benefit from birds' pollination, seed dispersal, and pest control services [14, 15, and 16]. The relationship between birds and forests is a delicate one. When forests are degraded or destroyed, birds lose their homes and food sources [17]. This can lead to population declines and even extinctions. The importance of forests to birds is essential. Forests are home to about three-quarters of all bird species and are the primary habitat for most bird species [18]. Birds have evolved to live in various habitats and use different foraging strategies [19]. This diversity is unmatched by any other terrestrial vertebrate, meaning birds can be found in forests, deserts, grasslands, mountains, and even the open ocean. They have also evolved to use various foraging strategies, from eating insects to catching fish to scavenging dead animals.

We provide a detailed examination of the relationship between forests and birds. We explore how forests provide birds with food, shelter, and nesting sites. We also discuss how birds help to pollinate plants, disperse seeds, and control insect populations (Figure 1). We use a technical approach to our analysis and draw on the latest scientific research. We also provide practical recommendations for how to protect forests and birds. We aim to provide a comprehensive and informative resource for scientists, practitioners, and anyone interested in the relationship between forests and birds.

Further, we explore different contributing factors to the nexus in both positive and negative sides, including distribution, forest cover change or fragmentation, and seasonality within the habitat. The relationship between forests and birds is complex, and there are many factors to consider. This review covers a wide range of topics, from the ecological benefits that birds provide for forests to the needs that forests have for birds to survive.

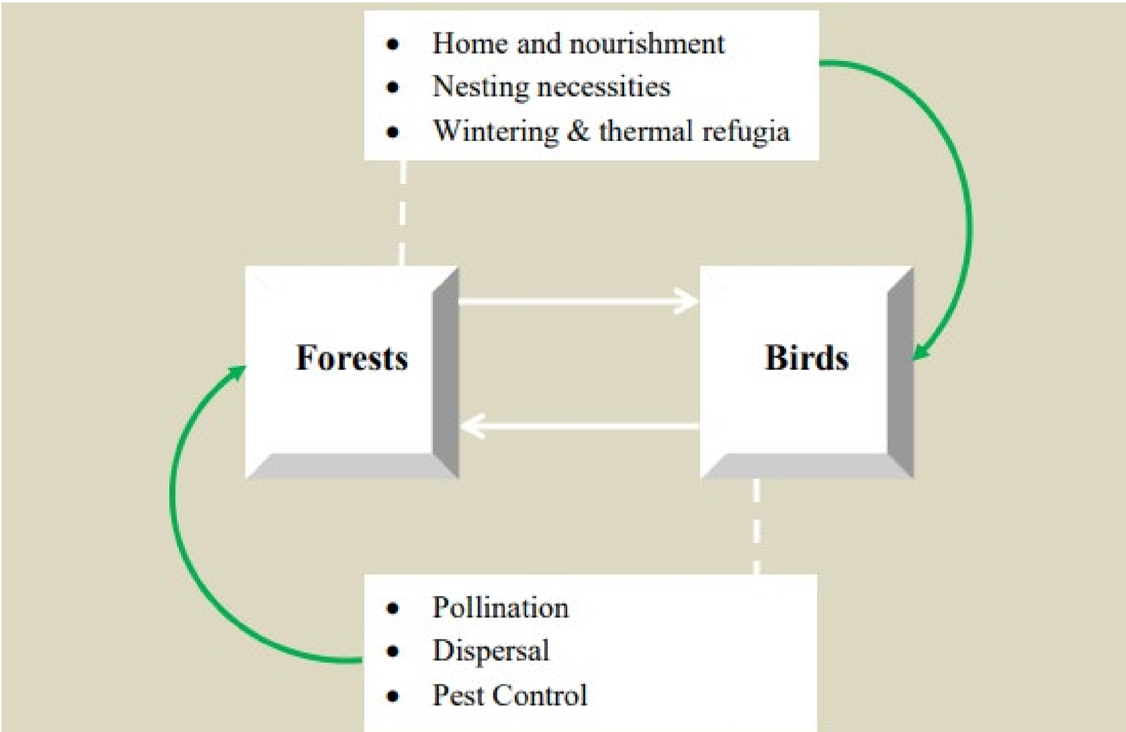

Figure 1: Harmony (two-way street) between Birds and Forests.

Birds Influence Forests

Pollination Agents: Birds are critical plant pollination agents. The pollination process involves transferring pollen from the male reproductive organ of a flower to its female counterpart [20]. This process is essential for plants to reproduce. Plants can be pollinated naturally by birds, insects, and other animals. However, studies confirm that birds are more effective and steadfast pollinators than insects and other animals for different reasons. According to one reason for this is that birds are less sensitive to changes in climate and flowering season [21, 22]. Insects are often affected by changes in temperature and humidity, but birds are less reliant on these factors. Birds can still pollinate plants during unpredictable weather or short flowering seasons. Another reason why birds may be more reliable pollinators is that they fly further between plants than insects. They are more likely to transfer pollen between different plants, which can increase the chance of outcrossing. Plants have also evolved various adaptations to attract and favour certain pollinators over others. These adaptations can involve the colour, shape, and size of flowers and the production of nectar and pollen [23]. For example, hummingbird-pollinated flowers often have long, tubular corollas designed to fit the hummingbird's beak [23, 24]. These flowers also produce a lot of nectar, a high-energy food source for hummingbirds.

Dispersal Agents

Seed dispersal is an essential process in plant ecology. It helps to ensure that plants can reproduce and colonize new areas [25]. Birds are vital in spreading seeds in forested ecosystems due to their abundance, diverse plant interactions, and mobility [26]. Birds disperse seeds through two main mechanisms: endozoochory (birds eat fruits and then pass the seeds in their droppings) and epizoochory (seeds stick to the feathers or fur of birds). Both endozoochory and epizoochory are important mechanisms for seed dispersal by birds. Endozoochory is more common, but epizoochory can be important for plants that grow in areas with few fruits [27, 28].

The success of seed dispersal depends on both the type of disperser (such as birds) and the characteristics of the seed being dispersed. Several studies have examined the impact of body mass on seed dispersal effectiveness (SDE) in birds, but further research is necessary to comprehend this correlation fully. In line with this, Godinez-Alvarez and his colleagues unveiled through their study of the effect of body mass on seed dispersal effectiveness that small and medium size birds are relatively more effective seed dispersers when compared to the larger ones. One possible explanation for this is that the former is typically more prevalent in various habitats and less vulnerable to human impact [25]. However, found that larger birds are more effective dispersers than smaller ones [26]. Larger birds consume more fruits, increasing their chances of encountering diverse seeds. They also tend to have more robust digestive systems, which mean that they are more likely to be able to disperse seeds of a broader range of sizes. Additionally, larger birds are more likely to be able to fly long distances, which enable them to spread seeds to new areas. Studies have shown that even migratory birds, no matter their size, can transport seeds over long distances. According to this process enables the spreading seeds from the mainland to oceanic islands, colonizing new habitats and promoting biodiversity [27, 29].

The size and composition of fruits can also affect the number of potential seed dispersers a plant possesses. A wide variety of birds typically eats small fruits and large, soft fruits with many tiny seeds, whereas Larger, larger-seeded fruits are typically eaten by fewer birds [30]. This is because the former is easily digestible, and their seeds are small enough to pass through the digestive system without any harm. On the other hand, the latter are harder to digest, and their seeds are larger and more formidable [31]. As a result, only a small number of bird species, mainly larger ones, can effectively spread these seeds.

Insect Control

Birds are a natural enemy of phytophagous insects. They eat these insects, which helps to reduce their populations. A recent study found that birds consume between 400 and 500 million metric tons of insects yearly [32]. This can help reduce the amount of leaf damage these insects cause and lead to increased plant growth [33, 34]. Studies have proven that insect-eating birds are useful for managing insect-related harm to commercially valuable trees [35, 32]. The research was carried out in Costa Rica, a country where coffee is a major crop. The researchers found that coffee plantations with more birds had lower levels of insect infestations [14, 36].

Forests Influence Birds

Home and Nourishment: Forests provide birds with the home and nourishment they need to survive. The diversity of trophic levels that birds occupy is a testament to their adaptability and importance to the forest ecosystem. Some birds, such as warblers, are primary consumers that eat insects. Other birds, such as hawks, are secondary consumers that eat other birds. Still, other birds, such as owls, are tertiary consumers that feed on small mammals. The number of different bird species, the number of individuals of each species, and the breeding success of birds can all be affected by food availability [37].

Birds, as primary consumers, obtain nutrients from a variety of sources, such as nectar, fruits, seeds, and vegetative tissues (including roots, shoots, and leaves). Most forest birds are generalists, able to eat a variety of foods. Only a few species are dietary specialists, relying on a narrow range of food sources [38]. Birds generally prefer food items that they can process quickly. In other words, birds are more concerned with how quickly they can digest and absorb food than with the nutritional value of the food [39]. This is because birds need to eat frequently in order to maintain their energy levels. If they have to spend a lot of time processing food, they may need more to eat to meet their energy needs.

The diets of herbivorous birds are typically based on seeds (granivory) and fruit (frugivory), with other foods being eaten less frequently. The starches in seeds are a good source of energy for birds, and granivorous birds have adapted to efficiently digest and absorb these starches, and there are over 1,000 different species of birds that are primarily granivores, and they can be found all over the world [18]. The way that birds choose food suggests that the evolution of bird granivory has focused on developing physical adaptations for mechanically digesting seeds, while chemical adaptations for digesting seeds have been less important [39].

The majority of nectarivorous birds (approximately 600 species) are found in the tropics, where there is a year-round abundance of flowering plants [40, 18]. Nectar is a good source of energy for birds, but it is not very filling. This means that birds need to eat a lot of nectar in order to get enough energy. However, nectar is also a low-volume food, so birds need to visit multiple flowers in order to get enough nectar [41, 42].

Frugivory is a common feeding behaviour in forest birds. About one in seven bird species are frugivorous, supported by forest ecosystems [18]. Frugivorous birds eat the fleshy part of fruits, which is often the most nutritious part of the fruit. The seeds are usually discarded, but they can also be eaten by some frugivorous birds [43]. The availability of fruit is highest in tropical rainforests, which are located near the equator and have a warm, wet climate [26]. This is because the warm, wet climate is ideal for fruit production. The trees in tropical rainforests produce a wide variety of fruits throughout the year, which provides a reliable food source for frugivorous animals. Fruit availability is greater in gaps, such as tree-falls, in both temperate and tropical forests [44]. In temperate forests, gaps are often created by windstorms or ice storms. In tropical forests, gaps are often created by tree falls or by clearing land for agriculture.

The montane forests of mosaic montane landscapes in highland areas are rich in bird diversity. These areas are subject to conservation actions, as they have many restricted ranges and globally-threatened montane bird species [45]. To this end, the highland forest habitats, afro-alpine, sub-afro-alpine, or highland montane forests, are enormously rich in avian diversity and endemism. In several cases, the highland forest habitats host all bird species from sedentary, migrant visitors, over-flying raptors, water birds, and omnipresent birds of the open land [4].

Nesting

Forests provide a variety of nesting sites for birds, which allows different species to find suitable places to raise their young. Nests can be found in all layers of a forest. This is because different species of birds prefer different nesting sites. Some birds, such as robins, prefer to nest on the ground, while others, such as warblers prefer to nest in shrubs [46, 47, 48, 49, and 50]. Again others, such as woodpeckers, prefer to nest in tree cavities [51, 52]. The type of nesting site that a bird chooses is often influenced by the availability of food, predators, and other factors [53, 54, 55, and 56]. For example, birds that eat insects are more likely to nest on the ground, where they can easily find food. Birds that are preyed upon by other animals are more likely to nest in trees, where they are less vulnerable to predators. Generally, the variety of nesting sites that forests provide is important for the overall health of bird populations.

Wintering Sites and Thermal Refugia

Forests are important stopovers and breeding habitats for migrating birds in all major flyways. The importance of forests for migrating birds is especially evident in major flyways, the routes that migrating birds follow between their breeding and wintering grounds [57]. Without forests, many migrating birds would not be able to survive their long journeys. The studies show that riparian forests are an important part of the urban landscape for bird conservation. Riparian forest parks that are surrounded by urban development can provide a more favourable habitat for wintering birds than similar forests in more rural areas [58, 59]. This is because urban areas often have more food resources available for birds, such as discarded food from people and bird feeders. Moreover, urban areas also tend to have milder winter temperatures than rural areas, which can make it easier for birds to survive the winter. On the other hand, many studies have shown that the forests in more rural areas are often under threat from deforestation and human disturbances [60, 61, 62, and 63]. This is especially true for tropical rainforests, which are being cleared at an alarming rate. As a result, these forests are becoming less and less suitable for migrating birds to winter. As tropical forests are cleared, there is less available habitat for migratory songbirds. This forces them to winter in agricultural and disturbed habitats, which are often not as good for them as natural forests [64].

Forests provide microclimates that are safe havens from physiologically challenging temperatures [65]. Forests have a variety of factors that can moderate temperature, such as tree cover, shade, and moisture. The understory of tropical forests is often a very stable environment, with little variation in temperature. The consequences of the lack of microclimate variation in the understory of tropical forests for understory insectivores are serious [66]. As temperatures rise, these avian species may be unable to maintain their body temperature, which could lead to decreased fitness and even extinction. It is important to study the effects of climate change on understory insectivores and to take steps to mitigate these effects.

The study conducted in New Zealand shows that the effects of warming climate on predator-vulnerable species are likely to be negative, whereas small-bodied, non-cavity-nesting, mobile species are more likely to be able to adapt to warmer temperatures [67, 68]. Accordingly, as the climate warms, Predator-vulnerable species may be unable to find enough cool thermal refugia to maintain their body temperature. This could lead to decreased activity, reduced reproduction, and even death. However, warming is unlikely to jeopardize small-bodied, non-cavity-nesting, mobile species. These species are often able to adapt to warmer temperatures by changing their behaviour or diet. For example, they may be able to move to cooler areas or eat different types of food. Overall, thermal heterogeneity and thermal refugia are both important for the survival and diversity of species. By providing a variety of temperature ranges, they allow different species to find suitable habitats [69, 65]. This is especially important in a changing climate, when species may need to move to cooler areas to survive.

Diversity and Distribution of Forest Birds

Forests are the essential habitat of avian species. The lives of forest-dwelling birds depend on the forest ecosystem, either fully or partially. Forests provide birds with shelter and nourishment, nesting sites, wintering sites (habitat for migratory birds), and thermal refugia [70]. The diversity and distribution of avifauna in the forest vary according to forest type and location, particularly the elevational ranges on which the forest occurs. Recently, Chinese researchers researched the phylogenetic and functional diversity of understory bird communities in Chinese forests. Thus, they reported that phylogenetic diversity was negatively related to elevational gradient, whereas functional diversity was negatively linked to current temperature and rainfall [71].

The natural forest harbours higher species richness (higher number of birds) and is relatively more abundant than plantation forests. Heterogeneous habitats can assist the multi-diversity of avian species more than those roughly homogeneous [72]. Have studied the diversity, richness, composition, and abundance of avian species in intact forests, cultivated land, and open land in south-western Ethiopia [73]. In view of that, they found a strong positive statistical correlation between avian mean taxonomic diversity and forest habitat. Hence, maintaining and preserving large natural forest areas has great implications for conserving the diversity of forest birds [74].

Besides, the uppermost diversity of birds occurs in lowland tropical and sub-tropical forests near the equator but declines towards the pole [75, 70]. Elevation, one of the topographic factors, brings a change in microclimate, which significantly affects the vegetation cover of the area. Such a trend causes a potential change in the distribution and abundance of avifauna. Accordingly, as altitude decreases, the richness and abundance of birds increase due to habitat heterogeneity in lower altitude areas [72]. After all, forest habitats, especially natural forests, usually consist of the highest diversity and abundance of birds compared to wetlands and farmland habitats. This is believed to be because forest areas are more stable and undisturbed than wetlands and farmland habitats [2]. Forests are the primary habitat for most bird species, making them a potential home for approximately 75% of all bird species [18].

Factors Governing Distribution and Abundance of Birds

The distribution of birds across the globe is uneven and is determined by various factors. A habitat's vegetation structure affects the distribution and abundance of birds. The healthy, structured vegetation alongside complex habitats provides species with mature trees and fruit-producing shrubs [76]. The type and density of vegetation coverage in an area is a deterministic factor that influences bird species distribution and abundance [77]. Though different from habitat to habitat and species to species, food supply and relative humidity seriously affect the distribution and abundance of bird species in a given locality. In a geographically and structurally similar habitat, atmospheric moisture would indicate avian community composition [78].

In several cases, the area's characteristics, such as rainfall, temperature, tree density, floristic composition, and geographic situations, are greatly responsible for determining avian species' whereabouts and relative abundance [79]. Furthermore, farmland bird species' abundance and distribution can be affected by various factors. These include field size, diversity of crops, and the presence of semi-natural habitats such as hedgerows. According to a report by, the variation in bird species distribution and diversity is subject to cropped and un-cropped fields [80]. Thus, a cropped field with high crop diversity and an un-cropped field including edge habitats and ditches support a greater diversity of bird species in terms of diversity, richness and abundance. Cultivated areas with a large patch size of habitat can also support high avian species in terms of species richness, and abundance [81]. The human settlement also has positive and negative effects on the lives of birds [82]. In remote rural areas, settlements (moderate housing density) are regarded as patches and edge habitats harbouring several avian species [83]. Overall, access to and availability of food, vegetation composition, and seasons are the main determinants of avifaunal communities' species richness, abundance, diversity, and distribution pattern in a given habitat or ecosystem [84].

Forest Cover Change and Fragmentation Effects on Forest Birds

Forest cover is an essential feature of landscape structure manifested through vegetation [85]. Forest cover changes and fragmentation or patch sizes significantly affect forest bird distribution. The research in Canada revealed that a decrease in forest cover ultimately leads to the loss of the entire forest. The effect will be incomparable with the 'fragmentation effect' [86]. The fragmentation effect is everywhere, posing several patch sizes to decline; hence, conservationists should focus on more than those patch sizes rather entire forest cover [87]. Many scholars, including, also argue that woodland configuration, as an independent component of forest cover, should be incorporated into conservation strategies for it can persistently support many bird species [85].

Have put a spatial hierarchy for forest fragmentation effect on bird species distribution and abundance in their studies of birds of eastern forest in North America as regional, landscape, and local scale fragmentation [88]. The regional or biogeographic effect considers the relationship between prey and predator and land-use changes. Fragmentation is responsible for changes in bird species' productivity and abundance. Moreover, the rural settlement expansion has extensively exacerbated the local forest patches subject to a greater fragmentation effect [83]. When it comes to these situations, forest habitat specialists' birds are substantially influenced.

The extent of forest cover and populations of forest bird species are positively correlated [89]. In certain critical conservation hotspots, vulnerable bird species require a wide-ranging forest cover to persevere when setting conservation strategies [90]. To enhance the positive and increased relationship between the extent of forest cover and populations of forest bird species, changes in land use and management are critical [89].

The contribution of forest fragmentation to bird species decline, and loss is far-reaching. The study in Brazil reveals that the population proportion of bird species, particularly granivores, demonstrated a significant decline with an increase in fragment or patch size [91]. In support of this, suggested that such incident of species condition with fragment or patch sizes depends mainly on the species' sensitivity to forest conversion and fragmentation [92]. In this instance, the proportion of richness and abundance of less sensitive species decreased as forest cover (fragment size) increased, and the reverse is true for more sensitive ones. Patch size and isolation negatively affect bird species diversity and abundance [93]. Moreover, habitat with native vegetation cover is richer and more abundant than other land-use types such as agricultural lands, but in the case of the large vegetation cover conversion into agriculture (as in Argentina), many bird species, particularly raptors, decline due to harmful farm activities and pesticides [94].

As a result, birds of forested lands are encountering increased habitat loss from indiscriminate destruction of forest cover through anthropogenic disturbances, including expansion of unsustainable agriculture, illegal settlements, and expansion of grazing lands [95, 96].

Habitat and Seasonal Variations

The composition of bird communities varies depending on the type of habitat. In a study conducted by, it was found that the composition of bird species communities is influenced mainly by floristic composition and less by physiognomy [97]. Thus, bird richness and abundance are considerably associated with vegetation composition, which is the basis of habitat classification [81]. Some other scholars also agree that vegetation cover and structure create substantial variations between avian communities of different habitats or land-use types. Have compared avian community assemblage and association of protected and unprotected montane grassland ecosystems in Bale Mountains National Park (BMNP) [98]. The report concluded that variations in avian communities between the two land-use types (protected and unprotected) are due to the difference in vegetation structure.

The abundance and availability of food vary with season, significantly affecting avian species' distribution patterns and breeding cycles. It has also been suggested by that fruits and the abundance of insects determine the distribution and breeding of common birds [44]. Fruits are most abundant during the mid-to-late rainy season, and crop sizes are larger in the late rainy season; hence, the spatial and temporal variation pattern in birds' activity depends on the availability of food resources.

Climatic variability is the most substantial factor demonstrating a spatial pattern of avian species distribution and abundance in the tropical rainforest. Many bird species experience population declines or limitations due to changes in resource availability caused by climate change and variability [99]. In 2009, Schrag et al. utilized land use and climatic factors as predictors to forecast species' diversity, abundance, and distribution in different types of land use and seasons. The diversity of species and their makeup are affected by changes in temperature and rainfall across the area.

The extent of seasonality caused by global climate change has reasonably increased in the past decades, resulting in bird abundance decline, range sizes, fragmentation, and patchiness [99]. In such circumstances, species with high phenotypic and genotypic adaptability, high dispersal capability, low ecological specialization (generalists), and large population and range sizes are more advantageous than species with no such qualities [100]. Contrary to this, the study revealed that the species' survival could not be fail-safe by merely possessing the potential qualities indicated above. The study by analysed the impact of the Southern Oscillation Index (SOI) on the survival of tropical bird species in north-western Costa Rica [101]. The study evaluated the effects of SOI on local temperature and rainfall at different time intervals to determine its impact on the sex-specific survival of the bird. After careful analysis, they came to the conclusion that a further increase in temperature could pose a severe threat to the survival of local bird populations, even those that have already adapted to hot environments unless there is a shift in species distribution. The fact that certain species have better adaptability and related behaviours does not guarantee that they will be able to survive the increased seasonality caused by global climate change. Other alternative rescue measures plan out otherwise.

Concluding Remarks

The interaction of birds and forests is an alluring and complex relationship encompassing various elements that call for more research and conservation efforts. Forest birds, with their varied colors, songs, and behaviors, contribute to forest ecosystems' rich tapestry of biodiversity. These birds can be found in different habitats and regions, adapting to specific niches and ecological conditions. The diversity of forest birds not only adds to the aesthetic appeal of forests but also plays a crucial role in pollination, seed dispersal, and insect control, promoting these ecosystems' overall health and functionality.

Many factors influence forest birds' distribution and abundance, including habitat suitability, resource availability, climate, and human activities. Furthermore, habitat and seasonal variations also play a crucial role in shaping the dynamics of forest bird populations. Birds exhibit different habitat preferences during different seasons, with some species being migratory, traveling thousands of miles to access suitable breeding or wintering grounds. Understanding these factors and variations in habitat use and behavior allows us to accurately predict and monitor bird populations, aiding conservation efforts and formulating effective management strategies. However, forest cover change and fragmentation pose significant challenges to forest bird populations. Human activities such as deforestation and land conversion disrupt and degrade their habitats, leading to habitat loss and fragmentation. These changes can result in the isolation of bird populations, reduced gene flow, decreased availability of food and nesting sites, and increased vulnerability to predators. As a result, forest bird populations may decline or become locally extinct, disrupting the subtle balance of forest ecosystems.

To safeguard the harmony between birds and forests, conservation efforts should focus on preserving and restoring forest habitats, minimizing habitat fragmentation, and promoting sustainable land-use practices. By adopting an integrated approach that considers ecological, social, and economic aspects, we can strive to maintain the restrained balance between forest birds and the splendid landscapes they call home.

Data Availability

All data generated as bibliography in this study were retrieved from online sources.

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