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Understanding the Effect of Climate Change on Migratory Birds: A Review

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Abstract

Climate change is being referred to as a global plague and has significant negative consequences on the world's economic, social, and ecological systems. Extreme weather consequences like drought, floods, and heat waves have had unprecedented occurrences and have had substantial effects on animals and plants. Climate change significantly influences animal phenologies, such as bird arrival and egg-laying times. As a result of these present and future climate change impacts, species interactions with their local environment are anticipated to change, resulting in changes in population size, range extent, and extinction rates. The current review discusses the effect of climate changes on migratory birds and concludes that climate change is one of the most serious dangers to world ecological systems, as indicated by the numerous ecological impacts imposed by changing climate on migratory birds. Climate change significantly affects breeding strategies, migration, distribution, latitudinal or altitudinal shift, community structure change, morphological change, and elimination or extinction of migratory birds. The current review attempts to communicate research and advances in the effect of climate change on migratory birds to different actors in society, including researchers, conservationists, practitioners, and policymakers.

Keywords: Breeding; Migration; Distribution; Shifts; Community; Morphology; Elimination; Environment

Introduction

Climate change is referred to as a global plague [1]. The average worldwide temperature rise during the previous century was around 0.6-0.8°C, and the worst-case scenario predicts that by the end of the twenty-first century, the average global temperature rise will be 4.8°C [2]. This rise in global temperature is due to a variety of human economic activities that produce greenhouse gas emissions [3]. Climate change has significant negative consequences for the world's economic, social, and ecological systems [4]. Extreme weather events such as drought, floods, and heat waves, for example, have had unprecedented occurrences and have had significant socioeconomic effects on humans [4].

Climate change also has a significant influence on plant and animal phenologies [5], such as affecting bird arrival and egg-laying times [6]. As a result of these present and future climate change impacts, species' interactions with their local environment are anticipated to change, resulting in changes in population size, range extent, and extinction rates [7,8].

Climate change, in general, is one of the most serious dangers to the world's ecological systems, as indicated by the numerous ecological impacts imposed by changing climate. Drought-induced fire [9], floods [10], ocean acidification [11], melting of sea ice and sea level rise [12], heat waves [13], and diseases [11] are some of the effects of climate change on plants, human and animal populations [14]. In short, climate change has a wide range of effects on biodiversity. As a result of climate change, substantial evidence of climate-induced distributional shifts in birds has been observed in recent decades [15,16]. However, there is a paucity of literature on the effect of climate change on migratory birds. The current review aims to examine some of the major effects of climate change on biodiversity, with a focus on migratory birds.

Effect of Climate Changes on the Migratory Birds

Effect on Breeding Strategies

Many pieces of evidence imply that many species' phenology is altering as a result of climate change [16]. For example, a study of 65 species of UK birds found that between 1971 and 1995, 31% of species were observed to lay eggs an average of 8.8 days sooner [17]. Furthermore, between 1939 and 1995, Crick, et al. [18] discovered earlier egg-laying dates in 53% of birds, concluding that this tendency is driven by an increase in temperature. Dunn, et al. [19] conducted another phenological investigation in America and Canada, finding that Tree Swallows (*Tachycineta bicolor*) lay eggs nine days ahead of schedule for 32 years. Additionally, large-scale research in Europe found that flycatcher (*Muscicapidae*) egg-laying dates were earlier in locations where there was a larger increase in temperature [20]. The research examined the reproductive phenology of Great Tits (*Parus major*) in the United Kingdom over five decades, from 1961 to 2007, and discovered that these birds deposited eggs 14 days sooner than their regular egg-laying periods [21]. Further research looked at when the Blue Tit (*Cyanistes caeruleus*) and Great Tit (Parus major) laid their first egg during 30 years in response to spring temperature and discovered that these species pushed their egg-laying date by 11-12 days [22]. Furthermore, 20 years of real-time monitoring on Blue Tits (*C. caeruleus*) revealed that their breeding advanced by 0.41 days per year [23], and an analysis of the breeding cycle of Eurasian Reed Warblers (*Acrocephalus scirpaceus*) revealed an 18-day shift in first egg date due to increased temperature [24]. The progression of prey phenologies, such as the availability of plentiful insect larvae that are crucial for raising nestlings, is one of the mechanisms prompting animals to modify their breeding season in response to rising temperatures [25,26]. Absence or lack of temporal concurrence (asynchrony) may develop when the temperature rises. Plants, for particular, may blossom sooner, causing insect larvae to become a plentiful food source earlier, making them less coordinated with bird breeding periods [26].

Effect on Migration

An increasing body of research suggests that changes in bird migratory phenology in response to climate change are reflected in advances and delays in arrival and departure dates [27-30]. In terms of migratory patterns, synchronisation of migration time with the accessibility of seasonal supplies is an essential characteristic that helps birds survive. This is because the fundamental element prompting birds to migrate is seasonality in resource availability [31]. Climate change has resulted in a mismatch between birds' migration phenology and food availability, leading to a 90% reduction in many populations of Eurasian Pied Flycatcher (*Ficedula hypoleuca*) [25]. This climate-driven mismatch has detrimental implications, including decreased reproductive success and population shrinkage [32,33].

In response to global temperature change, many species move geographically [6,16,34]. Despite significant variability in bird migratory phenologies, research has shown that arrival and departure times have shifted in recent periods of global warming [35]. A phenological analysis of the mean spring passage time of 24 long- and short-distance migrants, for example, indicated a progression of spring passage time ranging from 1 to 7 hours each year [36]. The influence of the high North Atlantic Oscillation (NAO) detected throughout the research was responsible for this development. On the other hand, in research that looked at the initial arrival dates of six long-distance migratory trans-Saharan birds, Gordo, et al. [37] found that all species had a delay in spring arrival dates, with the Common Nightingale (*Luscinia megarhynchos*) having the longest delay of 8 days every year. The study concluded that the climatic conditions in these species' wintering grounds (Southern Africa) were likely to increase the availability of food sources and postpone their departure dates. As a result, changes in migratory phenology caused by climate change can be linked to changes in biodiversity.

Effect on Distribution

Among the key variables that determine species distributions are land-use change, habitat alteration, interactions among species, and adaptations to environmental changes [38-40]. Furthermore, global climate change has been shown to have a significant impact on the range limits of species throughout their distributional gradients [15,41,42]. Climate change causes species to migrate to higher elevations and latitudes [16]. Understanding why species experience these latitudinal and altitudinal shifts is critical for predicting climate change's impact on biodiversity. Although the main tendency of distributional changes is towards higher altitudes and latitudes, species demonstrate a variety of reactions [43]. These disparities in species' reactions to climate change might be due to a variety of causes. Spatiotemporal changes in climate change might be regarded one of the most significant factors [44,45]. Furthermore, certain species may adapt swiftly to climate change consequences while others may take longer [46,47].

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Furthermore, non-climatic variables may modify species' reactions to climate change. Species can migrate downward slope to meet ecological demands, such as water [48], or to take advantage of the decreased rate of competition in their ranges [49]. This is because species at lower elevations in mountainous locations have wider range sizes than those at higher altitudes [50]. Ecological interactions, such as changes in phenology and microhabitats of species, as well as evolutionary adaptations [6,16], may also explain variances in the degree and extent of variation in range shifts across species. Significantly, if climate change is not the primary driver of species' latitudinal and altitudinal changes, land use change caused by agricultural and industrial activities can induce species to move in several directions rather than moving straight to higher latitudes and altitudes [47].

Effect on Latitudinal Shifting

Species ranges are ever-changing [5]. Birds' latitudinal ranges have shifted as a result of climate change [51,52]. Lower-latitude species travel to higher latitudes to track their appropriate climatic niches in response to the influence of climate change. This climate-driven change in bird distribution has been well documented. For example, in the last 20 years, the northern borders of southerly bird species in the United Kingdom have shifted North by an average of 18.9 kilometres. McDonald, et al. [51] found that birds in eastern North America moved northward in response to a 1.3°C rise in regional temperature between 1966 and 2010. This is because temperate species' cold limits may respond to the direct effects of temperature fluctuation faster than warm species' warm boundaries. Similarly, the northern latitudinal border of some bird species in the United Kingdom [53] and North America [54] mirrored winter temperatures in these areas. Between 1990 and 2008, a community composition analysis revealed 37 and 114 km northward movements in birds and butterflies, respectively, at the European scale [55].

To monitor favourable circumstances, species are shifting their ranges by varying geographical extents and magnitudes in response to climate change [6,56-58]. For illustration, a global review of the impact of climate change on 273 plant, bird, mammalian, and marine invertebrates found that 54% of bird species migrated in various directions in distinct geographic zones [59]. A species distribution modelling investigation of the possible ranges of 431 European birds revealed a change in the average range of centroids of 258-882 kilometres [57]. Furthermore, various taxonomic groupings have shown varied rates of range extension [16]. For instance, climate change effect research in the United Kingdom that included data on lesser-known vertebrates and invertebrates found rates of northward and upward range boundary expansions ranging from 1.37 to 2.48 km per year [56]. However, it is not just environmental factors that cause species to shift their ranges, but also their other characteristics, for example, colour and morphology [60,61].

Effect on Altitudinal Shifting

Shifts in altitudinal range limits as a result of climate change have been a typical occurrence in recent decades. Altitudinal shift research on European breeding birds indicated that climate change is the principal driver driving birds upwards in elevation to name a few studies [62]. Climate change may be a factor pushing species to migrate to higher elevations, according to another case study on Spanish passerines [63]. A worldwide survey of 4978 terrestrial bird species found significant elevational temperature gradients in most regions of the world, except Australasia, insular Indo-Malaya, and the Neotropical lowlands, where the gradients were weak [61,64]. Because climate change can affect species to the point of local extinction in mountains with a large number of endemic species with narrow elevational ranges [65-68], understanding this altitudinal shift is critical for managing and conserving species. Mountains are also distinctive in that they are home to a high number of species with limited ranges. High mountain species will have a stronger inclination to go up towards the peaks when environmental circumstances change, to the point where they will be left with nowhere to go [69].

Climate change's effects on birds' migratory and reproductive phenology, as well as latitudinal and altitudinal range changes, influence the makeup of their communities and demographic rates [70]. In general, understanding organisms' ability to shift into their climatically preferred niches is beneficial to conservation because it provides information on the likelihood of extinction, extirpation, or range reduction of species [71], as well as potential changes in community composition [72,73].

Effect on Community Change

There is currently inadequate research available to highlight the effects of simply climate change in explaining spatiotemporal changes in species and community makeup. Instead, it has been discovered that the synergistic impacts of climate change with other variables have a significant influence in determining these compositions [74]. Nonetheless, studies have been conducted that show shifts in species composition as a result of organisms' responses to changing environmental circumstances. Dornelas, et al. [75] reported a multi-taxon worldwide analysis of 35,613 species from all biomes, including birds, fish, mammals, invertebrates, and plants, which revealed changes in species composition from 1870 to the present. Climate change, according to this study, might be one of the causes causing the shift in species composition in the terrestrial, marine, and freshwater biomes studied across time [75]. Climate change is known to affect bird demography, causing population levels to shrink over time [76]. As a result of this loss, species may become more sensitive to the effects of climate change [77,78]. The influence of temperature on bird communities was shown in research that looked at the change in species composition in European short- and long-distance migrants and residents between 1980 and 1990 [79]. The number and proportion of long-distance migrants decreased as the temperature rose; however, the number and proportion of short-distance migrants and residents grew. Short-distance migrants and residents benefit from fewer extreme temperatures, but long-distance migrants face a serious hazard from exceptionally warm winters [79]. Emperor Penguins (*Aptenodytes forsteri*) saw a significant reduction in mating pairs in Terre Adele, Antarctica, from 6,000 to 400, according to modelling research that looked at long-term population data (1962–2100) and the amount of sea ice [80]. Similarly, in a long-term investigation of changes in migration phenology of 100 migratory species in central Europe and Fennoscandia, Moller, et al. [81] found that species that failed to extend their spring migration timing had a drop in population size. Those species that progressed their migratory phenology between 1960 and 2006, on the other hand, saw an increase in population size. However, mistiming due to the synchronicity issue between migration and changing food availability in response to climate change can lead to low reproductive success in maintaining the population [25]. Furthermore, Pearce-Higgins demonstrated the impact of temperature and precipitation on variations in the abundance of 59 English bird species. A rise in spring and summer temperatures, in particular, has a severe impact on specialised species like the cold.

Effect on Morphology

Global patterns of variation in bird growth within species can be used to make predictions about how climate change would affect growth-related features [82]. Two hypotheses can explain the observed variance in endotherm body size responses to climate change: size rises with climatic variability (the hunger resistance theory) and size declines as mean temperatures rise (the heat exchange hypothesis), according to Gardner, et al. [83]. Even though not universal, the loss of species' body size as a result of climate change is a common occurrence [84-86]. Understanding the evolution of physical traits in birds aids in the identification of patterns of regional variation in body size. Furthermore, size dimorphism is important in the research on body size variation in response to environmental influences [87]. Variations in climate change, food availability, habitat appropriateness, and latitude are among these influences [88]. Changing body size can happen over time as a result of climate change [85]. For example, a long-time series of wing measurement data on 2,702 Citril Finches (*Carduelis citronella*) in the Pre-Pyrenees, Spain, revealed an increasing trend in wing length in relation to body size with increasing winter temperature, implying that this result is an adaptive response of the species to changing climate [89]. However, research including over 4,500 specimens of 11 bird species collected in central Germany and the Fennoscandia area between 1889 and 2010 found no clear trend in changes in physical features examined [90]. The lack of continuous change in morphological features through time, according to this study, may not be compatible with the concept that climate change is causing creatures to shrink in size. Salewski, et al. [91] found an inconsistent pattern of change in morphological features of European Stonechat (*Saxicola torquata*) with rising temperatures from 1989 to 2012, suggesting that the concept that climate change affects species body size is unclear. Similarly, Kruuk, et al. [92] found that different climatic factors had different effects on morphological features in Superb Fairy-wren (*Malurus cyaneus*) chicks in South-eastern Australia between 1988 and 2013. However, ecological laws play a vital role in characterising the ecology of organisms in their natural settings. Because of their thermoregulatory requirements, species in warmer geographic zones are smaller, according to Bergmann's rule [93]. A study of 94 bird species and 149 mammal species to support this rule found that resident species obey the rule more than migratory species [94]. Fasting endurance is one putative mechanism underpinning this rule, in which big species have a greater percentage of energy storage than small animals [95,96]. Another probable reason is that smaller bodies lose more heat and larger bodies save more heat, which gives a thermoregulatory advantage in hot and cold regions, respectively [85].

Conversely, recent research comparing the body masses of eight female and nine male House Sparrow (*Passer domesticus*) populations in Finland between 1984/85 and 2009 revealed the reverse of Bergmann's rule [97]. Between 1984/85 and 2009, this study discovered a 1.5g loss in a 33g bird as latitude increased, with no significant temporal change in meteorological factors. Allen's ecogeographical rule, for example, has been used to support morphological changes in species as a result of climate change. This rule asserts that endothermic animals living in hot climate zones have significantly larger appendages (to allow heat escape) whereas those living in cool climate zones have fewer appendages to assist them in saving heat [98,99]. For example, a study of long-term morphological data of five species of Australian parrots found a 4-10% increase in bill size with an increase in temperature from 1971 to 2008 [100]. In line with Allen's rule, in a global examination of 214 bird species, Symonds, et al. [101] found that birds living in colder climate zones have considerably smaller bills. Furthermore, a study by Danner, et al. [102] that looked at the impact of climate variables on changes in the bill sizes of 274 Song Sparrows (*Melospiza melodia*) along the eastern seaboard of the United States found that shorter bill sizes were preferred in colder winters to avoid extra heat loss. However, during global warming, both losses and increases in wing length of passerines have been seen, contradicting Allen's rule [103].

Effect on Extinction or Elimination

Temperature increases have been shown to accelerate the phenology of prey [16,41], which might lead to a mismatch between the availability of these and the predator reproductive period [26]. As a result, the population number may decrease [25], thus putting the species at risk of extinction. Concerns about biodiversity loss have grown as a result of the current high rate of species extinction [7]. Organisms' extinction risk is increased by a variety of processes. Because of the loss or decrease of their climatically appropriate locations, species are expected to face extinction as a result of the unprecedented increase in the pace of global warming (IPCC, 2013). Furthermore, various species' geographic ranges vary at different rates [56]. According to climate niche suitability analyses, the climatically suitable area of Stresemann's Bush-crow (*Zavattariornis Stresemann*) is predicted to become extinct under the climate change scenarios considered. Other bird species included in this study, on the other hand, remained and exhibited either a drop or an increase in their acceptable climatic niches.

The danger of extinction is particularly high when the rate of climatic change surpasses the ability of species to alter their ranges [42,104,105]. A recent worldwide analysis of bird elevational distribution found that having a small altitudinal range is one of the strongest predictors of bird extinction [106]. Another worldwide meta-analysis that used data from 131 research studies to predict the average extinction rate of species under future climate change found that under the business-as-usual climate change scenario, one in every six species will become extinct [107]. This research also explained that as a result of future climate change, species loss will not only grow but also accelerate. In general, bird species are affected not just by an increase in temperature, but also by the magnitude and frequency of extreme climatic events [108]. Furthermore, extinction risk is linked to morphological, ecological, and demographic changes [109-111].

Conclusion

The reviewed literature suggests that climate change has a significant effect on plant and animal phenologies in general and specifically on the lives and communities of migratory birds. Climate change in general is one of the most serious dangers to world socioeconomic and ecological systems, as indicated by the numerous ecological impacts imposed by changing climate, many of which have significant socioeconomic consequences. Climate change has a greater impact on breeding strategies, migration, distribution, latitudinal or altitudinal shift, community structure change, morphological change, and elimination or extinction of migratory birds. The current review explains the effect of climate change on migration birds but there is still a lack of information on how the migratory birds adapt themselves to the change of climate. However, less data is available to analyse the variation and correlation between published results on the effect of climate change on a specific strategy of migratory birds. Further studies should be carried out to investigate the adaptability of migration birds to the change of climate.

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