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(REVIEW ARTICLE)

A comprehensive review on the impact of climate change on the ecology, breeding seasonality, abundance and distribution of birds and possible approaches to address and conserve bird populations

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Abstract

The purpose of this paper is to review and evaluate published literature on the impact of climate change on birds. A systematic method was utilized to access research works of literature on "Impact of Climate Change on Birds". A total of sixty-seven (67) research papers published between the years 1962 to 2023 was accumulated and used for this review. A subjective approach was used to select the topics: impact of climate change and birds. In this paper, nine (9) threatening impacts of climate change on the bird populations were assessed and presented as well as three (3) detrimental impacts of climate change on birds inhabiting mangrove forests. Further, this paper assessed some birds that are threatened with extinction and it also provided a checklist of some migratory birds that are threatened due to the changing climate and that are found on the RED list of the IUCN. Approaches and strategies to enhance and address bird conservation to combat the effect of climate change was also presented in this review. The published works of literature established that the global bird population dynamics, ecology, breeding seasonality, abundance and distribution are all affected due to the threats of climate change. Climate change will affect birds indirectly in the future by modifying their habitats through sea level rise, changes in fire regimes, and changes in vegetation or land use. Birds are in particular vulnerable to environmental changes like climate change since they are subject to continuous changes that may be negatively connected. This review highlights the fact that more extensive studies on the impact of climate change on birds should be done in neotropical countries since there are gaps of such information on research and published data in these biodiversity rich regions.

Keywords: Climate change; Birds; Endangered; Extinction; Conservation

1. Introduction

Birds have important functions in our ecosystems and are extremely important to the human health and welfare, such as public hygiene, insect control, and plant reproduction [91] [101]. Birds are one of the few organisms that have been studied for both community reassembly and species adaptability to climate change. Climate change has caused birds to move their ranges and colonize new areas [22] [107] [153]. As a result, climate change has affected the species diversity and composition of bird communities within various geographic regions [99] [100] [107]. Specifically, changing climate provide unique challenges for migrating birds throughout seasons in other parts of the world [147].

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Climatic change coupled with other anthropogenic changes such as habitat loss are the most severe threats to biodiversity in the twenty-first century [32] [87] [107] [139], because climatic change causes changes in the number of migratory species as well as adaptations to migratory behavior. Bird communities are an ideal model system for comparing the effects of these threats [99] [100]. The proportion of species in a local community is a valuable indicator of the community's climate-dependent migratory inclination and activity as during community reassembly, populations may decline as a result of local migratory species extinction or non-migratory species immigration. Further the population of migratory species may drop if migratory species develop to become resident [99] [100].

Migration is a fascinating aspect of avian life. They gain the ability to move hundreds or thousands of kilometers across geographical boundaries to different parts of the world in response to changes in habitat, food supply, climate, and other variables [66] [107] [167]. For example, there are roughly eight hundred twenty-eight (828) species of migratory birds in Asia, but in Europe, there are four hundred twenty-nine (429) kinds [66] [107] [167]. The Species Migration Maps depict the movements of four hundred fifty-eight (458) species of migratory birds that routinely visit the United States and Canada as they journey across the hemisphere to finish their annual cycle. However, many migrating birds, mammals, fish, and invertebrates have seen population declines in earlier millennia due to the effect of earth's constant change in climate [66] [107] [167].

The current rate of climate change is faster than in the previous 65 million years [39] [49] [90]. Because climate is a major determinant of species distribution, recent poleward shifts in distribution in response to climate change have already been detected across a diverse range of taxa [39] [72] [124] [126] [128] [165]. Rapid temperature changes can influence organism survival or reproduction and pose a major threat to species persistence, particularly for species that cannot disperse or adapt quickly enough [13] [15] [17] [39] [124]. High temperatures, for example, can have both fatal and non-lethal impacts on wildlife, leading to mass mortality in severe circumstances [35] [39] [113].

Climate change caused by human activity is one of the most prominent issues in our century, and it is widely agreed that it has detrimental impacts on the majority of species and threatens the survival of many others. Climate change is of importance to birds because birds are well known to respond to numerous types of climate disturbances, and their responses are frequently well documented [91] [101]. Furthermore, according to current research, one-eighth of bird species face extinction in the coming decades, and they rely on people to intervene and safeguard them [91] [101].

According to literature, if the temperature rises by 3.5 degrees Celsius by 2100, 600-900 bird species will become extinct, with 89% of them occurring in the tropics [91] [101] [141]. Climate warming poses the greatest threat to birds with limited temperature variation and modest metabolic rates [101] [141]. Because they lack access to higher elevations, some tropical mountain birds, such as the northern snowbird, are especially vulnerable to climate change [91] [101] [141].

A book titled *Birds and Climate Change: Impacts and Conservation Responses* looks at how birds respond to climate change by analyzing metadata [101] [126]. Many researchers also investigated the effects of climatic change on egg-laying timing, distribution, population, and migration in various bird species and areas [41] [57] [101]. The paper by Şekercioğlu's team discussed the direct effects of climate change on tropical birds and the indirect effects of a link between climate change, food resources, and disease transmission, which can increase the likelihood of extinction of some birds by 50% [101] [141]. Other researchers have stated that mountain bird species are the most vulnerable to climate change and that scientists and policymakers must safeguard these birds by professional data gathering and expertise, as well as specific protection laws [101] [161]. However, potential solutions from many institutions are also required to alleviate the negative consequences of climate change on birds [101].

Tropical mountain birds, especially the Himalayas, are particularly vulnerable to climate change [172]. Climate change may have numerous effects on Sikkim's birds and some evidences of upward extension/shift in altitudinal ranges of species, change in breeding seasonality, and breeding failure are the most prominent. To assess range extension/shifts, data on the top and lower limits of bird species were compared and this was supplied by Ali (1962) with the latest findings. Similarly, breeding seasonality and breeding condition of some bird species in Sikkim are based on information supplied by Ali (1962) and Ali & Ripley (2001).

2. Material and Methods

The topic of "impact of climate change on birds" was the subject of a systematic review using "Google Scholar," a web-based search engine which provides a quick and easy way to search and access published literature from articles, journals and books. Thematic search terms such as impact, climate change, birds and conservation were used in the search.

The subjects that were evaluated in this research were chosen using an approach that involved assessing at the related works of literature. Publications between the years 2000 to 2023 were acquired for this review. However, not all of the articles that were reviewed, were used in this study because the major objective was to assemble data from recent research (past 10 to 20 years) on impact of climate change on birds. However, papers that contained relevant literature from as far back as the 1900's and the 2000's were also utilized for this review. Sixty-seven (67) research articles were included in this review and literature from fifty-six (56) papers published between the years 1962-2023 were presented in this paper.

The search yielded different results: Some articles had all the thematic keywords and some were obtained that were specific to conservation measures and approaches to protect birds, while others were specific on the effect of climate change on birds that dwell in mangrove forests, birds threatened with extinction and bird responses to environmental changes.

3. Results

When searching "Google Scholar" for information on impact of climate change on birds, a total of 85,300,000 was retrieved. Among the results obtained from the search, a total of 28,700 were published within the years 2000-2023, 31,700 were published between the years 2010-2023 and 52,400 were published within the years 2015-2023. 28,900 publications between the years 2010-2023 reviewed the impact of climate change on birds.

However, not all the results retrieved for this research focused on the impact of climate change on birds. While some focused solely on climate change on birds, others examined possible conservation measures and approaches to protect the bird populations from the impact of climate change and some were specific on the impact of climate change on birds inhabiting mangrove forests. Further, some papers focused on checklists of birds threatened with extinction and becoming endangered and bird responses to changes in the environment.

4. Discussion

4.1 Climate change affecting birds and bird responses to global climate

Climate change is having an increasing impact on ecosystems, habitats, and species. Environmental change has been linked to changes in temperature, precipitation, and moisture, as well as a more changeable environment and more extreme weather. Birds are the prototypical "canaries in the coal mine," and they are already responding to present levels of climate change [171]. Differential changes among species might readily disrupt communities, altering the structure and functioning of most, if not all, of the world's ecosystems. Variations in the timing of crucial life cycle events, as well as variations in range, are two major ways that birds and their ecological communities are already responding strongly to climate change. Importantly, these responses, in turn, represent new challenges and risks to birds [135] [171].

4.2 Effect of Climate Change on Birds

Research on birds has revealed that climate change has an impact on birds both directly and indirectly. Bird distributions are closely related to both winter and summer temperatures, and rising temperatures caused by climate change may have a direct impact on birds by pushing them to use more energy for thermoregulation. This can affect their maintenance (the energy required by organisms to maintain their basic levels of activity and condition), reproduction, breeding and migratory timing, and ultimately reduce survival or fitness [40] [107]. Birds may adapt to these changes by gradually extending their ranges to locations with more favorable temperatures, although habitat and other resources may be insufficient or sub-optimal for their needs [48] [107].

4.3 Impact on general Bird Population

Global climate change has caused phenological mismatches, which have resulted in changes in population size, population declines, or even extinction, and studies have found that climate change has been a major factor in population changes of birds in Central Europe in recent decades [62] [79] [171] [153]. In a study of songbirds in Arizona, Thomas and John discovered that the drop in their numbers was linked to climate-related snowfall. Gasner used models to forecast population changes in the Central American fish eagle under future climate scenarios, and found that the species' population will drop and a few species would become extinct. This is a major cause in the fall of bird populations [62] [80] [172] [154]. Warmer temperatures will diminish the quality of bird habitat, resulting in a decrease in the number of species. Warmer temperatures will also cause an uphill shift of montane species over the world, resulting in

mountaintop extinctions of species that only reside near the summit of mountains [31] [62] [155]. Warming, for example, has resulted in an 'escalation of extinction' for birds in isolated mountain areas of Peru-high-altitude species' ranges and populations have plummeted, and some previously common mountainside dwellers have vanished from local communities [101] [125] [156] [159].

4.4 Threat of extinction on bird species

Extinction rates due to the complete loss of core environments are predicted to be severe, nonlinear, with losses growing fast beyond a 2 °C increase, and exacerbated by other climate-related consequences. Extinction is the most severe and last effect of climate change on biodiversity. Climate change could endanger even bird species that are now protected (Table 3). This extinction threat for birds is still being quantified; however, first-cut estimates for mid-range climate change scenarios show higher extinction rates than habitat loss, which is currently regarded as the most serious threat to biodiversity, and conclude that climate change is likely to be the most serious threat to many, if not most, ecosystems [16] [79] [153] [156] [158].

Extinction rates are predicted to be high in northeastern Australia's Wet Tropics bioregion, where mid-range climate change will threaten nearly three-quarters of rainforest birds (including six species that are already critically endangered). In South Africa, mid-range climate change would result in a 33-40% extinction rate if birds were unable to migrate to other climate-suitable habitats. In Europe, recent research reveals that climate change poses a significant threat to bird variety, with a 60% reduction in species richness expected for 46 Europe-breeding birds with 2.5°C of global warming if birds are unable to relocate to other climatically suitable places [23] [45] [127] [154] [170].

Migratory, Arctic, Antarctic, island, wetland, mountain, and seabird species are all highly sensitive to climate change. Climate change threatens migratory birds more than all other human-caused dangers combined, with climate change posing a threat to 84% of migratory bird species. Breeding in arid areas, poor dispersal capacity, low population numbers or already poor conservation status, confined or patchy habitat, and limited climatic range are all factors that increase the risk of climate change to birds. Furthermore, although generalist and invasion species are projected to expand their ranges, specialist bird species are expected to diminish as a result of climate change [78] [155] [168] [169] [171].

Table 1 Climate Change and its general impact on bird populations

Effects	Description of impacts	Author(s)
Impact of Upward Extension/ Shift in Altitudinal Ranges of Species	Global temperatures generally decrease with increasing latitude and elevation, hence climate scientists project that species will relocate to the poles and upward in elevation. Long-term changes in North American bird populations reveal substantial evidence of latitudinal shifts, with several species migrating northward in recent decades. Long-term datasets have also revealed elevational variations, which appear to be associated with changes in both precipitation and temperature. Data from the Sierra Nevada mountains suggest that the majority of species ranges have changed upwards in elevation during the 1940s, with some bird species more closely connected with temperature shifts and others with precipitation changes. Many studies have discovered that species alter their elevational ranges to adapt to changing climatic circumstances; warming at lower elevation causes them to relocate to higher elevation. Some species, particularly migratory birds, will be able to adapt or relocate their ranges along the horizontal gradient. Elevational gradients create complex circumstances with a variety of climatic, ecological, and physiological consequences that limit species range expansion. As a result of physiological and ecological restrictions, most bird species' range extension is limited or non-existent, resulting in significant extinction risks or mass extinctions. Warming temperatures cause species ranges to shrink, sometimes completely, pushing them to mountain peaks. Because most highland species have very small range sizes, range size can be used to predict the threat of extinction. As a result, high elevation species face a greater danger of extinction than low elevation species, particularly where no	(Ali, 1962); (Markham, 1998); (Benning *et al*., 2002); (Walther *et al*., 2002); (Wormworth & Mallon, 2006); (Acharya & Vijayan 2007); (Hitch & Leberg, 2007); (LaSorte & Thompson, 2007); (Harris & Pimm 2008); (Rodenhouse *et al*., 2008); (Sekercioğlu *et al*. 2008); (Lawler *et al*., 2009); (Tingly *et al*., 2009); (Xu *et al*., 2009); (Jankowski *et al*., 2010); (Matthews *et al*., 2011); (Pautasso, 2011); (Acharya & Chetteri, 2012); Sekercioğlu *et al*., 2012); (Noske, 2016); (Trautmann,

	land or habitat exists at higher elevations. Endangered and restricted range species with little or no margin for upward mobility or the incapacity to shift higher due to intolerance to physiological restrictions imposed by geographical gradients are the most exposed to extinction threats. Climate change has an indirect impact on birds in several circumstances. Unusual weather patterns and rising temperatures have a wide-ranging impact on forests and bird habitats. Birds' ranges shift vertically and horizontally when environments change. Climate-induced consequences varies depending on the species' body physiology. While some species may not be impacted, the rate at which others are influenced varies, so that all species in a population do not coordinate their changing behavior. The asynchronous shift alters species assembly and community organization along elevation gradients. As the area and resources decrease at higher elevations, interspecific competition develops, potentially killing high elevation dwellers. In some circumstances, migrant species might fully outcompete their upland congeners, pushing them higher up or driving them extinct. Examples are seen in as the snowline in the Himalayas has begun to shift upwards in response to rising temperatures. This transition has created new niches for birds in alpine locations, causing their altitudinal ranges to expand upward. Species from low to mid-elevation locations have also pushed their altitudinal limits higher, demonstrating adaptation to climate change. In comparison to Ali (1962), it is discovered that the elevational range alterations in the lower and upper limits of some bird species in Sikkim is constantly shifting. The Blood Pheasant (*Ithaginis cruentus*), for example, has been recorded to occur as low as 1500 m and generally between 2600 m and 4500 m, yet recently, this specie is now observed over 3300 m, indicating a significant shift in lower elevational limits. Similarly, the Snow Pigeon (*Columba leconota*) is now found in sub-alpine and alpine zones far beyond its previous bottom limits of 1600 m (common at 3000 m). Another notable observation is of Ibisbill (*Ibidorhyncha struthersii*), which has previously been documented as low as Rangpo and Singtam along the Teesta, but recent records are generally from 3300 m and above. In Sikkim, the Rusty-bellied Shortwing's (*Brachypteryx hyperythra*) habitat has shifted from temperate broad-leaved evergreen woods (upper limit 2900 m) to temperate coniferous forest (3600 m). There is significant evidence of its 700 m elevational range extension. White-winged Redstart (*Phoenicurus erythrogastrus*) is found over 4000 m in the Tibetan Plateau, although the Loke-Salim Ali expedition in Sikkim in the 1950s documented it as low as around 1700 m. Most bird species in Sikkim have shifted northward from lower elevation restrictions, resulting in smaller range sizes. Elevational range extension/ shift has been recorded in several bird species in Sikkim, with certain species showing convincing evidence of elevational shift shown in Table 2. Many other species exhibit elevational range extension or seasonal movement along the elevational gradient; therefore, this list is not exhaustive. Some species' range extension appears to be quite high or overestimated. These statistics provide an average value based on historical records, pointing the way forward for a comprehensive field study to understand the varied consequences of climatic change on birds and their adaption strategies.	2018); (Manglani *et al*., 2023)
Impact of Change in Breeding Seasonality	Warmer temperatures, changes in habitat, and shifting climatic patterns may all affect bird reproduction techniques. Many tropical bird species may modify their mating seasons in response to temperature and rainfall patterns. Birds begin breeding sooner than usual or produce fewer young due to a lower reproductive rate, resulting in population decline. Changes in temperature and humidity have an indirect effect on	(Visser *et al*., 1998); (Ali & Ripley 2001); (Both & Visser, 2001); (Wormworth & Mallon, 2006); (Ahola *et al*., 2007) (Acharya

	bird activity and behavior. The abandonment of habitat due to bad weather conditions impedes vital behaviors such as eating and breeding displays. Erratic heavy rainfall resulting in lower temperatures during the breeding season in the mountains can potentially delay breeding activities. Birds will often begin breeding earlier than usual in reaction to climate change. In Sikkim, India, however, we have discovered that certain bird species are breeding in the latter half of their breeding season. Breeding activities such as habitat selection, nest building and even laying of eggs and emergence of hatchlings is supposedly delayed in birds such as Ashy Drongo (*Dicrurus leucophaeus*), Black Bulbul (*Hypsipetes leucocephalus*), Chestnut-crowned Laughing thrush (*Garrulax erythrocephalus*), Grey-backed Shrike (*Lanius tephronotus*), White-capped Water Redstart (*Chaimarrornis leucocephalus*) and White-collared Blackbird (*Turdus albocinctus*). This is due to unanticipated meteorological occurrences such as extended dry spells, altered plant phenology, and insect emergence, or it could be due to substantial rainfall at the start of the breeding season. Nonetheless, there is evidence of an increase in breeding activity in some species as a result of the cue provided by increasing temperatures. The breeding season of the Common Tailorbird (*Orthotomus sutorius*) in Sikkim lasted barely two to three months, despite the fact that it is known to breed virtually all year round. This is an indication of the climatic effect on this species' breeding habitats and food availability. It is also noted that a decrease in clutch size in some species, including the Chestnut-crowned Laughing thrush, Grey-backed Shrike, and White-rumped Munia (*Lonchura striata*), most likely as a result of climate change. Environmental variables are potential criteria for nest-site selection in Sikkim birds, among other nesting features.	2008); (Acharya & Vijayan 2009); (Carey, 2009); (Wormworth & Sekercioğlu, 2011); (Acharya & Chetteri, 2012); (Sekercioğlu *et al*. 2012); (Trautmann, 2018)
Impact on Breeding Failure	Climate-induced changes in plant phenology, food availability, and habitat disturbance, most avian species' breeding periods are either reduced or they fail to establish nests and reproduce. Because many birds' breeding seasons coincide with increasing resource abundance (mainly during the rainy season), longer and more unpredictable dry seasons as a result of climate change might impact reproductive effectiveness, resulting in population reduction or complete breeding failure in birds. Climate change has had a significant impact on avian breeding activities, particularly in higher elevation parts of Sikkim, resulting in reproductive failure. In Sikkim, breeding records exist for species such as the Ruddy Shelduck (*Tadorna ferruginea*), the Ibisbill (*Ibidorhyncha struthersiii*), the Common Redshank (*Tringa tetanus*), and the Black-necked Crane (*Grus nigricolis*). However, no breeding observations on these species have been made in recent years. The breeding performance of these birds has been affected by changes in water temperature during the breeding season in high altitude fresh water bodies in Sikkim (Gurudongmar Lake, Changu Lake, Thangu Chu, Yumthang Chu, etc.). Changes in the surface temperatures of bodies of water can affect the availability of prey for aquatic birds. Many bird species have a critical water surface temperature threshold at which chick mortality occurs due to a shortage of prey. Because birds require optimal temperature for egg laying and incubation, prolonged cold spells and snowfall occurrences may delay or prevent breeding activity in both terrestrial and aquatic birds. Climate change may have an effect on the timing of egg laying in birds, with preliminary research indicating that certain birds are producing eggs sooner than usual. High spring temperatures may hasten the	(Ali, 1962); (Ganguli-Lachungpa, 1990); (Crick *et al*., 1997); (Ganguli-Lachungpa, 1998); (Markham, 1998); (Kai & Corlett, 2002); (Wormworth & Mallon, 2006); (Ganguli-Lachungpa *et al*., 2007); (Acharya, 2008); (Huntley *et al*., 2008); (Williams & Middleton, 2008); (Carey, 2009); (Wormworth & Sekercioğlu, 2011); (Acharya & Chetteri, 2012); (Trautmann, 2018); (Li *et al*., 2022)

	average flowering and leafing period, impacting the availability of food for birds, and there is evidence that two species of wading birds in the Netherlands nest earlier in the warmer spring. In recent years, amphibians in the United Kingdom have been discovered to lay eggs when spring temperatures rise. Both *et al*. (2004) investigated low-flying moth populations and discovered that nine populations had earlier spring temperatures. Climate change can cause an inconsistency in the time of breeding and the availability of staple foods for birds. Visser *et al*. (2006) researched the Palouse specialist and discovered fluctuations in the peak abundance of caterpillar pairs on which it feeds, which led to changes in the breeding season of Great Tits (*Parus major*). Early nesting or breeding may be a more widespread feature in British animals. This could have serious ecological and conservation consequences for them. Early nesting may be advantageous for birds if there is a longer interval before winter to boost juvenile survival rates. The breeding and wintering grounds of Anatidae are widely distributed. Because of the warmer temperatures, the breeding area is larger than the winter area. Birds, on the other hand, may suffer if their physiography is out of sync with that of their food supply. Climate change can have an impact on where birds reproduce. Scientists examined the breeding ranges of British birds over a 20-year period and discovered that 59 species of southern British birds moved their breeding sites northwards during a period of gradual climate warming, indicating that scientists have identified one of the potential factors for anthropogenic warming to shift breeding sites northwards. Warmer temperatures are also causing birds to stay at their nesting locations for slightly longer than previously. Many short-distance migrants have much more individuals that spend the winter at their breeding grounds.	
Impact on Bird Phenology and Migration	Birds are susceptible to climate change since they are one of the most active components of the ecosystem. Using satellite monitoring techniques, scientists discovered that temperature changes are the primary driver of song crane migration. According to the studies, the first arrival date of most birds is negatively connected with the average monthly temperature, which means that the warmer the temperature, the sooner the bird's first arrival date. Warming, according to research, effects changes in the time of migration and the choice of wintering places for migratory birds. Spring migration arrives two days earlier for some bird species in Europe for every 1°C increase in average temperature. Long-distance migratory birds arrive an average of 13 days earlier, whereas short-distance migratory birds arrive an average of 4 days earlier. Climate change can have an impact on migratory patterns. Under the influence of global warming, Arctic temperatures are expected to rise more rapidly by the end of the twenty-first century and will be 2.2-2.4 times warmer than the global average, a process known as the Arctic amplification effect, to which geese will adapt by timing their migration earlier, leaving their wintering grounds and stopover sites before food supplies reach their peak. They will spend more time in the Arctic since they will leave their overwintering sites earlier. Migratory animals may adapt to warming in ways other than changing migration dates, especially if warming changes the spatial distribution of habitats and supplies. With rising temperatures, suitable breeding and staging sites are anticipated to relocate northward. In addition to driving birds to migrate relatively early, increases in temperature related with climate change are projected to cause a reduction in body size, a fundamental driver of animal physiology and ecology. Thus, climate change, considered one of the most important threats to biodiversity and ecosystems, may alter the distribution and survival of migratory birds (Table 4). Furthermore, a number of other	(Richardson, 1990); (Wormworth & Mallon, 2006); (Alonso *et al*., 2009); (Carey, 2009); (Pautasso, 2011); Chaudhary *et al*., 2015); (Jackson *et al*., 2015); (Langham *et al*., 2015); (Noske, 2016); (Scheffers *et al*., 2016); (Hu *et al*., 2017; (Lameris *et al*., 2017); (Liang *et al*., 2018); (Liang *et al*., 2018); (Trautmann, 2018); (Brown *et al*., 2019); (Weeks *et al*., 2019); (Horton et al., 2020); (Seri & Rahman, 2021); (Li *et al*., 2022)

	studies have predicted changes in species richness or distribution in China as a result of various climate change scenarios. Animals have evolved to withstand extreme temperatures, and climate change has had a significant impact on species physiology, including increased exposure to high temperatures, differences in sex ratios in species with temperature-dependent sex, and increased metabolic costs associated with living in a warmer environment.	
Impact on the Habitats of Birds	Climate change is widely thought to have pushed the distribution of numerous species to mountain peaks and poles. Climate change-induced habitat modification is also regarded as a major hazard to the survival of certain bird species. Lehikoinen and Virkkala discovered that in Finland, 128 bird species traveled 37 km northerly or north-easterly on average from 1970 to 1989 and 2000 to 2012, whereas temperatures moved 186 km in the same directions as birds. Freeman's team also discovered population reductions or even extinctions of some common high-altitude bird species in Peruvian highlands due to rising temperatures causing a widespread fall in their suitable habitats. They also believe that climate change is the principal cause of the extinction of high-altitude species in the tropical Andes, as well as a threat to bird groups in other tropic places. The habitat of the Vancouver Island White-tailed Ptarmigan (*Lagopus leucura*) would be reduced by 25% in the 2040s, 44% in the 2050s, and 56% in the 2080s, according to Jason's team. Habitats will diminish by 27%, 59%, and 74% if greenhouse gas emissions remain high. With rising temperatures, more and more alpine birds are losing their homes and becoming extinct.	(Wormworth & Mallon, 2006); (Carey, 2009); (Pautasso, 2011); (Şekercioğlu *et al*., 2012); (Lehikoinen & Virkkala, 2015); (Noske, 2016); (Freeman *et al*., 2018); (Trautmann, 2018); (Li *et al*., 2022)
Impact on the Disease Occurrence	While climate change creates changes in many birds' habitats, the risks of birds catching diseases are also growing. Dr. Gilbert's team, for example, contends that climate change has induced wild bird dispersion, resulting in the spread of avian disease. A good example is the Mute swan (*Cygnus olor*) population, which carried high pathogenic avian influenza H5N1 (HPAI H5N1) and traveled to Western Europe from the eastern Caspian Sea basin due to an old weather period. Because of the warmer temperatures during that time, the breeding area is larger than the winter area. They also did a comparison between places anticipated to have the greatest temperature fluctuations and Anatidae breeding sites. Furthermore, rising temperatures induced by climate change can allow illnesses to spread to higher altitudes and affect birds that reside there. According to the study, climate change is raising the temperature in Hawaii, allowing more locations available for illness to thrive, and so expanding the geographic distribution of Avian malaria transmission. Meanwhile, if the temperature rises by 2 degrees Celsius, available high elevation forest habitat with a low risk of Avian malaria is expected to drop by 57% in Hawaii. The disease transmission zone ranges from 1500 meters to 1800 meters. As a result of temperature change, animals between 1500 and 1800 meters will be particularly vulnerable to Avian malaria and pox. The low-risk region for species is shrinking, and the probability of infection is growing.	(Gilbert *et al*. 2008); (Stone, 2008); (Atkinson & LaPointe, 2009); (Li *et al*., 2022)
Impact on Food Availability	Climate change has gradually altered environmental circumstances, such as more extreme weather, global warming, and altered precipitation rates. Studies suggest that climate change has produced a drop in bird food abundance, which leads to possible hazards for bird life phases such as breeding and body growth. In terms of caterpillars, Visser *et al*.'s 1998 study concluded that spring temperatures increased considerably from 1973 to 1995, and consequently caterpillar biomass peaks advanced nine days, compared to their historical data. Climate change also produces a significant drop in ambient temperature, resulting in caterpillars' delayed growth and reduced feeding activities.	(Loeb *et al*., 1997); (Nicol *et al*., 2000); (Atkinson *et al*., 2004); (Parkinson, 2004); (Wormworth & Mallon, 2006); (Carey, 2009); (Pautasso, 2011); (Fletcher *et al*., 2013); (Noske, 2016); (Trautmann, 2018);

	It causes a decrease in caterpillar biomass abundance and a higher mortality rate. Krill and marine organisms exhibit a similar relationship with climate change. Because of climate change, sea ice has melted about 12% - 20% since the 1950s, resulting in a decrease in the abundance of krill and other marine animals, which happen to be the principal diet for five breeding seabirds in Adelie Land, Antarctica. Climate change has reduced the availability of food for birds. Food supply declines may have short- and/or long-term repercussions, such as a mismatch between bird reproductive and available food peak periods. The effects, however, may be influenced by birds' adaptation to changing environmental conditions.	(Harris *et al*., 2019); (Li *et al*., 2022)
Impact of Indirect Effects	Other indirect effects are mediated by variations in the types and timing of disturbance. Climate change is causing dry conditions in regions of the western United States, increasing the frequency and intensity of wildfires. These disturbances can directly affect birds by destroying nests and disrupting habitats. In the Great Basin the effects of dryness on fire regimes are aggravated by the invasion of cheatgrass (*Bromus tectorum*), an invasive species introduced from Eurasia. Cheatgrass is more flammable than native grasses, and as drought conditions worsen, fire frequency and severity rise, and plant species adapted to less severe fire regimes are replaced by cheatgrass, resulting in even more violent fire behavior. Climate, fire, and invasion are being blamed for the loss and fragmentation of big sagebrush habitats needed by sagebrush obligates such as the sage thrasher (*Oreoscoptes montanus*), sage sparrow (*Amphispiza belli*), and greater sage-grouse (*Centrocercus urophasianus*). Climate change is not a new phenomenon, and animals have always responded to it on evolutionary periods. However, the major challenge now is how organisms will react to the current seeming rapid rate of anthropogenic climate change.	(Root *et al*., 2003); (Round & Gale, 2008); (Finch, 2012); (Manglani *et al*., 2023)
Impact on bird responses to alarm calls	Songbirds are especially susceptible to temperature fluctuations due to their tiny size, high metabolic rate, and largely diurnal activities. To date, most studies on this topic have examined the effects of temperature on physiological traits, but it can also induce changes in behavior such as in foraging, cognitive performance, and acoustic communication. High temperatures have been reported to diminish birds' capacity to discern between conspecific and heterospecific songs, but less is known regarding the influence of heat on responsiveness to other forms of vocalizations. Understanding the influence of temperature on vocal information receptivity is crucial since vocal signals are a main mode of communication for many bird species. Responding to alarm sounds is an especially important behavior to evaluate in diverse contexts of communication because alarm cries are anti-predator signals that carry critical information for avoiding predation. At high temperatures, any failure to discern the information content of these calls may result in lower survival.	(Garson & Hunter, 1979); (Bradbury & Vehrencamp, 1998); (Templeton *et al*., 2005); (McKechnie & Wolf, 2010); (du Plessis *et al*., 2012); (Edwards *et al*., 2015); (Magrath *et al*., 2015); (Dubois *et al*., 2016); (Luther & Danner, 2016); (Xie *et al*., 2017); (Coomes *et al*., 2019); (Coomes *et al*., 2019); (Bourne *et al*., 2020); (Bourne *et al*., 2020); (Coomes & Derryberry 2021); (Soravia *et al*., 2021); (Blackburn *et al*., 2022); (Cordonnier *et al*., 2023)

4.5 Effect of climate change on birds inhabiting Mangrove

Mangrove forests provide habitat for many bird species around the world. According to data, over 130 bird species (both resident and migratory) have been spotted among mangroves and mudflats in Singapore [117] [175] and other regions of Southeast Asia [119] [160] [175]. Birds connect different species in the biosphere by foraging and demanding habitat or resources. However, climate change is having a significant impact not only on mangroves, but also on the

birds who reside in them [175]. Global warming induced by greenhouse gas emissions has raised the Earth's temperature. High temperatures have forced many birds to nest and lay eggs roughly a month sooner than their breeding season 100 years ago [175].

4.5.1 Impact of climate change on the nesting of land birds inhabiting Mangrove

Herons, storks, and owls use mangroves to nest. With the gradual removal of mangroves, these birds will lose their habitat. At the same time, severe weather has a significant impact on bird nesting. Birds may repair their nests multiple times after being destroyed by typhoons, decreasing their reproductive effectiveness [10] [77] [54] [174]. Planting and conserving mangroves can help improve the issue. Hurricanes Opal and Roxanne destroyed around 1,700 hectares of mangrove vegetation in Mexico in 1995. Since then, Mexico has prioritized the implementation of hydrological restoration techniques to conserve mangroves and biodiversity [10] [43] [81] [181] [174]. In 2019, Canales-Delgadillo *et al*. conducted an assessment and discovered increased bird species richness and relative abundance in disturbed and restored habitats.

4.5.2 Impact of climate change on the breeding colonies of sea birds inhabiting Mangrove

Another consequence involves the fact that seabird breeding colonies are shrinking, resulting in coral cay subsidence as sea levels rise [77] [174]. Land bird species diversity and richness were much higher in mangroves than in waterbirds, which could be attributed to habitat variations and mangrove vegetation diversity [10] [174]. Land birds can nest in trees, shrubs, herbs, and ferns, whereas seabirds rely primarily on marshes and open water. Cormorant species, such as the small cormorant and the little black cormorant, prefer to breed in coastal locations. In one of the research studies, the majority of cays are less than three meters above the high-water mark, and low-lying cays may be flooded during storm surges or even at high tide in the future. Most seabirds prefer low-lying cays, therefore young birds and unhatched eggs struggle to survive in flooded nests [54] [174].

4.5.3 Impact on the feeding of mangrove dwelling birds

Invertebrates such as oligochaetes, planarians, leeches, arachnids, insects, and crustaceans utilize aquatic plants as their home. These invertebrates are vital food sources for waterbirds [81] [174]. The feeding range of numerous birds in the Yucatan Peninsula's mangroves includes ten (10) to twenty (20) fish species. Egrets and great egrets, for example, will eat non-fish animals such as crabs, insects, and amphibians [10] [174]. Neotropical cormorants mostly eat fish, mollusks, amphibians, insects, and crabs. Climate change has had a profound influence on food resources; for example, some species of fish and insects have reduced dramatically due to rising temperatures or changes in seawater chemistry, and birds will starve to death [151] [174]. *Acartia tonsa*, a copepod zooplankton found in mangrove forests in India, has demonstrated a decreasing tendency in population density due to changes in more distinct dry and wet seasons, which resulted to higher salinity and phosphate concentrations [43] [174]. Climate change is also influencing the diversity of crustacean populations in mangrove forests. As precipitation in the rainy season increases annually due to climate change, crabs, as noted above, may be compelled to relocate and forsake their tunnels, putting them under significant survival pressure [174].

Table 2 Historical Elevational Range (HER) and Average Range Extension/ Shift (RES) (both upper and lower elevational limits) in some bird species due to the impact of climate change

Common Name	**Scientific Name**	**Elevation Range (HER)**	**Average Range Extension/ Shift (RES)**
Blood Pheasant	*Ithaginis cruentus*	2600-4500	700
Snow Pigeon	*Columba leconota*	3000-4880	250
Speckled Wood Pigeon	*Columba hodgsonii*	1500-3960	300
Ashy Wood Pigeon	*Columba pulchricollis*	1200-3000	550
Barred Cuckoo Dove	*Macropygia unchall*	450-2700	250
Great Barbet	*Megalaima virens*	450-2100	350
Hodgson's Hawk Cuckoo	*Hierococcyx fugax*	600-1800	600
Ibisbill	*Ibidorhyncha struthersii*	2600-4250	700

Peregrine Falcon	*Falco peregrinus*	1500-2750	650
Golden-fronted Leafbird	*Chloropsis aurifrons*	300-750	200
Large-billed Crow	*Corvus macrorhynchos*	1800-4250	700
Scarlet Minivet	*Pericrocotus flammeus*	300-1800	300
Yellow-bellied Fantail	*Rhipidura hypoxantha*	300-3650	400
Ashy Drongo	*Dicrurus leucophaeus*	300-2750	250
Plain-backed Thrush	*Zoothera mollissima*	1200-3650	500
Rusty-bellied Shortwing	*Brachypteryx hyperythra*	Up to 2900	700
Rufous-bellied Niltava	*Niltava sundara*	300-2100	250
White-throated Redstart	*Phoenicurus schisticeps*	3000-4550	500
Grandala	*Grandala coelicolor*	2800-5200	600
Coal Tit	*Parus ater*	2750-3800	250
Black-throated Tit	*Aegithalos concinnus*	1200-2450	300
Striated Laughingthrush	*Garrulax striatus*	750-2300	600
Black-chinned Yuhina	*Yuhina nigrimenta*	350-900	300
Fire-tailed Sunbird	*Aethopyga ignicauda*	1400-4000	600
Scarlet Finch	*Haematospiza sipahi*	600-2000	600

(Taken from Ali, 1962 and Acharya & Chettri, 2012)

Table 3 Checklist of some migratory birds that are endangered due to the effects of climate change and severe weather

Scientific Name	**Common Name**	**Global (IUCN) Status**
Leucogeranus leucogeranus	Siberian crane	Critically Endangered
Fregata andrewsi	Christmas Island Frigatebird/ Andrew's Frigatebird/ man-o-war bird	Critically Endangered
Vanellus gregarius	Sociable lapwing	Critically Endangered
Calidris pygmaea	Spoon-billed Sandpiper	Critically Endangered
Thalasseus bernsteini	Chinese crested tern	Critically Endangered
Oxyura leucocephala	White-headed Duck	Endangered
Sypheotides indicus	Lesser florican/ likh/ kharmore	Endangered
Pterodroma baraui	Barau's Petrel	Endangered
Papasula abbotti	Abbott's Booby	Endangered
Numenius madagascariensis	Eastern curlew	Endangered
Calidris tenuirostris	The great knot	Endangered
Haliaeetus leucoryphus	Pallas's fish eagle/ Pallas's sea eagle/ band-tailed fish eagle	Endangered
Larvivora ruficeps	Rufous-headed Robin	Endangered

(Taken from Birdlife International, 2021and Seri & Rahman, 2021)

Table 4 Some migratory birds that are threatened by extinction due to climate change

Scientific Name	Common Name	Description	Author(s)
Prionodura newtoniana	Golden Bowerbird	Many bird species are threatened with extinction as a result of climate change. With a 1-2°C increase in global mean surface temperature above pre-industrial levels, many unique and fragile biological systems will be jeopardized, and many species would become extinct. Risk varies depending on the species. The golden bowerbird, like many other bird species in northeastern Australia's Wet Tropics, is very threatened. The golden bowerbird (*Prionodura newtoniana*) is a bird species from the Ptilonorhynchidae family, which includes bowerbirds. It is native to Queensland, Australia, and is restricted to the Atherton region. The golden bowerbird's appropriate habitat would drop by 63 percent with less than 1°C of future warming, demonstrating why Williams *et al*. (2003) refer to this zone's climate scenario as "an impending environmental catastrophe." Impacts are projected to be more severe for migratory, Arctic, Antarctic, island, wetland, mountain, and seabird populations.	(Hilbert *et al.*, 2004); (Noble *et al.*, 2005); (van Vliet & Leemans, 2006); (Birdlife International, 2016); (Manglani *et al*., 2023)
Branta ruficollis	Red Breasted Goose	Climate change poses the same harm to migratory birds as all other human-caused risks combined, with 84% of migratory bird species experiencing some form of climate change threat. The Arctic-breeding red breasted geese, which is already internationally threatened, is anticipated to lose 99 percent of its tundra breeding habitat owing to climate change. The red-breasted geese (*Branta ruficollis*) are vividly coloured goose species from Eurasia belonging to the Branta genus. It is currently listed as vulnerable by the IUCN. Birds that are habitat specialists are more vulnerable than generalists. Birds that breed in arid areas, as well as those with low population numbers, poor dispersal capacity, poor conservation status, confined or patchy habitats, or narrow climatic ranges, are particularly vulnerable to climate change.	(Zöckler & Lysenko, 2000); (RSPB & WWF 2003); (Bolger *et al*., 2005); (DEFRA, 2005); (Reid *et al*., 2005); (Huntley *et al*., 2006); (Birdlife International *et al*., 2017); (Manglani *et al*., 2023)
Loxia scotica	Scottish Crossbill	The entire extinction danger of climate change for birds is still being calculated. However, preliminary estimates suggest that more than a third of European bird species could become extinct under a maximum (>2.0°C) climate change scenario if birds are unable to migrate to new climatically suitable habitats. Given Europe's substantially transformed geography, their ability to shift is inherently unclear. The Scottish crossbill is one species on the verge of extinction, with its existing habitat predicted to disappear completely. The Scottish Crossbill *Loxia scotica* is considered Britain's only native bird species. The genus name *Loxia* comes from the Ancient Greek word loxos, which means "crosswise," and *scotica* is Latin for "Scottish." In the Australian Wet Tropics bioregion, mid-range climate change is expected to wipe out nearly three-quarters of rainforest birds within the next century.	(BOURC *et al.*, 1980); (Thomas *et al.*, 2004); (Thomas *et al.*, 2004); (Shoo et al., 2005); (Huntley *et al.*, 2006); (Jobling *et al.*, 2010); (Manglani *et al.*, 2023)
Sibirionetta formosa	Baikal teal	The Baikal teal is a waterbird that breeds in northeastern Siberia and winters in South Korea, Japan, and China. The bird was once common, but by 1990 only an estimated 50,000 survived, and it is now classified as vulnerable. This bird is especially sensitive to climate change because it only nests in wetlands. Lower water tables and increasing frequencies of drought result in less available habitat. Habitat destruction may jeopardize the bird's ability to complete its migratory trek. The Baikal teal (*Sibirionetta formosa*), sometimes	(Georgi & Gottlieb, 1775); (Mayr *et al.*, 1979); (DEFRA, 2005); (Manglani *et al.*, 2023)

		known as the bimaculate duck or squawk duck, is a dabbling duck that breeds in eastern Russia and spends winters in East Asia. Johann Gottlieb Georgi, a German scientist, gave the Baikal teal its first formal description in 1775 under the binomial name *Anas formosa*.	

4.6 Strategies to enhance bird conservation to combat climate change

4.6.1 Identifying vulnerable species and habitats

A variety of models suggest that many bird species will struggle to adapt to climate change and will eventually become extinct within their current ranges. Many traits can contribute to a species' vulnerability to climate change: dispersal ability, tolerance of only a narrow set of temperature or precipitation regimes, dependence on a particular disturbance regime (such as fire) that is likely to be altered by climate change, dependence on ice or snow-covered habitats, a high degree of habitat specificity, reliance on specialist inter-species interactions (e.g. for food or habitat), low genetic variation, and a lack of phonological response to climate change [24] [46] [141] [169].

Researchers are beginning to establish indices of susceptibility to climate change, but the data required to draw significant conclusions is frequently inadequate. Individual species studies will require measuring these and other features in order to anticipate how species will respond to climate change. Because some of these characteristics are difficult or time-consuming to quantify, indicators may be able to provide 'quick and dirty' estimates of vulnerability. For example, current population size is frequently employed as a measure of vulnerability to a variety of risks [46] [72] [84] [142].

Populations with a small number of individuals can be wiped out by a single disturbance event, and they have lesser genetic variation, restricting their potential to develop in response to changing environment. Phylogenetic relationships may also offer insights. Species frequently share characteristics with other species to which they are closely related. If one species possesses a characteristic that renders it vulnerable to climate change, it is likely that other closely related species will be vulnerable as well. This notion has recently been effectively applied to plants, but it has not yet been tested with birds [46] [113] [143].

4.7 Inclusion of climate change in IUCN and other species' classification systems and management planning exercises

The IUCN has established a framework for classifying species' levels of endangerment. The current system is mostly based on the number of individuals of a species that are currently living, forecasts of future population growth, and the area that a species inhabits [80] [113] [162]. Immediate hazards to the habitat should also be evaluated. In addition to the hazards posed by human activities, such as over-harvesting and habitat loss, climate change should be considered as an important threat that could harm species [80] [113] [162]. Future climate change may result in a direct drop in a species' population size and number, as well as an indirect effect due to habitat loss. research of the 2008 IUCN Red List of Threatened Species (www.redlist.org) discovered that 35% of the world's 9856 existing bird species had characteristics that render them vulnerable to climate change. A new initiative is ongoing to investigate how the IUCN Red List criteria might be used to identify species most at danger from climate change, and whether a 'possibly threatened by climate change' classification should be considered for the Red List.

4.7.1 Support for species in their current range

Many species are diminishing within their present ranges as a result of the various human activities, including habitat degradation, fragmentation, pollution, invading species, illness, and others. Climate change will increase the burden on many species of conservation concern. Although we cannot stop climate change in the short term—we are already committed to significant changes in climate regardless of mitigation strategies currently in place and being proposed—we can manage for many of the other stresses that species face, maximizing species' ability to adapt to changing climatic conditions and associated changes in habitat. Many of the existing solutions for endangered and other bird species will work to varying degrees for species threatened by climate change [65] [70] [85] [86] [109] [113] [130].

The conservation tools will remain the same, but how they are used will differ. The most effective technique for averting species extinction is almost usually to protect and manage them within their natural ranges. This technique is more effective than relocating them elsewhere since only within a species' current range can we be assured that all of its biological and environmental requirements are met. The first strategy for any endangered species is to safeguard as much of its habitat as possible within its present range, preferably through protected areas such as national parks and

other legal bodies, or private conservation networks. Many species, particularly those found in the tropics, lack extensive information about their ecology [85] [113] [130].

Some species' ranges are simply approximate, and some of the most threatened and specialized species do not occur in the areas where they are assumed to exist. Even more species have poorly documented or unknown food and nesting requirements, species interactions, and movement and habitat use patterns. Thus, recording species' distributions, habitat associations, and other features of their ecology is crucial for directing conservation activities to the most appropriate sites. For example, if a species requires tiny, open habitats in which to gather food or establish eggs, periodic disturbances like fires or selective logging can be utilized to produce and sustain such habitats in otherwise forested environments [70] [109] [113].

Alternatively, a species may have very specific nesting and feeding requirements. Without ecological studies and population monitoring, some species may continue to disappear from seemingly intact habitats. Whenever possible, management should be paired with monitoring to assess the success of management therapies in an adaptive management setting. Climate change has heightened the importance of adaptive management strategies. Because the consequences of climate change and their interconnections with other global changes are difficult to forecast, managers must monitor key factors and evaluate the efficacy of management methods on a regular basis. If it is discovered that management actions are ineffective in stabilizing or expanding bird populations, the management strategy might be modified [66] [85] [86] [113].

4.7.2 Habitat restoration

In addition to controlling populations within their current ranges, land managers can help bird populations by restoring damaged habitat that is no longer occupied by a target species. Human-damaged habitat may hold minimal value for in situ conservation or ecosystem services. Conservation biologists may be able to use these areas to create new habitat for endangered bird species [9] [67] [104] [113] 114] [115] [157].

For example, if a bird species' riparian habitat is being lost in one site, restoring it in a new location or utilizing restoration to enhance an existing patch of habitat may be a worthwhile option. This new forest may eventually be colonized by the target bird species, or the bird may be released as part of a well-planned conservation framework. Islands are particularly valuable in restoration efforts because the effects of human activity and invasive species may be controlled. For example, if hunting is driving a species' loss across its range, managers may be able to control hunting on islands with limited access [9] [67] [104] [113] [114] [115] [157].

In addition, the entrance of invasive species on islands may be closely monitored and managed. It is possible to remove invasive animals, such as rats and feral cats, that depredate or harm birds from some islands, as has been done in New Zealand and elsewhere. If a species, whether endemic to islands or bigger landmasses, is diminishing across its range as a result of human activity and climate change, it may be trans-located to islands where it can survive, even if the species does not naturally reside there. Nonetheless, regulated translocations are a last resort activity that necessitates extraordinary caution and advance planning before any species is relocated. The challenges involved in deliberately introducing species outside of their natural range are described in further detail in a subsequent section [9] [67] [104] [113] [114] [115] [157].

4.7.3 Establishing new conservation areas or corridors for species

Government officials, conservation biologists, and members of conservation organizations face a dilemma in identifying locations that are not currently populated by endangered bird species but may be appropriate for them in the future due to climate change forecasts. The task is to expand the current system of protected areas to cover such sites that are not previously protected. Studies are beginning to employ down-scaled models of climate change and other landscape factors to identify habitats that will be essential to specific bird species in the future. Many models are still unknown, but this is an active area of research, and advances are being made at a quick pace. Long-distance migratory birds' flyways are previously known to some extent [49] [74] [113] [128] [129] [133] [145].

Many of the most significant stopping spots along the road are protected because it is understood that birds require someplace to rest and feed during their annual migrations. However, as the temperature warms, bird migrations are likely to become longer or shorter, and many bird species will gradually expand their ranges away from the equator. To accommodate changes in breeding grounds and migration paths, more protected areas will be needed. For example, if a rare bird species expands its territory further north in Canada to an island it did not previously occupy, habitat protection may need to be expanded to include its new area. In many circumstances, species will simply broaden their ranges by occupying habitat adjacent to their existing ranges [49] [74] [113] [128] [129] [133] [145].

Depending on their physiological tolerances and environmental requirements, many montane bird species will migrate up the slopes to cooler, wetter, and more humid environments. For example, a forest section further upslope that was previously too cold for a species may now be the perfect temperature. Alternatively, a forest bird species may progressively shift upslope as its forest environment does, indicating a changing climate. Conservation biologists can help with bird conservation efforts by protecting particular mountains and mountain chains that are home to endangered birds, as well as the entire gradient from the lowlands to the tops of the mountains. In many situations, such mountains are already protected because to their well-known importance in watershed preservation. Their role in protecting bird species vulnerable by climate change adds to the case for preserving montane forests throughout a wide elevation range [49] [74] [113] [128] [129] [133] [145].

4.7.4 Managed translocation of species

As the temperature changes, many bird species will be able to expand their range to regions both near and distant from their current ranges, occupying new suitable territories. However, this may not be true for some species for a variety of reasons. First and foremost, certain bird species, including ratites, some rails and ducks, and the kakapo (*Strigops habroptila*), have lost their capacity to fly. Other species are weak fliers, unable to migrate large distances. These species do not leave their native ranges to find new locations to live, and they may be unable to change their ranges except through slow overland migration. Species may be unable to find new homes with favorable climate conditions. Penguins, for example, can swim enormous distances but may still struggle to find unusual places appropriate for building new colonies. Third, for species with tiny populations, the number of individuals dispersing great distances may be insufficient to support a founding population [49] [63] [67] [113] [115] [141].

Bird species in tropical highlands are particularly endangered because they may be unable to travel the hot, bright open lowlands that between mountains, which are frequently controlled by farming and other human activity. One possible option for species that are declining as a result of climate change is to relocate groups of individuals to new areas where new populations can grow. These transfers of species have been referred to as assisted migrations, managed migrations, or managed translocations. New locations for such managed translocations must be thoroughly researched in advance to ensure that the location is sufficient and that the species will not have adverse ecological effects on its new habitat. Historical case studies can also help handle translocations. Human action has been moving birds to new regions for hundreds of years, such as establishing game species, translocating species familiar to European settlers, and conserving threatened species [49] [63] [67] [113] [115] [142].

Once the birds are released in their new habitat, the newly established populations must be monitored for size, individual health, and reproductive success. One worry with adopting managed migrations is that an imported species may rapidly increase, putting another endangered species or possibly an entire ecosystem at risk. Such considerations must be carefully explored before relocating a new species by tens or even hundreds of kilometers within the same biogeographical region. The risk of injury can be lowered by choosing a location with no other endangered or directly competing species. However, when translocating a rare species, there is a significant risk that the new population would fail to develop and the species will continue to fall toward extinction [49] [63] [67] [113] [115] [143].

4.7.5 Stakeholder Involvement

Government

Climate change policies should be developed by governments. Climate change has a significant impact on the distribution of migratory birds, thus efforts to preserve relatively steady temperature limitations for migratory birds are required. Increased temperatures caused by carbon emissions have a substantial impact on the dispersion of migrating birds, hence carbon emissions must be reduced [101]. The government can reduce greenhouse gas emissions by passing necessary laws and regulations, such as limiting the use of fossil fuels, improving energy efficiency, developing alternative energy sources aggressively, and managing methane emissions from water fields and landfills. At the same time, the government can pursue climate change public relations and education efforts to raise public awareness of the issue [101].

Corporate

As public and government awareness of climate change has grown, corporations should work with government restrictions and public expectations to adapt their business practices. Donations to non-governmental organizations (NGOs) that focus on environmental issues and compliance with government environmental policies and regulations are typical activities [42] [101]. A progressive approach to environmental awareness may also emerge in the form of private governance, in collaboration with NGOs and local communities, developing new programs as a governance

instrument for environmental sustainability. Additional steps should be taken to address climate change, such as going above and beyond legal requirements for environmental protection, using cutting-edge equipment to reduce industry pollution, and establishing an environmental department to manage the environmental impacts of the cooperation [92] [101].

The Public Solutions

Public education is required to understand how climate change impacts birds, the value of bird species, and how to protect them. Reducing greenhouse gas emissions, which are one of the major causes of climate change, is a simple and efficient strategy to moderate climate change and aid birds. For example, adjusting the journey mode is appreciated. According to the UK 2019 Greenhouse Gas Reporting, Conversion Factor, a domestic flight releases 154 grams of greenhouse gas per passenger per kilogram, whereas a domestic trial emits only 41 grams of greenhouse gas per person [44] [101]. Furthermore, employing footprint calculators to calculate personal carbon emission sources, as well as lowering emissions based on personal intentions, are viable options. As carbon emissions from personal item use such as clothing and shoes are the second largest source [44] [101].

5. Conclusion

Climate change is already affecting bird species' behavior, ranges, and population dynamics and some bird species are already experiencing significant negative impacts from climate change. In the future, depending on greenhouse gas emissions levels and climatic response, climate change will put a large number of bird species at risk of extinction, with estimates ranging from to 7%, depending on region, climate scenario, and potential habitats shift for birds. Climate change will affect birds indirectly in the future by modifying their habitats through sea level rise, changes in fire regimes, and changes in vegetation or land use. Birds are in particular vulnerable to environmental changes like climate change since they are subject to continuous changes that may be negatively connected. Conservation strategies to ensure the survival of the bird populations are critical since they are essential for ecosystem health. Relevant parties and global leaders must be more sensitive to the effects of climate change on these birds' life in order to prevent them from becoming extinct. Based on the findings of the literature review, researchers can conclude that migratory birds are currently under threat from environmental changes, particularly climate change, which has altered the temperature of the Earth's surface. As a result, it is critical to understand how these bird species adjust to continuous climate change and its effects on the bird itself.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors hereby declare that this manuscript does not have any conflict of interest.

Statement of informed consent

All authors declare that informed consent was obtained from all individual participants included in the study.

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