The Effects of Climate Change on Birds and Approaches to Response

Xiaohan Li1a*, Yang Liu2b*, Yuhui Zhu3c*

1Department of biological sciences, Tianjin Normal University, Tianjin, China.
2Department of Environmental Science and Policy, University of California, Davis, Davis 95616, California, US.
3Department of Geography, University of Guelph, Ontario N1G2W1, Canada.
a*10310@stu.tjnu.edu.cn, b*ghuliu@ucdavis.edu, c*Yzhu20@uoguelph.ca

Abstract-Complex changes in climate change have caused numerous changes, such as rising temperature and increasing in precipitation frequency, representing dynamic environmental changes for birds. It results in birds’ responses, such as changes in migration routes. To better understand the responses, the study aims to reveal the impacts of climate change on birds’ behavior and proper approaches toward addressing its effects. The study shows that climate change has caused advanced spring migration, changes in birds’ habitat, higher possibility of disease transmission, earlier egg-laying time, less food availability, and a decline in the bird population. The study also lists possible measures to mitigate climate change’s influence, including environmental policies, partnership with non-government organizations, and decreasing greenhouse emissions. In the future, people should consider identifying knowledge gaps of the link between climate change and birds from efforts of interdisciplinarity and multi-academic fields. The same approach also applies to plausible solutions exploration. The study provides a comprehensive summary of the effects of climate change on birds, as well as briefly illustrates the current approaches to mitigate its impacts. It increases the awareness of climate change’s impacts for the present generation, in turn encouraging them to take progressive actions to address the problem for the future generation.

1. Introduction
Climate change caused by human activities as one of the most popular topics in this century is globally accepted and considered to have negative effects for the majority of species and threaten the survival of a large number of species on the Earth. Climate change is of interest to birds due to birds are widely known to respond to various forms of perturbations to the climate, and their responses are often well-documented [1]. Moreover, based on current research, one-eighth of species of birds have a high level of danger of extermination in the recent future decades, and they need humans to take actions and protect them [1]. The research showed that if the temperature increases 3.5 degrees Celsius in 2100, 600-900 species of birds will become extinct, and 89% of them will happen in the tropic regions [2]. Captive birds that have limited temperature variation and low metabolic rates are most at risk from climate change [2]. Some tropical mountain birds, such as the northern snowbird, are especially vulnerable to climate change due to their lack of access to higher elevations [2]. Birds also play significant roles in ecosystems and are exceedingly related to human health and welfare, such as public hygiene, pest control, and the reproduction of plants [1].
A book called *Birds and climate change: impacts and conservation responses* basically introduces what kind of changes in birds respond to climate change by associating with other researchers’ related large studies [3]. Many researchers also studied the changes of time of egg-laying, distribution, population, and migration in different birds species and regions caused by climate change [4,5]. The paper from Şekercioğlu’s team not only discussed direct effects of climate change on tropical birds, but also included indirect influences from an association between climate change, food resources, and diseases transmission, which can increase the possibility of extinction of some birds by 50% [2]. Other researchers also mentioned birds species in the mountain regions suffer the greatest impact from climate change and need scientists and policy-makers to protect these birds by their professional data collection and knowledge and customized protection laws [6]. However, possible solutions from different institutions to mitigate the negative effects of climate change on birds are also needed.

In this paper, we discuss different negative effects of climate change on birds’ species and possible solutions to mitigate these situations. First, we introduce six different impacts of climate change on birds’ species: migration, habitat, the possibility of disease, breeding, food availability, and population, and using examples to exhaustively explain how climate change makes these changes. Then we provide possible solutions from three different angles, government, enterprise, and the public, to try to reduce detrimental influences caused by climate change.

2. The effects of climate change on birds

2.1 Migratory

As one of the most active components of the ecosystem, birds are sensitive to climate change. Using satellite tracking techniques, scientists have found that the main cause of song crane migration is changing in temperature. Fig.1 shows the Studies have shown that the first arrival date of most birds is negatively correlated with the average monthly temperature, meaning that the warmer the temperature, the earlier the bird’s first arrival date. Research suggests that warming influences changes in the timing of migration and the choice of wintering sites for migratory birds. For some bird species in Europe, the arrival time of spring migration is brought forward by two days for every 1°C increase in average temperature [7]. Changes in migration timing are more pronounced for long-distance migratory birds, which arrive an average of 13 days earlier, and for short-distance migratory birds, which arrive an average of 4 days earlier [8]. Climate change can affect migration paths. Under the influence of global warming, Arctic temperatures are expected to rise more rapidly by the end of the 21st 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. As they leave their overwintering grounds earlier, they will extend their stay in the Arctic. Migratory animals may respond to warming beyond changes in migration timing, particularly as warming affects the spatial distribution of habitats and resources. Suitable breeding and staging habitats are likely to shift northward with the temperature rise [9].

2.2 Habitats

Climate change is widely believed to have shifted the distribution of various species towards mountain tops and poles. The habitat transformation caused by climate warming is also considered as major threats to the survival of certain bird species. Lehikoinen and Virkkala found, in Finland, 128 bird species northerly or north-easterly moved 37 km on average during 1970 to 1989 and 2000 to 2012, while the temperature moved 186 km following the same directions as birds [10]. Freeman’s team also shows reduction or even extinction of populations of some common high-altitude birds species in Peruvian mountains because increasing temperature caused a mass decline of their suitable habitats [5]. They also consider this change as the primary reason for the mass extermination of high-altitude species in the tropical Andes and also threaten birds’ communities in other tropic areas [5]. Jason’s team also showed that under the low greenhouse gases emission level the habitat of Vancouver Island White-tailed Ptarmigan would be reduced by 25% in the 2040s, 44% in 2050s, and 56% in 2080s [11]. If it is under
the high greenhouse gas emission level, the habitats will decline by 27%, 59%, and 74% [11]. More and more mountain birds lose their habitats and are nudged to extinction while increasing temperature.

2.3 Possibility of disease
While climate change causes variations in the habitats of many birds, the risks of contracting diseases for birds are increasing, too. For example, Dr. Gilbert’s team claims that climate change has caused redistribution of wild birds leading to the spread of avian disease [12]. Mute swan population as a good example, carried high pathogenic avian influenza H5N1 (HPAI H5N1), moved to Western Europe from eastern Caspian Sea basin due to old weather spell [12]. The breeding area is bigger than the winter area because of the warmer temperature during that period. They also made a comparison between areas which were predicted to have the highest changes in temperature and Anatidae breeding habitats [12,13]. They are matched, which means due to climate change the original cold area, for example the north pole, became warmer and suitable for mute swans to survive and reproduce. Therefore, the mute swan can bring diseases to these new areas and transmit diseases to local species.

Moreover, increasing temperature caused by climate change studies allows diseases to move to higher altitude regions and infect birds that live in that region. Study shows that climate change is increasing temperature in Hawaii and making more areas available for disease to survive, which expanded the geographic distribution of Avian malaria transmission [14]. Meanwhile, available high elevation forest habitat which has a low-risk for Avian malaria is predicted to decrease by 57% in Hawaii if the temperature rises 2 degrees Celsius [14]. The disease transmission area extends from 1500 meters high to 1800 meters high [14]. Thus, the species in the area between 1500 meters and 1800 meters will be at high risk from Avian malaria and pox because of climate change [14]. As Fig. 1 shows, the low-risk region for species is decreasing, and the possibility of infection is increasing.

![Fig. 1 The diseases transmission zone](image)

2.4 Breeding
Climate change can have an impact on the timing of egg laying in birds, with early studies suggesting that some birds are laying eggs earlier than in the past. The average flowering and leafing period may be brought forward by high spring temperatures, thus affecting 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 UK have also been shown to lay eggs at spring temperatures have risen. Both et al. (2004) studied low-flying moths and found that nine populations had earlier spring temperatures. Climate change can lead to a mismatch between the timing of breeding and the availability of staple foods for birds [4]. Visser et al. (2006) studied the Palouse specialist and found changes in the peak abundance of caterpillar pairs it feeds on, which ultimately led to changes in the breeding season.
of Great Tits [4]. The trend towards early nesting or breeding may be a more general phenomenon in British wildlife. This may have considerable ecological and conservation implications for them. For birds, early nesting may be beneficial if there is a longer period before winter to improve the survival rate of young. Fig. 2 shows Anatidae’s breeding area and winter area. The breeding area is bigger than the winter area because of the warmer temperature during that period. Conversely, birds may be adversely affected if they are out of sync with the physiography of their food supply. Changes in climate can also affect changes in the breeding sites of birds. Scientists have analyzed the breeding ranges of British birds over a 20-year period and found that 59 species of southern British birds moved their breeding sites northwards during a period of gradual climate warming, so scientists have identified one of the potential factors for anthropogenic warming to shift breeding sites northwards. There is also some evidence that warmer temperatures are causing birds to stay at their breeding sites slightly longer than previously. Many short distance migrating birds have significantly more individuals spending the winter at their breeding sites [15]. Fig. 2 Predicted breeding range of the mainland population of Red-crowned Cranes in the 2030s, 2050s, 2070s and 2080s. Blue polygons are actual current breeding areas, green polygons are projected potential breeding areas under current climate conditions, and orange areas are projected potential breeding areas for climate change. The scenario is RCP2.6, the low emission scenario.

![Fig. 2 Distribution of Anatidae breeding and wintering areas [16].](image)

### 2.5 Food availability

Climate change has gradually changed environmental conditions, including the increasing frequency of extreme weather, global warming, and changed precipitation rates. To estimate the indirect effects of climate change on birds’ food availability, studies show that climate change has caused the decline in birds’ food abundance, which leads to potential threats for birds’ life stages, including reproduction and body growth. In terms of caterpillar, in 1998, Visser et al.’s study conclude that the spring temperature has been increased dramatically from 1973 to 1995, and thus the caterpillar biomass peaks have also advanced nine days, compared to their historical data. Climate change also causes dramatically decline in the ambient temperature, resulting in delayed growth and reduced feeding activities of caterpillars [17]. It leads to drops in the caterpillar biomass abundance, and a higher mortality rate [17]. Krill and marine organisms also show a similar link with climate change. Since the 1950s, the sea ice has melted about 12% - 20% due to climate change, resulting in a reduction in the number of krill and other marine organisms, which happened to be the main diet for five breeding seabirds in Adelie Land, Antarctica [18-22].
In conclusion, climate change has caused less food availability for birds. The decline in food availability may have short-term and/or long-term consequences, such as a mismatch between birds’ reproduction time and available food peak dates. However, the consequences may be affected by birds’ adaptation to dynamic environmental conditions.

2.6 Bird population
Global climate change has led to the occurrence of phenological mismatches, resulting in changes in population size, leading to 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. In a study of songbirds in Arizona, USA, Thomas and John showed that the decline in their numbers was linked to snowfall caused by climate[23].Gasner used models to predict population changes in the Central American fish eagle under future climate scenarios and showed that the population of the species would decline, and a few species would go extinct[24]. This is a major factor contributing to the decline in bird populations. Warmer temperatures will reduce the quality of the birds’ habitat, which will lead to a decline in the number of species. Warmer temperatures will also lead to an uphill shift of montane species around the world, and these uphill changes will lead to mountaintop extinctions of species that live only near the top of mountains. For example, warming has constituted an ‘escalation of extinction’ for birds in remote mountain areas of Peru - high-altitude species have declined in range and numbers, and some previously common mountaintop dwellers have disappeared from local communities [25].

3. Approaches to address the impacts of climate change

3.1 Government
Governments should develop effective policies to address climate change. Climate change has a crucial impact on the distribution of migratory birds, so there is a need to develop policies to maintain relatively stable Temperature restrictions for migratory birds. Increased temperatures due to carbon emissions have a significant impact on the distribution of migratory birds, and therefore there is a need to reduce carbon emissions. The government can reduce greenhouse gas emissions by enacting relevant laws and regulations, for example, reducing the use of fossil fuels; improving the efficiency of energy use; vigorously developing new energy sources; and controlling methane emissions from water fields and landfills. At the same time, the government can also conduct publicity and education campaigns on climate change to raise public awareness of climate change.

3.2 Corporate
As the awareness of climate change has sharply increased among the public and governments, corporates should cooperate with government regulations and the public expectation to modify their business behaviors. The common practices often include donations to non-government organizations (NGOs), which focus on environmental problems and compliance with environmental policies and regulations from governments [26]. The progressive approach with the environmental awareness could also emerge, in the form of private governance, in partnership with NGOs and local communities, creating new programs as a governance tool for environmental sustainability. One of the successful examples is Fishery Improvement Projects (FIP), in which corporate, in partnership with NGOs and private actors in the fishery supply chain, take a series of actions to make the fishery more sustainable [27]. Table 1 shows common practices for FIP, including data collection through individual fishermen; active data communication; policy discussion; and education programs in numerous local communities[27]. Further steps toward addressing climate change should also be initiated, including implementing environmental protection actions to the degree beyond legal requirements, using state of the art equipment to mitigate industry pollution, and creating an environmental department to manage the environmental impacts of the cooperation.
Table 1. The most common actions of FIP for different fish types [27].

| Crab/lobster | Shrimp | Tuna | Others |
|-------------|--------|------|--------|
| 1. Data collection | 1. Basic dialogue policy; Engaged dialogue practice; Data collection; Data dialogue | 1. Basic dialogue policy; Engaged dialogue practice | 1. Data dialogue |
| 2. Data dialogue; Engaged policy dialogue; Education | 2. Data collection; Data dialogue | 2. Data collection; Data dialogue | 2. Data collection |
| 3. Basic dialogue practice; Basic dialogue policy | 2. Education | 3. Basic dialogue practice | 3. Basic dialogue policy |

3.3 The public solutions

From the public level, it is necessary to have education about how climate change affects birds, the importance of birds’ species, and how to protect them. Reducing emissions of greenhouse gases, which is one of the major causes of climate warming, is an available and effective way to mitigate climate change and help birds. For example, changing trip mode is appreciated started. From the UK 2019 Greenhouse Gas Reporting, Conversion Factor, per passenger per kilogram by domestic flight emits 154 grams greenhouse gas, but by domestic trial per person only emits 41 grams greenhouse gas [28]. If only one passenger is in one car, per person will emit 171 grams of greenhouse gas, but it will reduce to 104 grams by taking the bus [28]. Moreover, using footprint calculators to calculate personal carbon emission sources and reducing emissions based on personal plans are good solutions. For example, from my calculation, besides large emissions from transportation, carbon emissions made by clothes and shoes is second large emission that can be reduced.

4. Conclusion

Birds have a very close relationship with humans. A good ecological environment is one of the most important conditions for a normal productive life for humans. Birds have been found to play a significant role in maintaining the ecological balance and protecting nature’s greenery. This paper discusses the effects of climate change on birds. For example, warmer temperatures can lead to earlier spring migration, as well as altering bird habitats and increasing the risk of virus transmission; climate change can also lead to a mismatch in phenology, reducing population size and species diversity, bringing forward the egg-laying dates of some birds, and affecting the food supply of birds. The paper also lists measures to mitigate the impact of environmental change on birds: governments should formulate policies to address climate change; companies should make changes in line with the relevant laws; and, on a personal level, we should reduce greenhouse gas emissions by traveling in a low-carbon manner. In the context of global warming, there are still many issues that need to be addressed, such as how to deal with the changes in the living environment of birds caused by climate change. This paper aims to raise awareness of the severity of the effects of climate change on birds, and these studies can contribute to changes in government policy and public awareness, thus helping us to better protect birds and preserve species diversity.

Reference

[1] D. King, D.M. Finch, Climate Change Resource Center U.S. The effects of climate change on terrestrial birds of North America, U.S. Dept. Of Agriculture, Forest Service, Climate Change Resource Center, Washington, Dc, 2013.

[2] D. Scridel, M. Brambilla, K. Martin, A. Lehikoinen, A. Iemma, A. Matteo, S. Jähnig, E. Caprio, G. Bogliani, P. Pedrini, A. Rolando, R. Arlettaz, D. Chamberlain, A review and meta-analysis of the effects of climate change on Holarctic mountain and upland bird populations, Ibis. 160 (2018) 489–515.
[3] J.W. Pearce-Higgins, R.E. Green, *Birds and Climate Change: Impacts and Conservation Responses* Ecology and Biodiversity Conservation, Cambridge: Cambridge University Press, 2014.

[4] H.Q.P. Crick, C. Dudley, D.E. Glue, D.L. Thomson, *UK birds are laying eggs earlier*, Nature. 388 (1997) 526–526.

[5] B.G. Freeman, M.N. Scholer, V. Ruiz-Gutierrez, J.W. Fitzpatrick, *Climate change causes upslope shifts and mountaintop extirpations in a tropical bird community*, Proceedings of the National Academy of Sciences. 115 (2018) 11982–11987.

[6] Mark, van Ommen, V.I. Morgan, K.L. Phillips, A.S. Palmer, *Ice core evidence for antarctic sea ice decline since the 1950s*, Science. 302 (2003) 1203–1206. https://doi.org/10.1126/science.1087888.

[7] D.J. Brown, D.M. Donner, C.A. Ribic, C.I. Bocetti, *Influence of climate change and postdelisting management on long-term population viability of the conservation-reliant Kirtland’s Warbler*, Ecology and Evolution. 9 (2019) 10263–10276.

[8] T.K. Lameris, I. Scholten, S. Bauer, M.M.P. Cobben, B.J. Ens, B.A. Nolet, *Potential for an Arctic-breeding migratory bird to adjust spring migration phenology to Arctic amplification*, Global Change Biology. 23 (2017) 4058–4067.

[9] M.M. Jackson, S.E. Gergel, K. Martin, *Effects of Climate Change on Habitat Availability and Configuration for an Endemic Coastal Alpine Bird*, PLOS ONE. 10 (2015) e0142110.

[10] A. Lehikoinen, R. Virkkala, *North by north-west: climate change and directions of density shifts in birds*, Global Change Biology. 22 (2015) 1121–1129.

[11] Ç.H. Şekercioğlu, R.B. Primack, J. Wormworth, *The effects of climate change on tropical birds*, Biological Conservation. 148 (2012) 1–18.

[12] M. Gilbert, J. Slingenbergh, X. Xiao, *Climate change and avian influenza*, Revue Scientifique et Technique (International Office of Epizootics). 27 (2008) 459–466.

[13] D. Stone, *Predicted climate changes for the years to come and implications for disease impact studies*, Rev. Sci. Tech. Off. Int. Epiz. 27 (2008).

[14] C.T. Atkinson, D.A. LaPointe, *Introduced Avian Diseases, Climate Change, and the Future of Hawaiian Honeycreepers*, Journal of Avian Medicine and Surgery. 23 (2009) 53–63.

[15] B. Huntley, Y.C. Collingham, S.G. Willis, R.E. Green, *Potential Impacts of Climatic Change on European Breeding Birds*, PLoS ONE. 3 (2008) e1439.

[16] M. Gilbert, J. Slingenbergh, X. Xiao, *"Climate change and avian influenza."* Revue Scientifique Et Technique 27.2(2008):459.

[17] C.E. Harris, M.S. Pritchard, R.W. James, E.E. Englehardt, M.J. Rabins, *Engineering ethics : concepts and cases*, Cengage, Boston, Ma, 2019.

[18] V. Loeb, V. Siegel, O. HolmHansen, R. Hewitt, W. Fraser, W. Trivelpiece, S. Trivelpiece, *Effects of seaice extent and krill or salp dominance on the Antarctic food web*, Nature. 387 (1997) 897–900.

[19] S. Nicol, T. Pauly, N.L. Bindoff, S. Wright, D. Thiele, G.W. Hosie, P.G. Strutton, E. Woehler, *Ocean circulation off east Antarctica affects ecosystem structure and seaice extent*, Nature. 406 (2000) 504–507.

[20] A. Atkinson, V. Siegel, E. Pakhomov, P. Rothery, *Longterm decline in krill stock and increase in salps within the Southern Ocean*, Nature. 432 (2004) 100–103.

[21] C.L. PARKINSON, *Southern Ocean sea ice and its wider linkages: insights revealed from models and observations*, Antarctic Science. 16 (2004) 387400.

[22] V. Loe, V. Siegel, O. HolmHansen, R. Hewitt, W. Fraser, W. Trivelpiece, S. Trivelpiece, *Effects of seaice extent and krill or salp dominance on the Antarctic food web*, Nature. 387 (1997) 897–900.

[23] S. Nicol, T. Pauly, N.L. Bindoff, S. Wright, D. Thiele, G.W. Hosie, P.G. Strutton, E. Woehler, *Ocean circulation off east Antarctica affects ecosystem structure and seaice extent*, Nature. 406 (2000) 504–507.

[24] A. Atkinson, V. Siegel, E. Pakhomov, P. Rothery, *Longterm decline in krill stock and increase in salps within the Southern Ocean*, Nature. 432 (2004) 100–103.

[25] C.L. PARKINSON, *Southern Ocean sea ice and its wider linkages: insights revealed from models and observations*, Antarctic Science. 16 (2004) 387400.

[26] K. Fletcher, D. Howarth, A. Kirby, R. Dunn, A. Smith, *Effect of climate change on breeding phenology, clutch size and chick survival of an upland bird*, Ibis. 155 (2013) 456–463.

[27] C.D. Thomas, *Climate, climate change and range boundaries*, Diversity and Distributions 16(3) (2010).

[28] M.R. Gasner, J.E. Jankowski, A.L. Ciecka, K.O. Kyle, K.N. Rabenold, *ScienceDirect - Biological Conservation : Projecting the local impacts of climate change on a Central American montane avian community*, (2010).
[25] B. HUNTLEY, Y.C. COLLINGHAM, R.E. GREEN, G.M. HILTON, C. RAHBEEK, S.G. WILLIS, *Potential impacts of climatic change upon geographical distributions of birds*, Ibis. 148 (2006) 8–28.

[26] B. Crona, S. Käll, T. Van Holt, *Fishery Improvement Projects as a governance tool for fisheries sustainability: A global comparative analysis*, PLOS ONE. 14 (2019) e0223054.

[27] H. Kobori, T. Kamamoto, H. Nomura, K. Oka, R. Primack, *The effects of climate change on the phenology of winter birds in Yokohama, Japan*, Ecological Research. 27 (2011) 173–180.

[28] Department for Business, Energy & Industrial Strategy, *Greenhouse gas reporting: conversion factors 2019*, GOV.UK. (2019).