

Categories of Climate Change and Impact on Bird Behavior

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Abstract. Birds are extremely vulnerable to even tiny changes in temperature, moisture and climate. The possible effects climate change, like temperature or precipitation, can have on their survival has gradually increased over time. This study looks at these effects, particularly on their behavior changes, which is categorized into either migration or reproduction. Furthermore, birds have managed to micro-evolve in order to avoid ecological mismatches that can lower their possibility of survival and reproduction. This study then discusses birds' behavioral microevolution as an alternative solution to the changes brought about by climate change. Overall, climate change influence both resident and migratory birds to a large extent. Although they are able to utilize microevolution, this effort might not be enough to cover for potential drawbacks.

Keywords: Climate change; bird behavior; ecological mismatch; microevolution.

1. Introduction

More than 9,000 species of birds exist on planet Earth and make up a vital part of its ecosystems. Some are extremely vulnerable to even tiny changes in temperature, moisture and climate. Therefore, climate change has become an important topic regarding biodiversity and species survival. Temperature is closely correlated with bird reproduction time and whether birdlings will be able to hatch, while drastic climate changes or extreme weather may influence birds' migration and chick survival rates. Further effects can include ecological mismatches, resulting in birds not being able to obtain enough food resources to breed their young. For instance, growing seasons have advanced by several days for plants in the northern hemisphere by 1997 [1]. As plant seeds are a part of the major bird food sources, many birds should be affected by this change and they wouldn't be able to find food during their time of optimum need, which usually matches with food source peaks.

In mountainous ranges like the Holarctic mountain regions, both positive and negative effects of climate change are observed with responses of different scales [2]. Despite birds' strong acclimatization abilities which enable them to maximize their reproduction efficiency and outcomes, in extreme weathers or long periods of warming their reproduction success is still quite low. This might thus lead on to possibilities of species population decline. In a word, climate changes can interfere with bird survival and eventually the total population is likely to be affected, which can lead on to greater consequences related with biodiversity. Previous research of this field has focused on bird phenology, such as migration patterns, or physical traits, such as plumage color. There has been various research on more specific bird species rather than the entire bird population.

This study first looks at the several possible outcomes that are generally associated with climate change based on past studies. Then the focus is put on the bird behavior changes due to climate change, which is categorized into either migratory changes or reproduction changes. This includes multiple species. Finally, birds' coping mechanism against these changes, microevolution, is discussed.

2. Categories of Climate Change

Climate change can have potential effects on temperature, precipitation and extreme weather, and all of these can alter bird behavior to a large extent. They can alter birds' natural habitats while some species might not be able to adapt, or extreme weather may interfere with migration routes for migratory species like plovers and avocets. Warming temperatures might influence the growth cycles

of insects and plants, which in the end affect whether birds have enough food to feed themselves, their young, and their population.

2.1. Temperature

Climate change is generally associated with increased mean annual temperature due to the increase in CO₂ production, which eventually results in global warming (Fig. 1) [3]. Primary sources of this production are emissions caused by human behavior. These emissions disrupt the original atmospheric composition, adds to the greenhouse effect, and trap radiation from Earth within the planet. Fuel burning, a major source of emission, can lead to gases being oxidized and forming aerosols, such as sulfate aerosols that reflect solar radiation, and black carbon [3]. Aerosol interaction with clouds or moisture in the atmosphere can either cause cooling or warming. The Arctic experienced regional warmings of 0.27 ± 0.04 K because the amount of sulfate and black carbon aerosols has declined.

Future projections of annual mean and maximum temperatures are still increasing. Studies conducted by Carvalho et al. for the Iberian Peninsula using climate projections suggest that for the future both local mean and maximum temperature will increase towards the end of the 21th century, specifically the 2046-2065 period, and at the same time frequencies of hot days increase as well [4].

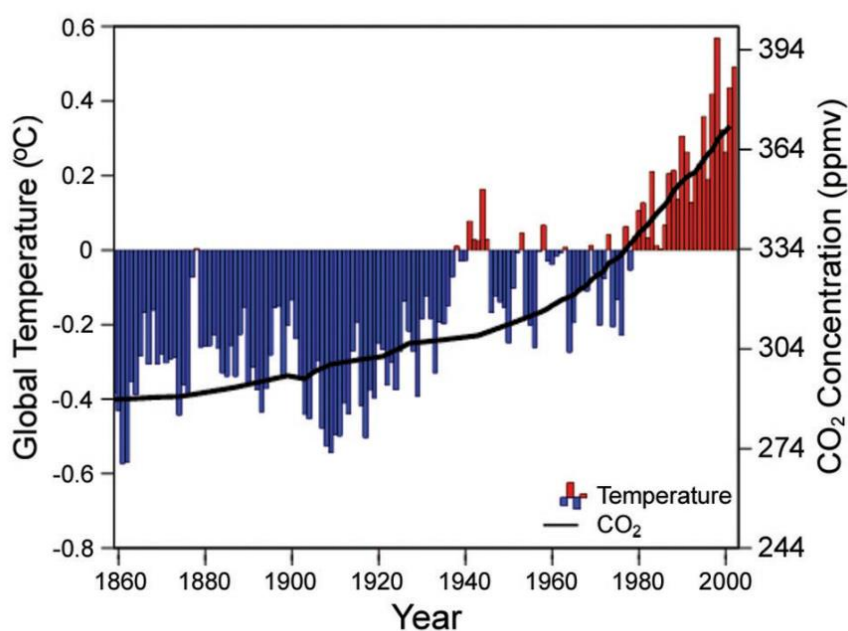


Fig 1. Global mean temperature rises with CO₂ concentration.
<https://www.science.org/doi/10.1126/science.1090228>

2.2. Precipitation

Precipitation, which includes rainfall, snowfall, sleet and hail, is influenced by climate change mainly because of increased evaporation. On the other hand, with an increase of temperature by 1°C, the air's ability to contain water rises by 7% [5]. In this case, moisture in air increases as water vapor accumulates; thus, thunderstorms or precipitation events become more intense and rainfall increases. The result of this change is that wet areas receive more precipitation, while dry areas are still experiencing droughts. Also, rain is more frequent than other precipitation forms like snow, and due to global warming snow melts earlier as well. There has been increasing trends of precipitation extremes as well [6]. Overall, flooding and intense precipitation events become more likely, and droughts are more widespread.

2.3. Extreme weather

El Niño events are climate anomalies that brings unusual warmings in the eastern equatorial Pacific Ocean. A specific type of El Niño increased its frequency in the late 20th century named the central Pacific El Niño (CP-El Niño). It is strongly associated with anthropogenic climate changes according to studies [7]. The development of CP-El Niño is favored by an increase in sea surface temperature in a particular zone, which is subsequently linked to the above-mentioned warming of temperatures. On average, anthropogenic climate change is predicted to result in 1 to 2 more extreme CP-El Niño occurrences.

3. Climate Changes Influence Bird Behavior

This paper focuses on bird behavior alone, which will include migratory changes and reproduction changes. Climate change, especially the warming of the planet, can result in avian populations shifting their migration patterns to increase fitness in the environment, or move laying dates ahead to correspond with the advanced or delayed growth cycles of their food like insects.

3.1. Migration

More than 5000 bird species across the world migrate, most of them waterfowl and seabirds, and they migrate for multiple reasons, including seasonal changes and restrictions in food availability. During migration, they search for more suitable habitats and locations where food is more abundant, which is key to their future reproduction. Global warming, as a part of climate change, may interfere with their migration routes. Warmer winters, for instance, has caused declines in migration route distances in 21 out of 24 species in Netherlands, with 12 showing significant reductions [8]. Their reduced distances vary with their natural habitats but not correlated with any other aspect such as diet, overall population of the species, or body weight. They shortened migration lengths the most for species from dry, open environments, but it's the opposite case for those from wet and open areas. For species from woodlands, they fit in the intermediate. This can be a result of the small effect of temperature on wet and open species' overwintering habitats or related to land use of open habitats. The yearly winter temperature at breeding sites and the Log10 migratory distance are inversely correlated. Therefore, it is proposed that this reduction is related with the advanced arrival date of short-distance migratory species. Another study by Zaifman et al. [9] looked at specifically three states of North America and suggests that long-distance migratory birds altered timing more than short-distance birds. Except from Alaska, summer species tend to leave later as the temperature increases, while winter species will leave earlier. Departure date for winter residents is influenced by the maximum temperature and so is the fall stopover date. This is true for both types of migratory birds in this study. In contrast to the previous study, short- and long-distance birds both modify the timing of their migration as a response to the change in temperature of their surroundings. Additionally, the fact that both types are adjusting is contradictory to previous beliefs that long-distance migratory birds rely on fixed cues, like photoperiods, when timing. Climate change is changing their migration timing schemes.

3.2. Reproduction

Seasonal temperature shifts also affects bird reproduction, specifically on the duration of breeding seasons and egg-laying dates. The former depends mostly on the duration of growing seasons, so a warmer spring means reproduction could start earlier than usual. According to the research of Jenson et al. [10], 8 out of 20 species significantly advanced their breeding dates while mean temperature of April increases, while only 1 species shortened their duration. Still, breeding durations vary among species. The study also focused on three specific species, the goshawk *Accipiter gentilis*, starling *Sturnus vulgaris*, and wood pigeon *Columba palumbus*. For these three both expansions and shortening of breeding seasons are seen. Already early-breeding birds don't expand their reproduction duration as much as late-breeding birds do. Overall, an increase in mean temperature of March and

April since 1970 in breeding grounds is directly linked to advances in phenology. With an advance in breeding date, duration of reproduction increases, having an average expansion of 6-7 days. Furthermore, for migratory birds laying dates are related with arrival dates because the latter functions as a restraint.

According to the research of Shipley et al. [11], particularly on tree swallows' laying date, insect biomass and chick mortality, further explores climate change's impact on bird survival and population maintenance. Tree swallows on average advanced their laying dates by almost 2 weeks. Potential advantages of doing so might be to match with the advance of insect growth cycles, which is also advanced due to warmer climates. Since if birds follow original breeding time schemes they will encounter ecological mismatches, causing them to miss the time with optimum food source and wouldn't have enough nutrients to feed their young. Parent birds' decisions on the time of reproduction is also closely related with cold snaps, a short period of time when temperature drops suddenly. It has been discovered that the difference in time between hatch date and the latest cold snap is related with newly hatched babies per nest. Poor weather conditions, like the cold snaps, have a negative impact on chick survival. Especially for advances the fledgling survival rate is lower. Although cues to time breeding migratory birds like the tree swallows use are still unclear, several components of the environment are likely influential, including food availability (insect biomass) and spring temperature. However changing birds' timing of reproduction, especially advancing it, also have risks. It might lead them to face more random unfavorable weather such as cold snaps that chicks may not endure.

4. Response Measures

Many birds undergo microevolution as a response to climate change. Climate changes have brought warmer temperatures that have, as a result, lead to advances in prey and food source phenology. As mentioned above in the previous section, birds that fail to adapt encounters mismatches that will eventually cause their population to decline. Hence in order to synchronize with advanced peaks of food, birds need to either arrive or breed earlier, or simply change their migration routes completely according to appropriate temperatures. This phenotypic plasticity allows individuals to react quickly, compared with evolution and adaptation that usually require a few generations [12]. For migratory birds, their timing and location systems are experiencing a microevolution. Studies by Thorup et al. [13] on red-backed shrikes show that shrikes are shifting their breeding locations alongside with climate warming. Their breeding ranges moved north alongside with suitable breeding areas. Shrikes used to reproduce in northern Africa during glacial periods, yet currently they are observed to be breeding in Europe. This strategy is proved to help with their continuous population over the past 40,000 years despite the increasing temperature. Migratory patterns haven't changed, but the areas shrikes stopped by experienced a displacement. In this way, during their migration routes there would always be suitable environments and resources. Yet despite this plasticity, it is estimated that areas available for shrikes continue to decline. Future climate change may be even more challenging for migratory birds' resource tracking. Apart from this, what is noticeable is that although birds change their migratory patterns as a part of microevolution, there seems to be no significant size or shape shifts especially for smaller passerines over the past 40,000 years, although a decline is expected [14].

5. Conclusion

Climate change can cast multiple forms of results: rise or decrease in temperature, precipitation changes, and extreme weather. In order to deal with the impacts these changes can bring to bird populations, which includes extensions or delays of arrival dates and reproduction timing, bird species are found to utilize microevolution. This coping mechanism allows them to catch up with possible ecological mismatches so that they can obtain enough food for themselves and their young, either

delays or advances in plant or insect growth. Additionally, in order to deal with changes in available habitats, they shift their migratory patterns to seek for the most suitable habitat. This study overviews several possible effects of climate change and how they influence bird behavioral response. As the globe warms, more and more species face challenges of survival, and the unpredictability of climate change makes this situation even more severe. Since the exact mechanism and reason why birds go through these changes in different scales are unclear, future efforts of research could delve deeper into those two areas. A viewpoint on bird microevolution might also be offered in order to implement more protection measures and lessen the effects of climate change.

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