

Climate Change Impact on Bird Reproduction

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Abstract. Climate change is a popular topic with increasing attention recently. It is impacting many organismal processes harming some species and also benefiting some others. Birds are playing an important role in the diversity of species because they are highly mobile and are able to distribute in a wide range with smaller populations. However, climate change is impacting a lot on this animal category, especially their reproduction. This article reviewed several previous studies of climate change's impact on birds, particularly on the impacts on their reproductive processes of mating, nesting, and breeding. The aim is to make a summary of what climate factors are influencing birds on their reproduction and investigate and find out the insufficiency of current research on climate change factors. From summarizing the past experiences of bird reproduction, future studies will be able to make clear and accurate predictions on the impact of changing climate on the dynamic of birds' diversity and richness.

Keywords: Climate change, birds, mating, nesting, breeding.

1. Introduction

Climate change is an important topic being investigated by many researchers. It is considered the largest environmental problem nowadays. Climate change can impact every organism living on this planet, including animals as large as a blue whale and as small as an ant. The class of animal Aves contains more than 10,000 species. Aves, also birds, are special vertebrates. They can fly and lay eggs and incubate them externally. They are so widely distributed that they can be found on the top of mountains and by the seashore. Even, this can happen to one bird species during their migration seasons. Often, adult birds migrate from their non-breeding field to the breeding field to find mates and babysit their nestlings. However, climate change has some influences on birds' reproduction. Several factors were found to impact birds, such as CO₂ level rise and extreme weather.

Seventy-two bird species nesting in Northeastern Illinois were found to be influenced by the changing atmospheric CO₂ levels [1]. They were experiencing a mismatch of food availability and energy requirement according to 143 years of data. On average, their nesting date was found to be advanced more than 20 days. Most of them were correlated with an increase in atmospheric CO₂ levels, for both residents and migrants.

Arctic-breeding shorebirds' food is more affected by the advanced snowmelt because of the temperature rise [2]. Such mismatch was found to lead to more unpredictable weather for the birds and their invertebrate food resource, so their hatching period is even more fluctuant.

Adult birds were well investigated and were found that they are suffering from the impact of climate change. Therefore, this article focuses on bird reproduction to understand how breeding birds and newly hatched chicks are doing with the consequences caused by climate change.

2. Reproductive Processes Being Impacted by Climate

The whole reproductive process can be divided into three processes --- mating, nesting, and breeding. Mating is the process before completing successful copulation. In this process, migrant bird species migrate poleward usually to their breeding field to meet their old mates or make new ones. Meanwhile, resident bird species do the same except for migration. In the nesting process, male birds or together with female birds build nests, lay eggs, and do all the other preparations for hatching chicks. The process of breeding refers to the time after the chicks break their eggshells until they leave their parents at the age of fledging. Nature provides them with habitats and food but is also full

of risks. The changing climate is even riskier for bringing unpredictable and extreme weather to organisms in a rapid and ephemeral pattern that they can hardly adapt to. Reproducing birds face plenty of processes in a yearly cycle, where they learn the experience and are able to retrieve them in the next year. Thus, climate changes are troublesome to them.

2.1. Mating

2.1.1 Migration between non-breeding and breeding fields

Migration is an important process for migrants to reproduce. Birds migrate for pleasant environmental conditions to obtain abundant food for them to breed their chicks. Such that, birds tend to optimize their strategy of migration by minimizing their energy cost and maximizing the number of their offspring they can breed. Generally, birds can learn from their experiences in previous years to decide when to leave and where to go. However, climate changes disrupt what they've learned. Evidence shows that birds are changing their migratory decisions. A selection experiment on Southern German Blackcaps (*Sylvia atricapilla*) for over 20 years monitored their migratory restlessness behaviour, which refers to the active level at night for migrating birds. This study showed that birds reduced their migratory activities over generations when the ambient temperature was increased [3]. It also indicated that birds of earlier generations had more migratory activity reduction than the later generations, showing that birds can adapt the environmental change through time but still longer than the natural changes.

2.1.2 Successful male ornamentation

It is commonly seen that male birds have distinguishing ornamentations and plumage different from females. These ornamentations are mainly used for attracting females during the breeding season. Females tend to choose males with higher survivorship and ornamentations attracting mates that are heritable to their offspring with higher fitness. When the external environment is changing, the most successful strategy may vary. Birds can adapt to climate change because some secondary sexual traits are more adaptive to the changed environment, so this drives the sexual selection of females on males. Such selection happened to a population of Collared Flycatchers (*Ficedula albicollis*) breeding in Europe and wintering in sub-Saharan Africa [4]. Matured males in this population of Collared Flycatchers have a clear white forehead patch on their black heads which regrows in a yearly cycle during the breeding season. Their study observed that from 1981 to 2014, the patch size declines with the increasing temperature in spring, which increased the population density [4]. The main force driving this selection is to reduce interspecific competition with European Pied Flycatchers, *Ficedula hypoleuca*, who also have large forehead patches and breed in the same location as Collared Flycatchers [4]. The sexual selection might have something to do with females choosing males that are not injured in the competition and with a stable territory.

2.1.3 Mate bonding

When there is no pressure on looking for resources for reproduction, monogamy (one male pair with one female only) is relatively stable, because paternity and maternity are certain. Birds tend to form a stable social partner and continue mating with this mate in this breeding season and all the other seasons. However, with climate change, birds fail to foresee whether their current partner is doing well or not, thus, they may cheat or divorce with their partners and copulate with others with higher quality in the new environment to maintain gaining from their reproduction effort. Nevertheless, some birds may reduce their performance on cheating or divorce to avoid risking in such an unpredictable condition. Botero and Rubenstein built a model for a wide range of bird species on the relationship between avian infidelity, adult mortality, and climate variables (precipitation and temperature) [5]. It showed that the frequency of divorce is negatively correlated with the predictability of annual temperature cycles [5]. This proves that in unpredictable climate conditions, birds are more likely to divorce, forming a mate bonding with another partner. Yet, the pattern of partnership is also a factor affecting infidelity. Surely that birds maintaining year-long partnerships are more likely to divorce their current partners in unpredictable environments, and birds maintaining

short and temporary partnerships tend to stay with their partners longer. The study explained this phenomenon by the positive relationship of forming extra-pair broods with adult mortality. But the ability to make predictions has something to do with insight, which is not yet considered to exist in non-human animals.

2.2. Nesting

Laying eggs is the first step of narrowly considered reproduction, for this is the first step after fertilization. Female birds are able to control the time laying eggs by controlling the time and amount they intake a higher amount of calcium than usual which is used to form the eggshells. Incubating eggs is also costly for parent birds. They need to stay in the nest for a long time to keep the eggs warm, so it is more difficult than usual for them to flee from predators. They may be starving when nesting, waiting for their mates to take food back to them. Or they have to forage by themselves and come back quickly for some species. With many costs, birds are able to minimize their cost by changing the amount of time they incubate. Although the time of warming up an egg until hatch is fairly constant, the adult bird can stay longer in the nest in a day so it can advance into the next step of feeding the chicks. Tree swallows (*Tachycineta bicolor*) in North America were found to gradually advance their egg laying date through the 43 years between 1972 and 2015 [6]. This advancement was found to match the peak of insect activity but not the weather. The chicks were hatched in a dangerous condition with cooler temperature, thus leading to higher chick mortality and fledging failure [6].

2.3. Breeding

Chicks are bottomless reservoirs asking for food. They require a lot higher amount of energy than their adult parents, not only because they are developing, but also because they lack temperature regulation (mainly fat). Parenting chicks is a high cost to parents' fitness but their benefit for maintaining their gene pool outweighs the cost.

Usually, parent birds abandon a whole cluster when they felt a threat. Parental corticosterone or other stress hormones level may elevate after abnormal weather [7]. This is the cause found by Astheimer and colleagues that Lapland Longspurs (*Calcarius lapponicus*), who breed in the Arctic, increase the probability of abandoning their cluster or even the brood after a snowstorm happening in 1989 with a following three-day low temperature. Not only because of the stress hormone elevation, but the food depletion in the snow for days also explains the cruelty of nature.

3. Factors Impacting Reproductive Processes

3.1. Temperature

Temperature increase can be seen in many cases affecting bird reproduction. It is seen as the primary factor influencing bird reproduction in many aspects, including reducing the fitness of young directly and indirectly by decreasing adult fitness directly and increasing the mortality of many individuals.

With higher temperatures, the amount of snowmelt also increased dramatically. This is a disaster for chicks because they haven't developed water-proof adult plumage. Adélie penguins (*Pygoscelis adeliae*) breeding on the Antarctic Peninsula were found to have reduced hatching success and chick survivorship. This reduction was caused by the heavy snow precipitation and the warm temperature following it, which made it almost impossible for these penguins to keep the warmth and dryness of their nests [8]. After the flood over their nests, the baby penguins had their feathers wet and were frozen to death.

3.2. Precipitation

Precipitation affects bird reproduction more indirectly than directly because birds' food is varying more with climate change.

American Redstarts in Font Hill Nature Preserve in southwestern Jamaica were monitored from 2003 to 2009. These American Redstarts either stayed in the black mangrove (*Avicennia germinans*) with some white (*Laguncularia racemosa*) and red mangroves (*Rhizophora mangle*), which become dry in early spring (February and March) or scrub containing primarily logwood trees (*Haematoxylon campechianum*) and other less common species, which can form a small water pool for several days after heavy rainfall. A delay leaving in spring migration (migration from Central America to North America) for American Redstarts living in both wood stands was found to correlate with the rainfall reduction from 2003 to 2009. The main factor affecting this was tropical rainfall and food resources. The American Redstarts were staying for the peak of arthropod biomass, which is greatest during March when the rainfall reached its highest point, to fill the fuel for migrating north [9].

3.3. Food Abundance

Food is a more important factor for the immatures than adults. The adults manage to vary the date of chick development to the peak of food abundance. Especially for insectivores, because their food (caterpillars and other insects) is more sensitive than them to the changing temperature and precipitation, they fluctuate more on the date of matching their chicks to foods than other bird species.

3.4. Extreme Weather

Chicks are so vulnerable to things surrounding them that a small change may cause severe surviving difficulty even leading them to death. Parent birds may feel it difficult to survive or not able to survive extreme weather changes thus causing reproductive failure. Even though adult birds can survive the extreme weather, their stress hormone level may elevate resulting in abandoning their broods.

4. Measures Reducing the Climate Impact on Bird Reproduction

4.1. Habitat Restoration and Food Abundance

Continental Black-tailed Godwit (*Limosa limosa limosa*), who migrated from Siberia to the Netherlands, experienced the spring snowstorm in 1989 and a following temperature drop for three weeks [10]. They had some patterns changed during the migration, however, did not fail but instead did well in the following breeding season [10]. This is because they did not experience food deficiency and had time to offset the negative effect from the event [10].

Moreover, not specifically relating to bird reproduction, the boost of Snow Geese (*Chen caerulescens*) due to a change in agriculture yield was an overly successful example that with endless food, a population boost is easy to happen, even to the extent of being troublesome for the carrying capacity of Sandhill Cranes (*Grus canadensis*) [11]. However, the success of Snow Geese is not replicable for other species because their food is highly bonded with human activities – they eat crops on human farmland, which is continuously being renovated.

4.2. Reduce CO₂ Emission and Environmental Conservation

CO₂ as the most abundant greenhouse effect gas is the primary factor causing global warming, which furthermore causes a lot of climate changes. However, there are many CO₂ releasing resources commonly seen in usual life, such as the traffic, traditional coal electric stations and consumption of any carbon-containing fuels. What humans can do is reduce CO₂ emissions from these sources in daily life and turn to use other “clean” energies for electricity generation such as hydroelectric stations.

There are many studies revealing what wrongdoings humans have done to speed up climate change, which is not only affecting one animal category but influencing everyone as a chain effect. As

mentioned, food deficiency of birds could be pursued forward to the decline of insects and vegetation, which is a primary result of over-exploitation by humans. What the public can do is to prevent harm to wild animals, provide food for urban and rural wildlife and do their best to not harm wildlife's habitats as well. It is always not too late for now to start conserving this planet.

5. Integrations of Reproductive Processes and Climate Factors

Table 1 is a summary of what birds may face during every reproductive process if the mentioned climate factors happen to them.

Table 1. Summary of different climate factors impacting the reproductive process

| | Mating | Nesting | Breeding |
|-----------------|--|-------------------------------|---|
| Temperature | | Warmth advanced egg-laying | |
| Precipitation | | Snowmelt floods the nests | Wet chick feathers cause heat loss |
| Food abundance | Not enough support for a long migration | | Not enough nutrients for chick development |
| Extreme weather | Prevent migration route | | Higher mortality for adults and chicks |

During the mating process, migrant birds have to migrate to their breeding fields. Because of climate change, birds initiate migration earlier with the temperature rising earlier to signal the spring. However, the time they leave does not match their food (insects and plants) growth. With not enough food, birds are not able to migrate over long distances. Thus, birds tend to migrate fewer distances, migrate in partial sections and rest more on their journey. Extreme weather happening during bird migration is another preventing factor. Because birds tend to migrate earlier when it is not warm enough, the colder weathers mean that birds need to burn more fuels to prevent heat loss, so they require more food and rest. Also, the weather is getting more fluctuating and unpredictable, during which birds cannot do well preparation before the extremes happen, leading to higher mortality.

Birds are less mobile when they are nesting so they are less responsive to sudden climate changes. Precipitations are more frequently seen in early spring at bird nesting time, wetting the nests and eggs, which make it difficult for adult birds to incubate eggs, causing reproduction failure. Because springtime is advancing and speeding up gradually every year, birds are laying eggs in advance to hatch chicks earlier so that adults can find enough food to feed chicks. But it comes to a similar problem, which is that the temperature is not high enough, so it is more difficult to successfully hatch.

In the period of breeding, problems fall more on chicks than adult birds. Chicks are not developed, not having water-proof plumage and proper heat regulation and require a lot higher enough consumption. With higher precipitation, chicks are less possible to keep themselves dry, resulting in heat loss and freezing to death. What's worse is when extreme climates happen at this time, both adults and chicks may be influenced. Chicks might be directly affected --- winds blowing them off the nest, rains making them wet, and snows freezing them. Adults may also be affected by these weathers, making it impossible to parent the chicks. If chicks cannot get enough nutrients for them to grow, not only their development will be delayed, but their maturity will be affected. Bird adult plumage can reflect their developmental nutrient conditions, so it may be more difficult for less well-developed adults to enter the reproduction cycle.

6. Conclusion

Climate change is affecting birds worldwide and is changing their physiological and behavioural responses to the environment. Concluding from the above research, there are many climate events affecting bird reproduction. Climate change can impact every process of bird reproduction, from mating, and nesting to breeding. The factors influencing bird reproduction processes are

multitudinous, that temperature, precipitation, food abundance and extreme weather can easily alter a bird's reproduction activities. Birds varying from chicks to adults all can be impacted by climate change, however, the extent they are being impacted is various. Adult birds are more likely to change their reproduction preparation behaviours, while chicks are very vulnerable after hatched.

There is not enough research studying the influence of extreme weather on birds. Understandably, such studies take decades, and the climate was mild at that time. However, with more frequent happening extreme climate events in recent years, more severe consequences may happen to wildlife and the environment if researchers are not investigating the impacts. Especially birds, which are highly mobile that they can flee from their habitats after climate hazards, are hard to be studied as subjects under the influences. But still, diverse bird species are doing different roles in the ecosystem, representing their importance and significance in animal studies. This study summarizes several observations from 5 years before this century to most recently, finding out what climate factors impacting bird reproduction have been studied.

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