The varying impacts of climate change on bird migration patterns and reproduction

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Introduction

Climate change is considered one of the greatest perils to our global ecosystem (Robinson et al. 2009) as it is significantly transforming our weather patterns and ecological environment. Since the second half of 20th century, Earth's average temperature has been rising by 0.6 degrees Celsius (Møller et al. 2008). Climate change also caused a change in frequency of severe events such as floods and droughts (Robinson et al. 2009). Meanwhile, different factors affect bird migration patterns such as food source availability and seasonality (Robinson et al. 2009). Rate of bird migration is strongly correlated to food abundance (Marra et al. 2005, Jonzén 2007) as birds move to a different breeding ground to optimize a more abundant food source (Somveille et al. 2015, Coppack and Both 2002). They migrate to avoid the harsh winter (Somveille et al. 2015, Coppack and Both 2002), and their migration patterns can also be influenced by their endogenous rhythms (Both and Visser 2001). Thus, climate change can significantly affect these factors and lead to a shift in the life history of birds (Coppack and Both 2002), which has a significant impact on the survival and reproduction of birds and thus the fitness of the population (Knudsen et al. 2011).

In fact, it has been shown to be affecting birds and other species by changing their phenology of wintering, breeding and migration (Both and Visser 2001, Cotton 2003, Jonzén 2007). There is a variety of results of different studies on the effects of rising temperature on the phenological change of birds, as some studies show the timing of birds' arrival at breeding grounds is advanced (Knudsen et al. 2011, Cotton 2003), while others show that there is an insignificant relationship between the increased temperature and the arrival date of birds (Both and Visser 2001, Marra et al. 2005). Climate change varies temporally and spatially, leading to its differing impacts between temperate and tropic regions and between different migrant birds' annual migration cycle (Marra et al. 2005, Knudsen et al. 2011). The

effects of climate change also vary among different species from different trophic levels (Both et al. 2006, Knudsen et al. 2011), for example, it advances the phenology of birds and its food source to different extents, leading to birds' less optimal exploitation of food and less successful reproduction (Both et al. 2006).

This paper will examine the impacts of climate change on different factors that drive bird migration by linking to phenological advancements and the reproductive success of different types of birds, and explore the implications of different phenological advancements among birds and its preys on birds' feeding patterns and its reproductive success.

Varying reported impacts of climate change on bird's migration behavior

Various studies have shown diverse and even contradictory results for the correlation between increased temperature due to global warming and birds' arrival in breeding grounds. For example, some studies found few significant change in mean arrival date of birds in response to increase in temperature (Both and Visser 2001, Marra et al. 2005), while other studies show a general advancement of migration timings (Knudsen et al. 2011). The arrival date of 17 out of 20 UK species of birds was shown to be advanced due to increased temperatures over the course of 30 years (Cotton 2003). In another study, the arrival date of birds was shown to be overall advanced, but the individual's arrival dates are fairly consistent (Gill et al. 2014). The study justified this dichotomy by showing the individuals could exploit less food if they arrive early and so they tend to migrate at a consistent timing, while only new recruits would migrate earlier than before, leading to an overall advancement of migration date of the whole population (Gill et al. 2004). Similarly, another study found that the earliest recorded springtime arrival date occurred 0.20 days later each decade, but mean arrival dates for birds of each species occurred 0.78 days earlier each decade (Miller-Rusing et al. 2008). This discrepancy in migration timing between individuals and the whole

population that includes the new migrating individuals might mean that climate change has a more profound impact on the new migrating recruits (Knudsen et al. 2011).

Overall, the above studies imply a slight change in overall migration timings of birds in response to increased temperature, though there may not be a clearly established relationship between the individuals' arrival date and climate change. While some studies proposed environmental-related mechanisms such as phenological plasticity and optimal food source exploitation (Gill et al. 2004, Cotton 2003), others argued that other factors such as inherent endogenous rhythms and day-length variation can affect the arrival dates of some species of birds to a greater extent than increased temperature due to climate change (Both and Visser 2001, Miller-Rusing et al. 2008, Coppack and Both 2002).

Meanwhile, climate change can also cause a change in migration route and distance on birds as they are observed to winter at a closer distance to their breeding grounds (Robinson et al. 2009) and move towards areas with usually severe climate conditions due to warmer winter there and thus better conditions for food exploitation (Knudsen et al. 2011).

Different impacts of climate change on short-distance migrants and long-distance migrants

One of the factors proposed for how climate change influence the migration timing is birds' phenological plasticity (Cotton 2003, Gill et al. 2004, Knudsen et al. 2011). This can be shown in variation of response to a shift in seasonal patterns between long-distance migrants and short-distance migrants. Long-distance migrants are less flexible in their response to changing weather conditions than short-distance migrants (Both and Visser 2001, Gill et al. 2004). Other studies also show that while short-distance migrants respond to changes in temperature, long-distance migrants do not seem to respond to climate change as their migration times tended not to change over time (Miller-Rusing et al. 2008) due to their lower

phenotypic plasticity (Knudsen et al. 2011). Because of marked difference between the impacts of climate on temperate and that on tropical regions (Both and Visser 2001), long-distance migrants' ability to foresee the optimal timings to move to breeding grounds is limited, leading to mismatched migration timing with food peak availability (Both and Visser 2001, Gill et al. 2004, Robinson et al. 2009).

However, long-distance migrants could respond quickly to a persisting trend of increased temperature over a period of time (Marra et al. 2005). This may be because most long-distance migrants are believed to probably rely on endogenous rhythms and small changes in day length rather than their depending on environment predictions for their migratory tendencies (Marra et al. 2005). Therefore, individual plasticity in response to climate change can be an explanation for change in phenology in short-distance migrants, which can respond fast to environment variation, but it may account for long-distance migrants' lack of change in phenology to a smaller extent, as long-distance migrants' migrating behavior can also be influenced by endogenous rhythms and day length variations (Both and Visser 2001, Miller-Rusing 2008).

Difference in advancement of phenology between birds and their preys due to climate changes

Another suggested factor that potentially drives bird migration is food abundance, meaning a change in phenology of a birds' food abundance would lead to a change in phenology of birds in response (Jonzén 2007). This can be shown by a strong correlation between reproduction and food source availability as the egg laying date of birds advanced in response to advancement of resource availability (Robinson et al. 2009, Cotton 2003). For example, the mean laying date of pied flycatcher was shown to have advanced by ten days (Both and Visser 2001).

However, climate change influences the phenology of birds and other species to different extents, as species from different trophic levels have different phenological responses to climate changes (Both et al. 2006, Coppack and Both 2002). Insects and plants have been shown to advance their phenology to a greater extent than birds due to climate change (Møller et al. 2008), as the impact of increased temperature on insect phenology is greater than that on birds (Robinson et al. 2009) and the impact of increased temperature on plant phenology is three times greater than that on bird phenology (Marra et al. 2005). This means that there may be other forces that make phenology of birds not advance in sync with the advancement of the phenology of their food resources. For example, territorial competition and pre-breeding mortality can cause birds' lack of phenological response to food peak advancement (Jonzén 2007). Thus, the advancement of breeding in birds may not be in time to match the food peak availability (Both and Visser 2001, Robinson et al. 2009, Møller et al. 2008).

Negative impacts of climate change on birds' reproductive success and population fitness

The discrepancy in advancements of phenology between birds and their food source leads to birds' inability to maximize the benefits of food abundance and experience optimal resource exploitation, leading to mistimed reproduction (Both et al. 2006, Møller et al. 2008) and thus lower reproductive success. Birds that do not advance their phenology adequately have been shown to experience a population decline (Both et al. 2006; Møller et al. 2008; Knudsen et al. 2011); the greater the extent of mismatch between food source availability and breeding date, the greater the extent of population decline and thus decreased fitness (Knudsen et al. 2011, Both et al. 2006). In turn, declining populations may not advance their migration timings while consistent populations advanced their phenology to a significant

extent (Møller et al. 2008). Some studies also believed long-distance migrants to be more vulnerable to destructive effects of climate change, as they may be less responsive to increased temperature and thus advance their breeding date to a smaller extent that increased the mismatch between food availability and reproduction (Both and Visser 2001, Robinson et al. 2009, Miller-Rusing 2008).

Moreover, climate change can also cause a population decline in birds by increasing the frequency of severe weather events such as droughts and floods, leading to habitat degradation and loss of suitable habitats for birds (Knudsen et al. 2011).

Conclusion

Climate change causes bird migrants with greater individual plasticity, mostly short-distance migrant birds, to advance their migration timings more significantly than those with more inflexible phenological response to environmental fluctuations, which are long-distance migrant birds (Both and Visser 2001, Gill et al. 2004). The impacts of climate change also vary among migrant birds and their preys, leading to negative impacts on bird's reproductive success and abundance. By advancing bird phenology less significantly than its food source phenology such as insects and plants, climate change causes late birds' reproduction timing relative to food peak availability, leading to less efficient exploitation of resources and less successful reproduction (Robinson et al. 2009, Møller et al. 2008). Eventually, it may cause a population decline in birds that do not advance their phenological traits (Both et al. 2006; Møller et al. 2008; Knudsen et al. 2011). Though climate change may leave a significant impact on bird populations, whether warmer climate advances arrival dates of birds is still up for debate as other factors such as endogenous rhythms and day length may influence bird migration to a greater extent than climatic factors (Both and Visser 2001, Miller-Rusing

2008). Thus, more research is needed on understanding the mechanisms that drives the advancement in phenology of birds (Knudsen et al. 2011, Gill et al. 2004, Marra et al. 2005).

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