OPEN ACCESS PEER REVIEW
DOI: https://doi.org/10.52756/boesd.2023.e02.002

Chapter- 2

Migratory Birds in Peril: Unravelling the Impact of Climate Change

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Keywords: Bird migration, temperature, habitat loss, altered route.

Abstract:
Avian migration, a phenomenon crucial for the survival and reproductive success of numerous bird species, is increasingly affected by the unprecedented changes in climate. Multifaceted impacts of climate change, encompassing alterations in temperature, and precipitation patterns directly impact the timing, duration, and routes of bird migration. Such changes disrupt food sources, breeding grounds, and crucial stopover sites, challenging the migratory journeys of numerous bird species. Rising sea levels and habitat loss further threaten the survival of these migratory birds. Understanding and addressing these climate-induced shifts in migration patterns are imperative for conservation efforts. The book chapter delves into observed and projected shifts in migratory behaviors, exploring specific case studies and examples that highlight the adaptive responses of avian species to changing environmental conditions.

Introduction:

Climate change is a natural process that has occurred throughout Earth's history for millions of years. However, anthropogenic activities including burning fossil fuels, deforestation, and

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Shubhadeep Roychoudhury, Tanmay Sanyal, Koushik Sen & Sudipa Mukherjee Sanyal (eds.), A Basic Overview of Environment and Sustainable Development [Volume: 2]. ISBN: 978-81-962683-8-1; pp. 35-48; Published online: 17th December, 2023

industrial processes, release greenhouse gases like carbon dioxide and methane into the atmosphere, accelerating natural climate changes and causing global warming and weather patterns (Bhattacharya, 2015; Garcia et al., 2014; Saha & Sarkar, 2022). These actions have interconnected effects, intensifying and often permanently altering ecosystems and biodiversity. Widespread effects result from such changes, including unpredictable weather patterns, habitat degradation and the extinction of many species (Ambiya et al., 2016; Paul et al., 2017). Numerous studies have documented the consequences of global warming on various organisms particularly on the distribution and reproduction of species (Deb et al., 2020; Das et al., 2022). There have been reports of certain species adapting to mitigate the negative impacts of climate change. These adaptations include changing the time of their reproductive cycles or relocating from their current breeding zone to one that is more suited to the environment (Karl & Trenberth, 2003).

Avian migration is a remarkable natural phenomenon involving birds' seasonal movements across vast distances, responding to environmental cues like temperature, resource availability, and photoperiod, demonstrating evolutionary adaptations for survival (Rappole, 2013). Climate change significantly influences bird migration patterns, primarily due to alterations in temperature, weather patterns, and habitat availability. The rising global temperatures directly impact avian migration's timing, duration, and routes. Changing climatic conditions affect the availability of food sources and suitable breeding grounds, prompting shifts in migration timing and destinations for many bird species. Extreme weather events disrupt migratory routes and essential stopover sites crucial for resting and refueling during long journeys, further challenging bird migration. Additionally, rising sea levels and habitat loss threaten the nesting and foraging areas of numerous migratory bird species, impacting their survival (Carey, 2009). Understanding these climate change-driven alterations in migratory patterns is crucial for conservation efforts, necessitating adaptive strategies to safeguard critical habitats, ensure food availability, and mitigate the adverse effects on avian populations globally. Addressing the implications of climate change on bird migration requires urgent global initiatives to mitigate its effects and preserve the resilience of these migratory species in the face of ongoing environmental shifts (Bateman et al., 2020; Gogoi et al., 2023).

Climate change effects on bird migration:

Global temperatures have risen by approximately 1.5 degrees Celsius since the late 19^{th} century due to human-induced factors like greenhouse gas emissions. These temperature changes vary across regions and seasons, leading to uneven global warming patterns. Extreme temperature events, such as heatwaves and cold spells, have become more frequent and severe (Fang et al., 2011). Rising temperatures resulting from climate change profoundly influence the intricate phenomenon of bird migration. These temperature shifts trigger adjustments in the timing and routes of migration as birds respond to altered environmental cues. For instance, warmer temperatures may prompt birds to initiate their journeys earlier or later than usual, aligning with changes in resource availability or breeding conditions along their migratory paths (Cox et al., 2010). Moreover, temperature changes directly impact the availability of food sources and suitable habitats, prompting birds to modify their traditional routes in search of optimal conditions. Some species may expand their territories to newly hospitable areas, while others may face constraints or habitat loss due to less favorable temperatures, potentially leading to shifts or contractions in their migration ranges. Beyond these spatial and temporal adjustments, temperature variations during migration can influence birds' behaviors, affecting their foraging strategies, reproductive patterns, and social interactions. Such alterations in migration dynamics can reverberate throughout ecosystems, affecting not just bird populations but also influencing the relationships among various species and impacting biodiversity on a larger scale (Koleček et al., 2020).

Extreme weather events, intensified by climate change, pose significant challenges to bird migration. Severe storms, strong winds, or unseasonal conditions along migration routes can force birds to adjust their flight paths or delay their journeys. Damage to critical stopover sites where birds rest and refuel during migration can disrupt their ability to complete the journey successfully (Cohen et al., 2020). Such disruptions can also impact the synchronization between bird arrival and optimal breeding or feeding conditions at their destination, affecting reproductive success. Moreover, extreme weather events can lead to mortality, injury, or stress among migrating birds (Newton, 2007). Birds caught in adverse weather conditions might face difficulties finding food, causing nutritional stress and potential population decline. These events may trigger behavioral changes, altering feeding patterns or energy expenditure, impacting the birds' overall migration strategy. Precipitation also plays a crucial role in bird migration. It affects food availability by influencing insect populations, impacting the timing and routes birds take during migration. Precipitation can disrupt habitats along migration routes, affecting nesting sites and food sources. Rainy conditions increase the energy birds need for flight due to wet feathers, potentially impacting their ability to cover long distances. Some bird species adapt their behavior in response to precipitation, altering foraging strategies or migration routes to navigate unfavorable weather conditions (Studds et al., 2011).

Sea level rise, a consequence of climate change, profoundly affects bird migration in coastal and wetland areas. It leads to habitat loss, altered ecosystems, and changes in nesting and feeding patterns crucial for migratory birds. Birds face challenges in finding suitable resting areas, altering migration routes, and adapting breeding behaviors. The altered migration patterns of birds, influenced by various factors including climate change, have far-reaching ecological consequences. Changes in migration routes and timing can disrupt species interactions, affecting biodiversity and ecosystem dynamics (Galbraith et al., 2002). These alterations impact ecosystem services such as pollination and pest control, influencing agricultural productivity. Mismatched timing between bird arrivals and flowering plants can disrupt vital mutualistic relationships, affecting plant reproduction. Habitat alterations due to changed migration can impact the health and stability of ecosystems along these birds' routes.

These shifts also influence global connectivity between distant ecosystems, potentially affecting nutrient flow and genetic diversity exchange. Conservation efforts must address these consequences by preserving habitats, maintaining migratory corridors, and understanding the drivers behind altered migration patterns to safeguard ecosystem health and resilience (Iwamura et al., 2014).

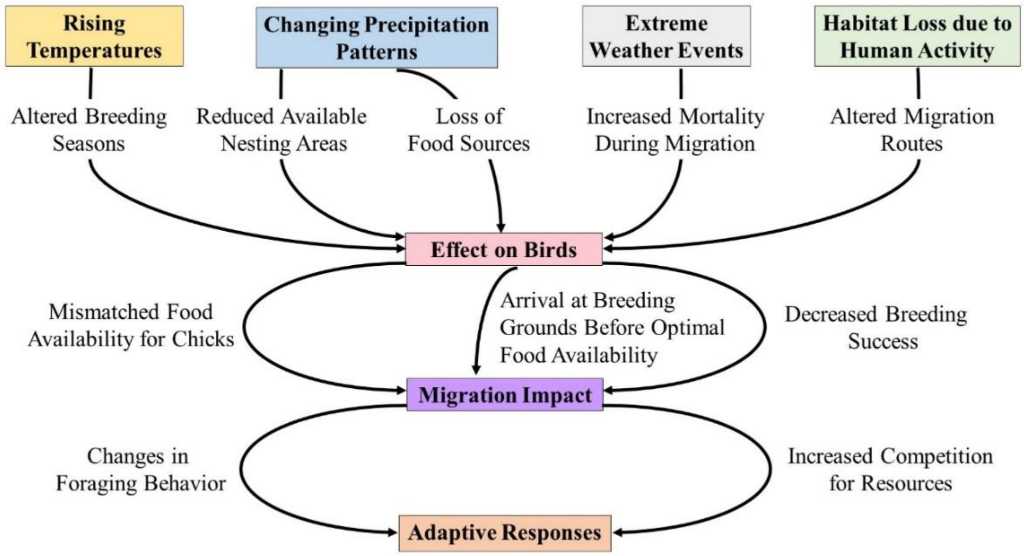

Figure 1. Diagram showing how climate change affects bird migration.

Case Studies:

There are several migratory bird species whose populations, behaviors, or habitats have been affected by climate change. The following tables showcase the intricate ways in which climate change disrupts migratory bird species, affecting their habitats, food sources, and migration patterns, ultimately impacting their survival and reproductive success.

Table 1: List of some non-Indian Migratory bird species impacted by climate change.

Bird Species	Scientific Name	Vulnerability	Migration Route	Reasons for Vulnerability
Red Knots	*Calidris canutus*	Moderate	Arctic to South America	Early snowmelt in the Arctic affected insect emergence, causing a mismatch in food availability for chicks (Meltofte, 2007).
Bar-tailed Godwits	*Limosa lapponica*	High	Alaska to New Zealand	Climate-induced changes in wind patterns make migration more difficult and energetically costly,

				especially for young birds (Batbayar, 2013).
Common Swifts	*Apus apus*	Moderate	Europe to Africa	Impact of climate change on insect populations, affecting food availability, and prompting changes in migration patterns and nesting sites (Gordo & Sanz, 2006).
Snow Geese	*Anser caerulescens*	Moderate	Arctic to warmer regions	Climate-induced earlier snowmelt leads to overcrowding in nesting areas, affecting breeding success and altering population dynamics (Hupp et al., 2018).
Barn Swallows	*Hirundo rustica*	High	Europe to Africa	Climate changes and pesticide use lead to declines in insect populations, forcing adjustments in migration routes and timing (Cheke et al., 2007)
Purple Martins	*Progne subis*	Moderate	South America to North America	Climate-induced changes in precipitation affect insect availability, impacting breeding success and population health (Greenlee et al., 2012).
Northern Wheatears	*Oenanthe oenanthe*	High	Sub-Saharan Africa to the Arctic	Changes in climate conditions along migration routes cause alterations in stopover sites, reducing access to crucial resources (Lehikoinen et al., 2010).
Blackpoll Warblers	*Setophaga striata*	High	North America to	Climate-induced habitat loss affects nesting sites

			South America	and changes in weather patterns impact migration timing (Rodenhouse et al., 2008).
Rufous Hummingbirds	*Selasphorus rufus*	Moderate	North America to Central America	Climate-induced changes in temperature and precipitation alter flower blooming patterns, affecting nectar availability.
Whimbrels	*Numenius phaeopus*	High	Arctic to the Southern Hemisphere	Climate-induced rising sea levels threaten coastal habitats, reducing crucial stopover sites essential for migration (Pearce-Higgins et al., 2017).
Arctic Terns	*Sterna paradisaea*	High	Arctic to Antarctic	Climate-related alterations impacting the availability of prey species are crucial for breeding success and overall population health (Bentley et al., 2020).
Sandhill Cranes	*Antigone canadensis*	Moderate	North America to South America	Climate-induced changes in weather patterns and human interference lead to disruptions in migration routes and stopover areas.
European Swallows	*Hirundo rustica*	High	Europe to Africa	Climate-related alterations in weather patterns and agricultural practices lead to declines in insect availability (Balbontín et al., 2008)
Sooty Shearwaters	*Ardenna griseus*	Moderate	Southern Hemisphere to Northern Hemisphere	Climate-induced changes in oceanic conditions impact the availability of food resources critical for

				survival during migration (McKechnie et al., 2020).
Eastern Curlews	*Numenius madagascariensis*	High	Siberia to Australia	Coastal habitat destruction and changing climate conditions cause loss of feeding grounds and affect breeding success (Pearce-Higgins et al., 2017).
Gray Catbirds	*Dumetella carolinensis*	Moderate	North America to Central America	Climate changes affect food availability and nesting habitats, impacting breeding success and overall population stability Mancuso et al., 2021).

Migratory birds flock to India during the summer and winter months, seeking refuge in its diverse landscapes. India's varied geography, spanning from mountains to wetlands, provides a welcoming environment for these avian species but the threat of climate change poses significant risks to Indian migratory birds (Chowdhury, 2023). These birds travel long distances across continents, relying on specific environmental cues, such as temperature, rainfall patterns, and food availability, to guide their migration. Climate change disrupts these cues, leading to various challenges:

Table 2: **Some Indian migratory bird species affected by climate change.**

Bird Species	Scientific Name	Vulnerability	Migration Route	Reasons for Vulnerability
Common Teal	*Anas crecca*	High	Palearctic to the Indian subcontinent and Southeast Asia	Loss of wetlands/marshes due to rising sea levels & human development (Chatterjee et al., 2017).
Bar-headed Goose	*Anser indicus*	High	Central Asia to the Indian subcontinent and Southeast Asia	Wetland depletion from rising seas & human development (Szabo and Mundkur, 2017).
Greenish Warbler	*Phylloscopus trochoid's*	High	Central Asia to the Indian subcontinent and Southeast Asia	Impact on wooded areas due to deforestation & climate (Katti, 1997).

Indian Pitta	*Pitta brachyura*	High	Indian subcontinent, Southeast Asia	Habitat fragmentation due to human activities (Dutta and Mohapatra, 2017).
Garganey	*Spatula querquedula*	High	Palearctic to the Indian subcontinent and Southeast Asia	Wetland loss, decreased suitable habitat & competition (Balachandran, 2007).
Rosy Starling	*Pastor roseus*	Moderate	Eastern Europe to the Indian subcontinent	Disease spread risks due to changing climate conditions
Northern Pintail	*Anas acuta*	Moderate	Palearctic to the Indian subcontinent and Southeast Asia	Temperature changes alter routes (Guillemain et al., 2013).
Black-tailed Godwit	*Limosa limosa*	Moderate	Arctic regions to Indian subcontinent and Southeast Asia	Weather shifts impacting routes & timing (Senner et al., 2019).
Blyth's Reed Warbler	*Acrocephalus dumetorum*	Moderate	Central Asia to the Indian subcontinent and Southeast Asia	Weather effects on routes & timing (Chernetsov et al., 2007).
Common Hawk-Cuckoo	*Hierococcyx various*	Moderate	Palearctic to the Indian subcontinent and Southeast Asia	Competition and overlap with resident species (Mukhopadhyay et al., 2017).
Common Sandpiper	*Actitis hypoleucos*	Moderate	Palearctic to the Indian subcontinent and Southeast Asia	Food source change, Altered aquatic invertebrate availability (Kannan et al., 2012).
Common Redshank	*Tringa totanus*	Moderate	Palearctic to the Indian subcontinent and Southeast Asia	Weather changes affecting routes & timing (Maclean et al., 2007)
Greater Flamingo	*Phoenicopterus roseus*	Low	Europe, Africa, Asia to the Indian subcontinent	Disrupted migration, Changes affecting routes & timing (Balachandran, 2012).

Eurasian Wigeon	*Mareca penelope*	Moderate	Palearctic to the Indian subcontinent and Southeast Asia	Temperature changes affect routes & timing (Chatterjee et al., 2023).
Yellow Wagtail	*Motacilla flava*	Low	Palearctic to the Indian subcontinent and Southeast Asia	Temperature impact on traditional routes (Aich and Mukhopadhyay, 2008).

Mitigation and future directions:

Mitigating the adverse effects of climate change on bird migration involves a multifaceted approach. Efforts focus on habitat restoration along migratory routes, aiming to restore vital features like wetlands and stopover sites. Creating and managing protected areas ensures these sites serve as safe havens for migratory birds. Key strategies involve identifying and conserving crucial stopover sites and securing vital resting and refueling spots during migration. Implementing climate-resilient land use practices and raising public awareness about the importance of migratory birds. Conducting continuous research and monitoring helps gather essential data on bird populations, migration patterns, and habitat changes, guiding conservation plans (Xu et al., 2020). Implementing adaptive management allows for flexible strategies that adjust to changing climate impacts. Adaptive management is crucial for bird species facing changing environments due to climate change. Its flexibility allows for real-time adjustments, aiding birds in adapting behaviors and habitats to dynamic conditions. Continuous monitoring and learning from feedback refine conservation strategies, reducing risks and tailoring approaches to different species' needs. This proactive approach ensures long-term sustainability, engages communities, and addresses uncertainties, making adaptive management indispensable in supporting bird species amid environmental changes (Faaborg et al., 2010).

Conclusion:

The phenomenon of avian migration encapsulates a complex interweaving of ecological, behavioral, and evolutionary mechanisms crucial for the persistence and resilience of bird species in the face of dynamic environmental challenges. To safeguard avian migration amidst climate change necessitates ongoing interdisciplinary efforts, including monitoring, predictive modeling, and diverse research. Prioritizing conservation, global collaboration, and public engagement is crucial, alongside policy focus on mitigation and resilient habitats. A holistic approach uniting research, adaptive management, and international cooperation is imperative to protect avian migration in the face of climate challenges.

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HOW TO CITE

Goutam Biswas, Sarthak Ranjan Sarkar, Bonhishikha Roy, Arkaprabha Pal, Somvit Nandi, Souvik Banerjee, Swapnendu Roy (2023). Migratory Birds in Peril: Unravelling the Impact of Climate Change. © International Academic Publishing House (IAPH), Shubhadeep Roychoudhury, Tanmay Sanyal, Koushik Sen & Sudipa Mukherjee Sanyal (eds.), *A Basic Overview of Environment and Sustainable Development [Volume: 2]*, pp. 35-48. ISBN: 978-81-962683-8-1. DOI: https://doi.org/10.52756/boesd.2023.e02.002