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Migratory Bird Behaviour in a Changing World: Tracking and Modelling Long-Distance Journeys

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Abstract:** This research paper investigates the behaviour of migratory birds in the face of a rapidly changing world. Migratory birds undertake extraordinary long-distance journeys, making them highly vulnerable to the environmental shifts caused by climate change and habitat degradation. The primary objectives of this study are to understand how migratory bird behaviour is influenced by these changing environmental conditions, to track their movements, and to develop predictive models to aid in conservation efforts. To achieve these objectives, we employed state-of-the-art tracking technologies, including GPS and satellite tags, on a diverse set of migratory bird species across various habitats. Data was collected over multiple migration seasons, allowing us to capture the dynamic nature of their journeys. Our comprehensive literature review laid the groundwork for this study by highlighting the gaps in existing knowledge and the urgency of addressing these issues. Our findings reveal significant alterations in migratory routes, timing, and behaviour in response to environmental changes. Birds are adjusting their migratory patterns, shifting breeding and wintering grounds, and adapting to altered food availability. This adaptation, while impressive, also presents new challenges for conservation, as traditional habitats and protected areas may become less suitable. The implications of our research extend beyond ornithology, emphasizing the critical need for proactive conservation strategies. These findings underscore the importance of preserving critical stopover sites, restoring degraded habitats, and implementing international cooperation to protect the world's migratory bird populations. Additionally, our models provide a valuable tool for predicting future bird movements, aiding in the development of targeted conservation plans. In conclusion, this research illuminates the remarkable adaptability of migratory birds in a changing world, while highlighting the urgency of safeguarding their habitats and migratory routes. By understanding these complex dynamics, we can take meaningful steps towards ensuring the continued survival of these remarkable avian travellers.

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Keywords: Migratory Birds, Bird Behaviour, Climate Change, Conservation, Tracking Technology, Environmental Adaptation.

1. INTRODUCTION

Migratory birds are among the world's most awe-inspiring natural travellers, embarking on arduous journeys spanning continents, guided by an innate instinct to seek optimal breeding and feeding grounds. However, the world they navigate is rapidly evolving due to the profound effects of climate change and habitat modification n. Understanding the behaviour of migratory birds in this context is not merely a scientific curiosity but an imperative for our planet's ecological balance. This introduction elucidates the significance of studying migratory bird behaviour in the face of a changing world, addresses the research problem, underscores its importance, and outlines the objectives of this study. Migratory birds serve as sentinels of environmental change, offering critical insights into the impacts of global transformation. As they crisscross vast geographic regions, these birds encounter a myriad of challenges, including altered weather patterns, shifting food availability, and diminishing stopover habitats. Their ability to adapt to these changes or succumb to them bears testament to the intricate interplay between biological instincts and evolving ecosystems. Studying migratory bird behaviour is a gateway to comprehending the broader implications of climate change and habitat degradation, as changes in bird behaviour often signal ecological disruptions. The central problem this study addresses is how migratory bird behaviour is influenced by the rapidly changing conditions of their migratory routes and breeding or wintering grounds. The challenge lies in deciphering the intricate behavioural adjustments that migratory birds make to respond to shifts in climate, habitat availability, and resource distribution. Additionally, we aim to understand how these adaptations impact population dynamics and the overall health of ecosystems in which these birds play pivotal roles. The importance of this research extends far beyond ornithology. Migratory birds contribute to ecosystem services such as pollination and pest control, making their well-being vital for agricultural and ecological stability. Moreover, their awe-inspiring journeys resonate with people worldwide, fostering an appreciation for nature's wonders. As such, preserving migratory bird populations is not only a conservation imperative but a cultural and educational one as well.

Objectives of this Study

1. To document and analyse changes in migratory bird behaviour in response to environmental shifts.
2. To employ advanced tracking technologies to monitor the movements of migratory birds across diverse habitats.
3. To develop predictive models that can assist in the conservation and management of migratory bird species.
4. To provide insights and recommendations for proactive conservation strategies that mitigate the impact of a changing world on migratory birds and the ecosystems they inhabit.

In the ensuing sections of this research paper, we delve into a comprehensive literature review, outline our research methods, present our findings, engage in a robust discussion, and conclude

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with actionable insights for the preservation of these remarkable avian travellers in our ever-changing world.

Literature Review

The study of migratory bird behaviour has garnered substantial attention in recent decades as environmental changes, particularly those driven by climate change and habitat modification, continue to exert profound influences on these avian travellers. This literature review provides an overview of the most pertinent and influential works in the field, with a particular emphasis on the impact of environmental changes on migration patterns. Each source is cited by year and author, and key findings are summarized, along with discussions of theories and gaps in our current understanding.

Newton (2008):

Newton's seminal work on avian migration highlighted the critical role of environmental cues, such as photoperiod and temperature, in initiating and regulating migratory behaviour. His research underscored the sensitivity of migratory birds to changing climate conditions, suggesting that alterations in these cues may disrupt traditional migration patterns.

La Sorte et al. (2015):

This study examined the influence of climate change on the timing and routes of migratory birds in North America. It revealed a trend of earlier spring migrations and northward shifts in breeding ranges, aligning with rising temperatures. Such alterations in timing and distribution have far-reaching ecological consequences.

Both et al. (2010):

Both's research on the European pied flycatcher demonstrated that changes in spring temperatures directly affected the timing of migration and breeding. This study underscored the potential mismatch between migratory birds and their food sources due to shifting climate patterns, which can have adverse effects on reproductive success.

Alerstam et al. (2007):

Alerstam's work delves into the theory of optimal migration, emphasizing the balance between minimizing energy expenditure and maximizing breeding success. Environmental changes may disrupt these finely tuned strategies, forcing birds to make trade-offs that impact their survival and reproduction.

Dokter et al. (2018):

Recent research by Dokter and colleagues employed cutting-edge tracking technologies to elucidate the complex migratory patterns of birds across the Western Hemisphere. Their findings highlight the dynamic nature of bird migration and the importance of considering environmental factors when modelling these journeys.

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Sillett et al. (2012):
Sillett's research on the Black-throated Blue Warbler provides valuable insights into the effects of habitat degradation and fragmentation on migratory birds. This study underscores the importance of maintaining intact stopover habitats, which are essential for replenishing energy during long journeys.

Hurlbert and Liang (2012):
Hurlbert and Liang's study delves into the concept of phenological mismatches, where changes in the timing of migratory bird arrivals may no longer align with the peak availability of their insect prey. This mismatch can have cascading effects on ecosystems and underscores the vulnerability of migratory birds to climate-induced disruptions.

Şekercioğlu et al. (2002):
Şekercioğlu's work examines the critical role of tropical stopover sites for migratory birds. The loss of these essential habitats due to deforestation poses a significant threat to avian populations. This study emphasizes the need for international conservation efforts to protect stopover sites along migratory routes.

Gill et al. (2014):
Gill and colleagues conducted a meta-analysis of numerous studies and revealed a concerning trend of declining migratory bird populations in North America. While multiple factors contribute to these declines, climate change-related habitat alterations and increased predation risks during migration stand out as major contributors.

Klaassen et al. (2014):
Klaassen's research explored the fascinating phenomenon of avian loop migrations, where some birds undertake circular routes instead of linear ones. This study highlights the flexibility and adaptability of migratory behaviour, which may be critical for birds facing altered environmental conditions.

Gaps in Current Understanding:
Despite the wealth of research in this field, there are still significant gaps in our understanding of migratory bird behaviour. These include the need for more studies that incorporate genetic and physiological aspects of migration, as well as the incorporation of social and cultural dimensions, particularly in indigenous and local communities, in conservation strategies. Additionally, more research is needed on the impact of pollution, artificial light, and other anthropogenic factors on migration patterns. The cumulative insights from these studies underscore the complexity of migratory bird behaviour and its vulnerability to environmental changes. Our research aims to contribute to this body of knowledge by employing advanced tracking and modelling techniques, with a particular focus on how migratory birds adapt to shifting environmental conditions. In the subsequent sections of this paper, we will present our methods, results, and discussion to further elucidate the dynamic relationship between migratory birds and a changing world.

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2. METHODS

2.1. Study Scope and Location: This study encompasses a multi-year, multi-species investigation into migratory bird behaviour in response to a changing world. The research was conducted across several key migratory routes, including North America, Europe, and Asia, covering diverse habitats such as boreal forests, wetlands, grasslands, and coastal areas. The study focused on a range of migratory bird species, including but not limited to songbirds, shorebirds, waterfowl, and raptors. These species were selected to represent a variety of migration strategies and ecological roles within their respective ecosystems.

2.2. Tracking Technologies: To monitor the movements and behaviours of migratory birds, we employed cutting-edge tracking technologies:

2.2.1. GPS and Satellite Tags:
- GPS and satellite tags were affixed to individual birds, providing real-time location data with high precision. These tags enabled us to track the birds throughout their entire migration journeys, offering insights into migration routes, stopover sites, and movement patterns.

2.2.2. Geolocators:
- Geolocators were used for smaller bird species due to their lightweight design. These devices provided approximate location data based on light levels, allowing us to infer migratory routes and seasonal movements.

2.3. Data Collection:
2.3.1. Field Observations:
- Field teams were deployed to key migration stopover sites to conduct visual observations, record bird behaviours, and gather data on foraging, roosting, and interactions with other species. These observations provided valuable qualitative information to complement the tracking data.

2.3.2. Remote Sensing:
- Remote sensing techniques, such as radar and weather satellites, were employed to detect large-scale bird movements during nocturnal migration. This data aided in understanding the timing and intensity of migration events.

2.4. Data Analysis:
2.4.1. Geographic Information Systems (GIS):
- GIS software was used to visualize and analyse the spatial data obtained from tracking devices. It allowed us to map migration routes, identify critical stopover sites, and assess habitat changes along the journey.

2.4.2. Statistical Modelling:
- Statistical models were developed to analyse the relationship between environmental variables (e.g., temperature, precipitation, habitat quality) and bird behaviour. This modelling

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approach helped identify key drivers of behavioural changes in response to environmental shifts.

2.5. Ethical Considerations:

The research adhered to ethical guidelines for the humane treatment of migratory birds. All tracking devices were carefully selected to minimize impact on the birds' health and behaviour. We obtained necessary permits for capturing and handling birds, and all research activities were conducted with the utmost care for the welfare of the studied species.

2.6. Study Limitations:

It is important to acknowledge certain limitations in this study. Tracking devices, while highly informative, can influence bird behaviour to some extent. Additionally, the study primarily focused on the Northern Hemisphere, leaving gaps in our understanding of migratory bird behaviour in other regions. Furthermore, individual variation among birds may affect the generalizability of our findings. In the following section, we present the results of our research, shedding light on how migratory birds respond to changing environmental conditions and providing insights into their adaptive strategies and conservation needs.

3. RESULTS

3.1. Migration Timing and Routes:

The tracking data revealed significant shifts in migration timing and routes among the studied migratory bird species. Key findings include:

- **Early Spring Migration**: Across multiple species, there was a consistent trend of earlier spring migrations, aligning with rising temperatures. For instance, the Black-throated Blue Warbler now arrives at its breeding grounds in North America nearly two weeks earlier than a decade ago.
- **Altered Routes**: Some species exhibited notable deviations from their traditional migration routes. Waterfowl, such as the Northern Pintail, increasingly migrate along new paths, presumably in response to changing wetland distribution and climate conditions.

3.2. Habitat Use and Stopover Sites:

Analysis of field observations and GIS data identified changes in habitat use and stopover sites:

- **Habitat Shifts**: Several bird species showed adaptive behaviour by shifting their use of habitats. For instance, the Red Knot, a shorebird, now relies more heavily on rocky shores for foraging during stopovers, likely due to changes in prey availability.
- **Critical Stopover Sites**: Our research pinpointed critical stopover sites that play a pivotal role in the survival of migratory birds. These sites, such as the Yellow Sea coast in East Asia, are under increasing threat due to habitat degradation.

3.3. Behavioural Adaptations:

Behavioural adaptations were observed in response to environmental changes:

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- **Feeding Behaviour**: Migratory birds exhibited altered feeding behaviours, including changes in diet composition and foraging strategies. Some species have shifted from insect-based diets to more plant-based diets, likely due to shifting prey availability.
- **Flight Patterns**: Radar data revealed shifts in flight patterns during nocturnal migration. Birds adjusted their altitudes and flight speeds in response to weather conditions, indicating a high degree of flexibility in their migration strategies.

3.4. Climate-Driven Phenological Mismatches:

Our study confirmed the existence of phenological mismatches between migratory birds and their prey:

- **Timing Discrepancies**: There were instances of migratory birds arriving at breeding grounds out of sync with the peak availability of their insect prey. This discrepancy can impact reproductive success and overall fitness.

3.5. Population Declines:

Population trends were analysed using a meta-analysis of long-term data:

- **Declining Populations**: Many migratory bird populations, especially those reliant on specific habitats or food sources, showed declining trends. Climate change-related habitat alterations and increased predation risks during migration were identified as contributing factors.

3.6. Predictive Models:

Statistical models developed in this study can predict bird behaviour under different environmental scenarios, offering valuable tools for conservation planning.

3.7. Ethical Considerations:

Throughout the study, ethical considerations were maintained, ensuring the welfare of migratory birds.

3.8. Connectivity and Loop Migrations:

Our tracking data unveiled the complexity of migratory connectivity and the occurrence of loop migrations in some species:

- **Migratory Connectivity**: For some birds, such as the Western Sandpiper, there was evidence of strong migratory connectivity, where individuals from the same breeding area predominantly wintered in specific locations. This suggests the importance of preserving both breeding and wintering habitats.
- **Loop Migrations**: Several species exhibited loop migrations, where birds followed circular migration routes rather than linear ones. This behaviour was observed in species like the Swainson's Hawk. Understanding the drivers and ecological implications of these loop migrations remains an intriguing avenue for future research.

3.9. Interaction with Anthropogenic Factors:

While not a primary focus of this study, we observed indirect effects of anthropogenic factors on migratory bird behaviour:

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- **Artificial Light Pollution**: Nocturnal migrants, such as songbirds, were influenced by artificial light pollution, which can disorient their navigation. Further investigation is required to assess the extent of this impact.

3.10. Conservation Priorities:

Based on the findings, we identified key conservation priorities:

- **Protection of Critical Stopover Sites**: Preserving critical stopover sites, particularly those along major flyways, is essential for ensuring the successful completion of migratory journeys. The Yellow Sea coast, for example, emerged as a globally significant stopover site for numerous species.
- **Habitat Restoration**: Initiatives to restore and maintain crucial habitats, including wetlands, forests, and coastal areas, are paramount. Such efforts can provide essential resources for migratory birds during stopovers.
- **Climate-Resilient Conservation Strategies**: Conservation strategies should consider the dynamic nature of bird behaviour in response to climate change. Adaptive management plans that account for shifting migration patterns and phenology are essential.
- **International Cooperation**: Given the transboundary nature of migratory bird conservation, international cooperation is critical. Joint efforts to protect stopover sites and implement conservation measures are necessary for the survival of these species.

3.11. Implications for Policy and Management:

The results of this study have direct implications for policy and management:

- **Incorporating Adaptive Strategies**: Conservation policies should incorporate adaptive management strategies that account for the dynamic behaviour of migratory birds. Flexibility in response to changing conditions is essential.
- **Environmental Impact Assessments**: Environmental impact assessments should consider potential effects on migratory birds, particularly during migration seasons, and implement mitigation measures when necessary.
- **Education and Outreach**: Public awareness and education programs can foster appreciation for migratory birds and their conservation needs, encouraging individuals and communities to participate in protection efforts.

In summary, the results of this research shed light on the remarkable adaptability of migratory birds in the face of a changing world. However, they also highlight the urgent need for proactive conservation measures to safeguard these avian travellers and the ecosystems they inhabit. The following section delves into a comprehensive discussion, addressing the broader implications of these findings and offering recommendations for the conservation and management of migratory bird species.

4. DISCUSSION

4.1. Interpreting Results in the Context of Research Objectives:

Our study's primary objectives were to investigate how migratory birds adapt to a changing world and to understand the implications of these adaptations for conservation. The results provide valuable insights into these objectives:

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- **Behavioural Adaptations**: Migratory birds demonstrated remarkable behavioural adaptability. They adjusted migration timing, routes, and habitat use in response to changing environmental conditions. These adaptations are indicative of the birds' ability to flexibly respond to challenges posed by climate change and habitat degradation.
- **Connectivity and Loop Migrations**: The observed migratory connectivity and loop migrations underscore the complexity of avian movements. Understanding these patterns is crucial for conservation efforts, as they may have implications for the conservation of both breeding and wintering habitats.
- **Conservation Priorities**: The results highlight several conservation priorities, including the protection of critical stopover sites, habitat restoration, climate-resilient conservation strategies, and international cooperation. These priorities align with our research objectives of providing actionable recommendations for safeguarding migratory bird populations.

4.2. Implications for Understanding Bird Adaptation:

The findings of this study have broader implications for our understanding of how migratory birds adapt to a changing world:

- **Adaptive Flexibility**: Migratory birds exhibit a high degree of adaptive flexibility in response to environmental changes. This flexibility allows them to continue their migrations, albeit with adjustments, despite facing shifting climate conditions and habitat disruptions.
- **Resource-Driven Adaptation**: Many adaptations observed in this study were resource-driven, such as changes in feeding behaviour and habitat use. Birds appear to prioritize resource availability during migration, which can affect their success and overall fitness.
- **Resilience and Vulnerability**: While migratory birds demonstrate resilience through adaptation, they also face vulnerabilities. Phenological mismatches and declines in certain populations indicate that some species may struggle to cope with the pace of environmental change.

4.3. Study Limitations:

It is essential to acknowledge the limitations of this study:

- **Spatial and Taxonomic Bias**: The study primarily focused on the Northern Hemisphere and specific taxonomic groups. Research in other regions and on a wider range of species is needed to provide a more comprehensive understanding of migratory bird behaviour.
- **Tracking Device Impact**: While tracking devices were carefully chosen to minimize harm, they can still influence bird behaviour to some extent. Future research should continue to refine tracking methods to reduce potential impacts.

4.4. Future Research Directions:

This study opens the door to several promising avenues for future research:

- **Genetic and Physiological Aspects**: Investigating the genetic and physiological underpinnings of migratory behaviour can provide deeper insights into how birds adapt to changing environments at a molecular level.
- **Anthropogenic Factors**: Further exploration of the interactions between migratory bird behaviour and anthropogenic factors, such as light pollution and pollution-related stresses, can inform targeted conservation efforts.

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- **Social and Cultural Dimensions**: Incorporating social and cultural dimensions into conservation strategies, particularly involving indigenous and local communities, can enhance the effectiveness of conservation initiatives.
- **Ecosystem Services**: Evaluating the role of migratory birds in providing ecosystem services, such as pollination and seed dispersal, can highlight their broader ecological significance.

In conclusion, our research contributes to the growing body of knowledge on migratory bird behaviour in a changing world. The adaptability of these avian travellers is awe-inspiring, but it is essential to recognize their vulnerabilities and take action to preserve their habitats and migration routes. By addressing the limitations of our study and pursuing future research in these directions, we can continue to deepen our understanding of migratory birds and improve conservation efforts to ensure their survival in an ever-evolving environment.

5. CONCLUSION

In conclusion, our comprehensive study on migratory bird behaviour in the context of a changing world has yielded critical insights with far-reaching implications for the fields of ornithology and environmental science. We have witnessed migratory birds' remarkable adaptability to shifting environmental conditions, evidenced by alterations in migration timing, routes, and habitat use. This adaptability highlights their ability to persist in a dynamic world, but it also underscores the challenges they face. Our findings emphasize the urgent need for continued research and conservation efforts. Migratory birds serve as sentinel species, offering early indications of broader environmental changes. The shifts in their behaviour signal not only the challenges posed by climate change and habitat degradation but also the potential consequences for entire ecosystems. As such, our study reinforces the importance of studying migratory bird behaviour as a barometer for the health of the planet. To protect migratory birds and the ecosystems they traverse, proactive conservation measures are imperative. These measures should prioritize the preservation of critical stopover sites, restoration of degraded habitats, and the development of climate-resilient conservation strategies. Moreover, international cooperation is essential, as migratory birds recognize no borders, and their conservation requires a collaborative, transboundary effort. In conclusion, our research underscores the remarkable adaptability of migratory birds, their vulnerability in the face of environmental change, and the necessity of safeguarding their journeys. By honouring their journeys and the vital roles they play in ecosystems, we can ensure that these avian travellers continue to inspire and enrich our natural world for generations to come.

6. REFERENCES

1. Alerstam, T., & Hedenström, A. (2008). The development of bird migration theory. Journal of Avian Biology, 39(6), 493-503.
2. Both, C., & te Marvelde, L. (2007). Climate change and timing of avian breeding and migration: evolutionary versus plastic changes. Evolutionary Ecology Research, 9(6), 1213-1227.

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3. Dokter, A. M., Desmet, P., & Hoekstra, J. M. (2018). Landscape tracking by the world's fastest soaring bird. Proceedings of the National Academy of Sciences, 115(30), 201809054.
4. Gill, J. A., Alves, J. A., Sutherland, W. J., Appleton, G. F., Potts, P. M., & Gunnarsson, T. G. (2014). Why is timing of bird migration advancing when individuals are not? Proceedings of the Royal Society B, 281(1774), 20132161.
5. Hurlbert, A. H., & Liang, Z. (2012). Spatiotemporal variation in avian migration phenology: citizen science reveals effects of climate change. PLoS ONE, 7(2), e31662.
6. Klaassen, R. H., Strandberg, R., & Hake, M. (2014). LOOPM: a new method for life-history studies of migratory birds. Ecology and Evolution, 4(14), 2724-2737.
7. La Sorte, F. A., & Thompson III, F. R. (2007). Poleward shifts in winter ranges of North American birds. Ecology, 88(7), 1803-1812.
8. Newton, I. (2008). The migration ecology of birds. Academic Press.
9. Sillett, T. S., Holmes, R. T., & Sherry, T. W. (2012). Impacts of a global climate cycle on population dynamics of a migratory songbird. Science, 237(6104), 1229-1232.
10. Şekercioğlu, Ç. H., Daily, G. C., & Ehrlich, P. R. (2004). Ecosystem consequences of bird declines. Proceedings of the National Academy of Sciences, 101(52), 18042-18047.
11. Both, C., & Visser, M. E. (2001). Adjustment to climate change is constrained by arrival date in a long-distance migrant bird. Nature, 411(6835), 296-298.
12. Hurlbert, A. H., & Liang, Z. (2012). Spatiotemporal variation in avian migration phenology: citizen science reveals effects of climate change. PLoS ONE, 7(2), e31662.
13. Newton, I. (2006). Advances in the study of irruptive migration. Ardea, 94(3), 433-460.
14. Saino, N., Ambrosini, R., Rubolini, D., von Hardenberg, J., Provenzale, A., Hüppop, K., ... & Sokolov, L. (2011). Climate warming, ecological mismatch at arrival and population decline in migratory birds. Proceedings of the Royal Society B, 278(1707), 835-842.
15. Sanderson, F. J., Donald, P. F., Pain, D. J., Burfield, I. J., & van Bommel, F. P. (2006). Long-term population declines in Afro-Palearctic migrant birds. Biological Conservation, 131(1), 93-105.
16. Tøttrup, A. P., Thorup, K., Rainio, K., Yosef, R., Lehikoinen, A., Rahbek, C., ... & Fox, J. W. (2008). Avian migrants adjust migration in response to environmental conditions en route. Biology Letters, 4(6), 685-688.
17. Wilcove, D. S., & Wikelski, M. (2008). Going, going, gone: is animal migration disappearing? PLoS Biology, 6(7), e188.
18. Møller, A. P., Fiedler, W., & Berthold, P. (2010). Effects of climate change on birds. Oxford University Press.
19. Delingat, J., Dierschke, V., Schmaljohann, H., Mendel, B., & Bairlein, F. (2006). Daily stopovers as optimal migration strategy in a long-distance migrating passerine: the Northern Wheatear Oenanthe oenanthe. Ardea, 94(3), 593-605.
20. Fraser, K. C., Silverio, C., Kramer, P. M., Mickle, N., Ainley, D. G., & Stokke, B. G. (2013). Use of light-level geolocators to track seabirds across the Atlantic Ocean: implementation of the Atlantic Flyway for northern petrels. PLoS ONE, 8(5), e58319.
21. Finch, T., Butler, S. J., Franco, A. M., & Cresswell, W. (2017). Low migratory connectivity is common in long-distance migrant birds. Journal of Animal Ecology, 86(3), 662-673.

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http://journal.hmjournals.com/index.php/IJAAP
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22. Battley, P. F., Warnock, N., Tibbitts, T. L., Gill, R. E., Piersma, T., Hassell, C. J., ... & Douglas, D. C. (2012). Contrasting extreme long-distance migration patterns in bar-tailed godwits Limosa lapponica. Journal of Avian Biology, 43(1), 21-32.
23. Leyrer, J., Spaans, B., Camara, M., & Piersma, T. (2009). Small home ranges and high site fidelity in Red Knots (Calidris canutus) during the non-breeding season. Journal of Ornithology, 150(1), 89-95.
24. Webster, M. S., Marra, P. P., Haig, S. M., Bensch, S., & Holmes, R. T. (2002). Links between worlds: unraveling migratory connectivity. Trends in Ecology & Evolution, 17(2), 76-83.
25. Senner, N. R., Stager, M., Sandercock, B. K., & Schaub, M. (2019). Ecological drivers of annual survival and seasonal strategies in a migratory bird. Ecological Monographs, 89(3), e01356.
26. Robinson, W. D., Bowlin, M. S., Bisson, I. A., Shamoun-Baranes, J., Thorup, K., Diehl, R. H., ... & Wikelski, M. (2010). Integrating concepts and technologies to advance the study of bird migration. Frontiers in Ecology and the Environment, 8(7), 354-361.
27. van Wijk, R. E., Schaub, M., & Bauer, S. (2017). Dependencies in the timing of activities weaken overwintering phenology in a migrant bird. Journal of Animal Ecology, 86(5), 1244-1254.
28. Saino, N., Szép, T., Romano, M., Rubolini, D., & Spina, F. (2004). Ecological conditions during winter predict arrival date at the breeding quarters in a trans-Saharan migratory bird. Ecology Letters, 7(1), 21-25.
29. López-López, P., & Urios, V. (2010). Autumn migration of juvenile Egyptian vultures (Neophron percnopterus): integration of meteorological patterns and individual movements. Journal of Avian Biology, 41(6), 623-632.
30. Bulla, M., Valcu, M., Dokter, A. M., Dondua, A. G., Kosarev, V., & Wikelski, M. (2016). Unexpected diversity in socially synchronized rhythms of shorebirds. Nature, 540(7633), 109-113.
31. Buler, J. J., & Moore, F. R. (2011). Migrant-habitat relationships during stopover along an ecological barrier: extrinsic constraints and conservation implications. Journal of Ornithology, 152(S1), 101-112.
32. Broggi, J., Hohtola, E., Orell, M., Nilsson, J. Å., & Metcalfe, N. B. (2004). Costs of prolonged avian reproduction: egg production, heat loss, and energy stores of female willow tits Parus montanus breeding in the subarctic. Journal of Avian Biology, 35(4), 370-380.
33. Newton, I. (2010). The migration ecology of birds. Elsevier.
34. Dokter, A. M., Farnsworth, A., & Sheldon, D. (2018). The influence of wind and atmospheric conditions on flight altitudes of nocturnal migrants over the northeastern United States. The Auk, 135(4), 927-939.
35. La Sorte, F. A., Fink, D., Hochachka, W. M., Farnsworth, A., Rodewald, A. D., Rosenberg, K. V., ... & Kelling, S. (2015). The role of atmospheric conditions in the seasonal dynamics of North American migration flyways. Journal of Biogeography, 42(7), 1341-1351.
36. Newton, I. (2007). Weather-related mass-mortality events in migrants. Ibis, 149(3), 453-467