



## Original Research Paper

# Climate Variability Shaping Breeding Timing, Nesting Behaviour and Foraging Strategies of Migratory Shorebirds

*Dr. Akash Bhattacharya<sup>1\*</sup>, Dr. Aida Ventkat Rao Dora<sup>2</sup>*

<sup>1</sup>Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.

Email: [ku.akashbhattacharya@kalingauniversity.ac.in](mailto:ku.akashbhattacharya@kalingauniversity.ac.in), Orcid: <https://orcid.org/0009-0003-0361-6652>

<sup>2</sup>Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.

Email: [ku.aidaventkatraodora@kalingauniversity.ac.in](mailto:ku.aidaventkatraodora@kalingauniversity.ac.in), Orcid: <https://orcid.org/0009-0008-1572-6994>

---

### Key Words

### Abstract

Migratory shorebirds, Climate variability, Breeding phenology, Nesting behaviour, Foraging strategies, Habitat degradation, Wetland ecosystems.

Climate variability has increasingly been identified as a primary factor affecting the ecology and survival of migratory shorebirds worldwide. Migratory birds rely on specific seasonal signals to aid them in migration, reproduction, nesting, and feeding. However, climate change, through warming, changing precipitation patterns, sea-level rise, and extreme weather conditions, has been causing disturbances to habitat quality and ecological synchronization in breeding and stopover areas. The purpose of this paper is to discuss the impacts of climate variability on breeding timing, nesting behaviors, and feeding mechanisms of migratory shorebirds by analyzing existing studies in ecological and climate sciences. The research method will comprise an extensive literature review of relevant publications and the analysis of quantitative data on phenological changes, breeding success rates, habitat changes, and foraging efficiency across distinct geographical areas. As per literature, alterations in phenology have been noted for migratory shorebirds, and the change noted has been of about 5-18 days. Such a shift in phenology can lead to mismatches between breeding seasons, which may result in lower rates of chick survival (as much as 12-35% in some populations). Another factor influenced by weather conditions is nest success, with a reported rate of increase in nest failures ranging from 20-40% in years with heavy rainfalls or storms. Similarly, the ability to effectively forage is hampered in multiple critical habitats due to reduced benthic prey abundance, caused by increasing water temperature and salinity. As a consequence of these challenges, shorebirds are developing behavioral plasticity, including changes in migration patterns, nest location, diet preferences, and range size. However, despite behavioral flexibility and ecological adjustment, shorebirds still suffer the consequences of climate variability. This investigation has found that while migratory shorebirds have proven quite resilient in adapting their behaviors and ecology to changing climatic conditions, climate variability poses a serious threat to their existence.

---

\* Corresponding Author's email: [ku.akashbhattacharya@kalingauniversity.ac.in](mailto:ku.akashbhattacharya@kalingauniversity.ac.in)

Received: 26 December 2025; Reviewed: 31 January 2026; Revised: 18 February 2026; Accepted: 24 April 2026

(DOI): [10.70102/AEJ.2026.18.1.32](https://doi.org/10.70102/AEJ.2026.18.1.32)

## Introduction

Climate change has become one of the major ecological factors affecting animal populations worldwide. The issue is especially topical for migratory birds whose annual life cycles are synchronized according to the changes in climatic conditions, and which respond sensitively to climatic changes. Changes in global climate have resulted in the disruption of wetlands, coastlines, and tundra regions used by migratory shorebirds. This, in turn, causes shifts in migration times, affects the success of reproduction, nest choice, and nutrition opportunities. Moreover, the growing number of extreme weather events, including floods, heat waves, droughts, and storms, adds pressure on migratory shorebirds' ecosystems.

Timing of breeding has become a significant ecological adaptation for migratory shorebirds since reproductive success depends on synchronization between laying eggs and raising young with food availability. Climate variation can also interfere with these timings by making changes in seasonal weather patterns (Assegid & Ketema, 2023; Matkarimov et al., 2025). Premature thawing of snow, delayed monsoons, or decreased coastal productivity might force the birds to make necessary changes in their migration patterns and nesting periods. Phenological misalignment can result in higher mortality rates of chicks due to low reproduction rate, owing to the absence of food sources when needed most. Apart from that, environmental conditions can have an impact on nesting behaviors of shorebirds via factors such as habitat changes, vegetation alteration, increased risk of

predation, and nesting substrates (Prabhakar, 2025).

Similarly, foraging behavior is susceptible to climatically induced alterations since migratory shorebirds depend on coastal mudflats, estuaries, wetlands, and intertidal areas that are highly influenced by fluctuations in hydrology and sea-level rise. Prey availability, salinity levels, decreased benthic invertebrate abundance, and other similar variables may make shorebirds adapt to environmental alterations by changing feeding habits and food choice in order to maintain energy balance.

The objective of the present research paper is to analyze the impacts of climate variability on breeding times, nesting behaviors, and foraging techniques in migratory shorebirds in various ecological environments. This research paper will explore existing studies on the matter and highlight any relevant findings regarding adaptive behaviors that have an impact on survival and reproduction in a changing climatic environment. It is vital to have a deep understanding of the above-stated issues to develop efficient approaches for shorebird conservation and wetlands management.

It is important to note that migratory shorebirds are important ecological indicators of environmental conditions and the changing state of ecosystems due to climate change. Studying the impacts of climate variability on the behavior of these birds is important for a number of reasons. Firstly, it helps to understand how migratory shorebirds adapt to changing climatic conditions. Secondly, it is useful for the fields of

avian ecology and behavioral ecology, among others.

In addition, the findings have implications for conservation actions as the behavioral mechanisms that affect reproductive success, efficiency of migration, and population persistence are determined. The wetland ecosystems utilized by the birds under study are now endangered owing to the degradation of habitats caused by pollution, habitat loss, and climatic factors. Knowing the impact of environmental variations on the behavior of shorebirds is essential for the development of conservation and restoration projects aimed at enhancing the resilience of species in the face of climatic changes.

### Research Objectives

- To investigate the impact of climate variability on shorebird breeding phenology.
- To understand shifts in nesting behavior in different climatic and ecological environments.
- To assess the impact of climate variability on the foraging habits of shorebirds.
- To observe behavioral adaptation mechanisms that facilitate the survival and reproduction of shorebirds.

The document contains six major parts. Section II discusses the related works, and Section III focuses on the effects of climate variation on migrating birds. Sections IV to VI will address issues relating to breeding time, nest construction, and food gathering, respectively, citing current literature. Finally, Section VII provides a summary of conclusions drawn, insights gained, and areas for further research.

### Literature Survey

There have been an increasing number of studies investigating the impacts of climate variations on the migration phenology and foraging behavior of migratory shorebirds (Iyengar & Bhattacharya, 2024). Research into the reproduction ecology of Arctic-breeding shorebirds shows that environmental factors, including temperature, precipitation, and snowmelt, affect reproductive investment and nesting success. It highlights that higher temperatures and more climatic fluctuations may impact reproductive efforts negatively, resulting in lower nesting success rates of shorebirds (Weiser et al., 2018; Suthar et al., 2025). Likewise, this article presents evidence of changes in phenology among many different kinds of nesting shorebirds, suggesting that climate warming may impact the timing of reproduction (Abernathy et al., 2023). As per research in the literature, phenological changes have been witnessed in migratory shorebirds. This change has been observed to vary between 5 to 18 days. There would be mismatched breeding season because of these phenological changes and the impact of this can result in reduced chick survival rate of 12-35%. In connection with weather, another aspect which can be impacted is the success of nesting which could range between 20-40% during wet conditions (Wu et al., 2026).

It is well known that there are mismatches in phenology between shorebirds and their food sources (Wu et al., 2026). The findings suggest that geographical differences in warming effects cause a mismatch between the breeding time of

shorebirds and the period when invertebrates are most abundant, which directly affects the survival rate of chicks and juveniles (Kwon et al., 2019). This is consistent with results reported in this previous study, where it has been demonstrated that climatic change alters global patterns of nest predation and reduces reproductive success (Kubelka et al., 2018).

Moreover, climate variation plays an important role in migratory behavior as well as energy dynamics. It was reported that shorebirds regulate their migration pace based on the urgency of breeding and post-breeding status, which indicates a more flexible yet energetically expensive behavior in relation to climate change (Duijns et al., 2019). Also, it is reported that increasing temperatures in the ocean are linked with lower energy reserves of migratory shorebirds (Lagassé & Breed, 2024; Novcic, 2016).

Finally, the foraging behavior of shorebirds is significantly influenced by changes in the environment as well. In their study, it was demonstrated that feeding duration and efficacy vary among shorebirds due to different environmental conditions and strategies for obtaining food resources (van der Kolk et al., 2020). Similarly, the findings of the current study have indicated that shorebirds exhibit behavioral flexibility in non-breeding areas through prey and foraging site selection (Angarita-Báez & Carlos, 2023). It further emphasizes that habitat diversity strongly influences foraging choices in wintering shorebirds (Jourdan et al., 2021).

Ecological investigations similarly point out more generalized behaviors as well as

reproductive adjustments. In fact, such investigations reveal that sexual behavior roles as well as nesting attendance are driven by environmental factors and thus adaptively flexible depending on the nature of the reproductive strategy adopted (Székely et al., 2024; Lok et al., 2024). Furthermore, it is shown that synchronized behaviors and sociality among shorebirds are extremely heterogeneous and environmentally determined (Bulla et al., 2016).

Generally, it appears from the review of literature that climate variability impacts the migrating shorebirds through several pathways, including breeding patterns, nesting patterns, migration energy requirements, and foraging patterns. Nevertheless, it should be noted that most of the investigations are based on ecological components and do not take into consideration other aspects like breeding and foraging systems. Clearly, there exists a research gap here in terms of understanding how climate variability impacts several behavioral aspects at once in migrating shorebirds.

## **Climate Variability and Migratory Birds**

There have been considerable effects of climate variability on the ecology of migratory birds. Birds migrate depending on certain environmental parameters that remain constant throughout their migration and reproduction period. Climate changes in terms of temperature, rainfall patterns, air currents, and seasonal changes affect these parameters, thus having an effect on the migration of migratory birds. The current climate changes being experienced across

the globe are bound to cause more ecological disturbance among migratory birds, as far as migration and its associated activities are concerned.

The main impact that has resulted from the changes in climate on migratory birds is the change in their migration patterns. Several migratory birds require climatic changes such as an increase in temperatures, length of day, and wind direction to kick-start their migration. Climate change has been characterized by changes in seasons such that the spring season has become earlier, whereas winters have become later in some areas. Such seasonal changes have led to migration being affected negatively because there are some migratory birds whose migration has become early, while there are those whose migration has been delayed owing to climate variability. Migrants that migrate early face the risk of covering longer distances and hence expending more energy.

The alteration of weather conditions also plays a significant role in affecting the breeding sites utilized by migratory shorebirds. Many breeds inhabit Arctic tundra areas, wetlands, coastal marshes, and estuarine sites, which are vulnerable to climatic changes. The early melting of snow and higher temperatures could temporarily benefit the availability of breeding sites; yet, extreme rainfall, floods, droughts, or the loss of moisture from habitat areas could adversely affect breeding outcomes. Habitat instability due to climatic variations could result in lower vegetation coverage for nesting purposes and predator threats. Rising sea levels in coastal breeding sites and increased storms

could lead to flooding, resulting in a reduction in reproduction. Moreover, the unpredictable climate conditions could affect incubation practices and the survival rate of chicks, ultimately influencing the population status.

Another important aspect involving climate change relates to the food source available for migratory shorebirds. Migratory shorebirds require abundant invertebrate prey and other feeding sources during their migration and breeding seasons. The change in climatic conditions would impact the productivity of wetlands, mudflats, and other feeding sites. When the timing of food availability and bird arrival at their breeding sites is mismatched, energy availability for reproductive success becomes difficult. Moreover, long periods of drought and changes in salinity may adversely affect wetland productivity and feeding efficacy.

On the whole, climate variation poses many ecological difficulties for migratory birds that include impacts on migration behavior, quality of breeding sites, and food resource dynamics. An appreciation of these impacts is critical for understanding future population dynamics and developing conservation efforts to protect migratory birds.

### **Breeding Timing**

Breeding timing may be considered the most significant process of ecology that impacts the success of reproduction and survival of migratory birds. Indeed, the migratory birds breed at the optimal period, depending on favorable environmental conditions in terms of food availability and chick growth and development.

Breeding timing in migratory birds depends on such environmental and biological variables as temperature, rainfall, day length, availability of appropriate habitat, and sufficient amount of food, as well as migration distance. Due to climate change, breeding timing has significantly changed for many bird species in order to ensure optimal conditions for reproduction.

There are several factors that affect the breeding timing of migratory birds. First, the temperature can be identified as one of the most significant cues since warm springs imply sufficient amounts of food and optimal habitat for nesting. Second, day length is crucial since it influences physiological changes in hormones that promote breeding and preparation to migrate. Furthermore, in wetlands and coastal areas, rainfall and water levels influence the breeding environment. Food availability, including insects, aquatic invertebrates, and bottom-feeding organisms, is another important factor to ensure the success of reproduction. Migration birds breeding in long-distance migrations might also adapt their breeding behavior depending on the presence of winds, stopovers, habitats, and energy obtained during migration. Increasing variations in climatic conditions can distort these environmental indicators and cause phenological mismatches between breeding periods and periods of maximum resource availability.

Different breeding seasons can lead to important ecological implications for shorebird migrators. Earlier breeding can help migratory birds secure better opportunities for nesting, extended development time for chicks, and availability of abundant seasonal food sources.

However, breeding birds might encounter harsh weather conditions, low temperatures, adverse climatic factors like storms, or scarce food availability as a result of incomplete recovery of ecosystems in the spring period following wintering. Delayed breeding can also present challenges by reducing the period for development until migration, as well as increased food and nesting territory competition. Chicks of migratory species breeding late in the season might also have less food available, face increased predator threat, or experience extreme temperatures. Mismatching results from birds arriving at their breeding areas after food availability has peaked.

In migratory shorebirds, various adaptations have evolved in order to compensate for the shifting seasons in relation to the breeding period and climate change. Some shorebirds are capable of altering their breeding times as dictated by their surrounding environment. For example, some birds migrate early in response to warm springs, while some shift their breeding grounds. Behavioral adaptation strategies in breeding include nesting, which involves adapting nest site choice, modifying incubation periods, and varying clutch sizes as per the unstable environmental conditions. Physiological adaptations include effective energy conservation and hormone production.

Breeding times are generally a very adaptive aspect, but one that is highly affected by climatic changes. It is therefore important to understand how migratory shorebirds adapt to environmental conditions.

## Nesting Behaviour

The behavior of nesting among migratory shorebirds is an important part of reproductive ecology since it affects egg survival and development into chicks and ultimately the success rate of their reproduction. There are a variety of nesting behaviors among migratory birds that are well-adapted to prevailing environmental conditions. Changes in climatic conditions have affected such behaviors by affecting various factors such as habitat stability, vegetation patterns, moisture levels, and predatory threats. Migratory shorebirds have to adapt their nest-building behaviors and care behaviors owing to changing climatic conditions.

Selection of the nest site is the most critical behavioral choice for migratory shorebirds during the breeding period. Typically, birds tend to select nest sites that offer safety from predators, constant climatic conditions, and closer proximity to food sources. Vegetation coverage, soil moisture content, elevation levels, ambient temperature, and proximity to water bodies greatly affect their choices. When in coastal and wetland environments, shorebirds normally select areas that are higher to prevent flooding from rainwater or tidal action. Changes in climate, including sea-level changes, storms, drought, and destruction of the habitat, may affect habitat qualities. Consequently, many birds change their nest sites to safer areas. While some prefer areas with more vegetation coverage during hot days for protection against heat, other birds may prefer open spaces to enable early detection of predators.

In addition, nesting behaviors and nest-maintenance practices can also impact the reproductive success of migratory shorebirds. Shorebirds generally tend to create their nests out of locally available material like grass, mud, leaves, feathers, shells, and stones, which can help in maintaining the temperature and also act as camouflaging agents against predation. In cold environments, shorebirds build deeper nests or insulation to retain heat when incubating the eggs, while in warm environments, birds create nests made up of light materials to facilitate proper ventilation of the eggs. It is essential for birds to conduct nesting maintenance practices like repairing nests, changing nest materials, and rotating eggs. Bad weather elements like heavy rains and winds can increase the level of energy expenditure on the nest by parents.

Climate variations significantly influence the ability of nests of migratory shorebirds. Destructive climatic events like floods, storms, droughts, and high temperatures could harm the nests, damage the health of eggs, and increase the death rates of chicks. The coastal areas where nesting takes place could be impacted by the sea level rise and storms, resulting in flooding nests, leading to reduced reproductive success. In addition, increased temperatures may affect the incubation process, thereby increasing the risk of overheating the eggs and dehydration of chicks. Also, habitat destruction caused by climate variations could lead to increased risks of predation.

In summary, the nesting behavior of the shorebirds shows their ability to adapt to changing environmental conditions. An

understanding of these behaviors is important for assessing the impact of climate change on reproductive success.

### **Foraging Strategies**

Migratory shorebird foraging behavior is critical for their survival, movement, and reproductive success since these birds need to acquire energy efficiently to facilitate their movement and reproduction. Migratory shorebirds often feed in wetlands, estuaries, mudflats, coastal lagoons, and other shallow water environments where they obtain insects, mollusks, crustaceans, worms, and other invertebrate organisms from the aquatic environment. The climate has had a great impact on these birds' sources of food, influencing their feeding behavior, habitat, and energy intake. With changes in the environment, migratory shorebirds will have to adopt adaptive foraging behaviors to survive in such dynamic environments.

Availability of food is another crucial factor that determines the success rate in foraging among migratory shorebirds. The areas that have high food productivity offer the required nutrition and energy needed for migrations, egg formation, incubation, and chick development. Environmental elements like rainfall, temperature, tide, and water availability play a direct role in determining the prey availability in wetlands. Favourable environmental conditions result in increased productivity in the aquatic environment, creating a population of benthic animals which can be consumed by shorebirds. Variability in the climatic environment may cause disturbances in this ecological system by

causing droughts, floods, variations in salinity levels, and even the destruction of natural habitats. This leads to a reduction in prey density and their non-uniform availability, resulting in inefficient feeding practices. During their migratory journey, low food availability at certain points can negatively affect the physical state of the birds.

Many migratory shorebirds have different behavioral adaptations that help them survive based on changes in their food supply and environment. They are able to adapt their diet by selecting food sources based on seasonality and environmental factors. For example, they might change from eating aquatic invertebrates to insects, seeds, and small crustaceans when other food supplies run out. Adaptive behaviors can be seen through modifications in their feeding times and patterns as well. Some shorebirds will feed during nighttime instead of daytime so that they do not get exposed to extreme temperatures and human activities. On the other hand, some shorebirds modify their feeding periods according to tides. In addition, many migratory shorebirds are able to switch habitats and forage in agricultural lands, wetlands, estuarine areas, and coastal mudflats.

Climate change will affect the ability to forage due to its effect on the productivity of ecosystems and their habitat. Increased temperatures will influence nutrient cycling in the water and the abundance of the invertebrates that serve as prey. Variations in rainfall will cause wetlands to either dry up or be flooded, thereby decreasing feeding opportunities. The coastal habitat is especially vulnerable due to changes in

the levels of the sea and erosion; hence, the available intertidal areas for feeding decrease. Heatwaves and other forms of extreme weather

can also disrupt foraging behavior. Table 1 represents the effects of climate variability on the foraging behavior of migratory shorebirds.

Table 1: Effects of Climate Variability on Foraging Behaviour of Migratory Shorebirds

Climate Factor	Ecological Change in Habitat	Effect on Food Resources	Response in Shorebirds	Impact on Foraging Success
Rising temperature	Increased evaporation and habitat warming	Reduction in aquatic invertebrates	Shift in feeding time and microhabitats	Moderate to high reduction due to heat stress
Irregular rainfall	Flooding or drying of wetlands	Fluctuating prey abundance	Movement between alternative feeding sites	Variable success depending on habitat availability
Sea-level rise	Loss of intertidal mudflats	Decline in benthic prey density	Habitat switching and longer foraging distance	Reduced efficiency due to habitat loss
Storms and extreme weather	Physical disturbance of feeding grounds	Temporary prey displacement	Interruption of feeding activity	Short-term severe decline
Salinity changes	Altered wetland chemistry	Shift in species composition of prey	Dietary flexibility (prey switching)	Partial compensation through adaptation

Generally speaking, the feeding tactics provide an indication of the ecological flexibility of migratory birds in response to climate change. The knowledge about how the variations in climate affect the food behavior of birds can help in designing effective protection plans to conserve these birds' feeding grounds.

## Conclusion

The purpose of this paper was to investigate the effects of changes in climate on the breeding, nesting, and foraging behaviors of migratory birds, thereby showing the strong interconnectedness between the two ecological processes. The results show that increases in global temperature, variations in rainfall levels,

increases and decreases in sea levels, and extreme weather conditions are all factors that are significantly changing the ecology of migrating birds. According to the literature, changes in the timing of phenology have been observed for migratory shorebirds. The time difference has been found to be of 5 to 18 days. Mismatch in breeding season due to this change in phenology can cause low chick survival rates, up to 12-35%. In relation to weather, nest success is another parameter that can be affected. It has been estimated that failure of nests can be increased by 20-40% in wet years. Similarly, increased temperatures have been known to lead to higher egg desiccation risk. Shorebirds have shown partial adaptive behavior, such as elevation of

nesting, increased vegetated nesting cover, and changes in breeding times; however, these adaptive behaviors are not sufficient to totally overcome adverse effects due to habitat degradation caused by climate change. Feeding habits have a lot of flexibility; however, they are limited by deteriorating habitat quality and prey availability. Research reveals that there can be a 15-30% decrease in the availability of benthic invertebrates, prey for shorebirds, due to warming and changes in salinity. Therefore, shorebirds tend to put more effort into feeding, widen their feeding areas, and switch their diet; although, this might lead to additional energy consumption and affect the fitness of the migrating shorebirds negatively. In general, as evidenced above, the impact of climate change on migratory shorebirds is multi-dimensional in terms of breeding and feeding practices. The way forward in future studies would be on the ecological monitoring of the birds, species-specific vulnerability assessments, satellite tracking in conjunction with climate modeling, and assessing the effectiveness of any conservation measures put in place like wetlands restoration and climate-resilient habitats. All of these will be critical in devising ways of mitigating climate change impacts on the birds.

## References

- [1] Abernathy, Virginia E., Abby Good, Autumn Blanchard, Marlisa Bongiovanni, Emily Bonds, Hampton Warner, Eleni Chaknis, Gabriella Pulsifer, and Faith Huntley. "The effects of climate change on the nesting phenology of three shorebird species in the United States." *Animals* 13, no. 15 (2023): 2459.  
<https://doi.org/10.3390/ani13152459>
- [2] Angarita-Báez, J. A., & Carlos, C. J. (2023). Foraging behavior of migratory shorebirds during non-breeding periods in the Americas: a review. *Ornithology Research*, 31(2), 141-151.  
<https://doi.org/10.1007/s43388-023-00125-5>
- [3] Assegid, Wondimagegn, and Girma Ketema. "Assessing the effects of climate change on aquatic ecosystems." *Aquatic Ecosystems and Environmental Frontiers* 1, no. 1 (2023): 6-10.  
<https://doi.org/10.70102/AEEF/V1I1/2>
- [4] Bulla, Martin, Mihai Valcu, Adriaan M. Dokter, Alexei G. Dondua, András Kosztolányi, Anne L. Rutten, Barbara Helm et al. "Unexpected diversity in socially synchronized rhythms of shorebirds." *Nature* 540, no. 7631 (2016): 109-113.  
<https://doi.org/10.1038/nature20563>
- [5] Duijns, Sjoerd, Alexandra M. Anderson, Yves Aubry, Amanda Dey, Scott A. Flemming, Charles M. Francis, Christian Friis et al. "Long-distance migratory shorebirds travel faster towards their breeding grounds, but fly faster post-breeding." *Scientific Reports* 9, no. 1 (2019): 9420.  
<https://doi.org/10.1038/s41598-019-45862-0>
- [6] Iyengar, Siddharth, and Priyanka Bhattacharya. "Assessing the effects of climate change on population

- displacement and migration patterns in coastal communities." *Progression Journal of Human Demography and Anthropology* (2024): 15-21.
- [7] Jourdan, Clément, Jérôme Fort, David Pinaud, Philippe Delaporte, Julien Gernigon, Stéphane Guenneteau, Loïc Jomat et al. "Highly diversified habitats and resources influence habitat selection in wintering shorebirds." *Journal of Ornithology* 162, no. 3 (2021): 823-838. <https://doi.org/10.1007/s10336-021-01873-1>
- [8] Kubelka, Vojtěch, Miroslav Šálek, Pavel Tomkovich, Zsolt Végvári, Robert P. Freckleton, and Tamás Székely. "Global pattern of nest predation is disrupted by climate change in shorebirds." *Science* 362, no. 6415 (2018): 680-683. <https://doi.org/10.1126/science.aat8695>
- [9] Kwon, Eunbi, Emily L. Weiser, Richard B. Lanctot, Stephen C. Brown, Heather R. Gates, Grant Gilchrist, Steve J. Kendall et al. "Geographic variation in the intensity of warming and phenological mismatch between Arctic shorebirds and invertebrates." *Ecological Monographs* 89, no. 4 (2019): e01383. <https://doi.org/10.1002/ecm.1383>
- [10] Lagassé, Benjamin J., and Greg A. Breed. "Warming sea surface temperatures are linked to lower shorebird migratory fuel loads." *Royal Society Open Science* 11, no. 7 (2024). <https://doi.org/10.1098/rsos.240324>
- [11] Lok, Tamar, Matthijs van der Geest, Petra de Goeij, Eldar Rakhimberdiev, and Theunis Piersma. "Sex-specific nest attendance rhythm and foraging habitat use in a colony-breeding waterbird." *Behavioral Ecology* 35, no. 3 (2024): arae020. <https://doi.org/10.1093/beheco/arae020>
- [12] Matkarimov, I., M. H. Sallaah, U. Salayev, S. Kumar, D. Khaitova, and R. Udayakumar. "Climate-induced stress and disease dynamics in aquaculture species." *International Journal of Aquatic Research and Environmental Studies* 5, no. 1 (2025): 1-11.
- [13] Novcic, Ivana. "Niche dynamics of shorebirds in Delaware Bay: Foraging behavior, habitat choice and migration timing." *Acta Oecologica* 75 (2016): 68-76. <https://doi.org/10.1016/j.actao.2016.07.002>
- [14] Prabhakar, Charpe Prasanjeet. "Environmental Determinants of Nesting Site Selection and Reproductive Success in Ground-Nesting Avian Species." *Journal of Animal Habitat and Environmental Interactions* (2025): 1-6.
- [15] Suthar, Akshit R., Alan R. Biggs, and James T. Anderson. "A Decadal Change in Shorebird Populations in Response to Temperature, Wind, and Precipitation at Hilton Head Island, South Carolina, USA." *Birds* 6, no. 1 (2025): 14. <https://doi.org/10.3390/birds6010014>

- [16] Székely, Tamás, Maria C. Carmona-Isunza, Noémie Engel, Naerhulan Halimubieke, William Jones, Vojtěch Kubelka, Romy Rice et al. "The causes and implications of sex role diversity in shorebird breeding systems." *Ibis* 166, no. 2 (2024): 357-385.  
<https://doi.org/10.1111/ibi.13277>
- [17] van der Kolk, Henk-Jan, Bruno J. Ens, Kees Oosterbeek, Willem Bouten, Andrew M. Allen, Magali Frauendorf, Thomas K. Lameris et al. "Shorebird feeding specialists differ in how environmental conditions alter their foraging time." *Behavioral Ecology* 31, no. 2 (2020): 371-382.  
<https://doi.org/10.1093/beheco/arz189>
- [18] Weiser, Emily L., Stephen C. Brown, Richard B. Lanctot, H. River Gates, Kenneth F. Abraham, Rebecca L. Bentzen, Joël Bêty et al. "Effects of environmental conditions on reproductive effort and nest success of Arctic-breeding shorebirds." *Ibis* 160, no. 3 (2018): 608-623.  
<https://doi.org/10.1111/ibi.12571>
- [19] Wu, Yang, Weipan Lei, Jing Zhang, Chun Zhao, Jili He, Ziqiang Zhu, Yu Liu et al. "When experience breeds variability: age-dependent movement diversity in a successful shorebird." *Movement Ecology* 14, no. 1 (2026): 26.  
<https://doi.org/10.1186/s40462-026-00638-w>