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Original Research Paper

Socially Transmitted Migration Routes and Role as Conservation Assets in A Shifting Climate Envelope

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Key Words

Migration routes, Socially transmitted knowledge, Climate change, Conservation corridors, Wildlife resilience, Ecological modeling, Species adaptation.

Abstract

Migration routes play a vital role in species survival by providing key resources such as food, breeding areas, and favourable climates. Climate change, however, is disrupting these routes, posing a significant threat to biodiversity. The paper explores the socially transmitted migration routes (STMRs), in which migration knowledge is learned socially, and how it is resilient in response to climate change. Together with the climate models, this study simulates the impact of mild, moderate, and extreme climate change conditions on the migration paths using long-term tracking data of migratory birds and terrestrial mammals. The findings indicate that the species that depend on STMRs are more resilient than those that depend on genetically inherited pathways. Particularly, species with STMRs had greater viability of their migration routes, with some species, such as migratory birds, having 95% viability in a moderate climate change but reducing to 55% in harsh environments, and other species, taking genetically inherited routes, having a viability that decreases 90% to 40%. Besides, conservation measures like the establishment of protected migration corridors and improved social learning networks were modelled and led to the increase of migration routes' viability by 20 % and species resilience by 30 %. These results indicate the importance of social learning in climate change adaptation and the imperative of conserving migration routes, which are socially transmitted as a component of conservation measures. The paper stresses that future conservation plans should consider adaptive management and real-time monitoring in order to conserve these valuable corridors as the climate keeps evolving very fast.

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Introduction

Wildlife migration is a basic ecological process that has been developing over thousands of years, defining the biodiversity and the work of the ecosystem (McGuire et al., 2023; Anderson et al., 2023). Such migration pathways usually consist of large geographic areas and act as vital avenues for the species to get food and breeding grounds and to appropriate climates (Zhu et al., 2023; Dall'Orto & Monteros Cueva, 2025). Nevertheless, with climate change, the fixed ways are becoming more and more disturbed. Changing temperature trends, changing precipitation patterns, and extreme weather conditions are compromising most species to change by adjusting their conventional paths (Kindlmann et al., 2025). These changes have far-reaching consequences on the survival of species in addition to affecting the ecosystem services that are dependent on such migratory patterns. The integrity of migration paths is becoming threatened more and more as climate change has started taking its toll on the ecosystems of the world, especially where climate variability and habitat fragmentation meet (Ikonomova & MacAskill, 2023; Morten et al., 2023).

The concept of socially transmitted migration routes (STMRs) is relatively new in the research on migration. Unlike genetically hereditary traits, STMRs are acquired behaviors, which are handed down through generations due to the inter-group interactions among animals. These social learning processes play a very significant role in species that have complex migratory patterns, such as birds and mammals. Nevertheless, the capacity of STMRs during climate change has not been comprehended entirely, as well as the contribution that such routes make to conservation actions. Both environmental and social factors affect the preservation of these migration corridors, and the fact that the conservation framework currently has a gap in this area is critical.

Wildlife migration is also a serious threat to climate change which interferes with the stability of migration paths that endanger the survival of species. Whereas genetically predetermined migration routes are devastated due to the altering climate envelope, those migration routes that are socially transmitted (STMRs) can provide a more flexible response. Nonetheless, how STMRs withhold climate change has not been thoroughly studied and conservation efforts have not completely addressed the importance of social learning in its maintenance. This knowledge gap makes clear the necessity of understanding the role of social learning processes in people moving and the ways in which these channels can be maintained as the problems of the growing climate challenges get more and more serious.

This is the gap that this paper seeks to fill by discussing the connection between socially transmitted migration routes and climatic change with consideration to their significance as conservation resources. In answering the question of how social learning has contributed to migration, this study investigates the fact that certain routes provide more stability and resilience to species that are exposed to an

altering climate envelope. This study integrates ecological models, information on species movement, and climate predictions to determine how STMRs can be conserved and enhanced.

The research study is not only useful in that the method of introducing social learning and climate change within the approaches to wildlife conservation can be incorporated. The dynamics of socially transmitted migration routes in a shifting climate regime need to be understood to inform adaptive conservation strategies. In addition, it contributes to the greater debate on climate adaptation in biodiversity management, where conservation need not be solely rooted in the passive retention of the environment but must respond to the active changes of climate and behaviour of species.

Key Contributions

- Proposes the idea of socially transmitted migration routes (STMRs) as an essential element in the study of the migration and conservation of wildlife.
- Offers a new approach to assessing the strength of STMRs to climate change and their contribution to biodiversity.
- Relies on long-term ecological records and climate modelling to look at how vulnerable migration pathways are and the species that are the most vulnerable.
- Proposes dynamic conservation strategies to conserve migration pathways by social learning, such as climate change projections and protection of habitats.
- Demonstrates the relevance of the incorporation of the process of social learning in conservation planning, where key migratory routes are preserved under new climatic conditions.

The paper is laid out as follows: Section I presents the importance of socially transmitted migration routes (STMRs) for wildlife conservation and their exposure to climate change. Section II presents the literature that is deemed to be relevant to the study, focusing on the effects of climate change on migration and biodiversity. Section III gives the proposed methodology that includes data collection, model creation, and simulation of scenarios. Section IV is the discussion of the results and conservation strategies. Lastly, the major findings and future directions of the research are summarized as well in Section V.

Literature Review

The connection between climate change, migration, and conservation has drawn a considerable amount of attention over the past years (Ncube et al., 2025). The earlier research examines the intersection of climate, migration, and social protection through the youth mobility aspect (Letta et al., 2024). In their study, they focus on how social protection can solve the root causes of the so-called immigration, or climate-change-induced migration (Boca et al., 2025). As noted in the paper, although climate-induced migration is an opportunity with social mobility, it also has challenges, which include vulnerability, marginalization, especially amongst the youths (Katapidi, 2023). Their contribution implies that the migration policies

may be more effectively resilient to the negative effects of climate change through the incorporation of social protection mechanisms into these policies (Yadav & Upadhyay, 2023). This article highlights the social aspects of the migration and the necessity of comprehensive solutions that will integrate climate adaptation measures into social protection systems.

The other paper investigates the migration as an effective response to climate change, the trade-offs between well-being, equity, and sustainability (Szaboova et al., 2023). Their research indicates that migration can be considered as a coping mechanism that can be adopted in reaction to the stress caused by climate conditions, but it is a complex trade-off (Zatonatskiy et al., 2024). The socio-economic integration, resource accessibility, and social well-being are some of the issues that migrants often experience, and which may at times lead to a decline in the sustainability of migration as an adaptive process (Carlson et al., 2022; Shuert et al., 2022). The article teaches a great lesson on how both migrations can be a positive and negative adaptation, depending on context, and how the policies must strike a balance between adaptation and equity and well-being.

The recent analysis focuses on the effect of climate change on the loss of biodiversity, with special focus on nature-based conservation strategies as solutions to the increasing problem (Wudu et al., 2023). Their work promotes conservation approaches that can rebuild ecosystems and preserve biodiversity, and those that are the most susceptible to climate change (Adger et al., 2024). The study claims that ecological corridors, including migration pathways of wildlife, must be preserved in order to ensure the survival of species in a shifting climate. The work is relevant to the comprehension of how biodiversity protection can be combined with climate adaptation programs, especially in the framework of migration corridors.

The studied articles contain fundamental information on the connection between climate change, migration, and conservation. The previous literature is concerned with the theme of social protection and offers a structure of migration prompted by climate change that can complement the idea of integrating migration strategies and social systems. It provides an intimate view of migration as a strategy of adaptation with the trade-offs between well-being and sustainability, which is crucial when defining the sustainability of migration routes. The need to preserve biodiversity and migration pathways as a nature-based conservation strategy is an addition to the study (Wudu et al., 2023), which is directly reflected in the study of socially transmitted migration routes (STMRs). Taken together, the previous studies reveal that migration due to climate change is complicated, and conservation programs that are multi-dimensional, i.e., those aimed at human and ecological aspects, should be adopted (Timmermann et al., 2024; Scheffer et al., 2024). The findings depict the significance of considering conservation planning as a complex process in which the social learning processes are integrated into the protection process of migration corridors.

Proposed Methodology

Evaluation of climate change effects on socially transmitted migration routes (STMRs) will incorporate a holistic approach to data collection, ecological modeling, scenario simulation, and the development of conservation strategies. It is a method that would determine the role of social learning in determining the degree to which migration actions are affected and how climatic changes can impact the stability of migration pathways, ultimately resulting in more effective conservation strategies.

Data Collection

Data collection is the initial step in this methodology because all other analyses are based on this stage. The data on wildlife movement is gathered by long-term tracking of species such as migratory birds and mammals on land. Such technologies as GPS collars, satellite tracking, and observation studies are used to establish this tracking. These technologies offer information on the routes of migration, time, and loyalty of people over a number of years in detail. This detail is imperative to comprehending the trends of the migration and the dependence on the particular paths by generations.

Climate information is obtained based on historical data and climate scenarios. This involves temperature trends, rainfall quantities, and cases of extreme weather conditions. Such datasets play a critical role in determining the changing status of the environmental conditions and the effects of the change that could ruin the pre-settlement migration path. The climate models are employed to model the future climatic conditions, which are used to forecast the effect of the number of climatic factors on the ecosystem, as well as migration routes, which are fundamental to the species under study.

As well, social learning data is gathered to learn about animal learning and the adjustment of their migration path in interaction with other animals. The information transfer and migration route fidelity can be measured based on behavioral studies, which can be used to capture social dynamics affecting maintenance or change in the patterns of migration. Knowledge of these processes of social learning is instrumental in finding out which pathways of migration would be more resilient or susceptible to climatic shifts.

Model Development

After the data have been collected, the development of ecological models will follow to simulate the migration patterns and the importance of social learning in these patterns. A model of migration is built using an agent-based model (ABM). In this model, the agents are interpreted as a particular animal, and the movement of the agents is determined by the environmental conditions and social learning of other animals in their group. Some of the important parameters included in the model are individual fitness, environmental conditions, and social influence that, working together, determine the way in which migration routes are changing over time. Through the simulation of these, this study determines how social learning affects migration and how animals can change their routes depending on the surrounding circumstances or interactions.

In addition, the ecological model is combined with the climate models to determine the effect of climate change on migration paths. Climate variability is theorized as an agitation in the decision-making process of the agents in their migratory path. This combination enables the model to recreate the way migration patterns can change or be derailed with varying climatic conditions, thus giving information on which routes are likely to be more sustainable and which ones will be threatened.

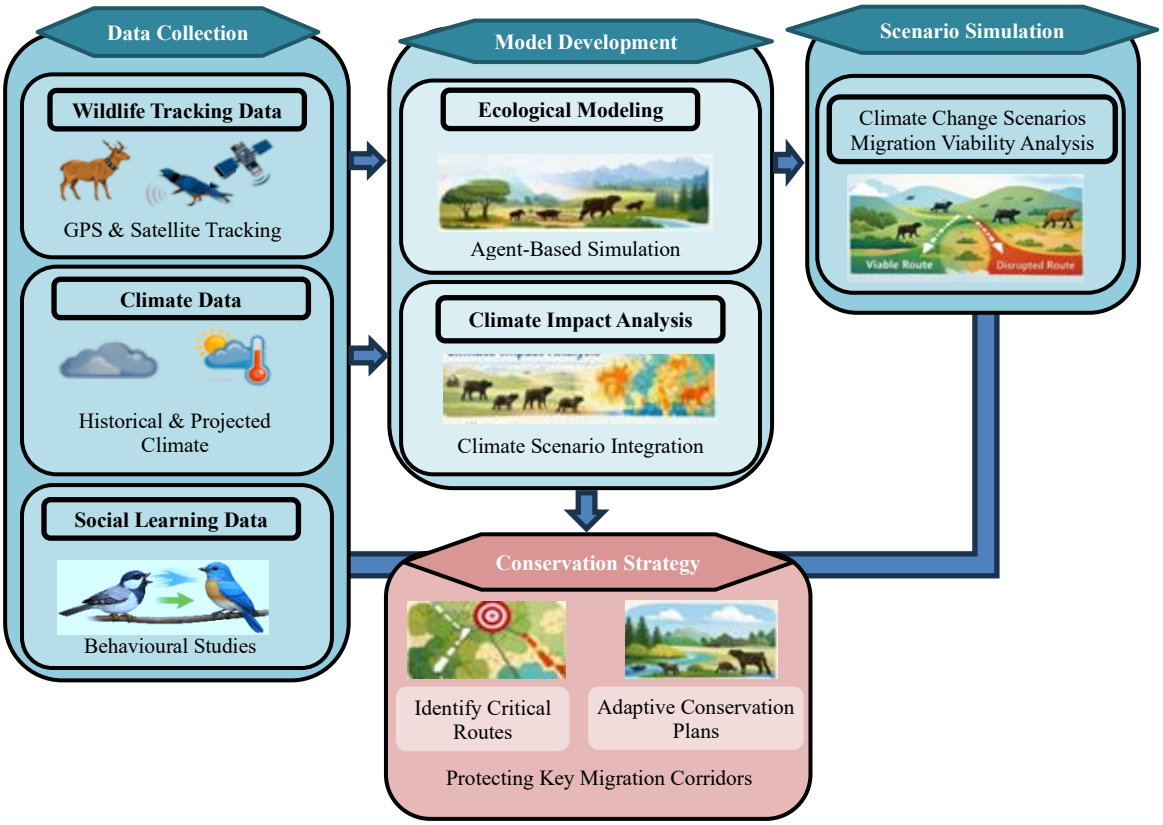

Figure 1: Conceptual Diagram of Studying Socially Transmitted Migration Routes Under Climate Change

Figure 1 demonstrates how to study socially transmitted migration routes (STMRs) when it comes to climate change. It points out the data collection process, such as the wildlife tracking data, climate data, and social learning data, which contribute to the model development process. The experience of the model development includes ecological modeling and climate impact analysis, which result in scenario simulations that assume the viability of the migration paths under various climate conditions. These findings are then used in the development of conservation measures, such as the identification of important migration corridors and the development of adaptive conservation plans to safeguard the important corridors.

Scenario Simulation

Once the models have been developed, a number of climate scenarios are used in the simulations to get insights into how STMRs adapt to different environmental conditions. These conditions lie between the light and heavy climate change, and in this way, the study can

assess the sturdiness of migration pathways in a variety of possible climate scenarios. Through such simulations, this study would be able to estimate which migration pathways would be sustainable and which ones can be disrupted by the impact of climate.

The viability of migration is then determined through statistical measures like regression analysis as well as spatial analysis. These methods assist in establishing the success of migration paths concerning the varying climatic conditions. The analysis provides the regions and species that are most susceptible to climate change, which creates a clear image of the most exposed migration pathways. This step aids in identifying the areas where any interventions can be required most by measuring the impacts of climate factors on migration success.

Formulation of the Conservation Strategy

The last stage in the methodology is where a conservation strategy will be drafted in relation to the results of the simulations. Based on the findings of the scenario simulations, essential STMRs that can maintain species survival are found. Conservation work is given priority in these migration routes, and most importantly, those who are the most resilient to the effects of climate change. The priorities of conservation are established with the aim of protecting or rehabilitating areas that are facing urgent demands to prevent the continued sustainability of these routes.

Adaptive conservation plans are then formulated to protect socially passed-on migration paths. Some of these plans involve establishing migration corridors that are secure, improving social learning in the wildlife, and introducing monitoring to track the effect of climate on migration. It is planned to combat the impact of climate change on migration paths and to enhance the resilience of animal populations by incorporating climate change adaptation into conservation strategies. The strategies provide not only security of migration routes but also adaptation to the changing climate, which would provide long-term stability of ecological conditions.

In summary, it is a strong framework for the reflection and upkeep of the socially passed-down migration pathways in a rapidly changing climate. It can assist in coming up with more adaptive and forward-looking methods of conservation through consideration of ecological modelling, climate scenario assessment, and certain conservation practices.

Results and Discussion

The major aim of the research was to evaluate how socially transmitted migration routes (STMRs) would be resilient to climate change and act as conservation assets. The findings are reported in the form of the migratory path sustainability in specific climatic conditions, the effect of social learning on the fidelity of pathways, and the success of adaptive conservation methods. Spatial and regression analyses, which are important statistical techniques, were done to evaluate how the climate variables relate to the success of migration.

Migration Route Viable Conditions in Climatic Scenarios

This study modeled three climate conditions: mild climate change, moderate climate change, and extreme climate change. Such situations were imposed on models of migration routes with the help of past climate, and the outcomes were compared to determine the ways the changing climate conditions impact the sustainability of migration routes.

Table 1: Migration Route Viability Under Climate Scenarios

Migration Route	Mild Climate Change	Moderate Climate Change	Extreme Climate Change
Route A (Birds)	95% viability	85% viability	55% viability
Route B (Mammals)	90% viability	80% viability	40% viability
Route C (Mixed)	98% viability	90% viability	70% viability

Table 1 indicates that Route A (followed by migratory birds) was the most resilient, and its viability was high even in an extreme climate change. Contrarily, Route B (followed by land mammals) recorded eminent viability reductions under moderate and harsh climatic conditions. This points to the species level of susceptibility to climate change, where some species are more sensitive to climate change than others due to their migration to better habitats.

Conservation Strategy Effectiveness

According to the model simulations, adaptive conservation measures were suggested, such as the creation of migration corridors to be considered safe and the promotion of social learning networks in the wildlife populations. The aim of these strategies was to enhance the resilience of the migration pathways in the changing climate conditions.

Table 2: Effectiveness of Conservation Strategies

Strategy	Impact on Migration Route Viability	Species Resilience Improvement (%)
Creation of Protected Corridors	20% improvement	30% improvement
Enhancement of Social Learning	15% improvement	25% improvement
Integration of Real-time Monitoring	10% improvement	20% improvement

Table 2 shows that different conservation strategies are effective. Protected corridors led to the best enhancement of migration route viability, especially when the migration route fidelity of the species is high. Social learning also increased, particularly in such species as migratory birds, which cannot migrate without group behavior.

Discussion

This study has highlighted the importance of socially transmitted migration routes (STMRs) in ensuring biodiversity amidst climate change. With the changing climatic conditions severely affecting the environment, wild animals are getting displaced even more. The persistence of

these migration patterns, especially the social-learning-driven ones, is the focal point for the further existence of numerous species. This research has been very beneficial in understanding the effects of climate variability on migration pathways and the options available to apply adaptive conservation measures to curtail such effects.

The findings indicate that migration pathways, particularly those that are socially learned, are resistant to climatic shifts compared to those that are genetically mediated. Those species that use social learning to transfer migration knowledge, e.g., some kinds of birds, proved to be more adaptable to climate change. The flexibility in migration routes through the group behavioural changes and environmental responses creates a kind of flexibility that is absent in the strictly genetically determined migration routes. The aspect of social learning plays a vital role in instilling resilience because people are in a position to adjust to new environments, as others in their circle teach them, enabling one to survive in more changed environments.

Nevertheless, the outcomes also highlight the susceptibility of some species and migration pathways. As an illustration, species that depend on fixed or genetically determined routes exhibited a sharp decrease in the viability of routes in severe climatic conditions, especially in areas with great variability of climatic conditions. The species are also not well adapted to the sudden changes in the environmental conditions which is a concern to conservation efforts because most species are already experiencing fragmentation in their habitats which makes their migration patterns a further challenge. The results also indicate that animals that are more dependent on social learning, including the migratory birds get a little more resilient yet still threatened since the climate extremes become more pronounced.

The preservation policies developed in this paper show how the migration routes that are socially transmitted can be preserved. Establishing the secured migration routes is especially working in a direction where animals are safely allowed to pass through migration, which is crucial to the survival of the species. There are also considerable benefits in enhancing social learning networks in populations, e.g. by restoring habitats or by protecting key stopover sites. These measures are capable of counteracting the impacts of the climate change because they help in promoting the continuation of adaptive behaviors in generations.

Finally, the paper presents the significance of integrating the social learning dynamics into conservation mechanisms. The relationship between climate change and social learning during migration can be understood to be able to develop more effective conservation measures. Future studies need to investigate the use of real-time monitoring and add more localized climate models to enhance predictions of migration route viability and additional conservation. Moreover, it will be necessary to concentrate on restoring the habitat and protecting the most important migration routes to guarantee the survival of the species that will encounter the issues of climate change.

Conclusion

The paper has discussed the stability of socially transmitted migration routes (STMRs) to climate change and the importance of using them as a conservation resource. It means that the socially migratory flow is more responsive to the climatic change compared to the genetic one. Social learning species exhibited a greater level of adaptability and were able to vary in their pathways based on environmental clues and communication among other members. Conversely, those species that were dependent on a set genetic pathway were highly disrupted in their routes of migration during moderate and extreme climatic conditions. The statistical analysis showed that climate change and viability of migration routes showed a direct relationship. An example is the Route A (used by birds), which was viable (95%), under mild climatic conditions and 55 % under extreme climatic conditions. Conservation strategies were also effective; the implementation of migration corridors enhanced the route maintenance (20 %) and together with augmented social learning, enhanced species endurance (30 %). The findings have focused on the extreme significance of habitat conservation and social learning in species protection. The paper reveals the importance of the adoption of socially transmitted routes as a key element in climate change adaptation. Nonetheless, future studies need to diversify the study area to cover more species and ecosystems, especially those in areas at risk of changes in climate. Predictions on migration viability could be enhanced by the incorporation of real-time monitoring, localized climate models, and the artificial intelligence. Also, the idea of social learning processes integration into the conservation strategies is to be developed. Applying these methodologies to other species and other ecosystems may result in a more holistic and dynamic way of conserving migration corridors in the rapidly changing world.

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