Research on Factors Influence the Migration of Pine Siskins

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Abstract. Avian migration is a remarkable phenomenon, and the migration behavior of Pine Siskins serves as a fascinating example, offering insights into the complex interplay of external and internal factors that shape migratory patterns. The migration behavior of Pine Siskins is influenced by various factors, including food availability, climatic influences, intrinsic regulation, and social interactions. This facultative migratory species exhibits year-to-year variations in migration patterns, with movements driven by the availability of food resources. Seasonal expressions, such as quiescence and early morning activity, contribute to their migratory behavior. Food availability plays a critical role in their decision to migrate, while climatic dipoles shape their movement patterns. Social interactions also influence their settlement decisions. Physiological regulation involves endocrine signaling components, although differences between pre-migratory and migratory periods were not observed. Biological rhythms, such as photoperiod, contribute to the transition to a migratory state. Understanding these multifaceted aspects of Pine Siskins' migration enhances the knowledge of avian migration and provides insights into the adaptive strategies employed by migratory birds. Further research is needed to fully comprehend the complexities of migratory behavior and develop effective conservation measures for these remarkable avian travelers.

Keywords: Avian migration, pine siskins, animal behavior, intrinsic regulation.

1. Introduction

Migration presents a compelling aspect of many bird species' lives, as they navigate extensive distances to complete incredible journeys [1]. This pattern of bird movement, or avian migration, is a spectacular event that has intrigued both researchers and bird lovers [2]. Among the migratory bird species, *Spinus pinus* is particularly noteworthy due to its notable migratory practices [3]. The migratory activities of Pine Siskins highlight the adaptability and navigational prowess inherent in birds that migrate. As petite songbirds, they embark on migratory journeys according to the seasons, transitioning between breeding territories in the northern areas and wintering sites towards the south [3]. Their migration schedules and pathways can change annually, influenced by a plethora of factors, which underscores the dynamic and multifaceted nature of their migratory behavior [4].

Pine Siskins are categorized as facultative migrants, which denotes that their migration tendencies are shaped by the environment, particularly the presence of food sources [5]. These birds exhibit a natural ability to evaluate the availability of food within their environment, which triggers their long-distance travel in pursuit of better feeding locales [5]. Such adaptability empowers them to exploit food resources that display seasonal variation and may be lacking in certain regions during specific periods.

The phenomenon of avian migration as a whole exerts a pivotal influence on the ecological and evolutionary trajectories of bird communities [2]. It fosters the use of diverse habitats and resources, supports breeding in ideal conditions, and enhances survival by circumventing harsh circumstances [2]. Pine Siskins, through their migratory practices, epitomize the flexibility and hardiness of migratory birds when faced with environmental shifts [3, 4]. The study of Pine Siskin migration provides essential insights into the mechanisms and motivations driving avian migration. Scientists probe into the determinants influencing their migration choice, the navigational skills they utilize during their travel, and the physiological adjustments that facilitate their long-distance journeys. In exploring the complexities of Pine Siskins' migration tendencies, researchers gain a comprehensive understanding of the wider patterns and processes that govern avian migration. This knowledge illuminates the evolutionary benefits of migration, the impact of environmental alterations on

migratory patterns, and the implications for the conservation of migratory bird species. Pine Siskins' migration habits underscore the remarkable flexibility and importance of avian migration within the natural ecosystem. Studying their travels enriches our understanding of the mechanisms, hurdles, and advantages tied to long-distance bird migration, thereby augmenting our collective knowledge of bird ecology and conservation.

This article aims to delve into the migratory habits of Pine Siskins, with an emphasis on elements such as food supply, climatic effects and inherent regulation, and social interactions that inform their migratory routes. By decoding the intricacies of their migration, we can deepen our comprehension of avian migration overall and the intriguing strategies migratory birds employ to navigate the ever-evolving natural environment.

2. The Migration Behavior

Pine siskins are diminutive avians recognized for their prominent migratory tendencies [2, 3]. They participate in remarkable biannual journeys, traveling extensive distances from their winter habitats to their breeding grounds during the spring, and retracing their path back in the autumn [4]. These significant migrations showcase the resilience and adaptability of these birds as they navigate varied environments and conditions, emphasizing their extraordinary navigational skills and endurance. Throughout these migratory periods, they are capable of spanning thousands of kilometers [6]. Interestingly, their precise migratory pathways are not set in stone but are subject to changes based on food availability. In times when food is plentiful, they may opt to stay in a single area, whereas a shortage of food may necessitate their migration to other locations [5]. The migratory patterns of pine siskins are molded by a host of intrinsic and extrinsic determinants, contributing to its intricacy and variability.

2.1. Migration Patterns

Migration patterns in the animal kingdom can generally be divided into two primary types: obligate migration and facultative migration [2]. Obligate migration refers to uniform and predictable seasonal movements, with creatures returning to identical locales each year, exhibiting consistency in terms of timing, direction, and the distance covered [1, 2]. This migration style has evolved in response to regular variations in resources. On the other hand, facultative migration is marked by significant annual fluctuations in migration patterns, including the timing, direction, and distance covered. Facultative migrants do not necessarily undertake annual migrations and often display low location loyalty or site fidelity [2]. This adaptive strategy has evolved to deal with the unpredictable availability of resources.

Pine siskins are typical examples of facultative migrants. Their migratory patterns can demonstrate considerable variations from one year to the next, in aspects of both timing and direction [4]. In certain years, they might decide to remain in a single location if the food resources, notably seeds from coniferous trees, are ample. In contrast, in other years, they might embark on extensive migrations in pursuit of food, frequently journeying in large groups. The direction of their migration is driven by the availability of food resources, which leads them to distinct locations each year, displaying a characteristic low site fidelity [4, 5]. This highlights the adaptability and unpredictability that typify facultative migration.

2.2. Seasonal Expressions

Seasonal manifestations in living organisms, including Pine Siskins, involve noticeable behavioral and physiological transformations that align with the changing seasons [6]. These regular and predictable adaptations reflect the species' response to fluctuating environmental conditions throughout the year. Despite Pine Siskins exhibiting nomadic movements as facultative migrants, there is evidence of a discernible seasonal aspect, especially during springtime. Observations of these birds disclosed a "quiescence" or resting state during the dark phases, displaying varied activity levels

across different months. This signifies early morning activity, a common feature among birds during winter, which is distinct from migratory restlessness (Fig. 1). Interestingly, Pine Siskins also demonstrate migratory restlessness, typified by behaviors such as jumping and wing whirring, akin to obligate migrants. This behavior reaches its maximum during spring, a time when free-living individuals often partake in migration [5, 6].

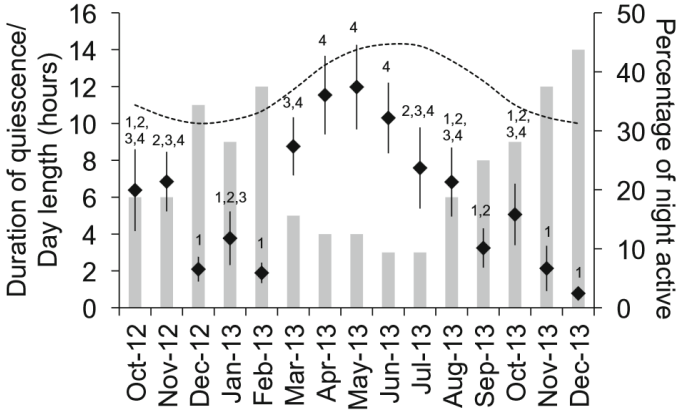

Figure 1. The length of the quiescent phase (gray) and the proportion of the dark phase, tracked across a span of 15 months. https://link.springer.com/article/10.1007/s00265-016-2248-2

3. Factors of Derteremined Behavior

Pine siskins are recognized for their migration practices, initiating extensive voyages every spring and autumn [2-4]. Their migratory paths are subject to alteration based on the accessibility of food resources [4]. Unforeseen environmental shifts, such as heightened energy needs or scarcity of food, can profoundly affect their physiological and behavioral reactions during migration. Multiple external elements play a role in shaping the migration habits of Pine siskins.

3.1. Food Availability

Environmental variations can notably impact living organisms, primarily affecting their energy requirements and food supply. Animals confronted with these shifts may experience allostatic overload, leading to negative energy equilibrium, increased corticosterone levels, and the potential initiation of an emergency life history stage (ELHS) [7]. This hormone, corticosterone, plays a central role in handling increased metabolic needs, fostering processes like gluconeogenesis and energy mobilization. It also aids in controlling metabolic needs during inactive periods, such as nighttime. Additionally, an increase in locomotor activity in reaction to environmental disturbances has been noted in relation to corticosterone. Nevertheless, the influence of corticosterone on activity can fluctuate depending on an organism's energy state. At minimal levels, corticosterone aids in physiological and behavioral adjustments to cater to foreseeable or manageable energy requirements. With regards to migration, corticosterone is considered vital for obligatory migrations, and it could also trigger facultative migrations in anticipation of environmental signals or as a preparatory step before entering an ELHS.

Distinct migratory behaviors between spring and fall seasons have been observed in other migratory species. However, for Pine Siskins, it is unclear if the physiological preparations and signs of migratory state seen in spring also occur in fall [5]. This physiological disparity and readiness for migration could explain the varied reaction to food scarcity [5, 6]. Energy reserves are critical for deciding to migrate. In the fall, despite initially exhibiting higher activity, birds had worse body conditions and might have already been in a migratory state [5]. Hence, their migratory behavior might have been impeded by their depleted energy reserves and increased energy needs, thereby clarifying their restrained response to food scarcity. Conversely, during the spring, birds exhibited a notable decrease in body situation despite having access to unlimited food [5]. This heightened

sensitivity to food resources during the spring season could be linked to the onset of spring nomadism or the transition into the breeding phase. Insufficient resources to support breeding activities resulting from a decrease in food availability could lead to unsuccessful breeding attempts.

3.2. Climatic Depoles

Climate dipoles, which are defined by simultaneous opposing climate anomalies in separate areas, have a profound impact on migratory paths, including the existence of sea surface temperature dipoles [8].

Migratory trajectories are influenced by climate dipoles, which create varying conditions across different regions, affecting seasonal migrations dictated by environmental variables [2]. On the other hand, facultative migrations, such as bird irruptions, involve extensive movement of individuals beyond their standard range [1, 2]. Bird irruptions, which occur on a continental scale, show multi-year variations, establishing a push-pull mechanism where birds are repelled from regions with harsh conditions and attracted towards regions with amiable conditions. This mechanism modifies the timing, scope, and geographical patterns of migrations. Climate dipoles, as evident in bird irruptions, contribute to birds' decisions to explore outside their usual range. Pine Siskin's facultative migrations are motivated by large-scale climate fluctuations [9]. Climate dipoles that result in poor seed crops in one area and bountiful seed crops in another can drastically affect bird movements.

Investigations into Pine Siskin irruptions have identified two distinct modes of mass movements: the North-South and the West-East Irruption Modes [9]. The majority of the climate factors contributing to these irruptions were found to be associated with variations in rainfall or temperature observed 1 or 2 years prior to the winter FeederWatch season [9]. Interestingly, a common factor in both irruption modes was the role played by a spatial dipole structure. This suggests that prevailing weather patterns typically lead to poor seed production in one region (due to cool-wet conditions) and abundant seed production in another (due to warm-dry conditions) [9]. While previous explanations for bird irruptions have largely focused on food shortages in the birds' original habitats, these findings propose a different perspective - a push-pull framework. In this model, large-scale irruptions are governed by climate dipoles that create unfavorable conditions in one location and more favorable conditions in another.

3.3. Social Environment

Social interactions play a substantial role in various elements of migratory behavior, encompassing choices related to direction, navigation, and habitation [10]. For roaming migrants like pine siskins, who exhibit inconsistent movements and do not have predestined destinations, dependence on local cues, including social ones, is vital for making habitation decisions. During their relatively predictable spring nomadic phase, pine siskins undergo physiological preparations and encounter migratory restlessness [4, 5].

In a controlled study, migratory birds were assigned to one of two conditions: they were either paired with non-migratory individuals of the same species or left alone. Additionally, a control group of non-migratory birds was also left alone for comparison [2]. Pairing migratory birds with non-migratory ones led to significant behavioral and physiological alterations [10]. These coupled birds displayed a marked reduction in nocturnal activity right after pairing, and this decreased activity level continued even after two weeks. Moreover, paired migratory birds demonstrated a decline in energy reserves and flight muscle size [10]. In contrast, migratory birds that were left alone maintained high nocturnal activity levels and energy reserves [10]. These findings indicate that the social environment plays a role in the termination of migration in pine siskins. The presence of conspecific birds appears to influence the decision to cease migratory movements, resulting in behavioral and physiological changes associated with the establishment of a new habitat. For nomadic migrants like pine siskins, social cues are pivotal, aiding in the recognition and establishment of high-quality but unfamiliar habitats [10].

4. Intrinsic Regulation

Migration serves as an adaptive strategy that enables animals to exploit resources that vary temporally and spatially. The regulation of migration involves a multitude of internal factors, including physiological processes and biological rhythms.

4.1. Physiological regulation

The pectoralis muscle, vital for migratory flight, undergoes significant alterations, such as hypertrophy, to accommodate the requirements of migration [11]. To explore the function of endocrine signaling elements in governing migratory preparations, an investigation was carried out involving captive birds at various points of the migratory cycle [11, 12]. The comparison between pre-migratory and migratory birds revealed unique integration patterns of endocrine signaling components. During the pre-migratory phase, a higher level of integration was noticed in genes tied to sex steroid signaling, while genes linked to glucocorticoid signaling displayed greater integration during the migratory phase (Fig. 2) [13]. However, there was no significant alteration found in the relative mRNA levels of various steroid receptors (such as estrogen receptor-α, androgen receptor) or enzymes associated with steroid processing (like aromatase, 5α-reductase Type 2, 11β-HSD type 2) in the pectoralis muscle of pine siskins, irrespective of their being in the pre-migratory or migratory phase [13].

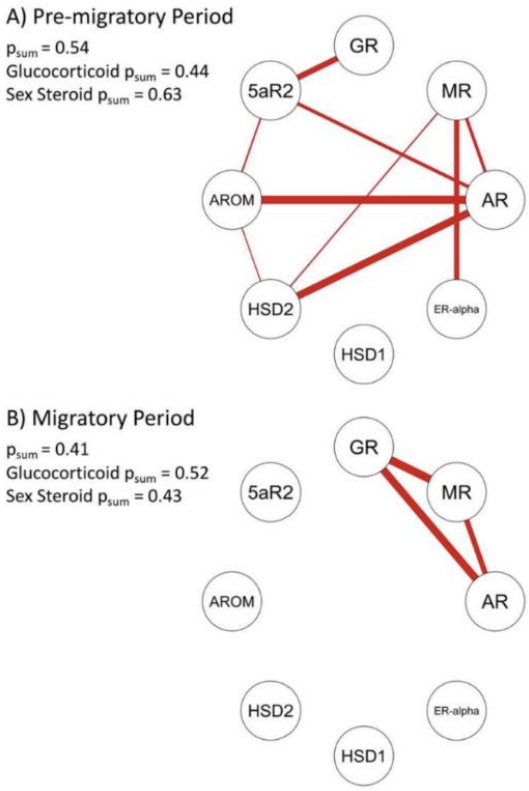

Figure 2. The pectoralis tissue of Pine Siskins, the integration of endocrine signaling genes during pre-migratory and migratory periods, with positive correlations represented by red indicators. https://linkinghub.elsevier.com/retrieve/pii/S0016648021000800

Even though there were clear shifts in flight muscle mass and behavior indicating a switch to a migratory state, no substantial differences were found in the measured endocrine elements pre and post migration onset. Nonetheless, significant variances were discovered in the integration patterns of all examined genes across the two life stages [13]. This suggests that the entire endocrine signaling network within target tissues is influenced by the varying demands of different life stages, rather than individual components being affected. These insights, specific to migratory birds like pine siskins, deviate from earlier research on obligatory migrants, suggesting the presence of distinct mechanisms

or interactions among endocrine signaling elements that may aid the transition to a migratory state in nomadic migrants.

Additional research is necessary to fully understand the role of the endocrine system in facilitating the initiation and progression of the spring migratory state in pine siskins. Further exploration will help uncover the specific mechanisms and interactions within the endocrine system that contribute to migratory behavior in these birds. The findings in pine siskins underline the intricate nature of endocrine regulation in migratory birds and emphasize the significance of analyzing diverse migratory strategies to gain a comprehensive understanding of migratory physiology.

4.2. Biological Rhythms

Migration is orchestrated by biological cycles, including circadian and circannual rhythms, which play a crucial role in coordinating physiological and behavioral adaptations in obligate migratory birds in response to lengthening daylight [1, 2]. These adaptations serve as preparatory steps for migration. The production of androgens is also affected by longer daylight, further assisting the transition into a migratory state.

A research conducted on pine siskins (*S. pinus*) investigated the impact of photoperiod on the initiation of spring migration. The birds involved in the study were subjected to two experimental conditions: a gradually lengthening day that emulated natural conditions and a constant short-day photoperiod [14]. Pine siskins exposed to increasing daylight underwent changes in body condition, flight muscle dimensions, hematocrit levels, and nocturnal activity, indicating the beginning of migratory preparations [14]. These modifications suggest that the lengthening daylight acts as a trigger for the physiological and behavioral adjustments required for migration in pine siskins. The changing photoperiod serves as an important environmental cue that signals the onset of the migratory phase and prepares the birds for their upcoming journey. However, pine siskins experiencing a constant short-day photoperiod only showed lighter flight muscle coloration, suggesting an unpreparedness for migration [14]. These findings imply that shifts in daylight, rather than an innate circannual rhythm, principally guide the transition to a spring migratory phase in pine siskins. Photoperiod acts as a predictive indicator for determining the timing of spring migratory movements, not solely for obligatory migrants but also for a broader spectrum of migratory birds.

In conclusion, the innate regulation of migration involves intricate interactions between physiological processes and biological cycles. Comprehending these mechanisms is vital for demystifying the complex nature of migratory behavior in pine siskins and can offer valuable insights into the adaptive strategies utilized by migratory creatures.

5. Conclusion

In conclusion, the migratory conduct of Pine Siskins is influenced by various elements, including food supply, climatic circumstances, internal regulation, and social connections. These elements interplay and contribute to their migratory patterns, highlighting the complex linkage between exterior environmental situations and interior physiological processes. The role of food availability is crucial, with variations in energy needs and food shortage inducing physiological responses and affecting migratory conduct. Climatic dipoles, marked by contrasting climate anomalies in different areas, impact migration patterns by creating suitable or unsuitable conditions. Bird irruptions occur as a response to these conditions, affecting the timing, scale, and geographical patterns of migrations. Social interactions also have a significant role, influencing decisions about settling and concluding migratory movements. The presence of birds of the same species can result in behavioral and physiological shifts, assisting Pine Siskins in settling in new habitats. Intrinsic regulation involves physiological processes and biological rhythms, including changes in the pectoralis muscle and the integration patterns of endocrine signaling components. The shift to a migratory state is primarily triggered by the photoperiod. Understanding the complexities of Pine Siskins' migration is essential for developing efficient conservation strategies that consider the adaptive methods used by migratory

birds in response to shifting environments. More research is needed to fully understand the intricacies of migratory behavior and to devise comprehensive conservation plans for Pine Siskins and other migratory species.

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