Examining the Predictors of White-throated Sparrow (*Zonotrichia albicollis*) Spring Departure Date

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Abstract

Migratory birds encounter a variety of obstacles while migrating that can have profound negative effects on breeding success. These obstacles and their effects are exacerbated by anthropogenic climate change in addition to novel obstacles arising, such as advancing producer phenology. As such, migratory decisions have the capacity to impact breeding success and therefore population dynamics which in turn have serious implications for conservation. At present, most studies of migratory and phenological decisions by migratory birds have focused on long-distance migrants. Here, I focus on examining the predictors of spring departure date for a boreal-breeding, short-distance migrant, the White-throated Sparrow. I determined the departure date for 42 motus-tagged White-throated Sparrows and qualitatively investigated spring departure date's relationship with a common spring phenology indicator, common lilac flowering, and winter weather. I found that sex best predicted spring departure date with male sparrows departing earlier. Additionally, departure date and winter weather remained stagnant while lilac phenology advanced. These results align with previous work regarding White-throated Sparrow migratory and phenological decisions and emphasize the occurrence of male migratory birds departing and arriving earlier than females in the spring. Furthermore, advancing producer phenology and stagnant White-throated Sparrow phenology highlight the need for future research to increase statistical power and identify phenological mismatches and associated conservation implications.

Keywords: Migratory decisions, phenological mismatch, climate change, White-throated Sparrow, *Zonotrichia albicollis*.

Introduction

Anthropogenic climate change has resulted in dramatic repercussions across ecosystems (Hitz & Smith, 2004; Karl & Trenberth, 2003). These remarkable changes have altered the timing in which many ecological events occur, referred to as phenology (Renner & Zohner, 2018; Visser et al., 2010; Visser & Both, 2005). Especially notable are impacts to the phenology of low trophic level species which often rely on external cues readily altered by climate change, such as average temperature (Thackeray et al., 2010; Visser & Both, 2005). Yet, these lower trophic level species often have high plasticity in regard to their response to climatic changes (Thackeray et al., 2010; Visser & Both, 2005). However, ecosystems are a complex web of interspecific interactions where the changes in phenology of producers can have sizable repercussions to their corresponding first order consumers and upwards (Hunter & Price, 1992). This is especially true when the consumer's phenology is less capable of shifting causing mismatches between consumers and their resources (Visser & Both, 2005; Both & Visser, 2001).

Misalignments of phenology occur when a producer's peak resource availability no longer aligns with when a consumer requires that resource. This misaligned timing is often referred to as phenological mismatch or phenological asynchrony (Miller et al., 2023; Renner & Zohner, 2018; Visser et al., 2012; Jones & Cresswell, 2010). The effects of phenological mismatches have the capability to result in population dynamic shifts as a consequence of a lack of resources, especially for species that are limited in their capacity to alter their phenology (Horton et al., 2020; Hurlbert & Liang, 2012; Jones & Cresswell, 2010). In particular, migratory birds often lack this capacity since many species are unaware of the conditions on their breeding grounds as they spend the winter in areas, such as the Neotropics, where the local weather cues are irrelevant to their breeding grounds. In these species, migratory phenology has been remarkably well timed to align with the historical phenology of producers (Horton et al., 2020; Jones & Cresswell, 2010; Visser et al., 2010). Thus, as climate change advances and producer phenology changes in turn, the decision behind when to depart the wintering grounds becomes even more critical for many migratory birds.

Alongside phenological mismatches, arrival date on breeding grounds can have an impact on breeding success where earlier arriving birds of both sexes experience increased breeding success (Dossman et al., 2023; Rockwell et al., 2012; Smith & Moore, 2005; Morris & Glasgow, 2001). The importance of migratory decisions is further emphasized and compounded by poor overwintering conditions which, in turn, result in birds of lower health on their breeding grounds, therefore also limiting their breeding productivity in a phenomenon termed “carry-over effects” (Rockwell et al., 2012; Marra et al., 1998). Thus, a migratory bird that is in poor overwintering condition that also happens to migrate later than other conspecifics will often have a relatively poor breeding season (McKellar et al., 2013, Rockwell et al., 2012). Therefore, alongside the established impacts of carry-over effects and relative arrival date, realized phenological mismatches are another mechanism for potential negative impacts on migratory bird population dynamics (Jones & Cresswell, 2010; Jonzén et al., 2006). Thus, it is imperative to understand what variables might serve as predictors of migratory decisions of species with varying life history traits in order to better anticipate conservation challenges arising as a result of phenological mismatches.

At present, most studies of phenological decisions by migratory birds have focused on long-distance migrants (Hurlbert & Liang, 2012; Rockwell et al., 2012; Studds & Marra, 2011). Yet, short-distance migrants remain in the temperate zone year-round and thus experience different phenological cues than long-distance migrants in the neotropical zone. Here, I focus on a boreal-breeding short-distance migrant, the White-throated Sparrow (*Zonotrichia albicollis*). White-throated Sparrows are readily found throughout the eastern United States during the winter where they then migrate north to the boreal regions of Canada and the northern Great Lakes in order to breed (Falls & Kopachena, 2020). These familiar sparrows in the eastern United States are obligate migrants, that is: Their decision to migrate is hardwired as something they must do (Newton, 2012; Wiltschko & Wiltschko, 2003). White-throated Sparrows are a relatively well studied species in part thanks to their ubiquitous nature in suitable habitat on their wintering and breeding grounds. Yet, despite the ample literature regarding White-throated Sparrows, there are still gaps in our knowledge of their migratory decision making, and a sizable portion of the existing knowledge comes from captive sparrows (Cristol et al., 2014; Jenkins & Cristol, 2002; Morris & Glasgow, 2001).

Despite this, many studies have suggested that for day-to-day decisions, external conditions seem to dominate; yet, for wide-scale seasonal trends, internal characteristics dominate. For example, Metcalfe et al. (2013) and Byrd et al. (2024) have suggested that these small-scale decisions, i.e., which exact night to depart on, are often mediated by extrinsic weather cues for a wide-variety of migratory birds, including for White-throated Sparrows. Amongst these extrinsic cues, dropping barometric pressure alongside rising temperatures and southerly wind direction often suggest an upcoming night of favorable migratory conditions, and thus the presence of these conditions greatly influence a bird’s migratory decision making (Byrd et al., 2024; Metcalfe et al., 2013; Åkesson & Hedenström, 2000). This trend holds true for many other Passerine species, including Dark-eyed Juncos (*Junco hyemalis*), a sparrow species that follows a similar migration pattern to White-throated Sparrows. Byrd et al. (2024) revealed that junco spring departure date was best predicted by overwintering fat reserves and wind direction where birds with heftier fat reserves were likely to depart earlier than those with less stored fat, specifically on nights with warm southerly winds. These results from Byrd et al. (2024) follow a similar trend across many species of Passerines that when looking at migratory decisions across a season or a broader temporal scale than day-by-day, such as week of departure, intrinsic conditions appear to dictate migratory decisions (Beauchamp et al., 2020). Perhaps the most familiar case of intrinsic conditions dictating migratory decisions is protandry, where male birds leave the wintering grounds earlier than females and, unsurprisingly as a result, arrive on breeding grounds earlier as well (Beauchamp et al., 2020; Jenkins & Cristol, 2002; Morris & Glasgow, 2001). Protandry holds true for White-throated Sparrows as well according to multiple studies (Beauchamp et al., 2020; Mazerolle & Hobson, 2007; Jenkins & Cristol, 2002). Protandry is not the only acting intrinsic stimulus; age also seems to have some effect on migratory decisions, however research on its effect on White-throated Sparrows is limited. Yet, many passerines exhibit differential migration on the basis of age (Cristol et al., 1999).

The likelihood of phenological mismatches increases alongside predicted increases in temperature and other effects of climate change (Horton et al., 2020; Jones & Cresswell, 2010). It is therefore imperative to have a better understanding of the ability of a species to adapt to the consequences of climate change. To do this for migratory birds, a further understanding of the predictors of spring departure date that includes short-distance migrants is needed. Thus, to best anticipate conservation challenges arising as a result of advancing producer phenology alongside stagnate consumer phenology, the objective of this study is to identify intrinsic predictors of White-throated Sparrow spring departure date. This can be divided into three components:

1. Examine White-throated Sparrow spring departure date.

2. Determine predictors of White-throated Sparrow spring departure date and create a model in which to predict White-throated Sparrow spring departure date.
3. Preliminarily look at how annual average White-throated Sparrow spring departure date relates to an indicator of spring phenology (common lilac, *Syringa vulgaris*) and local winter weather through a qualitative lens.

I predict that larger, older, male sparrows will depart earlier, similar to previous studies with Dark-eyed Juncos and studies conducted with captive White-throated Sparrows (Byrd et al., 2024; Cristol et al., 2014; Jenkins & Cristol, 2002; Morris & Glasgow, 2001). Additionally, I predict that local common lilac phenology will shift earlier while average annual White-throated Sparrow spring departure date remains stagnant. Finally, I expect that colder winters will correspond with later departures.

Methods

Study Area

We collected data for this study at The Ohio State University's Wilma H. Schiermeier Olentangy River Wetland Research Park (ORWRP) located in Columbus, Ohio (40.01992, -83.01838). The ORWRP occupies 52 acres that are a combination of bottomland hardwood forest and emergent wetland alongside the Olentangy River just shy of a mile north of The Ohio State University's Main Columbus Campus. The ORWRP is bordered by the Olentangy River and a paved multi-use path to the north and east, a cemetery to the west, and a 4-lane street and a business park to the south. The ORWRP consists of two experimental wetland basins whose water levels are controlled manually via pumps and weirs; in addition, the ORWRP has a seasonally flooded oxbow pond to the east and southeast of the experimental wetland basins. The vegetation of the ORWRP is a mix of native and invasive species. The overstory consists primarily of Eastern cottonwood (*Populus deltoides*) while the understory consists mostly of invasive bush honeysuckle (*Lonicera spp*.). Actions to curb honeysuckle and other invasives have occurred in parts of the park, primarily through manually removing bush honeysuckle invasions followed by cut stump herbicide application. In these areas where bush honeysuckle control efforts have occurred, there are sporadic dense brush piles consisting of cut branches reaching a few feet in stature located within the resulting thin understory consisting of mostly sapling white and green ash (*Fraxinus americana* and *F. pennsylvanica*) alongside missed sapling bush honeysuckle and other woody species. The vegetation of the experimental basins and oxbow pond changes alongside changing inundation levels, yet cattails (*Typha spp.*) maintain a constant presence in the experimental basins.

Data Collection

White-throated Sparrow Departure Date. The Tonra Lab of Avian Ecology conducts winter banding operations at the ORWRP from November until March-April. Most species caught are banded, while only a certain few receive radio tags. All species were caught with either mist nets or baited Potter cage traps set up throughout the ORWRP. Depending on the weather and station capacity, 6-10, 12- meter mist nets and 3-8 small potter traps were utilized either independently or simultaneously, depending on conditions. The Potter traps sites were baited with commercially available bird seed for 1-2 days prior to banding and intermittently baited throughout the banding day. Nets were opened at sunrise and closed shortly after midday and were occasionally closed due to adverse weather or intermittently due to predators stalking the nets. Once caught, White-throated Sparrows were carefully extracted from the nets/traps and banded with a US Geological Survey numbered aluminum band and a unique combination of three plastic color bands. Once banded, wing chord, tail length, and tarsus measurements were taken in addition to body condition measurements (fat score, breast muscle score) and mass. After measurements were recorded, the outermost tail feather (R6) was collected for genetic sexing. Occasionally, we were able to determine sex in the field for White-throated Sparrows when wing chord lengths crossed a certain threshold as suggested by Pyle et al, 1997 (Male ≥72cm, Female ≤66cm). We attached a Motus tag (model NTQB2-1 or NTQB2-3-2, Lotek Wireless, INC.) upon their back via a leg-loop harness constructed out of elastic bead cord as outlined by Rappole & Tipton (1991). This radio transmitter emits a unique identifiable code that is then detected by the nationwide array of radio receiver towers through the Motus Wildlife Tracking System (henceforth "Motus"; Taylor et al. 2017). We released all Motus-tagged birds back into the ORWRP where a Motus tower has been present in the central part of the wetlands since 2019. This tower was critical to this study as it provided the data to determine each departure date. I downloaded the detection data from the tower for all years of the study and filtered for tag IDs of all White-throated Sparrows using the "motus" package in R. With this data, I identified the bird's last detection at the ORWRP when possible, while considering the propensity for false detections as a result of urban radio noise. This was accomplished by viewing each individual sparrow's detection history in a spreadsheet, then finding the last continuous string of detections while ignoring infrequent, often singular, detections afterwards. The date the continuous detections ended was determined to be the departure date. Sparrows where departure date was unable to be determined were excluded from the study.

Lilac Phenology and Winter Weather. Phenology data is not yet taken at the ORWRP, so as a means to find applicable phenology data, I searched the USA National Phenology Networks (USA-NPN) open-source datasets (USA-NPN, 2025). I located the closest dataset to the ORWRP which was from the Benjamin Franklin School in Cleveland, Ohio (41.433689,

-81.693153). The Benjamin Franklin School collects phenology data each year for a variety of woody plants and forbs, including common lilac. I selected to isolate common lilac as the indicator for spring phenology as there has been an established protocol for monitoring lilac phenology across the country for many years (Schwartz et al., 2012; Schwartz, 1994). A useful indicator of spring phenology that the Benjamin Franklin School collects is the day in which all common lilac leaf buds had broken (Schwartz et al., 2012; Schwartz, 1994). Similarly, weather has not been consistently recorded at the ORWRP; I utilized Weather Underground (wunderground.com) to access weather data collected at John Glenn Columbus International Airport (40.002199, -82.890073) by an Automated Surface Observing System overseen by multiple federal agencies, such as the National Weather Service (National Weather Service, n.d., Weather Underground, 2025). Only simple measures of winter weather (December - April) were looked at. Primarily, I found the count of days each winter that had lows below freezing, alongside the days with highs below freezing.

Data Analysis

All data analysis was conducted in RStudio (v4.4.2). I began by first correcting body mass for body size by creating a linear model with mass as the dependent variable and wing chord as the predictor. This model then returned a list of residuals for each individual bird; these residuals represented the deviation from the expected mass for a bird with a specified wing chord. This created an index for body size in which a residual greater than 0 represented a bird of a set size being heavier than expected for said size and vice versa.

I then started to analyze the importance of a variety of morphological variables, such as sex or fat, when predicting departure date. In order to do this, I created univariate linear models that related the dependent variable, departure day, to each variable (sex, age, corrected body size, wing chord, body mass, fat, breast muscle, change in fat between recaptures, and change in mass between recaptures). This revealed which variables were informative and which were not; I removed uninformative variables ($p>0.05$) from consideration for the final model. To further look at how informative certain variables were, I created more linear models with departure day still as the dependent variable, but this time related to interactions between variables, like fat*year. There were no significant interactions and thus, interactions were not considered for the final model. I then created a final model now that I understood the significance of each variable and the lack of any significance across interactions. This final model had spring departure date as the dependent variable and then the predictors were sex, age, and corrected body size.

Due to the low statistical power of only 5 years to compare across, I looked at spring phenology and weather qualitatively. To accomplish this, I graphed the average annual departure date alongside the date in which all the leaf buds of common lilacs had burst (Figure 1). Similarly, to look at the relationship between winter weather and departure date, I graphed the average departure date alongside the sum of days each winter that were below freezing (Figure 2).

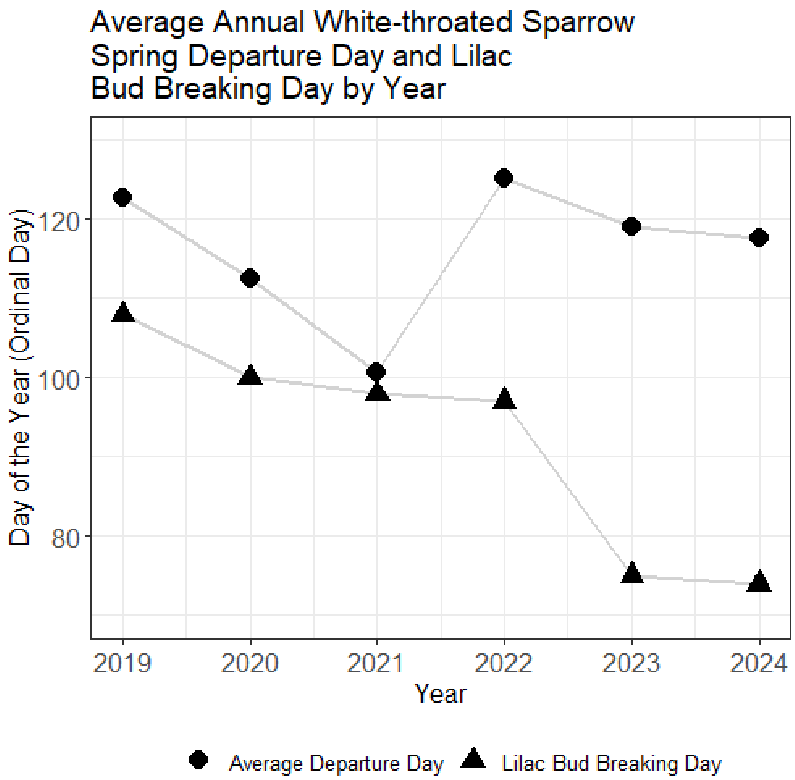

Figure 1

Average annual White-throated Sparrow spring departure day and lilac bud breaking day by year

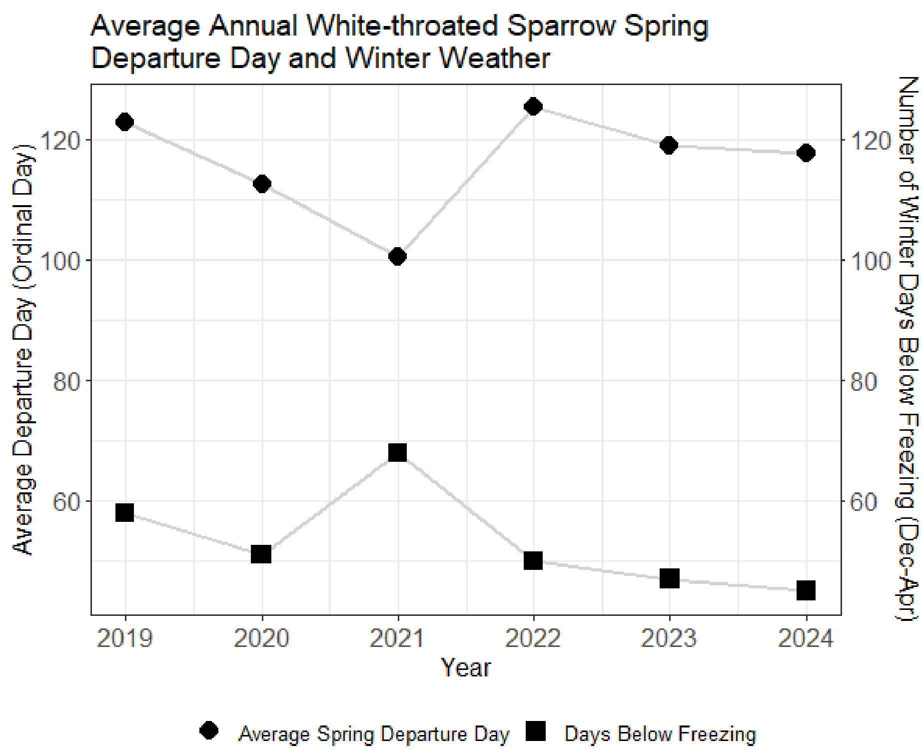

Figure 2

Average annual White-throated Sparrow spring departure day and winter weather

Results

Between 2019 and 2024, the Tonra Lab tagged 42 White-throated Sparrows that were included in this study. Of the sparrows, 28 were males and 14 were females; 27 were second-year (SY) and 15 were after second-year (ASY) (Table 1).

Table 1

Table of sample distribution of tagged White-throated Sparrows

	Year	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**Total**	**Total**
M	**SY**	6	3	3	1	0	2	15	**28**
	ASY	0	2	2	1	3	5	13	
F	**SY**	7	2	2	1	0	0	12	**14**
	ASY	1	0	0	0	1	0	2	
									42

The final model containing age, sex, and body size was insignificant ($F_{3,38} = 2.653$, $p > 0.0624$) with 11% of the variation in departure date being explained by the model ($adjR^2 = 0.11$). Sex arose as a significant variable ($t = -2.76$, $p = 0.0089$) with males departing earlier than females. Age did not predict departure date ($t = -0.870$, $p = 0.390$). Neither did body size ($t = -1.219$, $p = 0.230$).

The univariate model with sex as the predictor was also significant ($F_{1,40} = 6.054$, $p = 0.01829$). This model explained 11% of the variation in departure date ($adjR^2 = 0.11$) with male sparrows departing earlier than females (Figure 3).

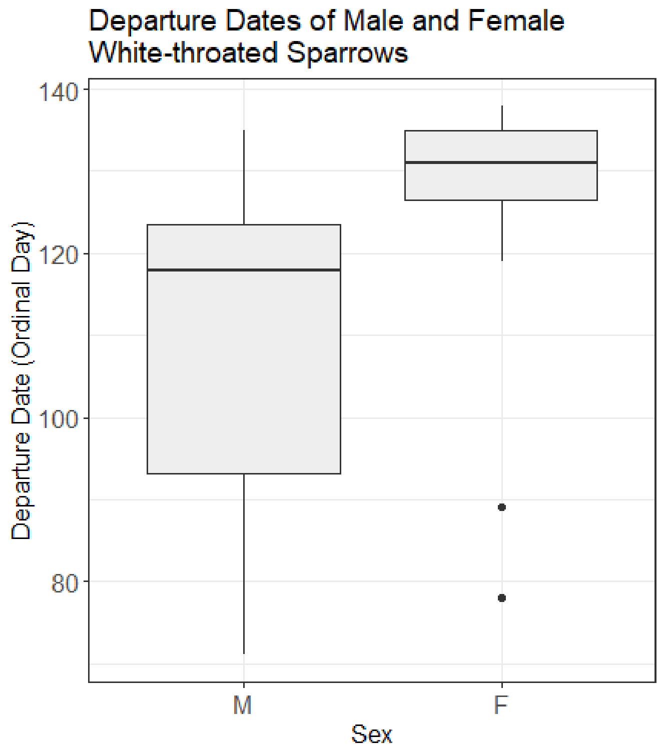

Figure 3.

Box plot of departure dates of male and female White-throated Sparrows

As mentioned above, with only 5 years of data, how the average annual departure date relates to shifts in common lilac annual phenology and shifts in winter weather were examined through a qualitative lens. Spring phenology in common lilacs shifted on average earlier across the 5 years with each year being consecutively earlier. This contrasted against the average annual spring departure date of White-throated Sparrows which remained as a whole, stagnant across the 5 years. There was no correlation between the sum of days below freezing each winter and spring departure date. Consistent with advancing common lilac phenology, the sum of days below freezing each winter was, on average, slightly decreasing as well.

Discussion

Predictors of White-throated Sparrow Departure Date

My goal in this study was to understand the predictors of White-throated Sparrow spring departure date. My prediction that males would depart earlier was supported. Meanwhile, my prediction that older, larger sparrows would depart earlier was unsupported.

Sex as a predictor of White-throated Sparrow departure date, in particular protandrous departure (i.e., males departing earlier), corresponds to other studies that have suggested protandrous arrival in White-throated Sparrow (Beauchamp et al., 2020; Mazerolle & Hobson, 2007; Jenkins & Cristol, 2002). Protandry is a well documented pattern across a multitude of migratory passerines and non-passerines (Morbey et al., 2012; Morbey & Ydenberg, 2001). Currently, there are three leading hypotheses for protandry in birds presented by Morbey et al. (2012) and Morbey & Ydenberg (2001). All three hypotheses are grounded in differential selective pressures acting on migration phenology. First, the "rank advantage hypothesis" suggests that earlier arriving males are able to better "claim" higher-quality breeding territories which in turn increases their ability to successfully breed (Morbey et al., 2012; Kokko et al., 2006; Morbey & Ydenberg, 2001). Thus, there is selection for earlier arriving males as a result of an increase in breeding success. Yet, in this hypothesis there is no selective pressure for females to arrive earlier therefore reinforcing protandry (Morbey et al., 2012; Kokko et al., 2006; Morbey & Ydenberg, 2001). Second, the "mate opportunity hypothesis" proposes that earlier arriving males in polygynous species have more opportunities to mate with more females thus increasing their fitness and consequently creating selective pressures for earlier arriving males (Morbey et al., 2012; Morbey & Ydenberg, 2001; Wiklund & Fagerström, 1977). For both the "rank advantage hypothesis" and "mate opportunity hypothesis" the selective pressure enforcing protandry is a sexual selective pressure. However, in the third hypothesis, viability selection drives protandry as a result of differential survival. This third hypothesis, the "susceptibility hypothesis”, suggests that, in sexually dimorphic species, males arrive earlier as a byproduct of their larger size allowing them to survive harsher weather that occurs early on in the breeding season, while females are selected against as their smaller size does not allow them to tolerate these harsher conditions (Morbey et al., 2012; Møller, 2004, Morbey & Ydenberg, 2001). The three hypotheses above can all be applied to protandrous arrival in White-throated Sparrows since they defend territories, occasionally exhibit polygyny, and show sexual dimorphism (Tuttle, 2003; Pyle et al., 2001; Kopachena & Falls, 1993). However, I found that departure date was not best predicted by body size within sex; this implies that it is more likely that one or both of the first two hypotheses are true for White-throated Sparrows. Furthermore, White-throated Sparrows are often monogamous and only occasionally exhibit polygyny which suggests that the “rank advantage hypothesis” may be most likely to be true here. It is important to note that Morbey & Ydenberg 2001 suggest that these hypotheses are not mutually exclusive and have likely occurred simultaneously. Yet, these various selective pressures, regardless of which, are such strong drivers that a recent study revealed that male American Redstarts (*Setophaga ruticilla*) that experienced a delayed departure would migrate faster even at the cost of their health and survival, presumably to prevent a late arrival (Dossman et al., 2023). Further research would be useful to examine if White-throated Sparrows follow a similar trend as well, given the current expansive array of Motus towers across the Great Lakes region.

While late arrival may be counterproductive to male breeding success, too early of an arrival can be detrimental as well. Not only do males with tardy departures experience decreases in health and survival, but so too do males that arrive too early; for example, a study conducted in Denmark by Lerche-Jørgensen et al. (2018) found that males of 11 different species of protandrous passerines suffered decreases in survival when they arrived too early. Therefore, male migratory timing must be finely tuned. The decreases in survival that male migratory birds incur as a whole are seemingly outweighed by any selective pressures that encourage protandrous arrival, and therefore protandrous departure as well.

Lilac Phenology and Winter Weather

The other component of the goal of this study was to qualitatively look at the relationship between spring departure date and both common lilac spring phenology and winter weather. I predicted lilac annual phenology would shift earlier and that average spring departure date would not change throughout the years of the study. This was the case as on average lilac spring phenology did shift earlier across the 5 years and spring departure date remained stagnant. Yet my final prediction that colder winters would yield later departures was not supported as there was no pattern between years.

Advancing producer spring phenology at one site is not an unexpected result especially within the context of past studies looking at producer spring phenology and climate change (Thackeray et al., 2010; Visser & Both, 2005). Additionally, the lack of change in White-throated Sparrow annual average spring departure date further reinforces previous research highlighting the inability for some migratory birds to readily alter their phenology (Visser & Both, 2005; Both & Visser, 2001). When both advancing producer phenology and stagnant consumer phenology are true, a phenological mismatch is likely to occur and have profound consequences on resource availability and therefore have the capacity to impact breeding success (Miller et al., 2023; Renner & Zohner, 2018; Visser et al., 2012; Jones & Cresswell, 2010). A future study that increases the sample size overall and within each year would be necessary before drawing strong conclusions about consumer phenology and White-throated Sparrow departure. This current study emphasizes the importance of such a future study in order to provide strong conclusions to best anticipate conservation challenges derived from phenological mismatches as producer phenology advances as a result of climate change (Thackeray et al., 2010; Visser & Both, 2005).

Limitations

The most evident limitation of this study is sample size. This study included 42 tagged sparrows that also had sufficient Motus data to determine departure date across 5 years, of these 42, 28 were males and 14 females. Of note was the dramatic unevenness in sample size distribution across years, in some cases exacerbated by the COVID-19 pandemic. Certain years have very small sample sizes that limit the strength of my conclusions regarding departure date, lilac phenology, and weather. Additionally, increasing the number of tags would increase the statistical power of any conclusions reached and allow me to better uncover other predictors. As a result of an increase in the number of tagged sparrows, there would also likely be an increase in the number of sparrows with sufficient Motus data.

Furthermore, the range of radio telemetry receivers is inherently limited by environmental factors such as topography or other factors not yet fully understood (Taylor et al., 2017). Therefore, a tagged White-throated Sparrow that had simply moved a short distance out of the ORWRP during the winter would not have the necessary spring detections needed to be included in the study. So, it is possible that an increase in tagged sparrows may not yield a greater sample size. Of note, prior to 2023 the ORWRP Motus tower antenna array was beneath the tree line. This would likely result in a lower detection probability prior to 2023 compared to afterwards (Taylor et al., 2017).

Phenology data was collected in Cleveland, OH rather than Columbus, OH; this was due to a lack of available standardized datasets in Columbus and nearby similar latitudes and elevation, i.e., Indianapolis. Similarly, standardized weather data was collected within Columbus but not at the ORWRP. Ideally, phenological data and weather data would have been collected at the ORWRP in order to best represent the weather that the White-throated Sparrows are experiencing.

Conclusion

Few previous studies of migratory bird phenological decisions have regarded short-distance migrants (Hurlbert & Liang, 2012; Rockwell et al., 2012; Studds & Marra, 2011). To fill this gap, I focused on a short-distance migrant, the White-throated Sparrow. I found that sex best predicted spring departure date and that male sparrows departed earlier than females. These results correspond with previous research regarding many long-distance migrants that often also experience protandry, suggesting similar conservation implications between short-distance and long-distance migrants (Studds & Marra, 2011; MacMynowski & Root, 2007). In addition, I highlighted the necessity for future studies to seek to increase statistical power and untangle how the average annual White-throated Sparrow departure date relates to producer phenology to best anticipate conservation challenges that are likely to arise if these two phenological events were to become out of sync. As climate change advances, phenological mismatches are more likely to occur (Miller et al., 2023; Renner & Zohner, 2018; Visser et al., 2012; Jones & Cresswell, 2010). The sooner these mismatches are identified, the sooner conservation efforts will be implemented before it is too late.

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