Migratory songbird abundance and body condition at a Wildlife Management Area in eastern Nebraska – Summary Report

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Migration is an important event in the lives of many avian species. It may account for over a quarter of the annual cycle for some birds (Bonter et al. 2009) and is a risky period for many species, with higher rates of mortality compared to the breeding or wintering periods (Sillett and Holmes 2002). Migratory stopover sites are critically important because they provide food resources and resting areas that birds need to complete migrations. Time spent at stopover sites often exceeds time spent in flight (Moore et al. 2005, Gomez et al. 2017). Birds likely select stopover habitat based on a wide-array of factors, and these factors have consequences on individuals' physical condition, subsequent breeding opportunities, and survival (Yong et al. 1998, Bonter et al. 2009, Skrip et al. 2015, Cooper-Mullin and McWilliams 2016). Many stopover areas are important because of their location along migration routes where resources are limited (Bonter et al. 2009). Additionally, certain habitat features may increase the potential benefit of a given stopover location. Areas with edge, scrub, and early-successional habitat featuring diverse structure and foraging opportunities often provide high quality stopover for migrating songbirds (Rodewald and Brittingham 2004, Smith and Hatch 2017). Thus, stopover areas are of extreme importance to the survival and life cycles of hundreds of bird species in North America.

Birds that migrate through the central Great Plains may not be restricted to narrow migration corridors as those species that migrate along coasts or over large bodies of water, but these species still require adequate stopover sites to complete migration. In the central Great Plains, the vast majority of area is either grassland or row crop agriculture and these habitats are essentially sub-optimal for a majority of Neotropical migratory songbirds; specifically, boreal breeders and other forest-dwelling species that overwinter in central and south America (Moore et al. 2005, Bonter et al. 2009, Liu and Swanson 2014a). However, areas of trees and shrubs within urban and agricultural landscapes provide habitat for songbirds during migration. Thus, any shrub and small tree-dominated habitat within these landscapes could functionally serve as and be considered stopover habitat if it can provide the resources necessary for individuals to continue their migration (Liu and Swanson 2014b). One of the best metrics for determining the value of a stopover habitat in individual birds is by evaluating their body-condition, specifically fat stores. Fat serves as the primary fuel source for songbirds during migration and is usually a strong indicator of migratory success and survival (McWilliams et al. 2004).

Neotropical songbirds are nocturnal migrants and tend to commence longer flights on evenings that will provide favorable wind profit (i.e. tailwinds, Deppe et al. 2015), typically southerly winds in spring and north winds in fall (Richardson 1978). Other atmospheric conditions are generally known to be favorable for migration, and increasing advances in radar technology, remote sensing, modeling, and vast community-science projects such as eBird (ebird.org) have greatly advanced our knowledge about migratory trends and patterns in North America (Van Doren and Horton 2018). This has led to the advent of migration forecasting ('BirdCast'; birdcast.info), which has been used successfully to predict major flights of birds on migration and used to reduce light-pollution based mortality events for many nocturnal migratory species. To what extent these migration forecasts translate to on the ground conditions the following mornings is unknown, particularly in under-studied areas with relatively uniform landcover such as the Great Plains.

We studied migratory passerine body condition at a stopover site in eastern Nebraska during two consecutive falls in 2020 and 2021. Our primary objective for this study was to determine to what extent Wildlife Management Areas (WMAs) in eastern Nebraska provide migratory stopover habitat for migratory songbirds. We predicted that birds captured at Conestoga WMA following evenings with southerly winds (i.e. birds on stopover) would have higher fat scores than birds captured at Conestoga

WMA following evenings with northerly winds (i.e. birds that just arrived after migrating). We also predicted we would catch more migratory birds on mornings following a 'high' BirdCast forecast compared to mornings following a 'low' BirdCast forecast.

Methods

Our primary focus during both years of this project was to monitor Neotropical migratory passerines moving through Nebraska to wintering grounds farther south. In eastern Nebraska, the majority of these species (i.e. warblers, flycatchers, vireos) pass through Nebraska in September, with some of these long distance migrants lingering through the first half of October. We began our banding efforts in the first week of September in 2020 and the last week of August in 2021 and continued to operate for at least one day a week through mid-October.

We conducted our banding operations in early successional habitats at the south side of Conestoga Lake in the WMA (approximate coordinates: 40.761, -96.852). Early successional habitat within the WMA is defined by tallgrass prairie with areas of encroaching small shrubs. The area was also bordered by mature trees. Dominant vegetation included warm season grasses (e.g., Big Bluestem, Indian Grass), forbs (e.g., Maximillian Sunflower) and shrubs (e.g., Roughleaf Dogwood, Smooth Sumac). We had 3 regular net locations that were all in areas of tallgrass prairie with shrubby incursions, with one of these nets also within 10 m of more mature wooded edge. We likely underrepresented overall species diversity relative to all migratory birds in eastern Nebraska and even at Conestoga WMA given the vegetative uniformity of our net locations.

We used standard mist-netting procedures during our efforts. We used 30 x 30 mm mesh nets at all net locations and opened 2-4 nets each morning in 2020 and 3 nets each morning in 2021. We opened nets at 30 minutes before sunrise and operated for 3 – 4 hours every morning, as bird activity decreased by 10:30 am. We completed net checks at ~45 min intervals. We measured wing chord, molt, fat, mass and determined age and sex (when possible) for most individuals captured. On a few rare occasions in 2020, we were unable to band all birds we caught as we were limited by the number of bird bags in our possession. These unbanded captures were noted and released.

Analysis

We used National Weather Service forecasts and weather reports (weather.gov) for measuring the wind conditions on each evening prior to a morning of net operation. We also recorded the BirdCast (birdcast.info) predictions each night prior to net operation. BirdCast compiles radar data across North America to make real-time predictions of bird movements and ranks predicted migration intensity on a scale from low to medium to high. We grouped BirdCast predictions into two broad categories for our analysis: high (medium, medium-high, and high predictions) and low (low and medium-low predictions). We also grouped wind directions from previous nights into two categories defined as having as southerly (S, SW, SE) or northerly (N, NW, and NNE) direction. For some analysis, we also combined species into four broad groups (Flycatchers, Warblers, Sparrows, and Others, Table 1).

We used fat score as our metric to determine condition of migrants at our station. Visual measurement of subcutaneous fat score is an accurate assessment of overall body fat and condition (Krementz and Pendelton 1990, Seewagen 2008). We used a fat scoring system from 0 – 8, with '0' representing no visible fat to '8' being an extreme amount of fat. We used only migratory individuals in our analysis of body condition, as we were primarily focused on the viability of Conestoga WMA as a migratory stopover area. Thus, resident species and lingering local breeders would not be using the habitat during migratory stopover. Most of the birds that were excluded from this analysis are considered resident species (e.g. Northern Cardinal, Black-capped Chickadee). Other individuals of certain species that we excluded do in fact migrate out of and through the region in fall (e.g. Gray Catbird, Bell's Vireo), but the extent of body molt when we captured these individuals suggest that these birds were local breeders at Conestoga WMA or at nearby locations. As molt is an annual energetically demanding physiological process for birds (Murphy 1998, Pyle et al. 2018), most species do not molt and migrate long distances simultaneously. Molt is scored from 0 (no molt) to 3 (heavy molt) and is easily detectable on the body feathers of either the face or breast. Thus, we eliminated any individual of a migratory species that had a body molt score of '1' or higher from our final analysis on migratory songbird use of Conestoga WMA. Individuals of the same migratory species that were not molting (e.g. Common Yellowthroat) were included in condition analysis.

We conducted minimal statistical analysis on the impact of weather on the numbers and condition of migratory individuals that we captured at our station. We used t-tests for comparison of wind direction on evenings prior to banding and migratory predictions prior to banding (i.e. BirdCast) on the number of migratory birds captured per net hour. As there were a high number of birds caught with body fat scores of zero and to avoid overdispersion, we completed additional statistical analysis to determine potential factors influencing individual body condition at our station. We conducted single-factor mixed models using zero-inflated Poisson regression to test the effect of wind direction, BirdCast forecast, time of year (Julian Date), time of day, and species group on individual body condition (fat score). We then compared these models using Akaike's information criterion. We conducted all statistical analysis in Program R (R Core Team 2021).

Results

We operated the banding station a total of 25 mornings and 231.75 net hours over the two seasons. We conducted banding efforts on 11 mornings in 2020 from 4 September 2020 to 13 October 2020 and totaled 85 net hours. In 2021, we operated for 15 mornings from 25 August to 14 October and totaled 146.75 net hours. We operated the banding station on 13 mornings following northerly winds and 12 mornings following southerly winds. We operated for a total of 15 mornings following a high BirdCast forecasts and 10 mornings following a low BirdCast forecasts. We banded 486 individuals representing 39 species and recorded 16 local recaptures of 5 species and zero foreign recaptures. Our most notable recapture was of one Common Yellowthroat that we banded on 10 September 2020 as an AHY male and was the only individual we recaptured in the following year on 22 September 2021, making this bird at least three years old.

The morning with the highest number of individuals banded was on 14 September 2021 with 41 new birds banded, and our least productive mornings were 4 October 2021 and 5 October 2021 with 4 birds banded. The days with highest species diversity was 22 September 2020 and 1 September 2021 with 13 species. Three-hundred and twenty-four individuals were aged as hatch-year (HY; 67%), 145 individuals were aged after hatch-year (AHY; 30%), and 17 birds of unknown age. Overall, we banded 2.1 birds per net hour. We continue to urge caution when comparing this rate of capture to other, more robust, and long-running banding stations, as most fall migration banding sites use far more nets and operate daily, whereas we were constrained to operate on less days and with reduced capacity.

Our most numerous species was Nashville Warbler (90), followed by Common Yellowthroat (85) and Gray Catbird (66, Table 1). We captured and banded three Nebraska Natural Legacy Project Species of Greatest Conservation need (Schneider et al. 2011); Savannah Sparrow (n=2), Swamp Sparrow (n=1), and most notably one Black-billed Cuckoo on 21 September 2021. This species has experienced dramatic population declines in Nebraska, and there are typically < 5 sightings a year throughout the state (Silcock and Jorgensen 2021).

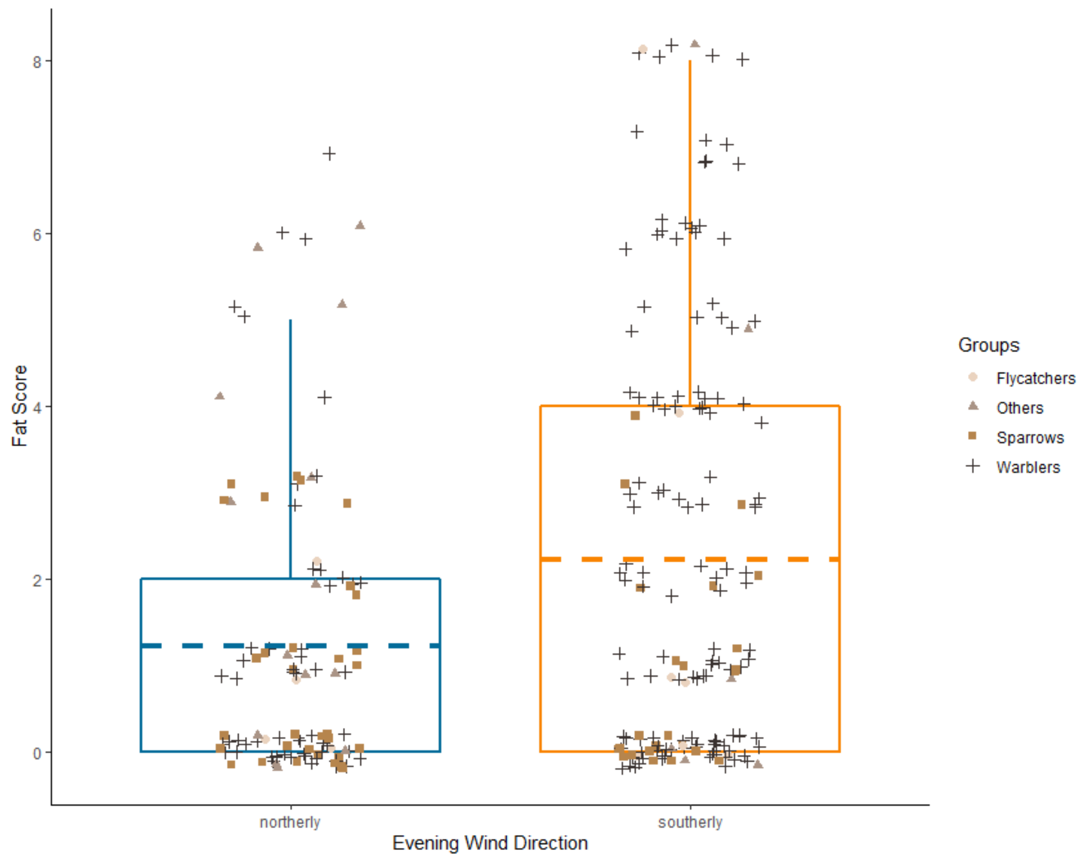

Figure 1. Fat scores of migratory individuals caught at Conestoga Lake WMA on morning following evenings with northerly winds (blue) or southerly winds (orange) in falls of 2020 and 2021. Dashed lines represent mean fat scores, with boxes encompassing the interquartile range of fat scores in each group.

Condition Analysis

We considered 275 individuals of 29 species to be 'probable migrants' or 'in a migratory state' when banded and used only these birds for fat and migratory condition analysis.

Average fat scores were lower following evenings with north winds (1.21 ± 0.16) compared to those following evenings with south winds (2.25 ± 0.19; Fig 1). There was no difference in the number of migratory birds banded per net hour on mornings following a High BirdCast forecast (μ= 1.01 ± 0.18) than on mornings following a low BirdCast forecast (μ =1.51 ± 0.3, $t_{(16)}$ = 1.5, p = 0.16, Fig 2). We captured more migratory birds per net hour on mornings following evenings with winds having a southerly component (μ = 1.55 ± 0.27) over mornings following evenings with northerly winds (μ = 0.89 ± 0.16, $t_{(18)}$ = 2.2, p = 0.041 , Fig 3).

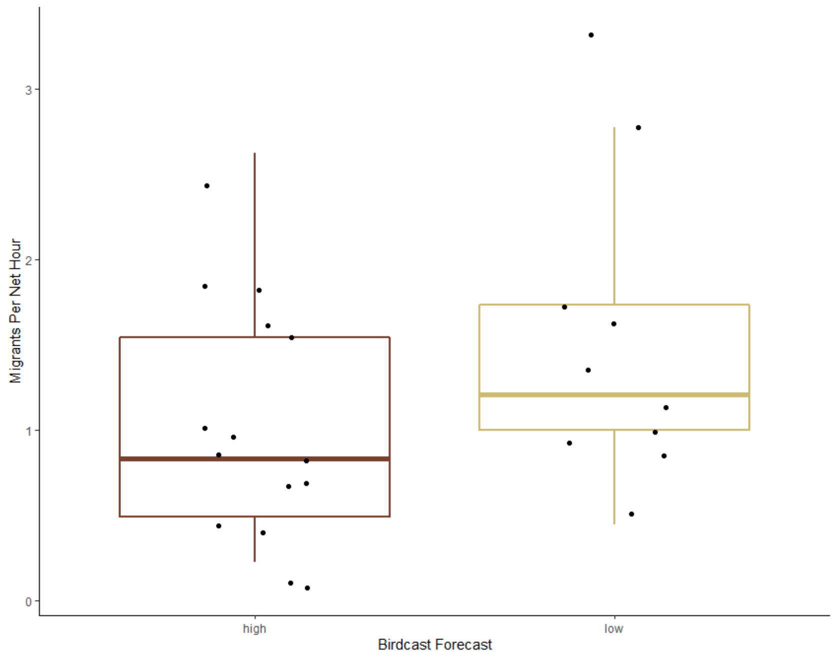

Figure 2. Migratory birds captured per net hour in mornings follow high (brown) or low (gold) BirdCast forecast. Solid line represents median values and boxes encompass the interquartile range.

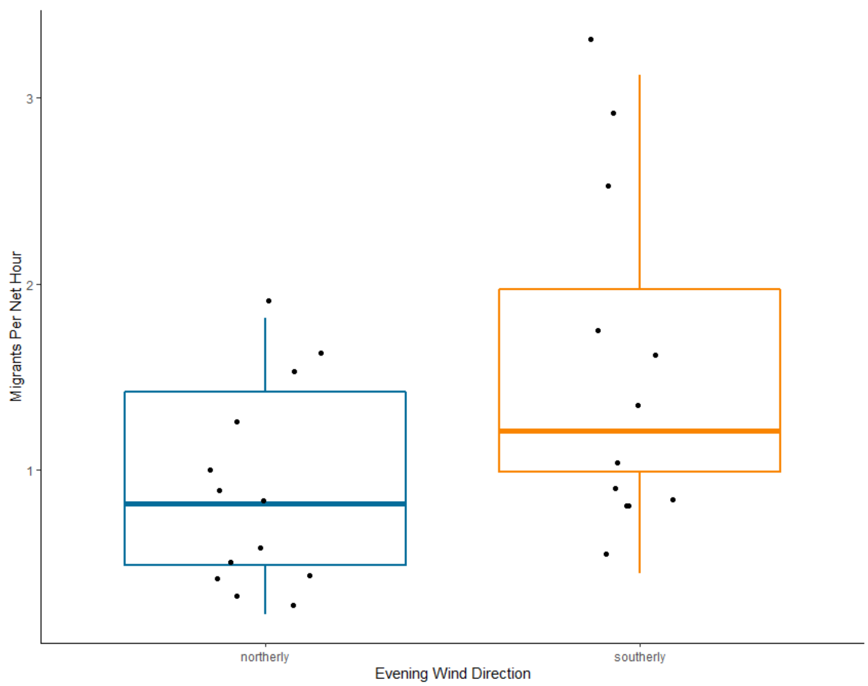

Figure 3. Migratory birds captured per net hour in mornings follow northerly (blue) or southerly (orange) winds. Solid line represents median values and boxes encompass the interquartile range.

The highest-ranking model to explain individual body condition (fat score) on migratory birds was evening wind direction, followed by species group (Table 2). Overnight wind direction had a significant effect on body condition (south wind estimate=0.48 ± 0.11, $p < 0.001$).

Table 2. Model comparison for single-factor models influencing fat score on migratory birds at Conestoga WMA.

Model	Δ AIC
~ wind direction	0.0
~ Species Group	3.7
~ Date	18.0
null	18.3
~ time of day	20.0
~ BirdCast	21.8

Sparrows showed a divergent trend towards lower fat scores later in the year when compared to all other species groups caught at our station (Fig 4). We captured most sparrows late in the season, and many of these species (e.g. Harris's Sparrow, Song Sparrow, White-crowned Sparrow) winter in or very close to southeastern Nebraska. This raises the possibility that many individual sparrows we captured could be at the terminus of migration and not on stopover, and subsequently would not be increasing their fat reserves during this time. When we eliminated sparrows from body condition analysis, time of year became a significant positive factor (Julian Date estimate = 0.02 ± 0.005, $p < 0.001$) along with wind direction (south wind estimate=0.44 ± 0.12, $p < 0.001$) on fat scores of neotropical migrants at Conestoga WMA (Fig 5).

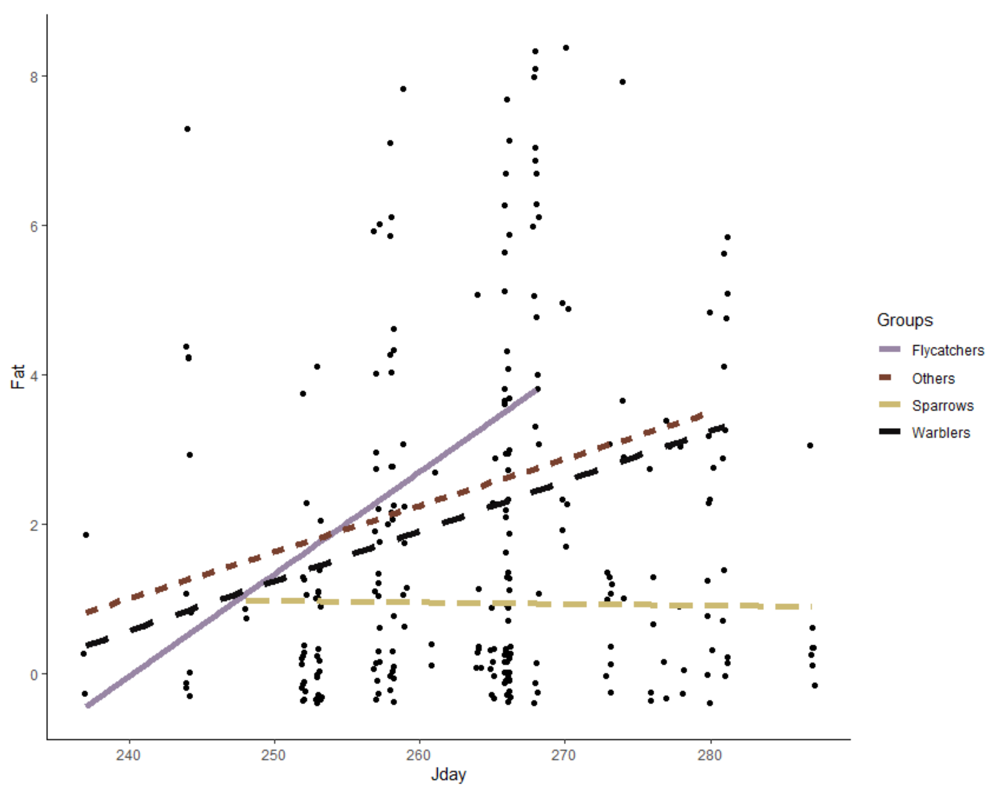

Figure 4. Fat score by Julian Day (Jday) in different groups of migratory birds at Conestoga WMA. Solid purple line are flycatchers, dashed burgundy line are others, dashed black line is warblers, and dashed gold line is sparrows.

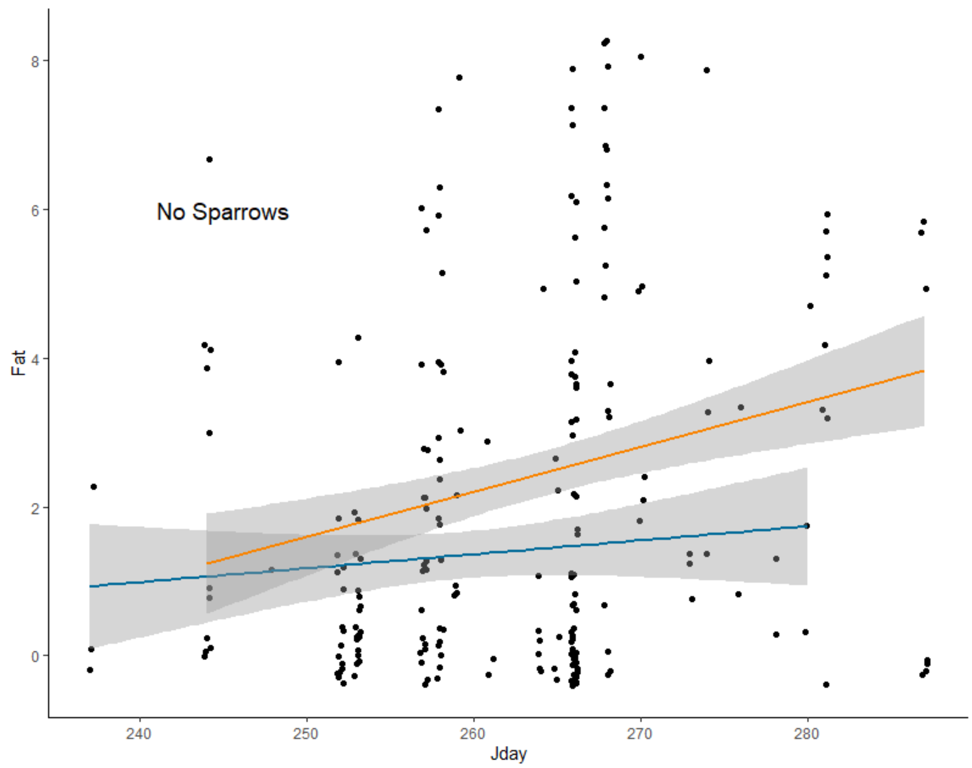

Figure 5. Fat score by Julian Date (Jday) and wind direction in all migratory birds, excluding sparrows, banded at Conestoga WMA. Orange line indicates fat scores by southerly evening wind, blue line indicates fat scores by northerly evening wind. Gray shaded areas are 90% confidence interval.

Discussion

Our most notable finding over two seasons was that average fat scores on migratory individuals were higher on birds that were presumably on stopover at Conestoga WMA compared to birds arriving to the WMA after migrating the previous evening. This suggests that Conestoga WMA can function as suitable migratory stopover habitat during the fall and that WMAs in larger agricultural landscapes in eastern Nebraska play an important role in supporting multiple migratory species in the region.

We have two major assumptions in this study: (a) birds will migrate given favorable wind profit (north winds in fall), and by extension most birds will remain at a location on stopover when faced with unfavorable, usually strong southerly winds. (b) fat score is a suitable proxy for overall migratory body condition and increased fat reserves increases the chance for completing migration in songbirds. There is evidence that birds will capitalize on north winds during fall migration (Richardson 1978, Deppe et al. 2015), particularly if individuals do not need to re-orient or complete a major flight across a large boundary (Smith and McWilliams 2014). Likewise, fat is known to be the main fuel for songbird migration (McWilliams et al. 2004), and higher fat reserves increase the chances for individuals to continue and complete migration (Deppe et al. 2015). In many ways, these two factors are linked, as multiple migration studies have also shown many individuals must achieve a certain amount of fat reserves before they will continue migration, even if presented with favorable wind conditions before their body condition improves (Smith et al. 2014, Deppe et al. 2015). The lower fat on birds captured following northerly wind evenings also supports this idea, as many of these individuals likely arrived at

Conestoga the morning after a night of extensive movement and thus depleted their energy (fat) reserves (Moore and Kerlinger 1987, Smith and McWilliams 2014). Furthermore, birds on stopover are likely to restrict diurnal movements when they achieve suitable body condition for migration (Ktitorov et al. 2010, Smith et al. 2014), which also supports our assumption that birds captured following evenings that were not favorable to migration were indeed on stopover at or very near (< 500m) our banding location.

Thus, our overall conceptual framework, albeit simplified, is reasonable and supports the broad conclusions surrounding migratory songbird use of early successional habitat and local WMAs as important considerations for future management. We simplified our wind measurements to two broad groupings (northerly vs southerly) and only investigated subcutaneous fat score as an index of overall body condition. Future work could focus on feeding and fuel deposition rates (Yong and Moore 2005, Liu and Swanson 2014b), available fat composition in local forage (Smith et al. 2007), and individual tracking and decision-based studies in different winds and landscapes (Ktitorov et al. 2010, Liu and Swanson 2015, Brenner et al. 2019) to expand upon the basic conclusion that management that promotes diverse habitat structure with relevant forage within agricultural and urban landscapes is benefitting migratory songbirds in the fall. This work could also be expanded to different locations within the state to explore the importance of diverse habitat within different contexts and flyways.

It is also encouraging that we caught a wide diversity of both migratory and resident species (Table 1) during our limited banding efforts. This included a very high number of Nashville Warblers banded during both seasons. Considering the limited coverage and effort we had at our single site alone, Nashville Warblers are likely an abundant migrant in suitable stopover sites throughout eastern Nebraska during the fall and clearly utilize WMAs while on migration. Nashville Warblers may seek out early successional habitats, such as our study site, during migratory stopover leading to locally high densities and this could also have contributed to the high number of captures. The relatively large number of other warbler and flycatcher species captured also reinforces the importance of early successional habitat to all migrating neotropical songbirds, and the high value of this habitat within the Great Plains (Lui and Swanson 2014a).

Wildlife Management Areas in eastern Nebraska usually contain early-successional habitat in a region where scrub and transitional habitats are naturally limited. While urban woodlots or parks can also function as adequate stopover areas in the Great Plains (Liu and Swanson 2014b), these features will be nearly absent further away from large human dwellings in the region. At this level, small woodlots bordering large agricultural fields have been shown to be beneficial stopover areas for migrating songbirds (Liu and Swanson 2014a, 2014b). In eastern Nebraska, WMAs like Conestoga are likely functioning the same way as these woodlots and could be better given the likelihood for more diverse habitat structure and larger footprints. Our small study agrees with consistent findings from other research emphasizing the importance of scrub and early successional habitat for songbirds during fall migration (Rodewald and Brittingham 2004).

The lower capture rate following north wind evenings (Fig 3) compared to south wind evenings coupled with our body condition data also supports our main conclusions and puts our system in context within regional migration. This suggests most birds will depart or fly over the area given favorable wind conditions but can remain at Conestoga WMA to maintain or improve their body condition until favorable wind profits arise. This also implies that north winds during fall would not necessarily result in more birds arriving in an area on a given night. This is also supported by the apparent lack of difference between capture rates following high BirdCast forecasts compared to low BirdCast forecasts (Fig 2). Importantly, BirdCast is not a predictive tool for bird densities in the morning *per se* (although this is often what is inferred by birders based on its use on social media and on listservs) but instead predicts overall bird movement, direction, and altitude as measured by radar. Thus, a large volume of birds could be migrating over or through a given area on a given night, but this does not mean a similarly high volume of birds will stop at the same location on the following morning. Also, mist-nets in scrub and fields will typically fail to capture species that prefer higher canopy habitat or wetlands, and thus we were not capturing a complete sample of all possible migratory species. If nothing else, our capture rate results indicate that localized bird movements, arrivals, or birding conditions during migration is difficult to predict and is likely dependent on multiple factors including weather, location, date, and other contextual factors that vary by region and year.

Cover: Conestoga WMA at dawn and a hatch-year Philadelphia Vireo. **Left:** Hatch-year Black-billed Cuckoo, a Tier 1 Legacy Species. **Right Above:** After-hatch-year female Mourning Warbler. **Right below:** After-hatch-year male American Goldfinch.

Table 1. The number and name of each species banded at Conestoga Lake WMA in the falls of 2020 and 2021. The early and last date banded are also included. Blue shaded species are Tier II Legacy species and orange shaded are Tier I (Schneider et al 2011).

Species Name	Species Code	Number Banded	Species Group	Early Date	Late Date
Nashville Warbler	NAWA	90	Warblers	09/01	10/07
Common Yellowthroat	COYE	85	Warblers	08/25	10/07
Gray Catbird	GRCA	66	Others	08/25	10/01
American Goldfinch	AMGO	49	Resident	09/01	10/14
House Wren	HOWR	30	Others	08/25	10/02
Lincoln's Sparrow	LISP	29	Sparrows	09/04	10/13
Orange-crowned Warbler	OCWA	22	Warblers	09/14	10/14
Yellow Warbler	YEWA	18	Warblers	09/01	09/27
Warbling Vireo	WAVI	10	Others	09/01	09/29
Northern Cardinal	NOCA	8	Resident	09/01	10/02
Bell's Vireo	BEVI	7	Others	08/25	09/09
Least Flycatcher	LEFL	7	Flycatchers	09/01	09/15
Song Sparrow	SOSP	7	Sparrows	09/29	10/14
Harris's Sparrow	HASP	6	Sparrows	09/29	10/13
Indigo Bunting	INBU	5	Others	09/14	09/24
Traill's Flycatcher	TRFL	5	Flycatchers	09/01	09/24
Clay-colored Sparrow	CCSP	4	Sparrows	09/29	10/02
Myrtle Warbler	MYWA	4	Warblers	09/22	10/14
White-crowned Sparrow	WCSP	4	Sparrows	10/06	10/14
Black-capped Chickadee	BCCH	3	Resident	09/09	10/01
Ruby-crowned Kinglet	RCKI	3	Others	09/22	10/01
Spotted Towhee	SPTO	3	Sparrows	10/02	10/14
Eastern Kingbird	EAKI	2	Flycatchers	08/25	09/01
Fox Sparrow	FOSP	2	Sparrows	10/14	-
Savannah Sparrow	SAVS	2	Sparrows	10/06	10/07
Wilson's Warbler	WIWA	2	Warblers	09/01	-
American Robin	AMRO	1	Resident	09/17	-
Black-billed Cuckoo	BBCU	1	Others	09/21	-
Downy Woodpecker	DOWO	1	Resident	09/14	-
Eastern Towhee	EATO	1	Sparrows	09/14	-
Mourning Warbler	MOWA	1	Warblers	09/09	-
Ovenbird	OVEN	1	Warblers	09/10	-
Philadelphia Vireo	PHVI	1	Others	09/14	-
Rose-breasted Grosbeak	RBGR	1	Others	09/14	-
Red-eyed Vireo	REVI	1	Others	08/25	-
Sedge Wren	SEWR	1	Others	10/06	
Swamp Sparrow	SWSP	1	Sparrows	10/06	-
Swainson's Thrush	SWTH	1	Others	09/27	-
White-throated Sparrow	WTSP	1	Sparrows	10/04	-

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