Toronto and Region Conservation Authority

Stopover Habitat Quality at Tommy Thompson Park

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Acknowledgements

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1. INTRODUCTION

Bird populations in North America have declined significantly since the 1970s (Rosenberg et al. 2019). Declines have also been identified in the biomass of migratory birds in the Eastern United States using radar technology (Rosenberg et al. 2019). While migration is an adaptation that promotes long-term survival, it is mired in threats such as bird-window collisions, extreme weather, physical exhaustion, and the loss of critical stopover habitat with many of these contributing to populations declines (Calvert et al. 2013, Moore 2018, Eng et al. 2019). Specifically, habitat loss has been identified as a leading cause of extinctions in Canada and is a threat to bird populations during the breeding season, on overwintering grounds, and during migration (Goss-Custard et al. 1995, Venter et al. 2006).

Stopover habitat, and the food and shelter provided therein, is essential for birds to be able to complete migration and contributes to annual productivity (Moore 2018). Past studies have examined stopover habitat quality at specific sites using recapture data and others have considered factors at multiple scales that predict quality; however, food availability is considered to be the primary factor affecting stopover habitat quality (Rodewald and Brittingham 2004, Buler et al. 2007, Morris et al. 1996, de Zwaan et al. 2022).

Tommy Thompson Park (TTP) in Toronto, Canada, is located on the Leslie Street Spit, a constructed landform on the north shore of Lake Ontario in the central Toronto waterfront (Fig. 1). The TTP Bird Research Station (TTPBRS) has been collecting data on songbird migration since 2003. Since then, restoration of both aquatic and terrestrial natural habitat throughout the park has been a priority to support biodiversity which includes the stopover habitat needs of migratory songbirds.

Maintaining and improving stopover habitat is key for supporting declining migratory bird populations. Previous studies that have assessed the quality of stopover habitat, have done so by comparing mass gain related to stopover length at various geographic locations (Kuenszi et al. 1991, Morris et al. 1996, Yong and Moore 1997). These studies have informed our understanding of stopover ecology for migratory birds and provide insight into habitat quality; however, there appear to be very few studies that have used this data to inform habitat restoration at stopover sites.

The purpose of this study was to assess stopover habitat quality at TTP using recapture data from the past 19 years (2003-2021). Specifically, we address this objective by answering several questions related to fuel acquisition:

i) Do birds that stopover acquire fuel?

ii) Do birds that stopover for longer acquire more fuel?

iii) How fast do birds accumulate fuel (i.e. rate of fuel accumulation)?

We examine these questions using the overall data set and include variation among migration season (e.g. spring, fall), species, feeding guild (e.g. insectivore, omnivore), and migration distance (short, medium, long).

We predict that fuel acquired during stopover would increase with longer stopover periods, the rate of accumulation would be higher for insectivores compared to omnivores, and that there is no difference in accumulation between spring and fall migration.

2. METHODS

2.1 Study site

TTPBRS is located on the Leslie Street Spit in Toronto, Canada (Fig. 1). Over the past 200 years, the pressures of land use change, including colonization, port expansion, industry, transportation, and recreation has changed the Toronto waterfront. The Leslie Street Spit is a constructed landform that is 5 km long and 500 hectares in size created by millions of cubic metres of concrete, earth fill, and dredged sand deposited at the site throughout the twentieth century. Significant habitat restoration and enhancement projects have been implemented over the past 20 years to support both terrestrial and aquatic species using the park year-round or during migration. Currently, it is listed as an Important Bird Area due to its vital stopover habitat for birds migrating over Lake Ontario.

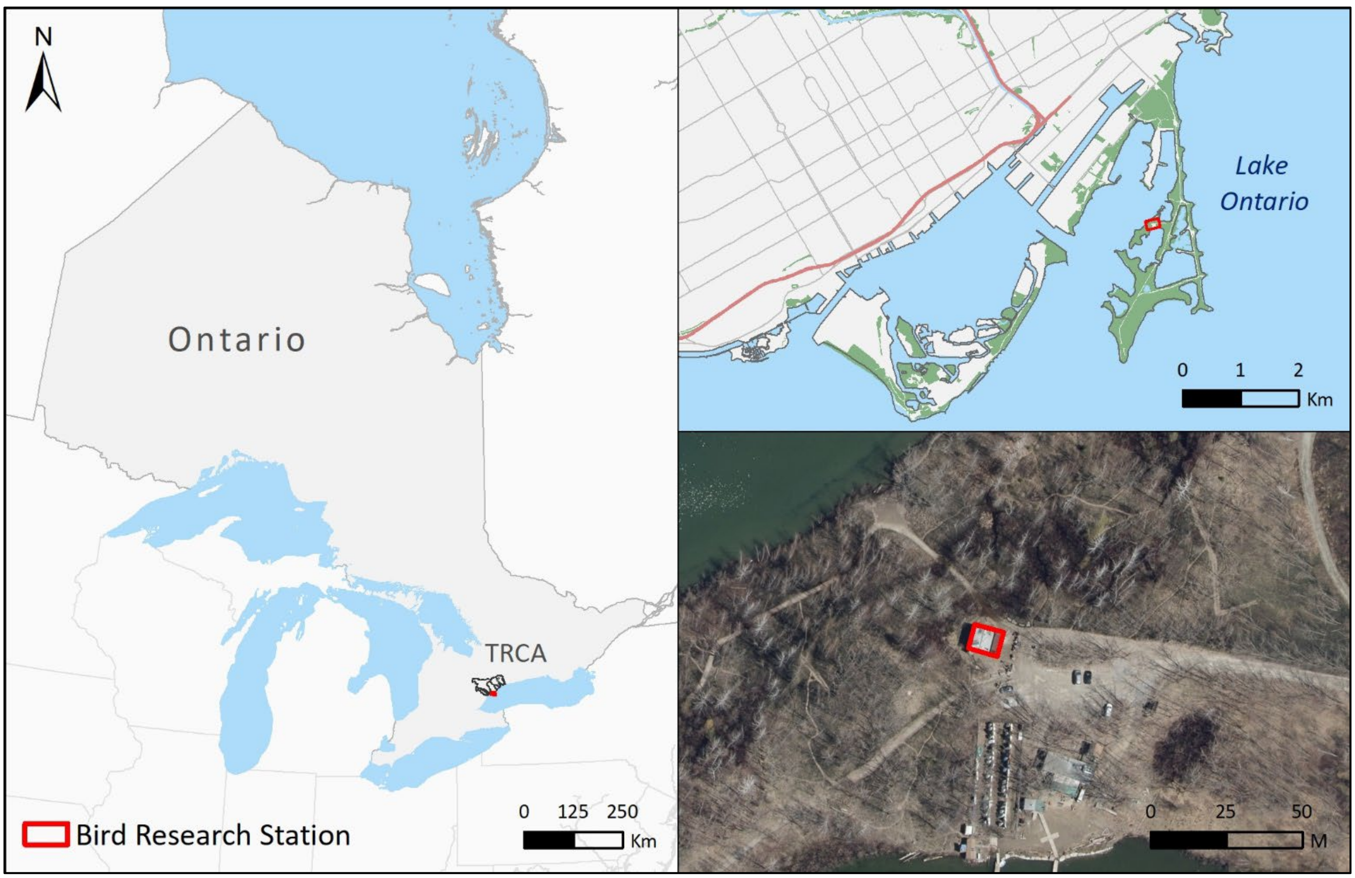

FIGURE 1. LOCATION OF THE TOMMY THOMPSON PARK BIRD RESEARCH STATION ON THE LESLIE STREET SPIT IN TORONTO, CANADA.

TTPBRS has been collecting data on migratory birds during spring and fall migration since 2003. Birds were captured using 20 mist nets (12 x 2.6 m, 5 shelves, 30 mm mesh) set up in several habitat types ranging from woodland (Fresh-Moist Cottonwood Tall Treed Woodland) to swamp (White Birch – Cottonwood Coastal Mineral Deciduous Swamp and Red-Osier Dogwood Mineral Thicket Swamp) to treed savannah (Fresh-Moist Cottonwood Tall Treed Savannah). Nets were located in the same location each year with small changes required due to specific needs (e.g. flooding, predation concerns). Weather permitting, nets were opened 30 min before sunrise and closed 6 hours after opening with nets checked approximately every 30 min or more frequently during high rates of capture. Captured birds were brought to the TTPBRS lab where they were banded with a standard aluminum Environment and Climate Change Canada leg band. We measured natural wing chord length and recorded mass to the nearest 0.1 g. We assessed fat score using the following scale: 0 - no fat, 1 – trace, furcular hollow <5% full, 2 – thin, 5-33% full, 3 – furcular hollow half full, 4 – furcular hollow full and fat in wing pits, 5 – fat slightly bulging above furcular hollow and wing pits, 6 – fat greatly bulging in all areas, and 7 – excessive, fat nearly joined from all areas. Assessing fat scores can be subjective, and even though efforts were made to ensure consistent staff training, some variation likely remains.

2.2 Data analysis

We used banding data from 2003-2021 for the analysis (excluding 2015 data since they were unavailable). Data were collected for many species, including those that may be breeding at TTP so we limited the analysis to include only species that would be migrating through TTP (Table 1). Banding time periods were based on Canadian Migration Monitoring Network protocols: spring migration April 1 to June 9 and fall migration August 5 to November 12. Records outside of this range were removed.

We grouped species based on feeding guild (omnivore, insectivore), broad species category (sparrow, warbler, kinglet, thrush, vireo, wren/creeper), and migratory distance (short, medium, long) using both local, expert knowledge and information from Cornell Lab of Ornithology (Cornell Lab of Ornithology 2019).

We calculated stopover length using recapture records by subtracting the date/time of initial capture from the date/time of the last recapture and only included birds with a stopover length of two or more days to minimize the inclusion of resident or transient birds or daily fluctuations in mass (de Zwaan et al. 2022). We used the methods of de Zwaan et al. (2022) to assess changes in body mass. This method uses estimates of lean body mass (i.e. fat score of zero) to determine the amount of mass attributable to fat.

Based on the methods of de Zwaan et al. (2022), we created a regression of body mass (dependent) versus wing length (independent) for each species only for birds with a fat score of zero (where β_0 and β_1 are regression coefficients):

$$\text{Lean body mass (LBM)} = \beta_0 + \beta_1(\text{wing length})$$

To estimate the proportion of mass consisting of fat at capture, we determined the difference between measured body mass at capture and estimated LBM (estimated LBM based on species-specific regression equation). The percentage of mass consisting of fat at capture is referred to as the fuel index:

$$\text{Fuel index (\% of body mass consisting of fat)} = ((\text{Measured body mass} - \text{Estimated LBM})/\text{Estimated LBM}) * 100$$

To assess change in fuel index during stopover, we determined the difference in measured body mass between initial capture and final capture as a proportion of LBM:

$$\Delta \text{ Fuel index } (\Delta \text{ in body mass consisting of fat})$$

$$= ((\text{Measured body mass}_{final} - \text{Measured body mass}_{initial})/\text{Estimated LBM}) * 100$$

We then divided the *Δ Fuel index* by the number of days between first and last capture to calculate the *Fuel Deposition Rate (FDR).*

Data were screened for errors and inconsistencies initially and outliers were removed at various stages of the analysis. For example, to determine birds with extended stays for each season, we created a box plot of all species combined showing stopover duration for each season. Stopovers longer than 9 days were excluded for fall migration and stopovers longer than 7 days were excluded for spring migration since these were considered outliers. Before running regression equations for each species, outliers for weight and wing chord length were removed. After calculating Δ fuel index, we assessed the data for outliers using information on the length of stay and fat scores at initial capture and final recapture.

We used non-parametric Spearman's Rho correlations to examine Δ fuel index versus stopover length due to non-normal data and unsuccessful transformations. We used Wilcoxon or Kruskal-Wallis tests to compare FDR between seasons and feeding guilds, and among migration distances with Wilcoxon non-parametric post-hoc tests to compare FDRs among short, medium, and long distance migrants. We used SAS JMP for all statistical analyses (SAS Institute Inc. 2018).

3. RESULTS

3.1 All data combined

On average, migratory songbirds stopped over for 3.53 ± 0.033 days, had a Δ fuel index of 3.66 ± 0.133%, and a fuel deposition rate of 1.08 ± 0.043 %/day (shown are means ± 1 standard error unless otherwise indicated; Table 1). This was based on data from 2956 birds recaptured between 2003 and 2021. Birds stopping over for more days had a higher Δ fuel index overall (ρ=0.236, p<0.0001; Fig. 2).

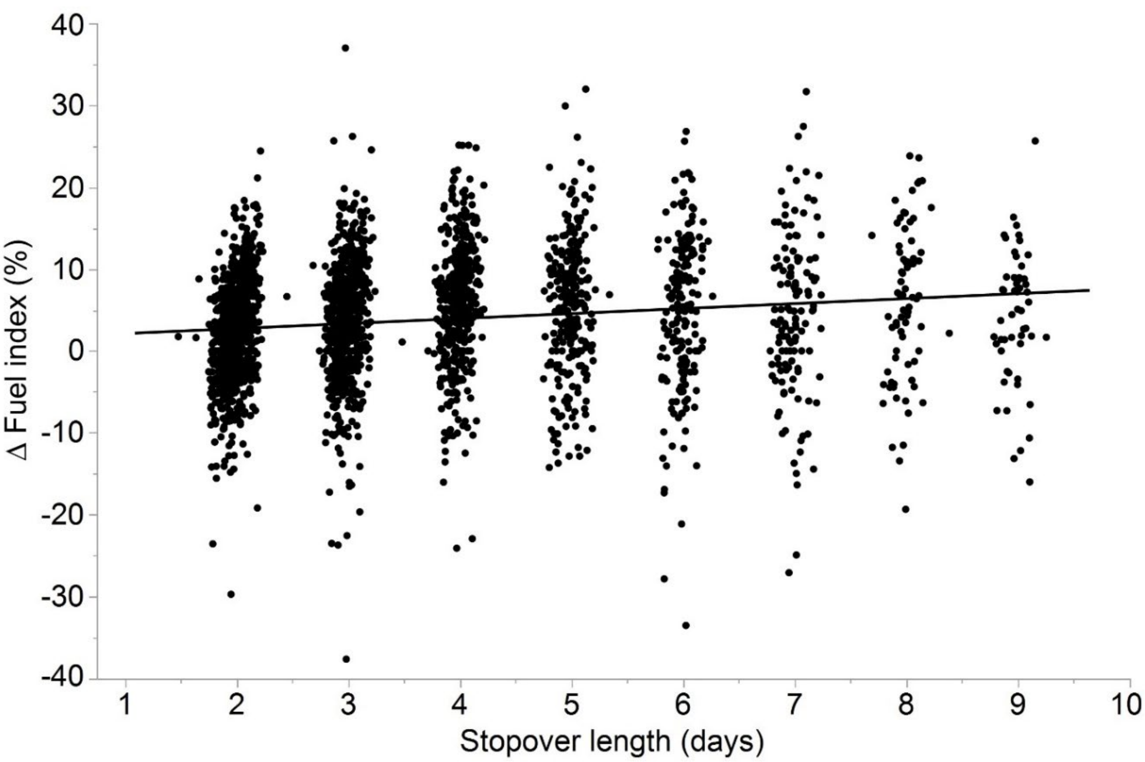

FIGURE 2. Δ FUEL INDEX (%) RELATED TO STOPOVER LENGTH (DAYS) FOR MIGRATORY SONGBIRDS RECAPTURED AT TOMMY THOMPSON PARK BETWEEN 2003 AND 2021.

TABLE 1. NUMBER OF RECAPTURES, MEAN Δ FUEL INDEX, AND MEAN FUEL DEPOSITION RATE (FDR) (± ONE STANDARD ERROR) FOR EACH BIRD SPECIES GROUPED BY BROAD SPECIES CATEGORY, FEEDING GUILD, AND MIGRATION DISTANCE. BETA VALUES FOR SPECIES-SPECIFIC REGRESSIONS BETWEEN WING CHORD (MM) AND WEIGHT (G) FOR INDIVIDUALS WITH NO FAT (FAT SCORE = 0) ARE ALSO SHOWN.

Common name	Scientific name	Broad species category	Feeding guild	Migration distance	# Recaptures	Mean Δ fuel index ± 1 SE	Mean FDR ± 1 SE	β_0	β_1
Golden-crowned Kinglet	*Regulus satrapa*	Kinglets	Insectivore	Short	527	3.6±0.3	1.1±0.1	2.66	0.05
Ruby-crowned Kinglet	*Corthylio calendula*	Kinglets	Insectivore	Short	373	5.9±0.3	1.9±0.1	1.09	0.09
American Tree Sparrow	*Spizelloides arborea*	Sparrow	Omnivore	Medium	23	-0.7±1.1	-0.5±0.3	-3.04	0.28
Slate-colored Junco	*Junco hyemalis*	Sparrow	Omnivore	Short	35	-0.5±1.2	-0.1±0.4	5.28	0.17
White-throated Sparrow	*Zonotrichia albicollis*	Sparrow	Omnivore	Short	272	0.2±0.5	-0.1±0.1	1.28	0.32
Gray-cheeked Thrush	*Catharus minimus*	Thrush	Omnivore	Long	29	5.2±1.3	1.6±0.4	-0.34	0.31
Swainson's Thrush	*Catharus ustulatus*	Thrush	Omnivore	Long	85	2.7±0.9	0.8±0.2	8.46	0.22
Veery	*Catharus fuscescens*	Thrush	Omnivore	Long	29	3.0±1.5	0.5±0.4	-6.07	0.38
Hermit Thrush	*Catharus guttatus*	Thrush	Omnivore	Short	239	3.4±0.4	0.8±0.1	8.61	0.22
Philidephia Vireo	*Vireo philadelphicus*	Vireo	Insectivore	Long	23	2.1±1.5	0.8±0.5	3.36	0.12
Red-eyed Vireo	*Vireo olivaceus*	Vireo	Insectivore	Long	79	5.0±0.8	1.3±0.2	3.34	0.17
Bay-breasted Warbler	*Setophaga castanea*	Warbler	Insectivore	Long	21	5.2±1.4	1.3±0.4	2.81	0.12
Blackpoll Warbler	*Setophaga striata*	Warbler	Insectivore	Long	22	7.5±2.5	3.0±0.7	1.85	0.14
Black-throated Green Warbler	*Setophaga virens*	Warbler	Insectivore	Long	28	2.9±1.0	0.8±0.3	2.24	0.11
Canada Warbler	*Cardellina canadensis*	Warbler	Insectivore	Long	32	6.3±1.1	2.1±0.4	3.87	0.10
Magnolia Warbler	*Setophaga magnolia*	Warbler	Insectivore	Long	249	5.9±0.4	1.9±0.1	2.48	0.10
Northern Parula	*Setophaga americana*	Warbler	Insectivore	Long	30	6.3±1.3	1.8±0.3	3.68	0.07
Northern Waterthrush	*Parkesia noveboracensis*	Warbler	Insectivore	Long	45	4.7±1.7	1.3±0.4	6.08	0.14
Ovenbird	*Seiurus aurocapillus*	Warbler	Insectivore	Long	59	4.4±0.9	1.1±0.2	7.58	0.15
Tennessee Warbler	*Leiothlypis peregrina*	Warbler	Insectivore	Long	25	5.3±1.8	1.8±0.6	7.35	0.03
Black-and-white Warbler	*Mniotilta varia*	Warbler	Insectivore	Medium	42	1.6±1.1	0.6±0.3	4.62	0.08
Black-throated Blue Warbler	*Setophaga caerulescens*	Warbler	Insectivore	Medium	60	2.1±0.7	0.6±0.3	4.13	0.08
Common Yellowthroat	*Geothlypis trichas*	Warbler	Insectivore	Medium	126	3.5±0.6	0.9±0.2	4.43	0.11
Myrtle Warbler	*Setophaga coronata*	Warbler	Insectivore	Medium	177	1.6±0.6	0.5±0.2	2.47	0.13
Nashville Warbler	*Leiothlypis ruficapilla*	Warbler	Insectivore	Medium	71	2.6±0.9	0.6±0.3	3.24	0.08
Palm Warbler	*Setophaga palmarum*	Warbler	Insectivore	Medium	52	7.1±1.0	2.3±0.3	3.30	0.11
Wilson's Warbler	*Cardellina pusilla*	Warbler	Insectivore	Medium	84	5.5±0.8	1.8±0.3	3.03	0.08
Brown Creeper	*Certhia americana*	Wren/Creeper	Insectivore	Short	90	1.2±0.7	0.3±0.2	1.14	0.11
Winter Wren	*Troglodytes hiemalis*	Wren/Creeper	Insectivore	Short	29	3.6±1.0	0.8±0.2	1.60	0.15

3.2 Spring vs fall

FDR was significantly higher during spring migration (1.30 ± 0.083) compared to fall migration (0.965 ± 0.047; χ^2=18.7, *p*<0.0001; Fig. 3). In both seasons, birds stopping over for more days had a higher Δ fuel index (spring: ρ=0.191, p<0.0001, fall: ρ=0.273, *p*<0.0001).

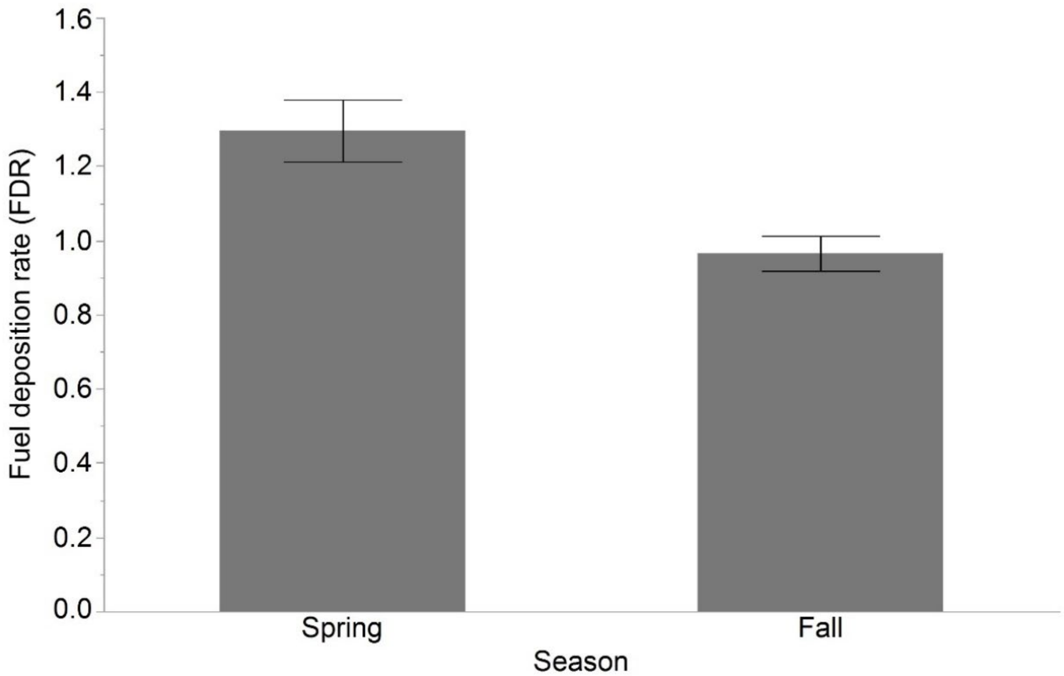

FIGURE 3. FUEL DEPOSITION RATE DURING SPRING AND FALL MIGRATION AT TOMMY THOMPSON PARK (MEAN ± 1 STANDARD ERROR).

3.3 Species-specific

FDR varied among species with Blackpoll Warbler (*Setophaga striata*) having the highest FDR (3.04 ± 0.725) and American Tree Sparrow (*Spizelloides arborea*) having the lowest (-0.495 ± 0.349; Fig. 4). Two other species had negative FDRs including White-throated Sparrow (*Zonotrichia albicollis*) and Slate-colored Junco (*Junco hyemalis*) suggesting that on average, these species are losing fuel.

There was variation among species in whether or not longer stays resulted in greater fuel accumulation (Fig. 5, Fig. 6). For most species (22/29), birds stopping over for more days had a higher Δ fuel index (12/22 species $p<0.05$). Seven species had a negative trend indicating a loss of fuel with a longer stopover although none of the trends were statistically significant (all $p>0.19$).

Specific species worth further investigation include Black-and-White Warbler (*Mniotilta varia*), Brown Creeper (*Certhia americana*), and Winter Wren (*Troglodytes hiemalis*). These species tended to have lower FDRs and lower fuel accumulation over time during stopover.

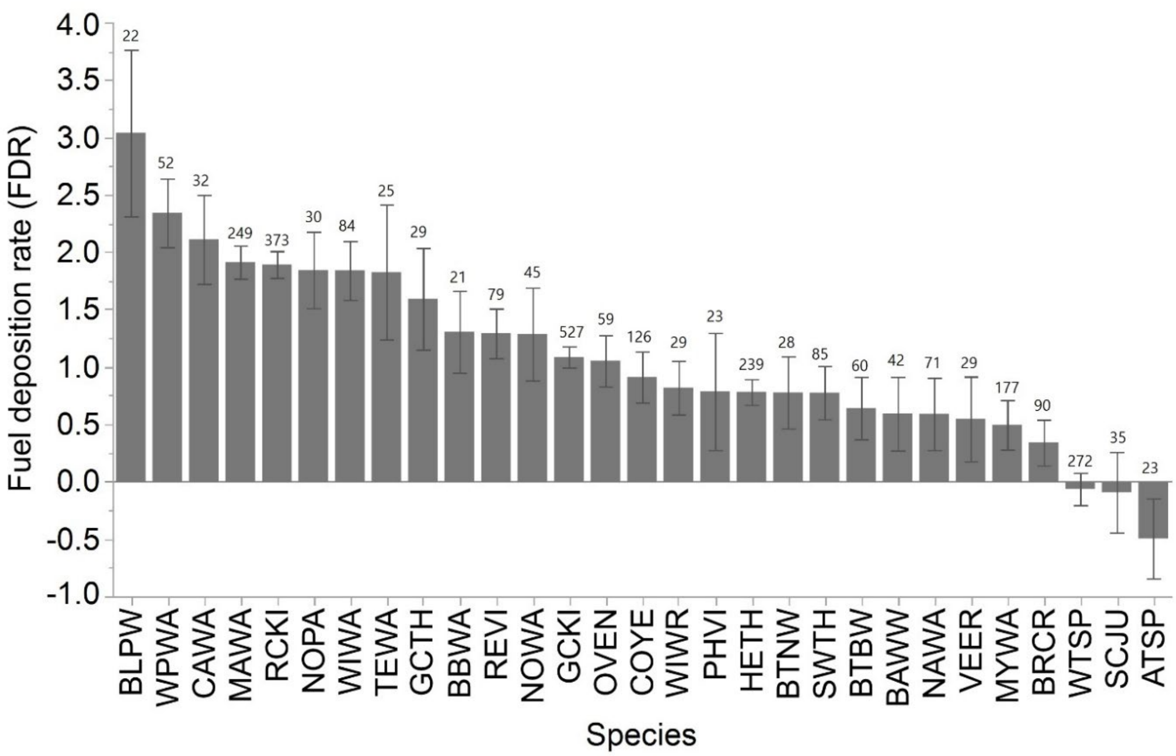

FIGURE 4. FUEL DEPOSITION RATE FOR MIGRATORY SONGBIRDS RECAPTURED AT TOMMY THOMPSON PARK BETWEEN 2003 AND 2021 (MEAN ± 1 STANDARD ERROR). SAMPLE SIZE IS SHOWN ABOVE EACH BAR.

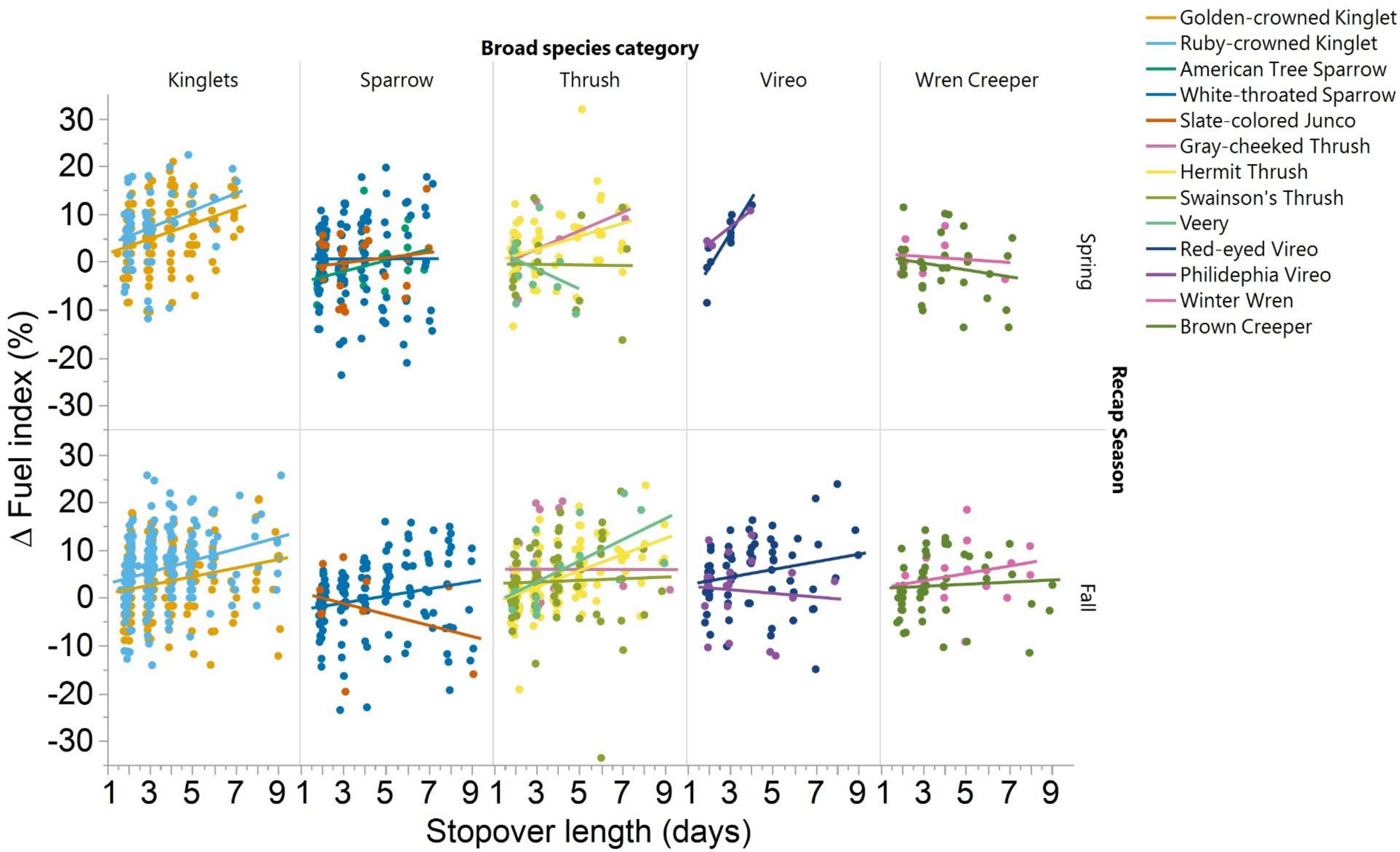

FIGURE 5. Δ FUEL INDEX (%) RELATED TO STOPOVER LENGTH (DAYS) FOR NON-WARBLER SPECIES OF MIGRATORY SONGBIRD RECAPTURED AT TOMMY THOMPSON PARK BETWEEN 2003 AND 2021.

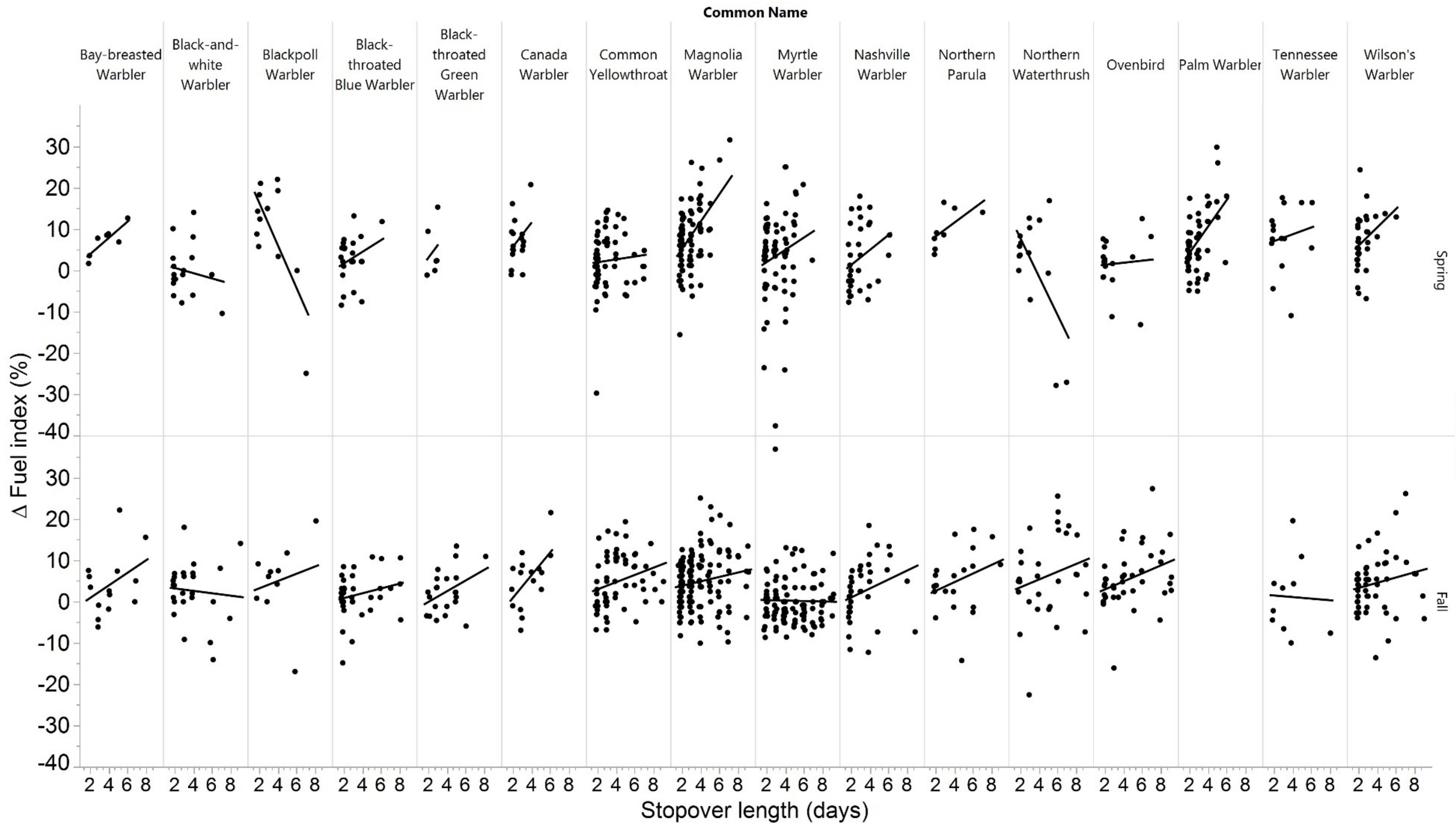

FIGURE 6. Δ FUEL INDEX (%) RELATED TO STOPOVER LENGTH (DAYS) FOR WARBLERS RECAPTURED AT TOMMY THOMPSON PARK BETWEEN 2003 AND 2021.

3.4 Migration distance

FDR was significantly higher for long distance migrants (1.49 ± 0.083) compared to medium (0.902 ± 0.102) and short (0.958 ± 0.056) distance migrants (χ^2=36.3, p<0.0001; Fig. 7).

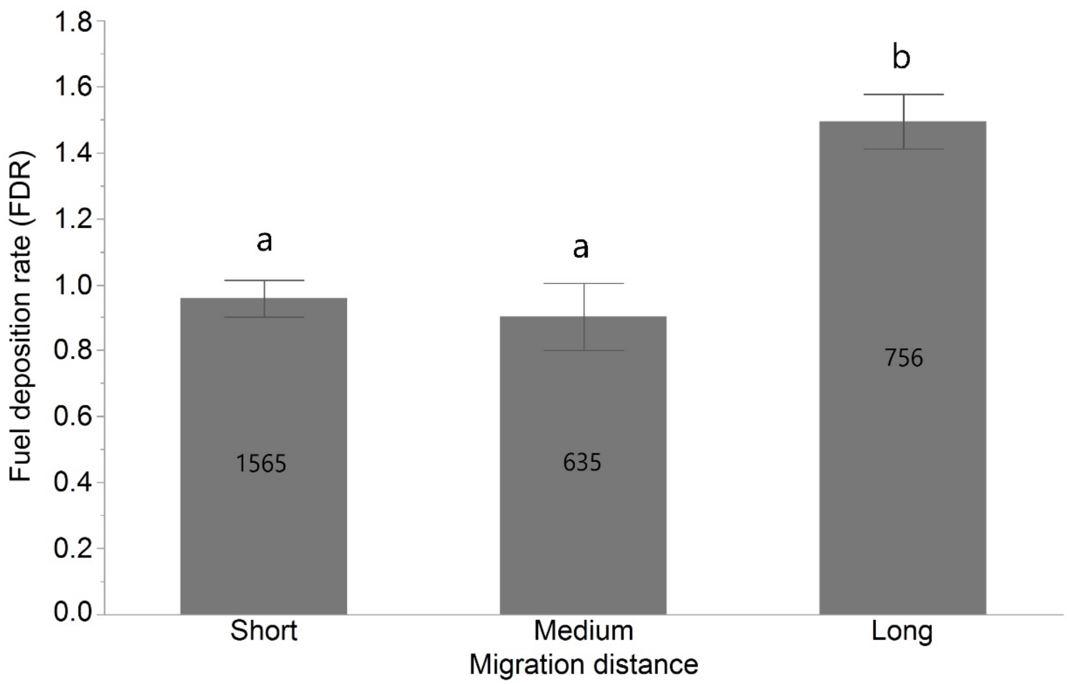

FIGURE 7. FUEL DEPOSITION RATE FOR MIGRATORY SONGBIRDS RECAPTURED AT TOMMY THOMPSON PARK BETWEEN 2003 AND 2021 BASED ON MIGRATION DISTANCE. DIFFERENT LETTERS DENOTE A SIGNIFICANT DIFFERENCE. SAMPLE SIZE IS SHOWN WITHIN EACH BAR.

3.5 Feeding guild

FDR was higher for insectivores (1.30 ± 0.050) compared to omnivores (0.40 ± 0.080; χ^2=83.2, p<0.0001; Fig. 8) and this pattern was consistent in both spring and fall. Birds stopping over for longer had a significantly higher Δ fuel index in both spring and fall and grouped as insectivores or omnivores (all p<0.018). Omnivores in the spring had the lowest correlation suggesting that if they stay around longer, they do not accumulate as much fuel as insectivores in the spring or birds in the fall (regardless of feeding guild).

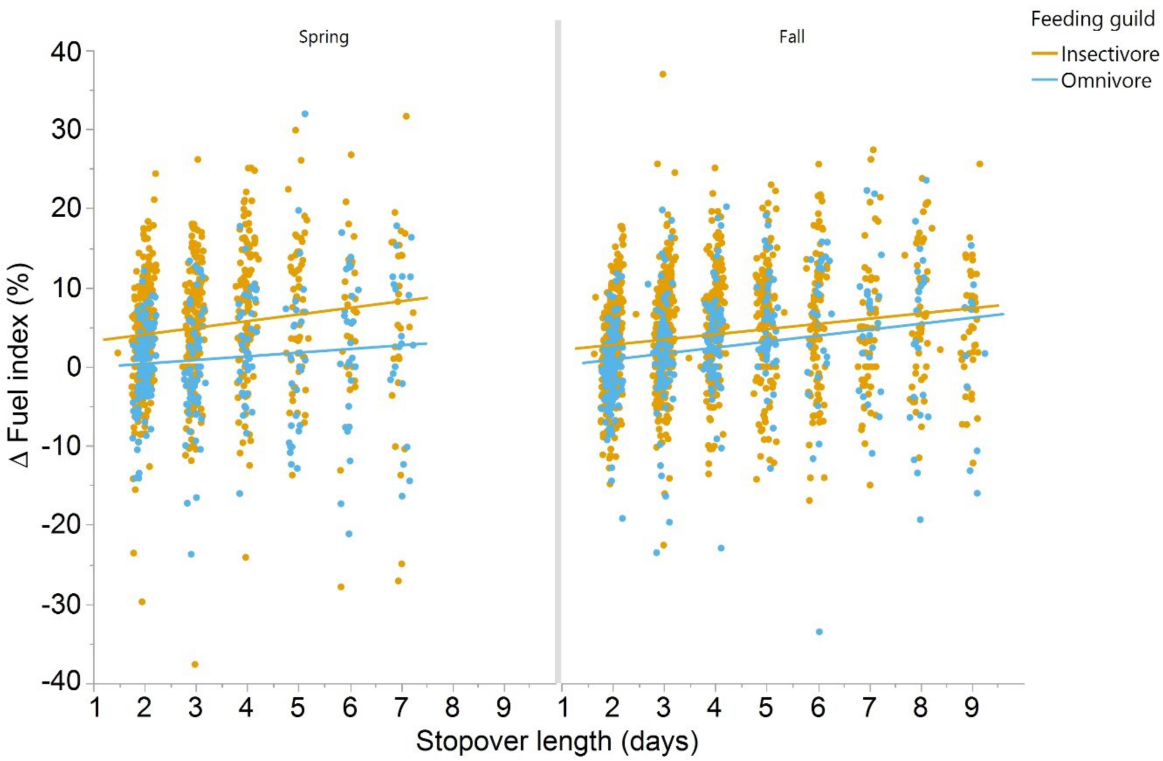

FIGURE 8. Δ FUEL INDEX (%) RELATED TO STOPOVER LENGTH (DAYS) FOR MIGRATORY SONGBIRDS RECAPTURED AT TOMMY THOMPSON PARK BETWEEN 2003 AND 2021 DURING SPRING AND FALL MIGRATION GROUPED INTO FEEDING GUILDS.

4. DISCUSSION

The objective of this study was to answer several questions including: i) do birds that stopover at TTP acquire fuel? ii) do birds that stopover for longer acquire more fuel? and iii) how fast do birds accumulate fuel? Recapture data collected at TTP from 2003 to 2021 suggest that migratory songbirds are accumulating fuel during stopovers. Fuel accumulation rates and the amount of fuel accumulated varied based on stopover duration, season, species, migration distance, and feeding guild. These results highlight the importance of this urban greenspace for migratory songbirds and they provide valuable insights that can be used to inform future habitat restoration at TTP.

Birds stopping over at TTP gained fuel with an FDR of approximately 1 %/day and birds that stopped over for longer tended to acquire more fuel. There was variation in FDR with higher FDRs in spring compared to fall, higher FDRs for insectivores, lower FDRs for sparrows, and higher FDRs for long distance migrants compared to short and medium distance migrants. Sparrows, including White-throated Sparrow, Slate-coloring Junco, and American Tree Sparrow, accumulated the lowest amount of fuel during stopover while warblers, including Northern Parula (*Setophaga americana*), Palm Warbler (*Setophaga palmarum*), and Blackpoll Warbler tended to accumulate the most fuel.

de Zwaan et al. (2022) also found overall fuel gains at their stopover site on Iona Island in Richmond, British Columbia and that sparrows tended to have lower amounts of accumulated fuel, spring FDRs were higher than fall, insectivores had higher FDRs than omnivores, and long distance migrants had higher FDRs. Since we used the same methods as de Zwaan et al. (2022), we can compare several species-specific FDRs and Δ fuel index values. Common Yellowthroat (*Geothlypis trichas*) had a higher FDR at TTP (spring=0.7, fall=1.1) compared to Iona Island (spring=0.1, fall=0), Wilson's Warbler (*Cardellina pusilla*) had similar and higher FDRs at TTP (spring=2.8, fall=1.3) compared to Iona Island (spring=2.7, fall=0.7), and Myrtle Warbler (*Setophaga coronata*) had a mix of higher and lower FDRs at TTP (spring=1.1, fall=0.06) compared to Iona Island (spring=0.7, fall=0.3). Common Yellowthroat, Myrtle Warbler, and Wilson's Warbler at TTP also had a higher percentage of their body mass attributable to fat compared to the same species at Iona Island (on average 6% higher in spring and 2% higher in fall).

Morris et al. (1996) also found that most species recaptured had increased mass and fat compared to initial capture on Appledore Island, Maine, although this study only included data for fall migration and did not include any sparrow species. Guglielmo et al. (2022) studied fat and lean body mass of refueling songbirds at Long Point, Ontario, and found that mass attributed to fat was higher in spring compared to fall; however, they did not find lower mass attributed to fat for sparrows or an effect of breeding region (e.g. migration distance) although breeding region was more limited than considered in this study. Dunn (2001) studied mass gain also at Long Point and found lower mass gain in the spring but only at one of three sites within Long Point since this study compared among different locations within Long Point. Sparrows showed similar mass gain across sites and season compared to insectivores (Dunn 2001).

Variation in fuel accumulation across sites, species, feeding guild, and season are likely related to several factors. Bird densities during spring and fall migration are highest in coastal areas and in areas with higher forest cover suggesting regional- and landscape-scale factors are important for migrating songbirds (Buler et al. 2007). Forest cover was positively related to arthropod abundance again stressing the importance of food availability in predicting habitat use during migration (Buler et al. 2007). Vegetation community-level differences in food production also likely affect fuel accumulation since many insects require specific habitat types or host plants and communities might also differ in seed production. Seasonal variation in the abundance of seeds and/or insects could also affect fuel accumulation. Higher FDRs in the spring could also be adaptive to deal with more variable weather conditions or to facilitate reaching the breeding grounds sooner since higher FDRs mean shorter stopovers are required to reach the necessary fuel load (Guglielmo et al. 2022). FDRs can also be affected by predation risk where birds under higher predation pressure spend less time foraging (Cimprich and Moore 2006). The type of predator might also affect a bird's ability to acquire food. For example, many sparrows feed on the ground and if there are a high number of ground predators, sparrows may need to limit foraging. Several other factors could explain the variation we found including inter and intra-specific competition for food resources and foraging disturbance related to nature-based recreation (de Zwaan et al. 2022, Verhulst et al. 2001).

4.1 Management recommendations

Based on the results of this study, we provide several management recommendations for consideration to maintain and improve stopover habitat quality at TTP.

- Continue ongoing management, restoration, and protection of both terrestrial and aquatic areas at TTP since it is an essential urban greenspace providing beneficial stopover habitat for migratory songbirds.
- Assess current abundance and consider planting species that support food preferences of sparrows due to their low FDRs and low fuel accumulation. These species could include native, fall fruiting species that would help support White-throated Sparrow foraging during the fall since fruits are often high in fat or sugar and may lead to increased fat synthesis (Smith and McWilliams 2009). White-throated Sparrows eat the fruits of sumac, grape, cranberry, mountain ash, rose, blueberry, blackberry, and dogwood (Cornell Lab of Ornithology 2019). In the spring they eat the buds, young seeds, and blossoms of oak, apple, maple, beech, and elm. These species are not currently abundant at TTP (pers. comm.). Slate-colored Juncos are primarily seed eaters with species including chickweed, buckwheat, lamb's quarters, and sorrel comprising approximately 75% of their diet year-round. During fall and spring, American Tree Sparrows eat seeds from grasses, sedges, ragweeds, knotweeds, goldenrods, among others, along with occasional berries, catkins, along with the occasional insects.
- Assess current abundance and consider planting species that support food preferences of the Black-and-White Warbler. Black-and-white Warblers primarily eat lepidopteran (butterfly and moth) larvae during spring migration and the breeding season so consider appropriate host plants for lepidopterans with larval stages during peak spring and fall migration periods.
- Continue to maintain mid- to upper-level vegetation to allow for safe foraging on both insects and seeds away from ground predators.
- Consider limiting recreation in areas where birds are foraging during peak spring and fall migration.

4.2 Future research

Even though this study was the first to examine stopover habitat quality at TTP, there are many more questions that could be answered with the existing data or additional data including:

- What food is available at TTP during migration? For example, what species of invertebrates and seeds/fruits are available and in what quantity? This research would inform restoration work to provide habitat for insects and consider species to plant to provide seeds.
- Observational studies of bird foraging behaviours would also be beneficial to understand current food sources (e.g. which plant species are commonly used by each species of bird?). For example, Brown Creeper and Winter Wren had lower FDRs and fuel accumulation particularly in the spring. These species are primarily insectivores that forage on the bark of mature trees. Also, Black-and-white Warbler had a low FDR and struggled to accumulate fuel during stopover. Observational studies of these species in the spring or further research into local food sources on spring migration may be helpful to inform future restoration for these species. Black-and-white Warblers could also be considered for observational study to better understand prey selection.
- Do age and sex affect FDRs and fuel accumulation during stopover?
- How far can each bird fly (potential flight distance) based on the fuel accumulated at TTP?
- Has the composition of migratory bird communities at TTP changed over time? Can this be related to changes in vegetation or invertebrate communities?

5. REFERENCES

Buler, J., F. Moore, and S. Woltmann. 2007. A multi-scale examination of stopover habitat use by birds. Ecology 88:1789-1802.

Calvert, A., C. Bishop, R. Elliot, E. Krebs, T. Kydd, C. Machtans, and G. Robertson. 2013. A synthesis of human-related avian mortality in Canada. Avian Conservation and Ecology 8:11.

Cimprich, D., and F. Moore. 2006. Fat affects predator avoidance behavior in Gray Catbirds (*Dumetella carolinensis*) during migratory stopover. Auk. 124:1069–1076.

Cornell Lab of Ornithology. 2019. All About Birds. Cornell Lab of Ornithology, Ithaca, New York. https://www.allaboutbirds.org Accessed on [27 September 2022].

de Zwaan, D., Huang, A., McCallum, Q., Owen, K., Lamont, M., and W. Easton. 2022. Mass gain and stopover dynamics among migrating songbirds are linked to seasonal, environmental, and life-history effects. Ornithology ukac027, https://doi.org/10.1093/ornithology/ukac027

Dunn, E. 2001. Mass change during migration stopover: A comparison of species groups and sites. Journal of Field Ornithology 72:419-432.

Eng, M., B. Stutchbury, and C. Morrissey. 2019. A neonicotinoid insecticide reduces fueling and delays migration in songbirds. Science 365:1177-1180.

Goss-Custard, J., R. Clarke, D. Durell, R. Caldow, and B. Ens. 1995. Population consequences of winter habitat loss in a migratory shorebird. II. Model predictions. Journal of Applied Ecology 32:337-351.

Guglielmo, C., Y. Morbey, L. Kennedy, J. Deakin, M. Brown, and A. Beauchamp. 2022. A scaling approach to understand the dynamics of fat and lean mass in refueling migrant songbirds measured by quantitative magnetic resonance. Frontiers in Ecology and Evolution 10:787623.

Kuenszi, A., F. Moore, and T. Simons. 1991. Stopover of neotropical landbird migrants on East Ship island following trans-Gulf migration. The Condor 93:869-883.

Moore, F. 2018. Biology of landbird migrants: a stopover perspective. The Wilson Journal of Ornithology 130:1-12.

Morris, S., D. Holmes, and M. Richmond. 1996. A ten-year study of the stopover patterns of migratory passerines during fall migration on Appledore Island, Maine. The Condor 98:395-409.

Rodewald, P., and M. Brittingham. 2004. Stopover habitats of landbirds during fall: Use of edge-dominated and early-successional forests. The Auk 121:1040-1055.

Rosenberg, K., A. Dokter, P. Blancher, J. Sauer, A. Smith, P. Smith, J. Stanton, A. Panjabi, L. Helft, M. Parr, and P. Marra. 2019. Decline of the North American avifauna. Science 366:120-124.

SAS Institute Inc. 2018. SAS JMP 14.0.0.

Smith, S., and S. McWilliams. 2009. Dietary macronutrients affect lipid metabolites and body composition of a migratory passerine, the White-throated Sparrow (*Zonotrichia albicollis*). Physiological and Biochemical Zoology 82:258-269.

Venter, O., N. Brodeur, L. Nemiroff, B. Belland, I. Dolinsek, and J. Grant. 2006. Threats to endangered species in Canada. BioScience 56:903-910.

Verhulst, S., K. Oosterbeek, and B. Ens. 2001. Experimental evidence for effects of human disturbance on foraging and parental care in oystercatchers. Biological Conservation 101:375-380.

Yong, W. and F. Moore. 1997. Spring stopover of intercontinental migratory thrushes along the northern coast of the Gulf or Mexico. The Auk 114:263-278.

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