MASS CHANGES OF MIGRATORY LANDBIRDS DURING STOPOVERS IN A NEW YORK CITY PARK

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ABSTRACT.—We measured rates of mass change of eight species of migratory passerines in a New York City park during three consecutive spring and autumn migrations to evaluate the quality of an urban habitat as a stopover site. We also examined seasonal differences in body condition. Linear regressions of a condition index on time of day detected significant hourly mass gain by Magnolia Warbler (*Dendroica magnolia*), Black-throated Blue Warbler (*D. caerulescens*), Ovenbird (*Seiurus aurocapilla*), and Northern Waterthrush (*S. noveboracensis*) during spring, and Common Yellowthroat (*Geothlypis trichas*) during autumn. Swainson's Thrush (*Catharus ustulatus*) showed significant mass loss during autumn. Significant spring mass gain rates ranged from 0.99 to 2.46% of mean body mass/hr. Common Yellowthroat gained 1.28% of mean body mass/hr during autumn. Most species were heavier and fatter in spring than autumn. The significant mass gain rates were comparable to those in similar studies in more pristine areas. Our results suggest the urban stopover site we examined is a place where migrants can sufficiently replenish energy stores. This highlights the importance of conserving and properly managing remaining green spaces in urban areas along major migratory bird flyways. *Received 1 June 2007. Accepted 17 August 2007.*

Nearctic-neotropical migratory passerines engage in episodes of intense exercise during nocturnal migratory flights followed by periods of hyperphagia and rapid fat deposition during stopovers. Stopover habitats in which depleted energy stores can be promptly replenished are necessary for successful and timely migrations (Moore et al. 1995). The fate of birds during this stage of their life-cycle can limit population sizes (Sillett and Holmes 2002), and meeting the habitat requirements of migration has become a primary component of current migratory landbird conservation strategies (e.g., Dettmers and Rosenberg 2000).

Despite the rapidly growing interest over the last 20 years in stopover ecology (Moore and Kerlinger 1987, Woodrey and Moore 1997, Wang et al. 1998, Carlisle et al. 2005), stopover site quality (Russell et al. 1994; Dunn 2000, 2001; Rimmer and McFarland 2000), and stopover site conservation (McCann et al. 1993, Moore et al. 1995, Mehlman et al. 2005), migrant use of urban habitats has received little attention. The Atlantic Coast migration routes overlap with the most urbanized region of North America and the habitats remaining within cities may have an important role in landbird migration (Mehlman et al. 2005). However, it is unknown whether urban parks provide migrants with resources they need during stopovers. The high densities of birds, predominance of exotic invasive plants, and overall degraded habitat conditions often present in such areas may elevate competition for resources and constrain the ability of migrants to sufficiently refuel. City parks and similar habitat fragments will represent an increasing proportion of the stopover sites available to migrants as urbanization proceeds. Thus, the stopover ecology of birds in these areas is deserving of greater attention. Our objective was to measure the mass change of migrants during stopovers in Bronx Park, New York City, and gauge the quality of an urban habitat as a migratory bird stopover site. We also examined seasonal differences in body condition to learn if migrants carried greater fat loads in spring than autumn, as has often been observed in non-urban areas (e.g., Winker et al. 1992b, Morris and Glasgow 2001).

METHODS

Site Description.—Bronx County, New York, has a human population of ~1.4 million and a total land area of 109 km^2, equaling a population density of 12,844 people/km^2 (U.S. Census Bureau 2004). Bronx Park is a 229-ha municipal park at the center of the county. The park is composed almost entirely of the

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campuses of the Bronx Zoo and New York Botanical Garden. The Bronx River bisects Bronx Park before joining the East River to the south. Our study area was an approximately 4.9-ha section of riparian and upland forest on the grounds of the Bronx Zoo (40° 85′ N, 73° 87′ W). The site does not contain any animal exhibits and is not open to zoo visitors. The west side of this area is a mature dry upland deciduous forest dominated by red oak (*Quercus rubra*) and sweet gum (*Liquidambar styraciflua*) with some white ash (*Fraxinus americana*), mockernut (*Carya tomentosa*), black cherry (*Prunus serotina*), and American elm (*Ulmus americana*) also present. The upland forest transitions rapidly down a steep rocky gradient to the east into a riparian zone with wet or seasonally wet soils. The most common riparian species are willows (*Salix* spp.) and swamp dogwood (*Cornus foemina*). Two non-native invasive plants, Japanese knotweed (*Polygonum cuspidatum*) and Oriental bittersweet (*Celastrus orbiculatus*), are prevalent.

We note that urban habitats can vary considerably with regard to size, vegetation composition, extent of human use/recreation, historical and current management practices, abundance of birds using them as stopover sites, and other factors that may influence their quality as migratory bird stopover habitat. Therefore the birds captured in Bronx Park should not be considered representative of birds that use dramatically different types of habitats within cities during migration (e.g., Seewagen 2008).

Data Collection.—Birds were captured in 10–14 mist nets during spring and autumn of 2004–2006. Nets were operated from sunrise until ~ 1200 hrs EST, 5 days/week (weather permitting). Autumn sampling began on 4–6 September each year and ended on 17–18 October. Spring sampling began on 28 April–2 May and ended on 1–2 June. Nets were set in 10 locations (some nets were doubled) throughout the site and remained in place for the duration of the study. Six net locations were within close proximity to the river's edge (<10 m), while the remaining four locations were ~40 m from the river in the upland area.

Nets were checked approximately every 30 min. Captured birds were measured (tail and unflattened wing length in mm), classified to age and gender when possible (Pyle 1997), weighed to the nearest 0.1 g (Ohaus 400 g digital balance), and banded with federal metal bands. Visible subcutaneous fat in the furcular hollow was rated on a six-point scale (Moore and Kerlinger 1987). Fat was scored by the same observer throughout the study with the exception of 5 days during autumn 2004 and 2 days during autumn 2005 to minimize inter-observer variation (Krementz and Pendleton 1990).

Focal Species.—We selected eight focal species based on their sample sizes (>25 total individuals of each in spring and autumn) and a lack of large breeding or over-wintering populations in or near our study site: Swainson's Thrush (*Catharus ustulatus*), Wood Thrush (*Hylocichla mustelina*), Magnolia Warbler (*Dendroica magnolia*), Black-throated Blue Warbler (*D. caerulescens*), Yellow-rumped Warbler (*D. coronata*), Ovenbird (*Seiurus aurocapilla*), Northern Waterthrush (*S. noveboracensis*), and Common Yellowthroat (*Geothlypis trichas*). Common Yellowthroat and Yellow-rumped Warbler are exceptions to our criteria in that the former breeds locally and the latter often over-winters in nearby coastal areas (NYSBBA 2000; DeCandido and Allen 2005; CLS, pers. obs.). However, because sample sizes for both species were relatively large, we assumed the majority of individuals that we captured were transients. Only one Common Yellowthroat was recaptured more than 1 week following initial capture during spring, and no Yellow-rumped Warblers were recaptured during autumn suggesting the individuals in our samples did not remain in the study site to breed or over-winter. There were no between-season or between-year captures of Common Yellowthroats or Yellow-rumped Warblers, unlike individuals of other species that nested, over-wintered, or resided year-round in the study site during 2004–2006 (e.g., Warbling Vireo [*Vireo gilvus*], American Robin [*Turdus migratorius*], Gray Catbird [*Dumetella carolinensis*], Song Sparrow [*Melospiza melodia*], and Baltimore Oriole [*Icterus galbula*]).

Statistical Analyses.—We used Mann-Whitney *U*-tests to compare fat scores between seasons (Hailman 1965). Medians and means are both presented, as the median is the most appropriate measure of central tendency for

fat score data but the mean is more commonly reported in other studies (Hailman 1965, Benson and Winker 2005).

We calculated a condition index (mass × 100/wing length) to correct body mass for body size variation (Winker 1995, Dunn 2002, Bonter et al. 2007). We used *t*-tests to examine differences in condition indices (Carlisle et al. 2005) between seasons. We first tested the relationship between condition index and fat score in spring and autumn with Pearson's product-moment correlations because differences in body mass may not be entirely attributable to differences in fat content (Piersma 1990, Scott et al. 1994, Karasov and Pinshow 1998).

Simple linear regressions of condition index and time of day (converted to hours since sunrise at time of capture) were used to estimate hourly changes in condition (Morris et al. 1996; Dunn 2001, 2002; Carlisle et al. 2005; Bonter et al. 2007). Changes in condition were converted to changes in mass using the mean spring and autumn wing lengths for each species. We first regressed wing length on time of day to reveal any existing temporal biases in body size that might distort mass change estimates when using this method (Winker 1995).

Statistical tests were performed with SYSTAT, Version 10.0 (Systat Software Inc. 2000), and PRISM, Version 4.0 (GraphPad Software Inc. 2005) software packages. We considered results statistically significant when $P \leq 0.05$.

RESULTS

Capture Rates and Species Richness.—Our sampling effort totaled 2,599 net hrs in spring and 3,764 in autumn. The average spring capture rate of Nearctic-neotropical species ($n = 49$) equaled 53.9 birds/100 net hrs; the average spring capture rate of all species ($n = 63$) equaled 59.5 birds/100 net hrs. Nearctic-neotropical species ($n = 48$) were captured during autumn at an average rate of 37.3 birds/100 net hrs and all species ($n = 70$) were captured at an average rate of 49.8 birds/100 net hrs.

Fat Score and Condition Index.—Condition indices were significantly correlated with fat scores in each species in both seasons (Pearson's product-moment correlation tests, all $P < 0.001$) suggesting that differences in condition indices reflected differences in lipid stores. Fat scores and condition indices were higher in spring than autumn for Black-throated Blue Warbler, Common Yellowthroat, Magnolia Warbler, and Yellow-rumped Warbler (all $P < 0.005$; Table 1). Swainson's Thrushes had higher fat scores in spring than autumn, but showed no seasonal difference in condition indices. Fat scores for Northern Waterthrush did not differ between seasons and condition indices were higher in spring than autumn. Wood Thrush was the only species for which fat scores and condition indices were higher in autumn than spring (Table 1).

Rate of Mass Change.—Linear regressions of wing length on time of day were negative for Yellow-rumped Warbler during spring and autumn (spring: $r^2 = 0.03$, $P = 0.020$; autumn: $r^2 = 0.04$, $P = 0.027$) and Swainson's Thrush during autumn ($r^2 = 0.22$, $P = 0.011$). No other species showed significant interactions between body size and time of day.

The relationship between condition index and time of day was significant in six (all $P < 0.05$), and nearly significant in one ($P = 0.067$) of 16 combinations of species and season. Slopes were positive in six of these seven regressions. During spring, Magnolia Warbler, Black-throated Blue Warbler, Ovenbird, and Northern Waterthrush showed significant mass gains, ranging from 0.99 to 2.46% of mean body mass/hr. Common Yellowthroat gained 1.28%/hr during autumn. Swainson's Thrush in autumn was the only species to lose significant mass (-4.46%/hr; Table 2). Swainson's Thrush was the only species for which spring and autumn mass change rates differed ($F_{1,78} = 8.80$, $P = 0.004$). However, linear regressions were not significant for any species in both seasons, preventing meaningful comparisons of mass change rates among spring and autumn.

DISCUSSION

Fat Score and Condition Index.—Most of the species we examined were heavier and fatter in spring than autumn, similar to another recent study in New York City (Seewagen 2008). These results are consistent with findings in non-urban areas (e.g., King et al. 1963, Winker et al. 1992b, Morris and Glasgow 2001, Dunn 2002, but see Benson and Winker 2005). Greater fat loads during spring are be-

TABLE 1. Seasonal differences in condition indices (mass × 100/wing length, *t*-test) and fat scores (Mann-Whitney *U*-test) of migratory landbirds during stopovers in Bronx Park, New York City, 2004-2006. Values are mean ± SD; fat score medians presented in parentheses.

Species	Season	n	Condition	t	P	Fat score	Z	P
Swainson's Thrush	Spring	53	0.339 ± 0.032	0.7	0.489	2.4 ± 1.3 (2)	2.83	0.005
	Autumn	29	0.334 ± 0.043			1.5 ± 1.6 (1)		
Wood Thrush	Spring	34	0.478 ± 0.029	5.9	<0.001	1.1 ± 0.9 (3)	3.78	<0.001
	Autumn	33	0.540 ± 0.053			2.6 ± 1.6 (1)		
Magnolia Warbler	Spring	28	0.163 ± 0.013	10.3	<0.001	3.5 ± 1.1 (4)	6.42	<0.001
	Autumn	76	0.141 ± 0.009			1.6 ± 1.1 (1)		
Black-throated Blue Warbler	Spring	30	0.175 ± 0.010	7.37	<0.001	3.1 ± 1.4 (3)	4.84	<0.001
	Autumn	62	0.154 ± 0.014			1.3 ± 1.5 (1)		
Yellow-rumped Warbler	Spring	194	0.192 ± 0.015	16.82	<0.001	3.2 ± 1.1 (3)	11.40	<0.001
	Autumn	132	0.165 ± 0.012			1.2 ± 1.2 (1)		
Ovenbird	Spring	110	0.274 ± 0.019	0.59	0.559	2.2 ± 1.2 (2)	1.93	0.054
	Autumn	40	0.271 ± 0.025			1.8 ± 1.7 (1)		
Northern Waterthrush	Spring	138	0.239 ± 0.022	2.3	0.022	2.4 ± 1.4 (2)	1.80	0.072
	Autumn	71	0.231 ± 0.024			2.0 ± 1.5 (2)		
Common Yellowthroat	Spring	128	0.200 ± 0.016	5.66	<0.001	2.9 ± 1.5 (3)	4.92	<0.001
	Autumn	147	0.189 ± 0.015			1.9 ± 1.6 (2)		

TABLE 2. Estimated hourly mass changes of migratory landbirds during stopovers in Bronx Park, New York City, 2004–2006. Mass change rates are based on linear regressions of condition index (mass × 100/wing length) and hours since sunrise at time of capture.

Species	Season	n	Wing (mm)	Mass (g)	r	F	df	P	g/hr	% mean mass/hr
Swainson's Thrush	Spring	53	97	33.1	0.15	1.18	1,51	0.283	0.29	0.87
	Autumn	29	97	32.3	0.43	6.25	1,27	0.019	−1.44	−4.46
Wood Thrush	Spring	34	105	50.1	0.02	0.02	1,32	0.893	−0.05	−0.09
	Autumn	31	105	56.8	0.08	0.53	1,29	0.471	0.50	0.87
Magnolia Warbler	Spring	28	58	9.5	0.51	9.27	1,26	0.005	0.24	2.46
	Autumn	76	59	8.3	0.18	2.53	1,74	0.116	0.07	0.88
Black-throated Blue Warbler	Spring	30	62	10.8	0.39	5.12	1,28	0.032	0.20	1.86
	Autumn	62	63	9.6	0.01	0.00	1,60	0.969	0.00	0.00
Yellow-rumped Warbler	Spring	195	71	13.6	0.08	1.13	1,193	0.288	0.06	0.43
	Autumn	132	70	11.6	0.16	3.40	1,130	0.067	0.14	1.20
Ovenbird	Spring	110	74	20.2	0.24	6.53	1,108	0.012	0.22	1.11
	Autumn	40	74	20.1	0.08	0.26	1,38	0.613	0.12	0.62
Northern Waterthrush	Spring	138	75	17.8	0.17	3.98	1,136	0.048	0.18	0.99
	Autumn	71	75	17.3	0.01	0.01	1,69	0.916	0.02	0.11
Common Yellowthroat	Spring	126	54	10.7	0.00	0.00	1,124	0.967	0.00	0.00
	Autumn	147	54	10.2	0.19	5.54	1,145	0.020	0.13	1.28

TABLE 3. Hourly mass changes of migratory landbirds at urban and non-urban stopover sites. Rates from previous studies are based on linear regressions of body mass or size-corrected body mass on time of day. Some original values from other studies were converted to g/hr or % mass/hr to allow for closer comparison with the results of this study.

Species	Season	Minnesota[a] (g)	Minnesota[b] (g)	Ontario[c] (%)	Ontario[d] (g)	New York State[e] (%)	This study g (%)
Swainson's Thrush	Autumn		0.20	0.21	0.02	0.41	−1.44 (−4.46)
Magnolia Warbler	Spring			0.82		0.41	0.235 (2.46)
Black-throated Blue Warbler	Spring			1.02		0.52	0.20 (1.86)
Ovenbird	Spring	0.11		0.38			0.22 (1.11)
Northern Waterthrush	Spring		0.17				0.18 (0.99)
Common Yellowthroat	Autumn	0.10		1.01	0.00	1.58	0.13 (1.28)

[a] Table 3 in Winker et al. 1992a. Gross Δg/day divided by 12 hrs to convert rate to hourly mass change.
[b] Table 6 in Winker et al. 1992b. Gross Δg/day divided by 12 hrs to convert rate to hourly mass change.
[c] Table 1 in Dunn 2001. Values are expressed as % lean mass. The highest significant rate among the three study sites for each species is presented.
[d] Table 1 in Jones et al. 2002. Rates are presented as the average of the hatching-year and after-hatching year rates.
[e] Table 1 and 2 in Bonter et al. 2007. Values are expressed as % lean mass.

lieved to provide subsequent reproductive benefits upon arrival in breeding areas (Sandberg and Moore 1996, Smith and Moore 2003). The trend we observed may also be a result of autumn migrants not depositing large fat stores until further south of our site (Winker et al. 1992b).

Rate of Mass Change.—The ability to replenish depleted fat stores may be the greatest constraint birds have during migration (Moore et al. 1995), and the rate at which migrants gain mass during stopovers is a commonly used indicator of habitat quality (Dunn 2000, 2001; Bonter et al. 2007). Six of the seven significant or marginally significant interactions between condition and time of day were positive in our study indicating the study site is stopover habitat in which migrants can gain body mass. Moreover, negative relationships were in the minority (2 of 16), and only one was statistically significant. The extreme rate of mass loss predicted by linear regression in Swainson's Thrush during autumn may be a consequence of small sample size and the method's assumption that birds arrive at the site at or prior to dawn on the day of capture (Dunn 2000, Jones et al. 2002). Swainson's Thrushes with extremely high condition indices (and fat scores of 5) were captured shortly after sunrise on two occasions, strongly influencing the slope of the regression line. It is unlikely these individuals just arrived in the study site as the regression method assumes. Additionally, Swainson's Thrush body size during autumn was significantly correlated with time of day, in which case the regression method is likely to produce a misleading estimate (Winker 1995).

Some mass gain rates measured in this study exceed those from less disturbed, non-urban areas (Table 3) and suggest ample resources are available to migrants in Bronx Park. Urban ecosystems often support higher densities of arthropods than non-urban habitats (Kahn and Cornell 1989, Hanks and Denno 1993, reviewed by McIntyre 2000) and, in turn, potentially provide plentiful food sources for insectivorous migrants. Increased densities of arthropods in urban habitats have been attributed to several factors, including warmer microclimates that result from the "urban heat island effect". We speculate that another potential benefit of the urban heat island effect to migrants is a reduction in over-night thermoregulation costs. Warmer temperatures at night in urban habitats might permit greater net energy gains than are possible in cooler non-urban areas (see Wikelski et al. 2003). Migrants at our study site may be advantaged by the relative absence of predators (e.g., small-bodied diurnal raptors; CLS and EJS, pers. obs.) compared to larger, more pristine areas. A lack of predators might allow for uninhibited foraging intensity relative to situations where migrants need to be concerned with predator avoidance (Cimprich et al. 2005). We recommend that future studies of urban stopover ecology investigate these topics in concert with measurements of migrant mass change rates.

City parks often represent the only stopover habitat available to migrants encountering

North America's vast metropolitan areas. It is therefore important to learn whether these areas are providing migrants with resources they need. This study provides evidence of migrants gaining body mass through the morning hours in Bronx Park, suggesting that an urban habitat is serving as a suitable stopover site. It also highlights the need to conserve and properly manage the green spaces remaining within cities along major flyways.

Our findings cannot be generalized across all urban habitats because of great variation in intrinsic characteristics that likely influence site quality. We encourage further research in a diversity of urban areas to more comprehensively understand the stopover ecology of migratory birds in urban habitats.

ACKNOWLEDGMENTS

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