MASS CHANGES AND ENERGETIC CONDITION OF GRASSLAND AND SHRUBLAND SONGBIRDS DURING AUTUMN STOPOVERS AT A RECLAIMED LANDFILL IN THE NEW JERSEY MEADOWLANDS

CHAD L. SEEWAGEN[1,4] AND MICHAEL NEWHOUSE[2,3]

[1]Great Hollow Nature Preserve & Ecological Research Center, 225 State Route 37, New Fairfield, CT 06812, USA

[2]New Jersey Sports and Exposition Authority, 1 DeKorte Park Plaza, Lyndhurst, NJ 07071

[3]Current address: Kleinfelder Inc., 300 Westage Center Drive, Suite 407, Fishkill, NY 12524

[4]Corresponding author; email: cseewagen@greathollow.org

Please send page proofs to the corresponding author at the above e-mail address

ABSTRACT.--- Former landfills have long been recognized as a potential source of early successional habitat for wildlife, but their use by migrating grassland and shrubland songbirds has yet to be studied. We estimated mass change rates of five grassland and shrubland songbird species during autumn stopovers at a reclaimed landfill in New Jersey to assess the quality of a former landfill as a stopover habitat. We also examined minimum length of stay, age ratios, and age differences in body mass and fat scores. Regressions of capture time and body mass were statistically significant and indicated gains of 0.8-1.2% of average body mass/hr in Savannah Sparrows (*Passerculus sandwichensis*), Lincoln's Sparrows (*Melospiza lincolnii*), and Palm Warblers (*Setophaga palmarum*), but coefficients of determination were weak (< 0.06). White-crowned Sparrows (*Zonotrichia leucophrys leucophrys*) and Indigo Buntings (*Passerina cyanea*) did not gain significant mass. Minimum length of stay based upon recaptures ranged from an average of 4.7 d in Savannah Sparrows to 10.1 d in Indigo Buntings. Adults did not have higher mass gain rates, body mass, or fat scores than immature birds in any species, with the exception of adult Savannah Sparrows being heavier than immatures in one year. The age ratio was significantly skewed towards immatures in all species except the Indigo Bunting, in which the opposite pattern occurred. Food availability at our site may have been poor and limited the ability of birds to gain mass, or it is possible that time is not as important of a currency to these species at this stage of their migration as energy minimization and predator avoidance are. Considering the low temporal pressure and slow pace of autumn migration relative to spring, these autumn migrants might be using the landfill for rest, energy maintenance, and predator avoidance more so than rapid and substantial fuel deposition. The independence of mass change rate and energetic condition from age suggests that there were no age differences in dominance or foraging ability in these species that affected their ability to refuel during stopover.
Key words: brownfields, early successional habitat, habitat restoration, migration, refueling.

Many species of birds that inhabit grasslands, shrublands, and other early successional, disturbance-dependent habitats are in steep decline in the northeastern United States, as fire suppression, abandonment of agriculture, and other changing land use patterns over the past century have reduced habitat availability (Norment 2002, Shriver et al. 2005, Sauer and Link 2011). This has prompted a strong response from some agencies and conservation organizations to protect and create new breeding habitat for these species in an effort to reverse population trends (Vickery and Herkert 2001, Norment 2002, Shriver et al. 2005). Much less attention has been paid to meeting the habitat requirements of grassland and shrubland birds during migration, and we also know little to nothing about the stopover biology of the majority of these species. Stopover habitats in which birds can rest and refuel are critical for successful migrations (Mehlman et al. 2005, Kirby et al. 2008). As for other groups of migratory birds (Moore et al. 1995, Mehlman et al. 2005, Kirby et al. 2008, Sheehy et al. 2011), successful conservation of migratory grassland and shrubland bird species will partly depend on the conservation of suitable stopover habitat throughout their migration routes and a sound understanding of the biology and habitat requirements of these species during their migrations.

Restored or naturally revegetated landfills have been advocated as a potential source of habitat for grassland, shrubland, and early successional forest wildlife, particularly in urban and industrial areas where large open spaces are often extremely limited (e.g., Davis 1989, Watson and Hack 2000, Tarrant et al. 2013). However, the ability of reclaimed landfills to support productive and diverse communities of birds or other wildlife has not been well studied (Harrison and Davies 2002, Rahman et al. 2011, Tarrant et al. 2013). We are unaware of any research on the use of reclaimed landfills by migrating birds in particular, and it is unknown whether former landfills can provide migrants with suitable stopover habitat. Our objective was to estimate the mass change rates and stopover durations of autumn migrants at a recently closed landfill to gauge the quality of the site as stopover habitat for grassland and shrubland songbirds and add to what little is known about the stopover biology of these species in general. We also examined age ratios and age differences in body mass and fat scores to investigate whether immature birds significantly outnumbered adults and if adults were in better energetic condition, as is sometimes observed among migrating forest songbirds.

METHODS

Study Site and Data Collection.---We studied birds at the Erie Landfill, an approximately 17.5-hectare former landfill located along the Hackensack River in North Arlington, New Jersey, USA (40° 47' 24.3" N, 74° 06' 57.0" W). The landfill was closed to operations in 2005 and capped in 2006. In the years since, it has naturally become vegetated mostly by non-native plants. Mugwort (*Artemisia vulgaris*) is overwhelmingly dominant in most areas, and other abundant plant species on the site include eastern cottonwood (*Populus deltoids*), black locust (*Robinia pseudoacacia*), common reed (*Phragmites australis*), foxtail grass (*Alopecurus sp.*), and common sunflower (*Helianthus annuus*).

We used 9 mist nets (12 x 2.6 m) to passively capture birds at the site 5 d per wk, weather permitting, from 30 August to 20 November, 2011 to 2013. The nets were opened at sunrise and checked hourly for 8 hr unless weather conditions forced earlier closure. All captured birds were banded with a U.S. Geological Survey aluminum leg band, sexed based on plumage characteristics when possible, assigned to an age class of hatching-year (immature) or after-hatching-year (adult) based on degree of skull pneumatization and/or plumage characteristics when possible (Pyle 1997), measured (unflattened wing length to 1 mm), fat-scored on a 6-point scale (Helms and Drury 1960, Seewagen 2008), weighed to the nearest 0.1 g on a digital balance, and then released.

Statistical Analyses.---We focused our analyses on five songbird species that are associated with grasslands, shrublands, or other open habitats: Savannah Sparrow (*Passerculus sandwichensis*), Lincoln's Sparrow (*Melospiza lincolnii*), White-crowned Sparrow (*Zonotrichia leucophrys leucophrys*), Palm Warbler (*Setophaga palmarum*), and Indigo Bunting (*Passerina cyanea*). These species were chosen also because they are medium- or long-distance migrants (Ammon 1995, Chilton et al. 1995, Payne 2006, Wheelwright and Rising 2008, Wilson 2013), either uncommonly or do not at all nest or overwinter in the area (Fowle and Kerlinger 2001, McGowan and Corwin 2008, Boyle 2011), and were captured in numbers that we considered to be sufficient for our statistical analyses ($n > 50$).

We estimated mass change rates based on the relationship between body mass and time of capture (expressed as hours since sunrise) (Winker et al. 1992, Seewagen et al. 2011, Horton and Morris 2012, Ware et al. 2015). We tested this relationship in each species by first using general linear models (GLMs), with body mass as the dependent variable, time of capture and age as independent variables, and an interaction term between time of capture and age to identify potential age differences in mass change rates (Jones et al. 2002). When the interaction term was significant, we ran separate linear regressions of body mass and time of capture for the two age groups to measure age-specific rates of mass change. Otherwise, or if sample size was small for one or both age groups ($n < 25$), we combined age groups for calculating overall mass change rates. Body mass was adjusted to wing length before all analyses using a scaled mass model (Eq. 2 in Peig and Green 2009) unless a linear regression of these two variables was non-significant (Seewagen et al. 2011, Seewagen and Guglielmo 2011, Holzschuh and Deutschlander 2016).

We estimated minimum length of stay among recaptured birds by subtracting the date of first capture from the date of last capture, while recognizing that the minority of individuals that were recaptured may not have been representative of all birds (Winker et al. 1992), and that initial and final captures may not have occurred on the date of arrival and departure, respectively (Cherry 1982, Yong and Finch 2002). We report this information with the intent to provide only a general indication of whether birds were quickly departing the study site perhaps in search of more natural, less disturbed habitat elsewhere, or remaining onsite for a more extended stopover. We also used time between recaptures to investigate with a Mann-Whitney U-test age differences in minimum length of stay in the Savannah Sparrow, which was the only one of our study species with adequate numbers of recaptures (n = 109) for comparison.

We used chi-square tests to compare the ratio of immature to adult birds in each species and compared fat scores between age groups using Mann-Whitney U-tests (Hailman 1965). Age differences in body mass were determined from the significance of age as an independent variable in the GLM. In the analyses of mass change rates, age ratios, and fat scores, the data were pooled across the three study years for each species except for the Savannah Sparrow, which had an exceptionally large total sample size (n > 1500). Savannah Sparrow was examined in each year independently to reduce statistical power and inflation of the significance of effects. Analyses were performed using SYSTAT v. 12 and results were considered significant when $P \leq 0.05$.

RESULTS

The relationship between body mass and capture time was dependent on age in Palm Warblers ($F_{1,486}$ = 5.62, P = 0.018) but not in Indigo Buntings ($F_{1,120}$ = 1.29, P = 0.26) or in Savannah Sparrows in 2011 ($F_{1,653}$= 2.17, P = 0.14), 2012 ($F_{1,354}$ = 1.35, P = 0.25), or 2013 ($F_{1,528}$ = 2.74, P = 0.10). We did not test for age effects on mass change rate in Lincoln's Sparrows or White-crowned Sparrows because of small sample sizes of adults (n = 21 and 20, respectively).

Immature Palm Warblers showed significant mass gains over time, whereas adults did not (Table 1). Across age groups, Lincoln's Sparrows gained significant mass while there was no evidence of hourly mass changes in Indigo Buntings and White-crowned Sparrows during the 3 yr study period or in Savannah Sparrows in 2011 and 2013 (Table 1). Capture time also explained little variation in body mass in Savannah Sparrows in 2012 ($r^2 = 0.02$) even though the relationship was statistically significant because of the large sample size (Table 1). In groups with a significant relationship between body mass and time of capture, hourly mass change rates ranged from 0.11-0.21 g (Table 1) and represented 0.8-1.2% of their average body mass. However, coefficients of determination were very low in all cases (Table 1).

Excluding same day recaptures, recapture rates ranged from 3.2% in Palm Warblers to 18.5 % in Lincoln's Sparrows. Minimum length of stay averaged the highest in Indigo Buntings and the lowest in Lincoln's Sparrows, and was highly variable among individuals within each species (Table 2). Recaptured immature Savannah Sparrows stayed an average of 0.9 d longer than adults, but the difference was not significant ($U = 1197$, $P = 0.24$).

The age ratio was significantly skewed towards immatures in all species except the Indigo Bunting, in which the opposite pattern occurred (Table 3). Fat scores were generally low, with all species having a median fat score of only 0 or 1, and they did not differ between immatures and adults in any species (Table 4). Body mass also did not differ between age groups in any species with the exception of Savannah Sparrows in 2013, when adult birds were significantly heavier than immatures (Table 4).

DISCUSSION

The stopover biology of grassland and shrubland songbirds is poorly understood relative to that of forest songbirds, and we are unaware of any previous study of grassland and shrubland bird usage of a former landfill as stopover habitat. Here, among five species of songbirds that are associated with grasslands, shrublands, or other open habitats, we found little evidence of diurnal mass gains at our reclaimed landfill study site. We also found no indication that stopover refueling ability or energetic condition were superior in adults, unlike what is sometimes observed in forest songbirds during autumn migration (Woodrey 2000). Food availability may have been poor at the site and constrained the ability of birds to gain mass, or it is possible that time may not be an important currency to these species at this stage of their migration relative to energy minimization and predator avoidance (*sensu* Alerstam and Lindström 1990, Hedenström 2008).

The rate at which birds recover body mass has been used as an indicator of absolute stopover habitat quality (e.g., Seewagen and Slayton 2008, Craves et al. 2009), but this generally assumes that migrants are operating under a time minimization strategy that favors refueling at or near the maximum rate allowed by the conditions at the site. Optimal migration theory posits that birds may use alternate strategies in which the minimization of energy expenditure and predation risk are prioritized over the minimization of time taken to reach their destination (Hedenström 2008). These alternate strategies are likely to be common during autumn when selection pressures for, and the benefits of, early arrival at the destination are lesser than those experienced by migrants during spring (Schmaljohann et al. 2012, Nilsson et al. 2013). The lower pressure for time minimization during autumn manifests in a slower pace of migration than during spring (McKinnon et al. 2013), including less rapid and extensive refueling (Seewagen et al. 2013). We therefore cannot conclude that because we did not detect mass gains in most cases, the reclaimed landfill offers poor conditions for refueling. It is equally possible that the birds we studied are using the landfill site during autumn for rest, energy maintenance, and predator avoidance more so than rapid and substantial fuel deposition.

In cases where we did find a relationship between body mass and time of day, the rates of mass gain were comparable to, and often higher than, the few reports of spring or autumn mass changes by these species in more natural habitats. For example, the 1.1% of average total body mass per hour gained among immature Palm Warblers at the Erie Landfill is similar to the 0.6-1.3% of average lean body mass gained per hour during autumn stopovers at three sites along Long Point, Ontario, Canada (Dunn 2001) and the 0.99% of average lean body mass gained per hour during spring stopovers along Braddock Bay, New York (Bonter et al. 2007). Lincoln's Sparrows, which gained 1.2% of average total body mass per hour at the Erie Landfill, gained 0.3-1.1% of average lean body mass per hour during autumn stopovers at multiple sites across Canada (Dunn 2002) while showing no significant hourly changes in mass along Braddock Bay, New York during spring (Bonter et al. 2007) or in central New Mexico during spring or autumn (Yong and Finch 2002). Savannah Sparrows, which gained 0.8% of average total body mass per hour at the Erie Landfill in 2012 also showed no significant hourly changes in mass during spring or autumn stopovers in central New Mexico (Yong and Finch 2002).

More than 10 percent of Indigo Buntings, Lincoln's Sparrows, and White-crowned Sparrows were recaptured during their stopovers at the Erie Landfill, often multiple days after their initial capture. Minimum length of stay also averaged several days in Palm Warblers and Savannah Sparrows, although the lower recapture rates in these species question the extent to which the behavior of the recaptured individuals was representative of that of the many more birds that were captured only once. Nevertheless, we documented many birds using the landfill for extended stopovers, possibly indicating that the site was meeting their resource requirements. The minimum length of stay of White-crowned Sparrows averaged higher at the Erie Landfill than at a site in rural Maine during spring and autumn (Cherry 1982), but much lower than along the Rio Grande in central New Mexico (spring and autumn combined; Yong and Finch 2002).

Minimum length of stay in Savannah Sparrows and Lincoln's Sparrows was also much shorter at the Erie Landfill than in central New Mexico (Yong and Finch 2002), but comparisons may not be appropriate because of the distinctiveness of, and differences between, eastern and western North American migration systems (Kelly and Hutto 2005). We are not aware of any other reports of autumn stopover durations of our study species in eastern North America.

Among forest songbirds, immature birds can be socially subordinate to adults and sometimes show poorer foraging ability, poorer food selection, and less efficient nutrient assimilation (Hume and Biebach 1996, Woodrey 2000, Moore et al. 2003). Immatures of these species are consequently found to sometimes have smaller fuel loads and longer stopovers during migration (Woodrey 2000, Morris et al. 1996, Moore et al. 2003, Mackenzie 2010), yet it is rarely demonstrated that adults actually refuel at a faster rate (see Seewagen et al. 2013 for discussion). Here too, among five species of birds that are associated with grassland and shrubland habitats, we did not find any evidence of greater refueling performance by adults than immatures. We also found no difference between adults and immatures in the size of their fat stores or their body mass (with the exception of Savannah Sparrows in one of the three study years), and we found no age difference in minimum stopover duration in the one species we were able to investigate. This may mean that by the start of their autumn migration, there are no longer any age differences in dominance or foraging ability in our study species that would affect their ability to refuel during stopover. Indeed, Wheelwright and Templeton (2003) found that immature Savannah Sparrows are less efficient foragers than adults during the post-fledging period, but are able to forage as well as adults by the time they depart on autumn migration.

The immature-skewed age ratio that we observed in four out of our five study species is consistent with what is often found among forest songbird migrants at autumn stopover sites (Robbins et al. 1959, Murray 1966, Ralph 1981, Morris et al. 1996). In coastal areas (such as our site) this has been suggested to be the result of immatures migrating closer to coasts than adults (Ralph 1981). However, age ratios among migrating forest songbirds can be just as heavily skewed towards immatures in inland areas (Dunn and Nol 1980, Rimmer and McFarland 2000, Mills 2016). Based on known fecundity and survival rates of migratory forest songbirds, Mills (2016) found the proportion of immature birds captured at autumn migration banding stations to be too implausibly high to be an indication of true population age structure, and suggested instead that it was an artifact of sampling biases. This may also hold true for shrubland and grassland songbirds; at our study site, longer stopovers or other attributes of immature birds may have made them more likely to be captured than adults (Mills 2016) and partly accounted for the skewed age ratios among our study species.

In conclusion, we found a recently reclaimed landfill being used by an abundance of grassland and shrubland songbirds in a heavily urbanized and industrialized region where alternative stopover habitat for these species is limited. Although we did not observe strong trends of increasing body mass during the morning hours, there was no evidence to suggest that the landfill we studied is an energy sink where birds lose mass. Former landfills, mining fields, and other such areas that have been reclaimed following human disturbances have the potential to provide an important source of habitat for rest and energy maintenance for these species during migration, as other sources of open, early successional habitats continue to decline. However, additional research on the stopover biology of grassland and shrubland bird species at a variety of reclamation sites and in multiple geographic regions will be needed to comprehensively understand the value of reclaimed landfills as stopover habitat for these declining groups of birds. In addition, a commitment by landowners to maintain such sites in an early successional stage is required for the sites to be able to provide appropriate habitat for these species over long time periods.

ACKNOWLEDGMENTS

We thank E.Weiner and the many students and volunteers from Ramapo College of New Jersey who assisted us with this project. Special thanks to C. Tackacs, M. Ratajczak, A. Totha, B. D'Amato, M. Cavanaugh, S. Apgar, G. Bennett-Meany, R. Duffy, E. Duffy, Z. Batren, H. Ellerbusch, D. Fariello, L. Haag, R. Hergenrother, A. Iverson, H. Kopsco, D. McQuaid, E. Mueller, J. Rondon, K. Ruskin, O. Stringham, and N. Bass for their help in the field. Funding was provided by the New Jersey Sports and Exposition Authority (formerly known as the New Jersey Meadowlands Commission). All field work was conducted under USGS master banding permit #23561 (to MN).

LITERATURE CITED

Alerstam, T. and Å Lindström. 1990. Optimal bird migration: the relative importance of time, energy, and safety. Pages 331-351 *in* Bird migration (E. Gwinner, Editor). Springer-Verlag, Berlin, Germany.

Ammon, E. M. 1995. Lincoln's Sparrow (*Melospiza lincolnii*). The birds of North America online. Number 191.

Bonter, D. N., T. M. Donovan, and E. W. Brooks. 2007. Daily mass changes in landbirds during migration stopover on the south shore of Lake Ontario. Auk 124:122-133.

Boyle Jr., W. J. 2011. The birds of New Jersey: status and distribution. Princeton University Press, Princeton, USA.

Chilton, G., M. C. Baker, C. D. Barrentine, and M. A. Cunningham. 1995. White-crowned Sparrow (*Zonotrichia leucophrys*). The birds of North America online. Number 183.

Craves, J. A. 2009. A fifteen-year study of fall stopover patterns of *Catharus* thrushes at an inland, urban site. Wilson Journal of Ornithology 121:112-118.

Davis, B. N. K. 1989. Habitat recreation for butterflies on a landfill site. Entomologist 108:109 122.

Dunn, E. H., and E. Nol. 1980. Age-related migratory behavior of warblers. Journal of Field Ornithology 51:254-269.

Dunn, E. H. 2000. Temporal and spatial patterns in daily mass gain of Magnolia Warblers during migratory stopover. Auk 117:12–21.

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

Dunn, E. H. 2002. A cross-Canada comparison of mass change in birds during migration stopover. Wilson Bulletin 114:368–379.

Fowle, M. and P. Kerlinger. 2001. The New York City Audubon guide to finding birds in the metropolitan area. Cornell University Press, Ithaca, USA.

Hailman, J. P. 1965. Notes on quantitative treatments of subcutaneous lipid data. Bird Banding 36:14– 20.

Harrison, C. and G. Davies. 2002. Conserving biodiversity that matters: practitioners' perspectives on brownfield development and urban nature conservation in London. Journal of Environmental Management 65:95-108.

Hedenström, A. 2008. Adaptations to migration in birds: behavioural strategies, morphology and scaling effects. Philosophical Transactions of the Royal Society of London B 36:287-299.

Helms, C.W . and W. H. Drury.1960. Winter and migratory weight and fat: field studies on some North American buntings. Bird Banding 31:1-40.

Holzschuh, J. A. and M. E. Deutschlander. 2016. Do migratory warblers carry excess fuel reserves during migration for insurance or for breeding purposes? Auk 133: 459-469.

Horton, K. G. and S. R. Morris. 2012. Estimating mass change of migrant songbirds during

stopover: comparison of three different methods. Journal of Field Ornithology 83:412-419.
Hume, I. D. and H. Biebach. 1996. Digestive tract function in the long distance migratory garden warbler, *Sylvia borin*. Journal of Comparative Physiology B 166:388–395.
Jones, J., C. M. Francis, M. Drew, S. Fuller, and M. W. S. Ng. 2002. Age-related differences in body mass and rates of mass gain of passerines during autumn migratory stopover. Condor 104:49-58.
Kelly, J. F. and R. L. Hutto. 2005. An east-west comparison of migration in North American wood warblers. Condor 107:197-211.
Kirby, J. S., A. J. Stattersfield, S. H. Butchart, M. I. Evans, R. F. Grimmett, V. R. Jones, J. O'Sullivan, G. M. Tucker, and I. Newton. 2008. Key conservation issues for migratory land- and waterbird species on the world's major flyways. Bird Conservation International 18:S49-73.
Mackenzie, S. A. 2010. A scale dependent examination of stopover decisions in migratory passerines at Long Point, Ontario. Thesis. University of Western Ontario, London, Canada.
McGowan, K. J. and K. Corwin.. 2008. The second atlas of breeding birds in New York State. Cornell University Press, Ithaca, USA.
McKinnon McKinnon, E. A., K. C. Fraser, and B. J. Stutchbury. 2013. New discoveries in landbird migration using geolocators, and a flight plan for the future. Auk 130:211-222.
Mills, A. M. 2016. Banding data reveal bias in age-class sampling of songbirds during spring migration. Journal of Field Ornithology 87:323-36.
Mehlman, D. W., S. E. Mabey, D. N. Ewert, C. Duncan, B. Abel, D. Cimprich, R. D. Sutter, and

M. Woodrey. 2005. Conserving stopover sites for forest-dwelling migratory landbirds. Auk 122:1281–1290.

Moore, F. R., S. A. Gauthreaux, P. Kerlinger, and T. R. Simons. 1995. Habitat requirements during migration: important link in conservation. Pages 121-144 *in* Ecology and management of neotropical migratory birds: a synthesis and review of critical issues (T. E. Martin and D. M. Finch, Editors). Oxford University Press, New York, USA.

Moore F. R., S. Mabey, and M. Woodrey. 2003. Priority access to food in migratory birds: age, sex, and motivational asymmetries. Pages 281-292 *in* Avian migration (P. Berthold, E. Gwinner, and E. Sonnenschein, Editors). Springer-Verlag, Berlin, Germany.

Morris, S. R., D. W. Holmes, and M. E. Richmond. 1996. A ten year study of the stopover patterns of migratory passerines during fall migration on Appledore Island, Maine. Condor 98:395-408.

Murray, B. G., Jr. 1966. Migration of age and sex classes of passerines on the Atlantic coast in Autumn. Auk 83:352-360.

Nilsson, C., R. H. Klaassen, and T. Alerstam. 2013. Differences in speed and duration of bird migration between spring and autumn. American Naturalist 181:837-845.

Norment, C. 2002. On grassland bird conservation in the Northeast. Auk 119:271-279.

Payne, R. B. 2006. Indigo Bunting (*Passerina cyanea*). The birds of North America online. Number 4.

Peig J. and A. J. Green. 2009. New perspectives for estimating body condition from mass/length data: the scaled index as an alternative method. Oikos 118:1883–1891.

Pyle, P. 1997. Identification guide to North American birds. Part 1. Slate Creek Press, Bolinas, USA.

Rahman, M. L., S. Tarrant, D. McCollin, and J. Ollerton. 2011. The conservation value of restored landfill sites in the East Midlands, UK for supporting bird communities. Biodiversity and Conservation 20:1879-1893.

Ralph, C. J. 1981. Age ratios and their possible use in determining autumn routes of passerine migrants. Wilson Bulletin 93:164-188.

Rimmer, C. C. and K. P. McFarland. 2000. Migrant stopover and postfledgling dispersal at a montane forest site in Vermont. Wilson Bulletin 112:124-136.

Robbins, C. S., D. Bridge, and R. Feller. 1959. Relative abundance of adult male redstarts at an inland and a coastal locality during fall migration. Maryland Birdlife 15:23-25.

Sauer, J. R. and W. A. Link. 2011. Analysis of the North American breeding bird survey using hierarchical models. Auk 128: 87-98.

Schmaljohann, H., J. W. Fox, and F. Bairlein. 2012. Phenotypic response to environmental cues, orientation and migration costs in songbirds flying halfway around the world. Animal Behavior 84:623-640.

Seewagen, C. L. 2008. An evaluation of condition indices and predictive models for non-invasive estimates of lipid mass of migrating Common Yellowthroats, Ovenbirds, and Swainson's Thrushes. Journal of Field Ornithology 79:80-86.

Seewagen, C. L. and E. J. Slayton. 2008. Mass changes of migratory landbirds during stopovers in a New York City park. Wilson Journal of Ornithology 120:296-303.

Seewagen, C. L., and C. G. Guglielmo. 2011. Quantitative magnetic resonance analysis and a morphometric predictive model reveal lean body mass changes in migrating Nearctic-Neotropical passerines. Journal of Comparative Physiology B 181:413-421.

Seewagen, C. L., E. J. Slayton, C. D. Sheppard, and C. G. Guglielmo. 2011. Plasma metabolites and mass changes of migratory landbirds indicate adequate stopover refueling in a heavily urbanized landscape. Condor 113:284-297.

Seewagen, C. L., C. G. Guglielmo, and Y. E. Morbey. 2013. Stopover refueling rate underlies protandry and seasonal variation in migration timing of songbirds. Behavioral Ecology 24:634-642.

Sheehy, J., C. M. Taylor, and D. R. Norris. 2011. The importance of stopover habitat for developing effective conservation strategies for migratory animals. Journal of Ornithology 152:161-8.

Shriver, G. W., A. L. Jones, P. D. Vickery, A. Weik, and J. Wells. 2005. The distribution and abundance of obligate grassland birds breeding in New England and New York. USDA, Forest Service, Gen. Tech. Rep. PSW-GTR-191. Pacific Southwest Research Station, Albany, California, USA.

Tarrant, S., J. Ollerton, M. L. Rahman, J. Tarrant, and D. McCollin. 2013. Grassland restoration on landfill sites in the East Midlands, United Kingdom: an evaluation of floral resources and pollinating insects. Restoration Ecology 21:560-8.

Ware, H. E., C. J. McClure, J. D. Carlisle, and J. R. Barber. 2015. A phantom road experiment reveals traffic noise is an invisible source of habitat degradation. Proceedings of the National Academy of Sciences 112:12105-12109.

Watson, D. and V. Hack. 2000. Wildlife management and habitat creation on landfill sites: a manual of best practice. Ecoscope Applied Ecologists, London, UK.

Wheelwright, N. T. and J. J. Templeton. 2003. Development of foraging skills and the transition to independence in juvenile savannah sparrows. Condor 105:279–287.

Wheelwright, N. T., and J. D. Rising. 2008. Savannah Sparrow (*Passerculus sandwichensis*). The birds of North America online. Number 45.

Wilson, Jr., W.H. 2013. Palm Warbler (*Setophaga palmarum*). The birds of North America online. Number 238.

Winker, K., D. W. Warner, and A. R. Weisbrod. 1992. Daily mass gains among woodland migrants at an inland stopover site. Auk 109:853-862.

Woodrey, M. 2000. Age-dependent aspects of stopover biology of passerine migrants. Studies in Avian Biology 20:43-52.

Vickery, P. D., and J. R. Herkert. 2001. Recent advances in grassland bird research: where do we go from here? Auk 118:11-15.

Yong, W. and D. Finch. 2002. Stopover ecology of landbirds migrating along the middle Rio Grande in spring and fall. USDA Forest Service General Technical Report RMRS-GTR-99.

TABLE 1. Hourly mass change rates (± SE) of songbirds during autumn stopovers at a reclaimed landfill in the New Jersey Meadowlands, 2011-2013.

Species	Year	Age	*n*	r^2	*P*	g/hr
Palm Warbler	2011-2013	Immature	264	0.050	<0.001	0.11 ± 0.03
		Adult	226	0.001	0.73	
Indigo Bunting	2011-2013	All	124	<0.0001	0.83	
Lincoln's Sparrow	2011-2013	All	91	0.048	0.036	0.21 ± 0.01
White-crowned Sparrow	2011-2013	All	132	0.020	0.12	
Savannah Sparrow	2011	All	656	0.004	0.10	
	2012	All	357	0.021	0.006	0.14 ± 0.05
	2013	All	531	<0.0001	0.95	

TABLE 2. Recapture rates, length of stay (mean ± SD), and maximum time span between initial and final captures of songbirds stopping over at a reclaimed landfill in the New Jersey Meadowlands, 2011-2013.

Species	Rate (%)	Length of Stay (d)	Maximum (d)
Palm Warbler	3.2	4.8 ± 4.0	14
Indigo Bunting	12.7	10.1 ± 9.6	29
Lincoln's Sparrow	18.5	4.7 ± 4.3	16
White-crowned Sparrow	11.4	5.7 ± 4.9	14
Savannah Sparrow	7.0	7.3 ±5.2	28

TABLE 3. Age distribution of songbirds captured during autumn stopovers at a reclaimed landfill in the New Jersey Meadowlands, 2011-2013.

Species	Year	Immature	Adult	% Immature	X^2	*P*
Palm Warbler	2011-2013	273	229	54.4	3.9	0.050
Indigo Bunting	2011-2013	31	94	24.8	31.8	<0.0001
Lincoln's Sparrow	2011-2013	71	21	77.2	27.2	<0.0001
White-crowned Sparrow	2011-2013	112	20	84.5	64.1	<0.0001
Savannah Sparrow	2011	453	204	69.0	94.4	<0.0001
	2012	190	168	53.1	1.4	0.25
	2013	360	172	67.7	66.4	<0.0001

TABLE 4. Mean body mass (± SD) and median fat scores of immature and adult songbirds during autumn stopovers at a reclaimed landfill in the New Jersey Meadowlands, 2011-2013.

		Fat score				Body mass			
Species	Year	Immature	Adult	*U*	*P*	Immature	Adult	*F*	*P*
Palm Warbler	2011-2013	1	1	30730	0.85	10.2 ± 0.8	10.1 ± 0.7	1.4	0.25
Indigo Bunting	2011-2013	1	0	1208	0.24	15.8 ± 2.0	15.5 ± 2.4	1.8	0.18
Lincoln's Sparrow	2011-2013	1	1	729	0.88	17.2 ± 1.3	18.0 ± 2.0	0.3	0.57
White-crowned Sparrow	2011-2013	1	1	909	0.18	26.7 ± 2.0	27.1 ± 2.2	0.4	0.52
Savannah Sparrow	2011	0	1	45183	0.58	17.9 ± 1.4	18.1 ± 1.5	1.0	0.32
	2012	0	0	15948	0.89	17.3 ± 3.6	17.7 ± 2.1	0.1	0.76
	2013	0	0	30108	0.67	17.6 ± 1.4	18.0 ± 1.6	9.0	0.003