PROGRESS REPORT FOR GRANT AGREEMENT WRCP-05109,

USE OF FORESTED AND UPLAND SHRUB/SCRUB HABITATS BY SPRING MIGRATING LANDBIRDS IN NORTHEASTERN PENNSYLVANIA

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28 AUGUST 2006

Introduction

Long-term data sets reveal population declines in many landbird migrant[1] species (Askins, Lynch & Greenberg, 1990; Robbins *et al.*, 1989). Declines are especially evident in shrub-nesting species – records from banding stations and bird observatories during migration demonstrate significant declines in many species of shrubland birds (Askins, 1999). Moreover, transitional shrub/scrub habitats are becoming scarce, reducing breeding habitat for these species (Askins 1999). In Pennsylvania < 5% of habitats are scrub/shrub (Pennsylvania GAP Analysis Project). Because migrating landbirds likely reference innate information about breeding habitat when making decisions about habitat use during migration, i.e., migrants occupy habitats *en route* that are similar to the breeding season (Moore & Aborn, 2000), the persistence of shrub-scrub habitats may be critical for these species during passage.

Although the debate over causes of these population declines continues, attention has mainly focused on events associated with the breeding and wintering phases of the annual cycle (Sherry & Holmes, 1995). As a consequence, the importance of stopover habitat has been overlooked in the development of conservation strategies (Hutto, 2000; Moore et al., 1995). There is a critical need for basic information describing the ecology of migrants during passage, including what types of habitat are important, where those habitats occur, what makes them important, and how their distribution and abundance are changing as a result of development and land conversion (Moore et al., 1995). Further, we know little about migrant-habitat relations, especially with respect to habitat use and the consequences of that use at inland, non-forested stopover sites. If persistence of migrant populations depends on locating favorable conditions throughout the annual cycle, factors associated with *en route* ecology of migrants must figure prominently in any analysis of population change and in the development of a comprehensive conservation plan for migrant species. Unless habitat requirements during migration are met, conservation measures focused on temperate breeding grounds and/or neotropical wintering areas will be compromised.

The purpose of this study is to assess the importance of forested and upland shrub/scrub habitat to spring migrating landbirds by understanding 1) spatial (forested vs. shrub/scrub) and temporal variation in resource (invertebrate) abundance, 2) migrant use of forested vs. shrub/scrub habitat during stopover, and 3) the fitness consequences associated with using each habitat during stopover. This work is identifying habitat and habitat elements important to landbirds migrating through northeastern Pennsylvania. These findings will enable more accurate recommendations with respect to land acquisition and habitat management practices, providing managers with a better idea of where to focus conservation efforts for landbird migrants. The ultimate goal of this work is to combine results with those from other studies examining migrant-habitat relations in an effort to identify and protect a network of stopover sites for landbird migrants in eastern North America (Duncan *et al.*, 2005).

[1] Long-distance migrants are those species that winter predominately in Mexico, Central or South America or islands in the Caribbean. Short-distance migrants winter predominately in the southeastern United States, and Residents are birds that spend the winter in N.E. Pennsylvania.

Methods

Data on bird-habitat relations are collected simultaneously from forested and upland shrub/scrub habitats. Fieldwork takes place in Lackawanna State Park and private lands (hereafter referred to as the Bushko site) immediately adjacent to the park, Lackawanna County, northeastern Pennsylvania (Figure 1). Forested habitats are dominated by red maple (*Acer rubrum*) and red oak (*Quercus rubrum*), with sugar maple (*Acer saccharum*) ash (*Fraxinus* spp.), yellow birch (*Betula alleghaniensis*), pin cherry (*Prunus pennsylvanica*), elm (*Ulmus* spp.), American beech (*Fagus grandifolia*) and eastern hemlock (*Tsuga canadensis*) appearing throughout. Upland shrub/scrub habitat chosen for this work is approximately 20-25 years post agriculture, consisting principally of viburnum (*Viburnum* spp.), blueberry (*Vaccinium* spp.), dogwood (*Cornus* spp.), Tartarian honeysuckle (*Lonicera tartaria*), multifloral rose (*Rosa multiflora*) and hawthorn (*Crataegus* spp.) Data collection efforts for the 2006 field season ran from 17 April through 17 June.

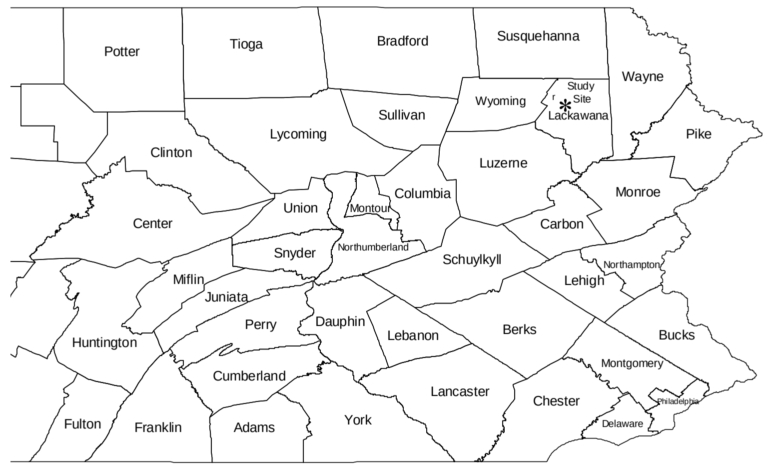

Figure 1. Study sites are in Northeastern Pennsylvania, Lackawanna County. The asterisk indicates approximate study location.

Invertebrate Sampling. Invertebrate sampling is designed to track the spatial and temporal pattern of arthropod abundance. These results will be combined with data describing foraging behavior and fat deposition to evaluate what invertebrates are present and how those invertebrates influence habitat use and ultimately fitness. All invertebrate sampling takes place within the two netting locations (the Bushko site or the Lackawanna State Park site). I use two sampling strategies - one targeted at flying invertebrates and one targeted at non-flying invertebrates. To assess flying arthropod abundance, I placed Malaise traps at 4 permanent sampling locations, 2 in each habitat type at the Bushko site and 2 in each habitat at the Lackawanna State Park site. Traps were cleared of invertebrates every 3 days.

I also had my field crew collect grab samples of each common tree/shrub species to estimate relative abundance of foliage (non-flying) invertebrates in both habitats (Cooper & Whitmore, 1990). Samples were collected from each common tree/shrub species at 9 randomly chosen locations every 6 days. Samples were collected by placing a bag over a branch, sealing the bag, clipping the branch, and fumigating the contents. All invertebrates will be sorted to taxonomic Order and size during the fall semester by undergraduates participating in the Faculty/Student Research Program at The University of Scranton. Invertebrates will be weighed to derive biomass estimates of the standing crop. Clipped branches will also be weighed and the results reported as milligrams invertebrate biomass per 100 grams of foliage.

Bird Census. Counting birds within a habitat is a common way evaluate habitat use (e.g., Moore & Kerlinger, 1987; Wilson & Twedt, 2003). Migrants were counted daily using strip transects, a widespread census technique that ensures results will be compatible with other studies.

Transects range from 200 - 300 meters in length. Censusing consists of slowly walking the transect line and recording species, number and sex for all birds heard or seen within 25 meters of either side of the line. During the 2006 field season we recorded birds on 24 transects, censusing each transect an average 9 times.

Mist-netting. Capturing birds permits evaluation of energetic condition, providing insight into the fitness consequences of using each habitat type and the overall quality of each habitat. I ran 2 banding sites, capturing (and recapturing) migrants using mist-nets checked at 30 minute intervals. Spatial replication of banding data within a study is rare even as replication increases the validity of conclusions drawn from results (Martin & Bateson, 1993). One site was located within Lackawanna State Park and the other site was located on private property immediately adjacent to the park. Straight-line distance between the two sites is 3.2 km. Forest (n = 22) and shrub (n = 25) nets were opened and closed at approximately the same time. Forest nets included a series of ‘high’ nets that were elevated into the canopy. Canopy nets were used in forested habitats to maximize capture probability and increase validity of comparisons between the two habitat types.

For each individual captured the following information was recorded: capture date and time, species, age and sex where possible (Pyle, 1997), mass and tarsus length. Subcutaneous fat (energy store) was quantified using the system developed by The Institute for Bird Populations Monitoring Avian Productivity and Survivorship program (MAPS; DeSante et al., 2003). All captured birds were banded with a USFWS aluminum leg band. Focal species (see below, Foraging Behavior) known to breed in northeastern Pennsylvania were fitted with a unique color band combination. Resights of colorbands during the breeding season permit differentiation of migrants from birds arriving to breed (Smith, 2003). Birds were sexed and aged according to characteristics outlined in Pyle (1997). All recaptured birds were measured as above without reference to previous records.

Foraging Behavior. Foraging behavior reflects both habitat quality and how migrants use habitat. For instance, birds forage at higher rates and selectively forage in particular plant species in response to increased food abundance (Smith, 2003). Observations were conducted on selected focal species including: Ruby-crowned Kinglet (*Regulus calendula*), Yellow-rumped Warbler (*Dendroica coronata*), Blackpoll Warbler (*Dendroica striata*), Common Yellowthroat (*Geothlypis trichas*), Yellow Warbler (*Dendroica petechia*) and Red-eyed Vireo (*Vireo olivaceus*). Foraging movements, attack rates and maneuvers along with microhabitat use were recorded for each observation.

Results/Discussion

Invertebrate Sampling – Malaise Traps. We collected 68 samples from Malaise traps placed in forested and shrub/scrub habitats during the 2006 field season. Because these samples are currently being processed, I am reporting results of samples collected in 2005.

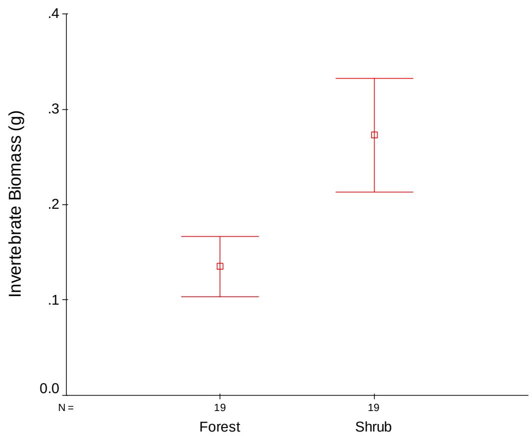

Figure 2. Comparison of invertebrate biomass between forested and shrub/scrub habitats, as estimated by Malaise Trap sampling, northeastern Pennsylvania, 2005. The Y axis indicates grams of invertebrate biomass captured per 100 hours trap time. Whiskers represent +/- 1 standard error.

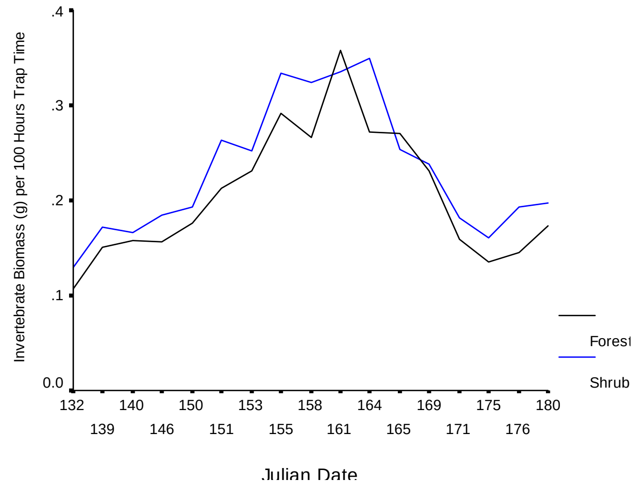

Figure 3. Spatial and temporal distribution of invertebrate abundance, as estimated by Malaise Trap sampling, northeastern Pennsylvania, 2005. Time series data were smoothed by calculating a moving average with a 5 day span . The Y axis indicates grams of invertebrate biomass captured per 100 hours trap time. Julian Day 132 = 12 May, Julian Day 158 = 7 June.

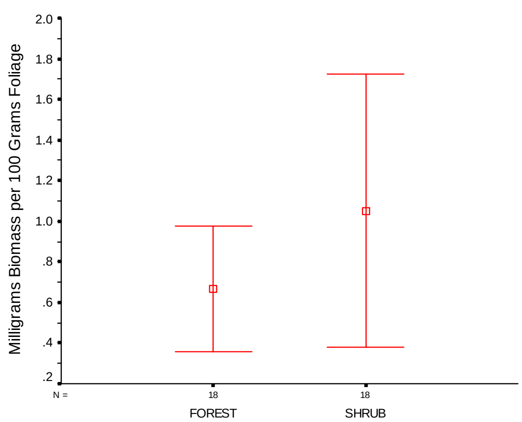

Figure 4. Comparison of invertebrate biomass between forested and shrub/scrub habitats, as estimated by grab sampling, northeastern Pennsylvania, 2005. Whiskers represent +/- 1 standard error.

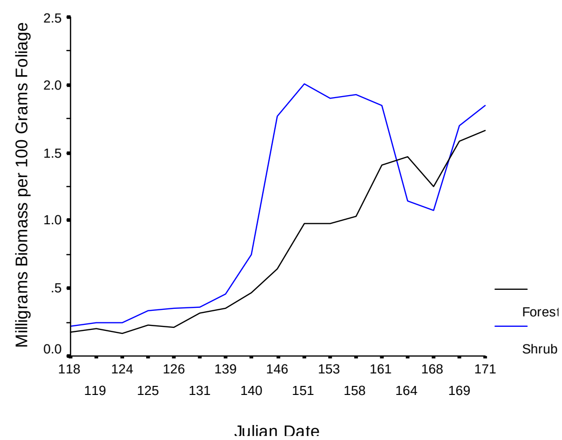

Figure 5. Spatial and temporal distribution of invertebrate abundance, as estimated by grab sampling, northeastern Pennsylvania, 2005. Time series data were smoothed by calculating a moving average with a 5 day span. Julian Day 118 = 28 April, Julian Day 146 = 26 May.

There was no difference between study sites in biomass estimates derived from Malaise sampling (Mann-Whitney *Z* = -0.029, Bushko n = 18; Lackawanna n = 20, P = 0.988) so I have pooled across study sites for the following analyses. A General Linear Model (GLM) on ranks indicated that there was more invertebrate biomass available to migrant landbirds in shrub/scrub habitat than forested habitat (*t* = 3.118. df = 36, *P* = 0.004) during spring migration

Table 1. Results of a GLM on ranked data examining the influence of habitat type (shrub vs. forested habitat) and sampling date on invertebrate biomass as estimated by Malaise trap sampling, northeastern Pennsylvania, spring migration 2005.

Source	Type III sum of Squares	df	*F*	*P*
Habitat Type	1589.064	1	35.316	**0.027**
Date	2018.750	117	2.624	0.311
Habitat Type*Date	931.803	17	1.211	0.545
Error	90.500	2		
Total	19019.000	38		

(Table 1, Figure 2). Further, shrub habitat consistently yielded more biomass through the course of the field season (Figure 3).

Invertebrate Sampling – Grab Sampling. My field crew collected over 150 grab samples through the course of the 2006 field season. Invertebrates were collected from these samples and preserved in alcohol. Under my supervision University of Scranton undergraduates have begun to identify and quantify these invertebrates, and will continue to do so through the fall 2006 semester. Consequently I cannot yet report on these results.

Samples collected during the 2005 field season have, however, been processed. Preliminary results generally seem to pattern those found in the Malaise Trap sampling, though the effects of the overall comparison (forest vs. shrub) are not as clean ($t = 1.237$, df = 30, $P = 0.23$; compare Figure 2 to Figure 4). A more detailed look at these data is required to determine if there are differences by habitat within particular taxonomic Order and to determine if different sampling methodologies are comparable. For instance, Malaise Traps sample the flying arthropod fauna whereas grab samples predominately sample substrate bound arthropods. There may or may not be correlations between flying and nonflying invertebrate abundance.

Census. In 2005 we placed and georeferenced 24 census transects, with 13 in forested habitat and 11 in shrub/scrub habitat. Most transects (15) are located within Lackawanna State Park. Logistics associated with transect placement in 2005 prevented us from sampling until later in the migratory period. Regardless, we sampled shrub habitat a total of 70 times and forested habitat 76 times. Results of the 2005 census effort indicated more long-distance migrants ($t = 5.971$, df = 144, $P < 0.001$) and short-distance ($t = 1.943$, df = 85, $P = 0.05$) were detected in scrub/shrub than forested habitat (Figure 6). There was no difference in habitat use by resident species ($t = 1.466$, df = 144, $P = 0.145$).

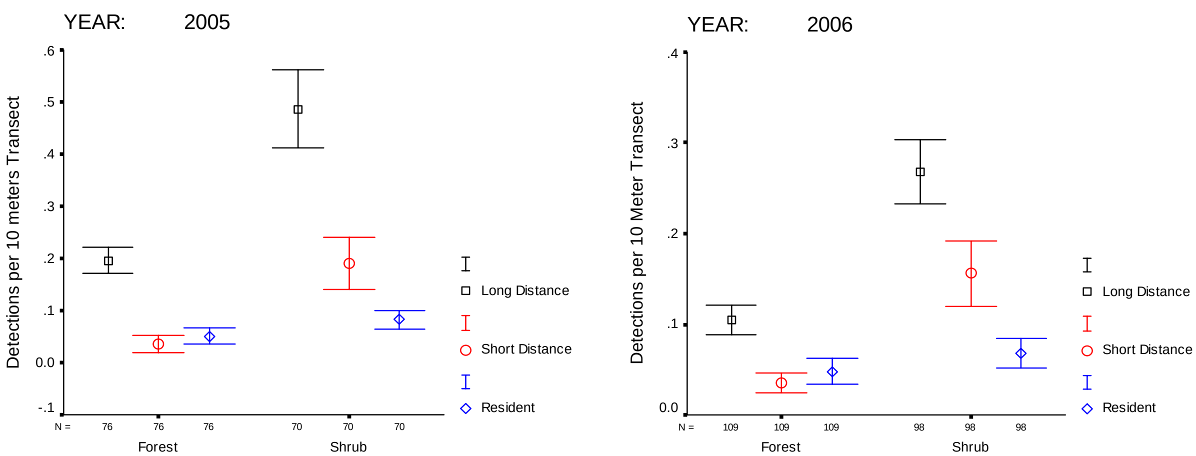

Figure 6. Habitat use by migrant and resident landbird species as determined by transect census, spring migration 2005 and 2006. Whiskers represent +/- 1 standard error.

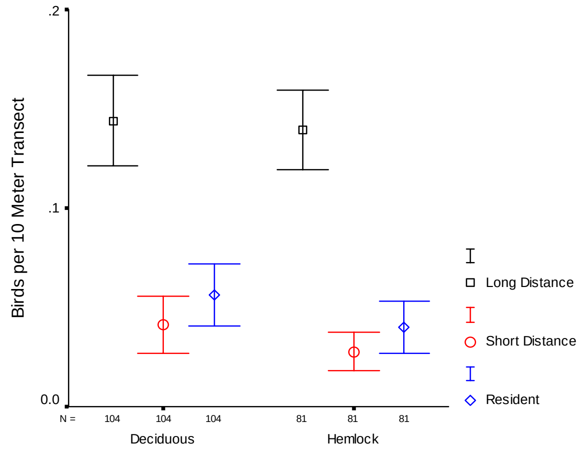

Figure 7. Bird detections by forest type based on transect censusing. There were no differences in number of Long Distance ($t = 0.287$, df = 183, $P = 0.767$), Short Distance ($t = 1.527$, df = 172, $P = 0.129$) nor Residents ($t = 1.528$, df = 183, $P = 0.128$) detected between deciduous and hemlock dominated forest plots. Whiskers represent +/- 1 standard error.

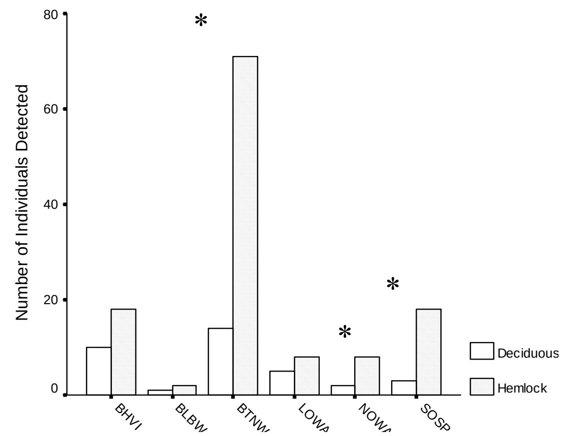

Figure 8. Species with more detections in hemlock than deciduous forest stands, as determined by transect census. An asterisk * indicates statistical significance. Blue-headed Vireo = BHVI, Blackburnian Warbler = BLBW, Black-throated Green Warbler = BTNW, Louisiana Waterthrush = LOWA, Northern Waterthrush = NOWA and Song Sparrow = SOSP.

In 2006 we began census work early in the spring migratory period (4/21/06), sampling shrub habitat 98 times and forested habitat 109 times. Results from our 2006 census effort patterned what we found in 2005, with more long-distance ($t = 8.353$, df = 138, $P < 0.001$) and short-distance ($t = 6.403$, df = 114, $P < 0.001$) migrants detected in scrub/shrub than forested habitat (Figure 6). There was no difference in habitat use by resident species ($t = 1.864$, df = 196, $P = 0.064$).

During the 2006 field season I began examining hemlock use by spring migrants. Census data indicate that hemlock groves were used to a similar extent as deciduous forest plots (Figure 7). Even so, there were a number of species for which hemlock stands appeared especially important (Figure 8). These included Black-throated Green Warbler ($\chi^2 = 38.22$, df = 1, $P < 0.001$), Northern Waterthrush ($\chi^2 = 3.60$, df = 1, $P = 0.058$), Song Sparrow ($\chi^2 = 10.71$,df = 1, $P = 0.001$), and possibly Blue-headed Vireo ($\chi^2 = 2.30$, df = 1, $P = 0.13$). Understanding the importance of hemlock stands will be especially relevant in light of the potential impact of Hemlock Wooly Adelgid (*Adelges tsugae*).

Transect Vegetation. I use a modification of James and Shugart (1970) to assess vegetation characteristics of shrub and forested transects. This methodology permits estimation of a variety of vegetation parameters, including tree and shrub stem densities and percent canopy, subcanopy and groundcover. Vegetation sampling is complete for 50 % of the transects, and the remaining transects will be sampled at the end of the 2007 field season.

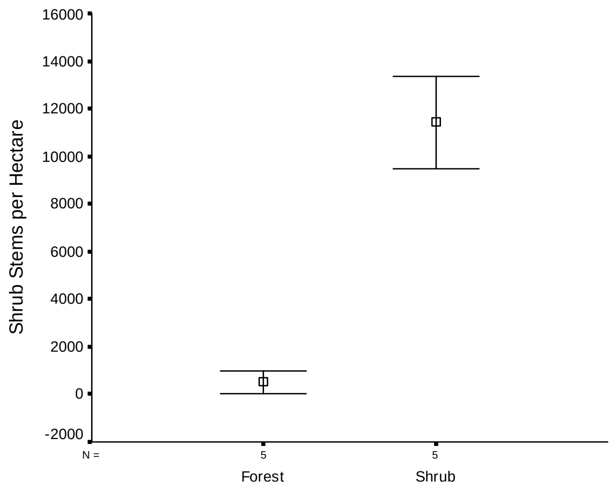

Figure 9. Comparison of shrub stem densities between bird census transects placed in forested and shrub/scrub habitats. Whiskers represent +/- 1 standard error.

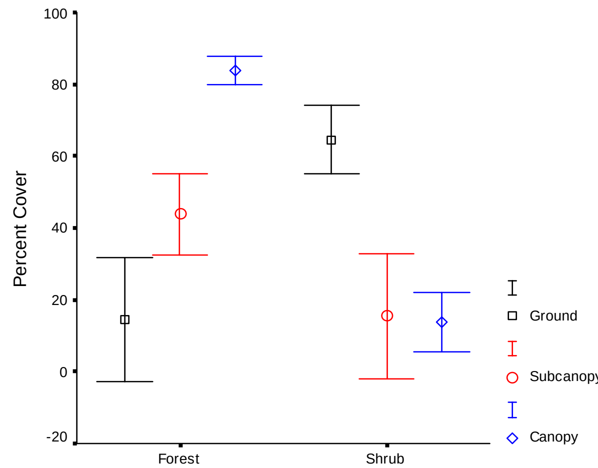

Figure 10. Comparison of structural complexity between bird census transect placed in forested vs. scrub/shrub habitats. Whiskers represent +/- 1 standard error.

Not surprisingly, there are fewer shrubs (Figure 9; $t = 10.852$, df = 8, $P < 0.001$) and more structural complexity (due to the presence of a subcanopy layer; Figure 10) in forested habitat. Throughout the study area the predominate shrub is Tartarian Honeysuckle (*Lonicera tatarica*) (Figure 11), a species not native to Pennsylvania. Other relatively abundant, non-native species include Autumn Olive (*Elaeagnus umbellata*), Eurasian Buckthorn (*Rhamnus cathartica*) and Multifloral Rose (*Rosa multiflora*). Dogwood (*Cornus spp.*) and Viburnum (*Viburnum spp.*) (spp.) are the two most abundant native shrubs.

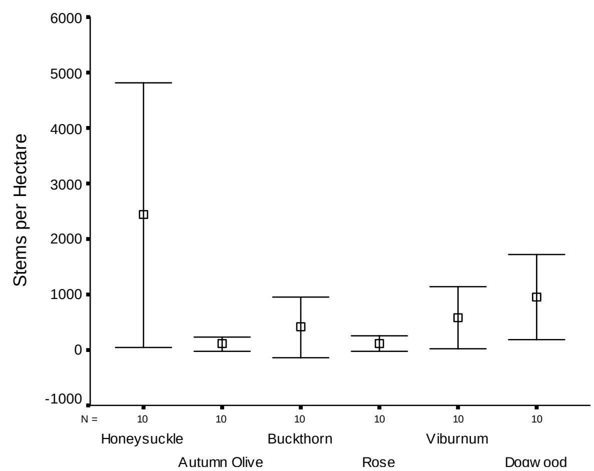

Figure 11. Comparison of stem densities for the six most abundant shrub species. Autumn Olive, Buckthorn and Mulitfloral Rose are not native to Pennsylvania whereas Viburnum and Dogwood are. Whiskers represent +/- 1 standard error.

Mist-net Sampling - Captures. To date, we have captured 3483 individuals of 78 species (see Appendix 1). Our overall bird capture rate (2005, 2006 pooled) was **20.5** birds/100 net hours, with forest net captures (22 nets) occurring at a rate of **6.7** birds captured/100 net hours and shrub/scrub captures (25 nets) occurring at a rate of **28.7** birds/100 net hours (see Table 1). Our overall capture rate and shrub capture rate are quite reasonable in comparison to established banding stations (e.g., Powdermill Avian Research Center, western Pennsylvania, spring 2006 = **27.9** birds/100 net hours; Rouge River Bird Observatory, southeastern Michigan, spring 2006 = **25.8** birds/100 net hours; Braddock Bay Bird Observatory, northern New York, spring 2005 = **29.5** birds/100 net hours. Interestingly, 2006 capture rates were lower than 2005 (Overall 2005 = **22.5** vs. 2006 = **19.5**; forest 2005 = **9.1** vs. 2006 = **6.9**; and shrub/scrub 2005 = **31.2** vs. 2006 = **27.2**).

There were only 3 species captured in forested habitat not captured in shrub/scrub (Red-shouldered Hawk, Brown Creeper and White-breasted Nuthatch) while there were 33 species captured in shrub/scrub habitat not captured in forested habitat (Appendix 1). Moreover, many forest-breeding birds used shrub/scrub habitat extensively during stopover, including Hermit Thrush, Veery, Swainson's Thrush, Wood Thrush, Red-eyed Vireo and Ovenbird (Appendix 1).

Mist-net Sampling – Fitness Consequences of Habitat Use. Birds use lipid stores to fuel migration (Blem, 1980), consequently the ability for a migrant to deposit fat is critical to ensure a successful migration. Further, because there are fitness consequences associated with when an individual arrives at its migratory destination (Sandberg & Moore, 1996; Smith & Moore, 2005) the ability to deposit fat stores quickly is of prime importance. One way to evaluate stopover habitat quality is to determine the rate at which migrants gain or lose fat stores, as indicated by changes in body mass, during their stay within that habitat (Dunn, 2000a; Smith, 2003). Mass change provides not only an index of food abundance but also of food availability, reflecting factors such as predation risk (Dunn, 2000a) or competition (Moore & Yong, 1991).

To estimate rate of mass change I used multiple linear regression (Dunn, 2000a; Smith, 2003) which is the recommended technique when assessment of relationships among variables is the goal (Tabachnick & Fidell, 1996). This technique allows estimation of mass change without the need to recapture individuals, making maximum use of the dataset rather than relying only on recaptures. However, as in any statistical technique, there are minimum sample size requirements. Consequently, I have limited the following analyses to species with greater than 50 individual captures. Future work will add captures to the data set, permitting evaluation of mass change in more species than included in this report.

This technique is based on the assumption that migrants are at a low mass early in the morning, and that they build mass through the course of the day as they convert food to fat. If birds are gaining mass during stopover (are in high quality habitat) then there will be a positive relationship between first captures of birds and the time elapsed since daylight (Dunn, 2000b; Winker, Warner & Weisbrod, 1992).

I used parameter estimates (unstandardized regression coefficients - β weights) to calculate mass change. β weights represent the change in the dependent variable (Mass) with a one-unit change in the independent variable (Minutes since daylight), with all other independent variables held constant (Tabachnick *et al.*, 1996). Mass gain was assumed to have continued at some average rate over all hours of daylight, and overnight mass loss of a bird stopping over equaled 4.5% of average body mass (see Dunn, 2000b; see Winker et al., 1992). I converted overnight loss to grams lost over 24 hours to estimate net 24-hour mass change. I subtracted this loss from the estimated 24-hour gain derived from the regression equations. Net mass change was then divided by the average mass of each species.

There were no negative relationships detected between mass and time of day (Appendix 2). That is, none of the species included in this analysis lost mass, regardless of whether they were captured in forested or shrub/scrub habitat. Daily mass change estimates for individuals captured in shrub habitats were generally high, ranging from 3.7% of body mass (Gray Catbird) to 17.5% of body mass (Ruby-crowned Kinglet). These estimates are some of the highest yet reported from studies that use mass change estimates as indicators of habitat quality (see Smith, 2003). Only Nashville Warbler did not appear to gain mass in shrub habitat.

Sample size limitations restricted analyses of forest captures to Common Yellowthroat, Gray Catbird, Wood Thrush, Hermit Thrush, Veery, American Robin and Ovenbird. While many species (but not all - no effect was detected in either forested or shrub habitats in Veery and American Robin) gained mass at relatively high rates in shrub habitat, only Wood Thrush showed a significant effect of time of day on mass in forested habitats. Even so, Wood Thrush rate of mass change was higher in shrub than forested habitat (16.4% in shrub vs. 1.4% in forested). Whereas Wood Thrushes appeared to gain mass at a low rate, these results suggest that, for other species, individuals in forested habitat did not gain (nor lose) mass. Birds using forested habitat appear to either increase condition more slowly than in shrub habitat or, if not increasing condition, are at least able to maintain it.

Foraging Behavior. Preliminary analyses of these data suggest no difference in foraging rates between birds observed in shrub habitat and those observed in forested habitat (Figure 12). There was no difference in mean foraging rate between Common Yellowthroats (t = 0.099, df = 24, P =0.922), Ruby-crowned Kinglets (t = 0.631, df = 17, P = 0.536) nor Yellow Warblers (t = 1.583, df = 27, P = 0.125) observed foraging in forested vs. shrub habitats.

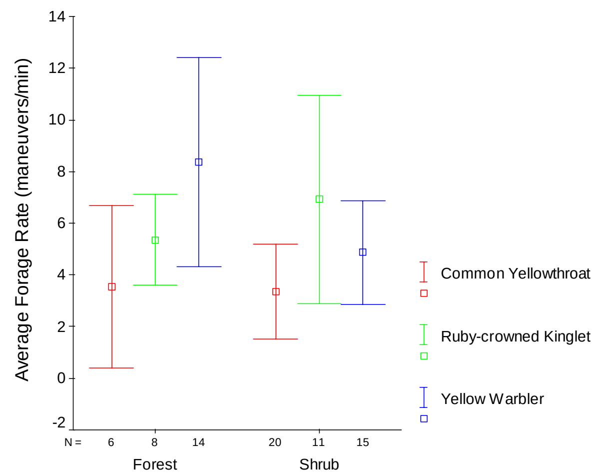

Figure 12. Habitat comparison of foraging rates of 3 landbird species observed during the 2005 field season, northeastern Pennsylvania. Whiskers represent +/- 1 standard error.

Conclusion. Shrub habitat in northeastern Pennsylvania is important to spring migrating birds. Results suggest that birds use shrub habitat more than forest habitat and migrants realize higher fitness by using shrub habitat. This seems to be a consequence of more resources available to migrants in shrub habitats. As with any ecological study of this nature, more work is needed to increase sample sizes and to assess the effects of annual variation in environmental conditions (notably weather) on resource abundance and consequently habitat use by migrants.

Estimated Percentage of Project Completed to Date. One hundred percent of the fieldwork and 85% of the data collection/entry is complete for this second year. There are a number of invertebrate samples to be examined during the 2006 fall semester by undergraduates at the University of Scranton. Once data are collected from these samples then 100% of the data collection for the 2006 field season will be completed.

Dependent upon funding, I plan to continue this study through the summer of 2007, consequently this report represents the midpoint of the second year of a 3 year project. With that in mind, approximately sixty percent of the overall project is complete.

Statement as to whether the project will be completed by the end of the grant agreement period. Data collection/entry for the 2006 field season will be complete by the end of the grant agreement period for grant WRCP-05109. However, I plan to collect data to address habitat use and the fitness consequences of using forested and shrub/scrub habitats for at least 1 more year.

Projected deliverables in addition to final report.

Undergraduate Research Experience: A number of undergraduates from the University of Scranton have involved themselves in this research project. Four students assisted with the fieldwork and an additional four processed invertebrate samples during the fall, 2005 semester. During 2006, 3 undergraduates assisted with the fieldwork and 3 have committed to processing invertebrate samples during the fall, 2006 semester.

Outreach: I led a number of field trips through the site (students from The Geneva School, Lackawanna State Park Environmental Education, Adult Nature History Series – Spring Migrants. There have been many other visitors to the site, including a number of faculty and their children from the University of Scranton.

Dissemination: I will publish this work in technical journals and will present results at University of Scranton functions, along with regional, national and international technical meetings.

Data Contribution: I will contribute data to the international bird-banding database (US Geological Survey Bird Banding Laboratory), the Monitoring Avian Productivity and Survivorship Program (MAPS), and the PA Breeding Bird Atlas. Further, I routinely share data with other researchers, and will make this database available in a similar manner.

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Appendix 1. Summary of birds captured from 15 April through 15 June, 2005, 2006 at Lackawanna State Park and private lands immediately adjacent to the park. During this period we tallied 3483 captures of 78 species[2]. Forest (n = 22) and shrub (n = 25) nets were opened and closed at approximately the same time. Forest nets include a series of 'high' nets that are elevated into the canopy. Bold text with an asterisk denotes Pennsylvania Game Commission Birds of Conservation Concern.

Species	Forest Captures	Shrub Captures	Total Captures	Individuals per 100 net hours Forest	Individuals per 100 net hours Shrub	Total Individuals per 100 net hours
*** Acadian Flycatcher**		2	2	0.000	0.019	0.012
*** Alder Flycatcher**		5	5	0.000	0.048	0.029
American Goldfinch		25	25	0.000	0.241	0.147
American Redstart		35	35	0.000	0.338	0.206
American Robin	25	22	47	0.377	0.212	0.277
*** American Woodcock**		2	3	0.000	0.019	0.018
Baltimore Oriole	1	11	12	0.015	0.106	0.071
Black-and-white Warbler	5	27	34	0.075	0.260	0.200
*** Black-billed Cuckoo**		18	18	0.000	0.174	0.106
Black-capped Chickadee	43	226	272	0.649	2.180	1.600
Blue-gray Gnatcatcher		1	1	0.000	0.010	0.006
Brown-headed Cowbird	4	5	9	0.060	0.048	0.053
*** Blue-headed Vireo**	1	8	9	0.015	0.077	0.053
*** Blackburnian Warbler**		3	3	0.000	0.029	0.012
Blue Jay	7	13	20	0.106	0.125	0.118
*** Blackpoll Warbler**		4	4	0.000	0.039	0.024
Brown Creeper	1		1	0.015	0.000	0.006
*** Brown Thrasher**	1	19	21	0.015	0.183	0.124
Brewster's Warbler	1	47	48	0.015	0.453	0.282
*** Black-throated Blue Warbler**	1	25	26	0.015	0.241	0.153
*** Black-throated Green Warbler**	2	20	24	0.030	0.193	0.141
*** Blue-winged Warbler**	5	83	88	0.075	0.801	0.518
Carolina Wren		1	1	0.000	0.010	0.006
*** Canada Warbler**		24	24	0.000	0.222	0.141
Clay-colored Sparrow		1	1	0.000	0.010	0.006
Cedar Waxwing	3	8	11	0.045	0.077	0.065
Chipping Sparrow		10	10	0.000	0.096	0.059
Common Yellowthroat	16	337	367	0.241	3.250	2.159
Chestnut-sided Warbler	2	88	90	0.030	0.849	0.529
Downy Woodpecker	3	3	6	0.045	0.029	0.035

[2] While there seem to be 79 species in this table, the grouping Trail's Flycatcher consists of birds that are either Alder or Willow Flycatcher. This grouping represents individuals which were impossible to identify to species.

Appendix 1 continued.

Species	Forest Captures	Shrub Captures	Total Captures	Individuals per 100 net hours Forest	Individuals per 100 net hours Shrub	Total Individuals per 100 net hours
Eastern Phoebe	5	2	7	0.075	0.019	0.041
Eastern Towhee	3	46	49	0.045	0.444	0.288
Eastern Tufted Titmouse	5	30	35	0.075	0.289	0.206
Eastern White-crowned Sparrow		1	1	0.000	0.010	0.006
Field Sparrow		53	53	0.000	0.511	0.312
Gray-cheeked Thrush	2	3	5	0.030	0.029	0.029
Gray Catbird	26	434	469	0.392	4.186	2.759
*** Golden-winged Warbler**		2	2	0.000	0.019	0.012
Hairy Woodpecker	9	1	10	0.136	0.010	0.059
Hermit Thrush	37	68	105	0.558	0.656	0.618
House Wren		11	11	0.000	0.106	0.065
Indigo Bunting	3	6	9	0.045	0.058	0.053
Least Flycatcher	2	32	34	0.030	0.309	0.200
Lincoln Sparrow		21	21	0.000	0.203	0.124
Magnolia Warbler	2	93	95	0.030	0.897	0.559
Mourning Warbler		6	6	0.000	0.058	0.035
Nashville Warbler	5	75	80	0.075	0.723	0.471
Northern Cardinal	9	31	40	0.136	0.299	0.235
Northern Flicker	4	11	15	0.060	0.106	0.088
Northern Parula		3	3	0.000	0.029	0.018
Northern Waterthrush	1	10	11	0.015	0.096	0.065
Ovenbird	84	120	212	1.267	1.157	1.247
Philadelphia Vireo		2	2	0.000	0.019	0.012
*** Prairie Warbler**		30	31	0.000	0.289	0.182
Purple Finch	2	40	43	0.030	0.386	0.253
Rose-breasted Grosbeak	4	19	23	0.060	0.183	0.135
Ruby-crowned Kinglet	1	106	109	0.015	1.022	0.641
Red-eyed Vireo	19	63	83	0.287	0.608	0.488
*** Red-shouldered Hawk**	1		1	0.015	0.000	0.006
Slate-colored Junco	1	16	17	0.015	0.154	0.100
*** Scarlet Tanager**	2	7	9	0.030	0.068	0.053
Song Sparrow	1	21	22	0.015	0.203	0.129
*** Sharp-shinned Hawk**		4	4	0.000	0.039	0.024
Swamp Sparrow		9	9	0.000	0.087	0.053
*** Swainson's Thrush**	6	18	24	0.090	0.174	0.141
Tennesse Warbler		1	1	0.000	0.010	0.006
Trail's Flycatcher		45	45	0.000	0.434	0.265
Veery	39	106	149	0.588	1.022	0.877
White-breasted Nuthatch	3		3	0.045	0.000	0.018
*** Willow Flycatcher**		3	3	0.000	0.029	0.018

Appendix 1 continued.

Species	Forest Captures	Shrub Captures	Total Captures	Individuals per 100 net hours Forest	Individuals per 100 net hours Shrub	Total Individuals per 100 net hours
Wilson's Warbler		19	19	0.000	0.183	0.112
*** Wood Thrush**	44	122	168	0.664	1.177	0.988
White-throated Sparrow	5	159	164	0.075	1.534	0.965
***Yellow-breasted Chat**		2	2	0.000	0.019	0.012
Yellow-billed Cuckoo		3	3	0.000	0.029	0.018
*** Yellow-bellied Flycatcher**		3	3	0.000	0.029	0.018
Yellow Palm Warbler		2	2	0.000	0.019	0.012
Yellow-rumped Warbler	2	5	7	0.030	0.048	0.041
Yellow Warbler		41	41	0.000	0.395	0.241
Total Captures	**447**	**2977**	**3483**	**6.742**	**28.713**	**20.491**

Appendix 2. Multiple regression analysis of mass change for eight common species of insectivorous landbird migrants arriving in northeastern Pennsylvania, 2005. Shown are *parameter estimates (β), their standard errors (SE), and t-statistics and probability values (*P*).*

Ruby-crowned Kinglet Shrub Captures

Parameter	β	SE	*t*	*P*	Daily Mass Change (g/24 hr)	Percent Daily Body Mass Change
Year	-0.189	0.044	-2.823	**0.006**	1.15	+17.5 %
Date	0.136	0.006	1.742	0.084		
Minutes since daylight	0.456	0.0001	6.730	**<0.001**		
Wing	0.359	0.019	4.583	**<0.001**		
Tarsus	0.313	0.057	4.392	**<0.001**		

Gray Catbird Forest Captures

Parameter	β	SE	*t*	*P*	Daily Mass Change (g/24 hr)	Percent Daily Body Mass Change
Year	0.431	1.075	2.509	**0.021**	Effect not significant	Effect not significant
Date	0.161	0.039	0.837	0.412		
Minutes since daylight	-0.042	0.004	-0.228	0.822		
Wing	-0.031	0.239	-0.171	0.866		
Tarsus	0.477	0.627	2.663	**0.015**		

Gray Catbird Shrub Captures

Parameter	β	SE	*t*	*P*	Daily Mass Change (g/24 hr)	Percent Daily Body Mass Change
Year	0.049	0.267	0.974	0.342	1.22	+3.7 %
Date	0.005	0.014	0.107	0.915		
Minutes since daylight	0.107	0.001	2.126	**0.034**		
Wing	0.161	0.069	3.071	**0.002**		
Tarsus	0.200	0.200	0.636	0.525		

American Robin Forest Captures

Parameter	β	SE	*t*	*P*	Daily Mass Change (g/24 hr)	Percent Daily Body Mass Change
Year	-0.291	2.721	-1.248	0.227	Effect not significant	Effect not significant
Date	-0.209	0.076	-0.874	0.392		
Minutes since daylight	-0.021	0.006	-0.091	0.928		
Wing	-0.035	0.293	-0.162	0.873		
Tarsus	0.106	0.847	0.476	0.639		

American Robin Shrub Captures

Parameter	β	SE	*t*	*P*	Daily Mass Change (g/24 hr)	Percent Daily Body Mass Change
Year	0.229	1.915	1.077	0.300	Effect not significant	Effect not significant
Date	0.206	0.075	0.999	0.335		
Minutes since daylight	0.154	0.021	0.328	0.748		
Wing	0.591	0.169	2.855	**0.013**		
Tarsus	0.024	0.640	0.051	0.960		

Hermit Thrush Forest Captures

Parameter	β	SE	*t*	*P*	Daily Mass Change (g/24 hr)	Percent Daily Body Mass Change
Year	-0.184	0.816	-0.811	0.428	Effect not significant	Effect not significant
Date	-0.101	0.023	-0.503	0.621		
Minutes since daylight	0.311	0.002	1.373	0.186		
Wing	0.128	0.152	0.527	0.604		
Tarsus	0.244	0.358	1.144	0.267		

Hermit Thrush Shrub Captures

Parameter	β	SE	*t*	*P*	Daily Mass Change (g/24 hr)	Percent Daily Body Mass Change
Year	0.113	0.387	0.886	0.380	2.96	+ 9.8 %
Date	-0.177	0.019	-1.333	0.189		
Minutes since daylight	0.273	0.001	2.042	**0.046**		
Wing	0.247	0.086	1.904	0.063		
Tarsus	-0.108	0.132	-0.837	0.406		

Veery Forest Captures

Parameter	β	SE	*t*	*P*	Daily Mass Change (g/24 hr)	Percent Daily Body Mass Change
Year	-0.065	0.723	-0.310	0.760	Effect not significant	Effect not significant
Date	-0.378	0.027	-1.912	0.070		
Minutes since daylight	0.234	0.001	1.235	0.231		
Wing	0.407	0.107	1.724	0.099		
Tarsus	-0.057	0.357	-0.250	0.805		

Veery Shrub Captures

Parameter	β	SE	*t*	*P*	Daily Mass Change (g/24 hr)	Percent Daily Body Mass Change
Year	0.167	0.393	1.567	0.121	Effect not significant	Effect not significant
Date	0.173	0.018	1.682	0.096		
Minutes since daylight	0.138	0.001	1.345	0.182		
Wing	0.182	0.070	1.636	0.106		
Tarsus	0.166	0.230	1.509	0.135		

Wood Thrush Forest Captures

Parameter	β	SE	*t*	*P*	Daily Mass Change (g/24 hr)	Percent Daily Body Mass Change
Year	0.272	1.300	1.588	0.125	0.69	+ 1.4 %
Date	0.699	0.046	4.101	**<0.001**		
Minutes since daylight	0.122	0.003	0.773	0.447		
Wing	0.228	0.176	1.344	0.191		
Tarsus	-0.340	0.422	-1.893	0.071		

Wood Thrush Shrub Captures

Parameter	β	SE	*t*	*P*	Daily Mass Change (g/24 hr)	Percent Daily Body Mass Change
Year	-0.117	0.862	-1.044	0.300	7.91	+ 16.4 %
Date	0.115	0.044	1.054	0.295		
Minutes since daylight	0.361	0.002	3.393	0.001		
Wing	-0.138	0.141	-1.202	0.233		
Tarsus	0.071	0.392	0.676	0.501		

Magnolia Warbler Shrub Captures

Parameter	β	SE	*t*	*P*	Daily Mass Change (g/24 hr)	Percent Daily Body Mass Change
Year	0.008	0.193	0.081	0.936	1.04	11.6 %
Date	0.038	0.014	0.340	0.735		
Minutes since daylight	0.329	0.0001	3.121	**0.003**		
Wing	0.252	0.043	2.181	0.033		
Tarsus	0.207	0.161	1.937	0.057		

Chestnut-sided Warbler Shrub Captures

Parameter	β	SE	*t*	*P*	Daily Mass Change (g/24 hr)	Percent Daily Body Mass Change
Year	0.095	0.152	0.840	0.404	1.00	+10.3 %
Date	0.095	0.005	0.822	0.414		
Minutes since daylight	0.382	0.00001	3.680	**<0.001**		
Wing	0.386	0.031	3.508	**0.001**		
Tarsus	0.176	0.116	1.645	0.105		

Nashville Warbler Shrub Captures

Parameter	β	SE	*t*	*P*	Daily Mass Change (g/24 hr)	Percent Daily Body Mass Change
Year	0.270	0.086	2.375	**0.020**	Effect not significant	Effect not significant
Date	0.113	0.007	0.934	0.354		
Minutes since daylight	0.00004	0.0001	-0.731	0.468		
Wing	0.256	0.036	2.170	**0.034**		
Tarsus	0.134	0.121	1.205	0.232		

Common Yellowthroat Forest Captures

Parameter	β	SE	*t*	*P*	Daily Mass Change (g/24 hr)	Percent Daily Body Mass Change
Year	0.115	0.929	0.223	0.830	Effect not significant	Effect not significant
Date	0.127	0.042	0.232	0.823		
Minutes since daylight	0.060	0.002	0.113	0.913		
Wing	-0.013	0.366	-0.020	0.985		
Tarsus	0.276	0.615	0.670	0.524		

Common Yellowthroat Shrub Captures

Parameter	β	SE	*t*	*P*	Daily Mass Change (g/24 hr)	Percent Daily Body Mass Change
Year	-0.025	0.069	-0.425	0.671	0.995	+10.1 %
Date	0.195	0.004	3.321	**0.001**		
Minutes since daylight	0.309	0.001	5.356	**<0.0001**		
Wing	0.415	0.021	7.043	**<0.0001**		
Tarsus	-0.065	0.0001	-1.143	0.254		

Ovenbird Forest Captures

Parameter	β	SE	*t*	*P*	Daily Mass Change (g/24 hr)	Percent Daily Body Mass Change
Year	0.224	0.440	1.541	0.131	Effect not significant	Effect not significant
Date	0.103	0.014	0.635	0.529		
Minutes since daylight	0.269	0.001	1.800	0.079		
Wing	-0.009	0.074	-0.053	0.958		
Tarsus	0.280	0.281	1.884	0.067		

Ovenbird Shrub Captures

Parameter	β	SE	*t*	*P*	Daily Mass Change (g/24 hr)	Percent Daily Body Mass Change
Year	-0.049	0.332	-0.485	0.629	2.00	+10.3 %
Date	0.090	0.011	0.897	0.373		
Minutes since daylight	0.348	0.001	3.343	**0.001**		
Wing	0.299	0.063	2.863	**0.005**		
Tarsus	0.153	0.141	1.523	0.132		