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Winter Ecology and Behavior of Eastern Towhees at Taylor Fork Ecological Area

Megan Martin
Eastern Kentucky University, megan.e.martin119@gmail.com

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Megan Martin

Mentor

Dr. David Brown

Department of Biological Sciences

ABSTRACT

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Megan Martin

Dr. David Brown, Dept. of Biological Sciences

The Eastern Towhee (*Pipilo erythropthalmus*) is a type of sparrow, which has declined in number by about 50% since the mid-1960s. Since both their summer and winter habitat use is affected by changes in the prevailing vegetation, it is possible that the declining populations are a result of factors in both breeding and nonbreeding seasons. The objective of the study was to describe the behavior, habitat use, and foraging habits of the Eastern Towhee during the winter at a site in central Kentucky. Nine Towhees were captured, radio-tagged, and tracked using homing and triangulation for a total of 528 locations from late November 2015 to early March 2016. Three towhees tracked in 2014-2015 were included in some analyses. The average (± SE) home range size (80% kernel isopleth) was 7.31 ± 0.22 hectares, and the average (± SE) core area (30% kernel isopleth) was 1.52 ± 0.94 hectares. The average overlap of home ranges between neighbors was 36.0% and 23.7% between neighbor core areas. The habitats of the study area were classified into four types: mowed, blackberry scrub, woody shrub, and wooded habitat. Woody shrub habitats were utilized most, with an average of 32.4% of home range area, and 37.8% of core area. Blackberry scrub habitats were also heavily utilized (29.5% of home range, and 28.1% of core areas). Towhees tended to gather in larger flocks when temperatures dropped below freezing. More work is needed to understand how habitat and weather conditions are related to overwinter survival.

Keywords and phrases: Eastern Towhee, *Pipilo erythropthalmus*, radio telemetry, GIS, kernel density estimation, home range, habitat, winter ecology, honors thesis, undergraduate research

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Introduction

Many bird species have seen population declines over the past decades. A possible contributor to the decline in many species may be poor winter habitat. Rappole et al. (2003) found that there was only enough quality habitat for about 15% of a population of Golden-cheeked Warblers wintering in central Texas, The research of Sherry and Holmes (1996) also suggests that winter is a limiting time period for some species, in part due to competition for habitat. The repercussions of poor winter habitat may continue even in the seasons following each winter (Johnson et al. 2006, Runge and Marra 2005). Winter conditions could have an impact on the breeding success of some species of birds (Norris et al. 2004, Johnson et al. 2006) and their chance of surviving the following year (Johnson et al. 2006). Johnson et al. (2006) found that in American Redstarts (*Setophaga ruticilla)*, an individual's likelihood of surviving over the next year decreased 6.8% for every one-tenth of a gram shed in the winter.

Rockwell et al. (2012) hypothesized that individual Kirtland's Warblers (*Setophaga kirtlandii)* with low relative body mass may need to remain in winter habitat longer before traveling to breeding grounds. While individuals may prolong their stay to accumulate more reserves, Saino et al. (2004) suggests that a poor body condition in Barn Swallows (*Hirundo rustica)* may result in late molting, which in turn slows weight gain further, requiring an even longer stay. Unfortunately, delaying migration may result in more problems. For every ten days late a male Kirtland's Warbler (*Setophaga kirtlandii*) delayed arriving to breeding habitat, the number of offspring decreased by 0.74 fledglings (Rockwell et al. 2012). There does seem to be a relationship between habitat quality and date of arrival to breeding habitat: Norris et al. (2004) found that with later arrival to breeding habitat, American Redstarts had a higher ratio of stable carbon isotopes indicative of poor winter habitat. Another study following the same species found that the males wintering in high quality habitat were able to arrive earlier to the breeding site than other males (Reudink et al. 2009). Those arriving first were able to produce more offspring in the breeding season (Rockwell et al. 2012), due to extra-pair copulations with the mates of males that arrived later (Reudink et al. 2009). In addition, fledgling success was about 25% higher for the offspring of earlier males (Reudink et al. 2009). Norris et al. (2004) also studied the effect of habitat quality on breeding. Their models predict that females wintering in high quality habitat have two more chicks on average, and those chicks will fledge about a month earlier than females that wintered in lower quality habitat (Norris et al. 2004). The difference was attributed to the arrival date of the males, as individual female American Redstarts did not seem to alter their arrival date based on quality of winter habitat (Norris et al. 2004).

Reudink et al. (2009) argues that the body condition resulting from a season spent in winter habitat is not necessarily a result of winter habitat quality for American Redstarts. A bird that selected a high quality winter territory was probably in good body condition upon arrival, especially if they were able to maintain their territory for most of the winter season (Reudink et al. 2009). Thus, as Reudink et al. (2009) points out, success in both breeding and non-breeding seasons is highly dependent on body condition. While both success and body condition are positively correlated, a bird isn't necessarily condemned to the same body condition and the same level of success throughout its life. Studds and Marra (2005) found that the body condition of American Redstarts can improve if it can upgrade to a higher quality winter habitat.

An important component of the quality of winter habitat and thus an important influence on winter body condition is food availability (Johnson et al. 2006). Studies of the ratio of stable carbon isotopes in the claws of Black-throated Blue Warblers (*Dendroica caerulescens)* showed that those wintering in forest habitats with more precipitation were in better condition than other individuals (Bearhop et al. 2004). Mesic locales tend to have more insects available at the end of the nonbreeding season, when birds in more xeric winter habitat types have depleted resources (Norris et al. 2004). Even in a single area, precipitation variations from year to year may affect body condition of ovenbirds (*Seiurus aurocapilla)* by directly affecting food abundance (Brown and Sherry 2006, Strong and Sherry 2000).

According to the Food-Limitation Hypothesis presented by Rogers (2005), birds living in winter habitat with plenty of food tend to have less fat and more nonfat mass; there is no need to accumulate extra reserves when food is so readily available. When habitat is poor, birds have more mass stored as fat but less mass stored as nonfat (Rogers 2005). On the other hand, the predation-food hypothesis suggests that in habitats with less food, birds have more fat in response (Rogers 2005). However, they have less nonfat mass because an active lifestyle of searching for food makes them more susceptible to predation (Rogers 2005). When food availability is high, Rogers (2005) asserts that birds will have less fat and more nonfat mass; food is so easy to find that little extra time would be spent exposed to predators when foraging to build nonfat mass.

Since food availability directly affects mass, food availability also influences avian population levels. Johnson and Sherry (2001) found that the population trends of American Redstarts in Jamaica fluctuate with any large changes in arthropod biomass during the nonbreeding period. While food availability affects how individuals distribute throughout an area, it is not the only factor involved (Johnson and Sherry 2001). However, it is still important enough that distribution is impacted if food availability changes (Johnson and Sherry 2001).

Much of this research describes migratory birds wintering in the tropics. There is considerably less literature about how habitat affects over-wintering migratory birds in the temperate zone. For this reason, the Eastern Towhee (*Pipilo erythropthalmus*) was selected for further study.

The Eastern Towhee is a type of sparrow native to the eastern half of the U.S. (Greenlaw 2015). Those living in the north tend to migrate south for the winter, while those living in the south tend to reside there year-round. (Hagan III 1993, Greenlaw 2015). Towhees commonly utilize habitat in the intermediate or closing stages of succession, as habitat transitions from shrubland to open forest to closed forest (Greenlaw 2015). Zuckerberg and Vickery (2006) found that Towhees breeding on Nantucket Island, Massachusetts, tended to favor habitat with leafy detritus and shrubs of mid-range heights or taller, and tended to avoid habitats with grasses of mid-range height, as well as mowed habitat. Favorable Towhee breeding habitat on both Nantucket Island (Zuckerberg and Vickery 2006) and in the southern Appalachians (Rush et al. 2012) included land undergoing a burning regime. The habitat preferences of Towhees in breeding habitat and winter habitat are considered to be similar (Greenlaw 2015), but not identical. In a study at the Tuskegee National Forest in Alabama, Eastern Towhees had a greater preference for dense vegetation in winter than in summer (McClure et al. 2013).

Rangewide, Eastern Towhee populations have declined by approximately 50% since the mid-1960s (Sauer et al. 2014). Their populations were initially helped in the mid-1900s by the increasing prevalence of abandoned farmland that transitioned into midseral vegetation, but were later negatively affected as those same lands matured to closed-canopy forest (Greenlaw 2015). Since both their summer and winter distributions are affected by such changes in the prevailing vegetation, it is possible that the declining populations are a result of factors in both breeding and nonbreeding seasons.

To my knowledge, the last published winter habitat study of Eastern Towhees in the state of Kentucky took place in 1941, when the bird was known as the Red-eyed Towhee (Barbour 1941). Barbour (1941) observed that Towhees prefer edge habitat and described two main categories of habitat utilization: those dominated by forest and those dominated by herbaceous vegetation. He also noted that Towhees were found near streams more often than not (Barbour 1941).

Little is known about how Eastern Towhees utilize available habitat in the winter, anywhere in their range. Also, there is a need for more current information on this subject in Kentucky, since the last study took place seventy-five years ago (Barbour 1941). Further research could be useful in the conservation of Towhees and other shrubland species. The objective of the study was to observe the behavior, habitat use, and foraging habits of the Eastern Towhee during the winter at a site in central Kentucky.

Study Area

This research was conducted at Taylor Fork Ecological Area (TFEA) in Madison County, Kentucky (N 37.716587, W -84.296000). TFEA is a 24-hectare plot of early successional habitat owned by Eastern Kentucky University and managed as a restored natural area by the EKU Division of Natural Areas (Brown 2015, unpublished report). Much of the land is open or shrubby, with the majority of trees along the perimeter of the property and along former fence lines. The trees comprising the forested areas include box elder (*Acer negundo*), sugar maple (*Acer saccharum*), black walnut (*Juglans nigra)*, blue ash (*Fraxinus* quadrangulata), and American elm (*Ulmus americana*). Trees occasionally occurring in the more open areas include white ash (*Fraxinus americana*), shellbark hickories (*Carya laciniosa*) and chinkapin oaks (*Quercus muhlenbergii).* TFEA is also home to several invasive plant species, including bush honeysuckle (*Lonicera maackii*) and multiflora rose (*Rosa multiflora*). Three ephemeral streams drain into Taylor Fork Creek, which flows (300 linear meters) through the northwest portion of TFEA. A variety of bird species winter at the study site, including White-throated Sparrows (*Zonotrichia albicollis*), White-crowned Sparrows (*Zonotrichia leucophrys*), Northern Cardinals (*Cardinalis cardinalis*), and Eastern Towhees.

Located in the Bluegrass region of Kentucky, TFEA was established from an abandoned cattle pasture in 2008 (Brown 2015, unpublished report) Since its acquisition, the site has mostly been used for student research, field trips, and recreational hiking. Although the site is undergoing succession from old-field to scrub-shrub, many areas still have Eurasian pasture grasses (e.g., tall fescue (*Festuca arundinacea*) and orchard grass (*Dactylis glomerata*), remnants of TFEA's agricultural past. Restoration efforts have included construction of wetlands, planting of tree seedlings, and removal of invasive species over several hectares of the property. The entirety of TFEA was used during the study, as well as a portion of surrounding pasture.

Methods

I captured Towhees using mist-nets and attached radio-transmitters. Mist-netting took place over fourteen days in November 2015 through January 2016. For each of those fourteen days, three to five mist nets measuring 2.5 m by 12 m (36 mm mesh) were set up throughout TFEA. Eastern Towhees were successfully captured on 7 of the 14 days (first successful day was November 13 (N = 1 individual captured), last successful day was January 21 (N = 4 individuals captured)). If a mist net was unsuccessful, it was moved to a different location. To increase the likelihood of capture, a taxidermied male Towhee specimen was set up near the net and vocalizations, including songs and calls, were broadcast using a portable speaker. Mist nets were checked every twenty minutes, or more frequently. Each captured Towhee (N = 11 [9 included in study]) was fitted with a size 1A aluminum band (issued by USGS Bird Banding Lab to Master Bird Bander permit holder Dr. David Brown), a plastic color band (pink, yellow, or white), and a Holohil BD-2 transmitter. Additional information including age (HY/SY [hatch year/second year], AHY/ASY [after-hatch-year/after-second-year]), sex, wing length, and body fat was recorded for each individual. The 1.3-gram transmitters (frequency 150.000−152.000, Holohil Systems Ltd., Carp, Ontario, Canada) had an expected battery life of approximately sixty days. They were attached to the Towhees using plastic beading threaded through tubes in either end of the transmitters to form leg loops held together by metal beading crimps, similar to the design described by Rappole and Tipton (1991). Handling methods were approved by the Eastern Kentucky University Institutional Animal Care and Use committee with protocol numbers 07-2014 and 12-2015.

Along with my 2015−2016 data, observations were completed during the winter of 2014−2015 by another EKU undergraduate student, Luke Romance, who captured, radio-tracked, and observed three Towhees. He used a similar radio-tracking protocol, and thus his observations are valuable for combining with my own data to describe home range sizes.

Radio-tracking began for each individual as early as the day after capture (first day was November 15th, last day was March 7th). A Yagi three-element antenna and a Telonics TR-4 receiver (Telonics, Inc., Mesa, AZ) were used to locate the Towhees. Most of the tracking (Figure 1) occurred during daylight hours (08:00–22:00 hrs), although night roost locations were occasionally observed (22:00–27:00 hrs.). Radio-tracking continued for each individual until the transmitter's battery died, until the bird died, or until the transmitter fell off the bird. Two tagged individuals died before adequate data were collected, thus their locations were not included in analysis of space use. Towhees were located with homing and locations were recorded onto maps that included a satellite image background layer. When I located an individual, I approached carefully to avoid disturbance. However, there were times that my approach flushed the birds. When this occurred, I recorded the original location at first detection. Tagged individuals were identified by their color band or the presence of the transmitter's antenna. In some cases, birds were not visually observed, in which case, locations were approximated by triangulation. In addition to the location, I recorded the date, time, channel number, whether or not I visually identified the individual, the size of the flock the towhee was associated with (not in flock, small [2–10 individuals], medium [11–25 individuals], or large [>25 individuals]), flock composition (number of male, female, and unknown sex Towhees in the flock), other flocking species associated with Towhees, habitat description (wooded, woody shrub, blackberry scrub, or mowed), and a foraging description (none, ground, fruit, or seed heads). I also recorded if vocalizations were made (none, call, or song), and weather observations (including temperature, wind speed, percent cloud cover, snow depth, and percent snow cover). Each Towhee was tracked for an average of 33.6 days (6.4 locations per day) and 58.6 locations per bird (range 40 to 77).

Locations recorded on paper datasheets in the field were transferred to a Geographic Information Systems (GIS) database using heads-up digitizing. I scanned the field maps and uploaded them into ArcMap Version 10 (ESRI, Redlands, CA). I aligned the corners of the property with the corners traced out on ArcMap and rectified the images using the Georeferencing toolbar in ArcMap. For each rectified image, I marked a point in the GIS to represent each Towhee location. For every point (N = 528), I entered all observational data into the corresponding row on the attribute table.

Once the data were entered, I used kernel utilization distributions to describe the home range and habitat use of each bird. I ran kernel distribution estimations (KDE) and isopleth analyses using Program R (The R Foundation, Vienna, Austria) and Geospatial Modelling Environment (Spatial Ecology LLC, Brisbane, Queensland, Australia). Home ranges were described as the 80% kernel isopleth, and core areas were described as the 30% kernel isopleth. I used the ArcMap intersect tool to determine the percent overlap of home ranges and core areas among neighboring birds. Using the home range data, I also determined the percent of roosting locations that fell within the home range and the core area of each individual.

I also generated an ArcGIS supervised image classification from 2014 National Agriculture Imagery Program imagery to classify habitat into four classes: wooded, woody shrub, blackberry scrub, and mowed habitat. This was then used to determine habitat use in three ways. First, I determined how much of each habitat type was available within TFEA, in terms of area and the percentage of each type comprising the total area. Second, I calculated the percent of each habitat type within each kernel home range. Third, I assigned a habitat class to each bird location, and calculated the percentage of points for each bird that fell within each habitat category.

The weather data included with my observations was compared with data from two sources: the Blue Grass Army Depot (BGAD) just outside of Richmond, KY (N 37.682054, W -84.22122) and the Blue Grass Airport in Lexington, KY (N 38.036667, W -84.602208). I compared my own weather recordings with BGAD's observations of wind speed and temperature and the snow depth measurements from the airport. Retrieving data from the Lexington airport was necessary because the BGAD did not have snow depth data. The BGAD weather data was recorded every 15 minutes, and the airport weather data was recorded every hour. For the comparison, the times for each location were rounded to the nearest 15 minutes for the BGAD and to the nearest hour for the airport. I then extracted the measurements from the airport and BGAD for those time periods, so that I would have weather data corresponding to each bird location. For any missing values in my weather observations, I made an estimation based on surrounding figures and the comparison data. When I compared my own observations with the weather station data, I found that the snow depth ($R = 0.82$) and temperature ($R = 0.94$) observations were similar. Thus, I chose to use my own data for further analysis involving these two measurements. However, the wind ($R = 0.46$) data were not as similar to the BGAD, so I used the BGAD weather station measurements for that variable in further analyses.

I compared foraging, habitat type, flock size, and vocalizations to wind, temperature, and snow depth using chi-square contingency tables. For the weather analyses, wind was divided into speeds of <4 m/s and ≥4 m/s. Temperatures were divided into ≤0°C and >0°C. Snow cover was divided into 0 cm and >0 cm.

In addition to testing how weather affects Towhee habitat use and behavior, I calculated the male-to-female ratio and the frequency of the different flock sizes. I compared flock size with foraging, habitat type, and vocalizations using chi-square contingency tables. I also reported descriptive analyses of the total number of locations for each hour of the day, the number of sightings of each individual, the number of locations of other species in flock with the Towhees, the average number of locations per day, and the average number of locations and days spent tracking each individual.

Results

Nine Towhees (seven males, two females; seven HY/SY, two AHY/ASY) were captured and thoroughly monitored in the course of this study, along with the three (two HY/SY, one of unknown age) captured in winter 2014−2015.There were also five birds for which data were insufficient to be counted in the study: one Towhee died during the attachment of the radio tag, two Towhees were later found dead (one from freezing and the other from accipiter predation), and two transmitters fell off. One individual from 2014−2015 was found dead with the radio transmitter still attached after the battery expired.

A total of 82 days were spent radio-tracking at TFEA from November 15, 2015 to March 7, 2016. Individual Towhees were tracked for an average (± SE) of 33.6 ± 6.76 days (range 25–41) and an average of 58.7 ± 4.43 locations (range 40–69) per bird. An average (± SD) of 5.125 ± 1.11 days per week were spent radio-tracking. Out of the 528 recorded locations, only 39.96% ± 0.03% (range 30–55.2%) included visual observation of the bird (Figure 2).

Home Ranges and Core Areas

The average home range size ([± SE], [80% kernel isopleth]) for all of the Towhees (including both data sets) was 7.31 ± 0.94 hectares (range 2.6 to 14.81), and the average core area ([± SE], [30% kernel isopleth]) was 1.52 ± 0.22 hectares (range 0.43 to 3.45) (Figure 3). Home ranges and cores areas tended to be smaller for birds observed during 2014−2015 (Table 1). The average overlap of the home range of any two individuals was 3.16 ha (range 0.16 to 6.35) or

36.0%, and the average overlap of the core areas of any two individuals was 0.42 ha (range 0.195 to 0.84) or 23.7%. In some cases, there were overlapping home ranges of three or more individuals. The intersection involving the most individuals included six Towhees with an overlap of 0.67 ha. There were also five sets of home range overlap between groups of five individuals, with a maximum overlap area of 1.98 ha. All roosting locations fell within home ranges, whereas only 16.7% fell within core areas.

Habitat Use

The average patch sizes of the four habitat types according to the GIS classified habitat map of TFEA were small (Table 2). The most abundant habitat types according to the ArcGIS supervised image classification of TFEA (Figure 4) differed from the average habitat composition of the home ranges and core areas (Table 3). The differences between 2014−2015 and 2015−2016 in habitat within home ranges were 1.2% for wooded habitat, 3.6% for mowed habitat, 0.30% for woody shrub, and 5.1% for blackberry scrub habitat. The core areas differed 0.07% for wooded habitat, 6.9% for mowed habitat, 7.6% for woody shrub, and 0.71% for blackberry scrub habitat between years.

Weather and Habitat Use

Temperatures over the 2015−2016 research period ranged from -12.22°C to 22.22°C, with an average of 4.89°C. Snow cover ranged from 0 to about 25 cm, with an average of 1.26 cm. Wind speeds ranged from 0.216 to 12.25 km per hour, with an average of 5.69 km/hr.

Habitat use did not differ significantly between temperatures that were above or below freezing ($X^2 = 6.097$, df = 3, $p = 0.10$). It did differ depending on whether snow was or was not present ($X^2 = 24.82$, df = 3, $p < 0.001$). When no snow was on the ground, woody shrub habitat comprised 47.7% of use, blackberry scrub habitat comprised 24.0%, wooded habitat comprised 23.4%, and mowed habitat comprised 5.0%. With the presence of snow, woody shrub habitat comprised 43.5% of use, wooded habitat comprised 41.9% of use, blackberry scrub habitat comprised 11.8%, and mowed habitat comprised 2.7%. Habitat use did not vary significantly between wind speeds of <4 m/s and ≥4 m/s ($X^2 = 1.03$, df = 3, $p = 0.79$).

Foraging

Out of the 192 times (of 528) that foraging was observed, 90.6% involved feeding off of the ground. Foraging habits differed between temperatures that were above or below freezing ($X^2 = 12.44$, df = 3, $p = 0.01$). For the 112 locations taken above freezing, foraging on the ground comprised 95.5%. Foraging habits also varied based on whether snow was or was not present ($X^2 = 11.56$, df = 3, $p = 0.01$) The ground foraging percentage was 83.8% when temperatures dropped to freezing and below. Ground foraging comprised 95.0% of foraging observations without snow present and 83.1% of observations with snow present. Feeding off seed heads changed from 1.8% to 13.8% when temperatures dropped, and from 2.5% to 14.1% with snow cover. Foraging habits did not vary significantly between wind speeds of <4 m/s and ≥4 m/s (X^2 = 0.49, df = 3, p = 0.92).

Vocalizations

There were 134 locations that included a Towhee vocalization. There was not a statistically significant association between vocalizations and foraging (X^2 = 0.78, df = 3, p = 0.85) or habitat type (X^2 = 0.73, df = 3, p = 0.87) when the categories within both of these were compared to whether vocalizations were recorded or not recorded. Also, when weather was compared to the three vocalization types (call, buzzy call, and song), there was no significant association related to whether snow present was or was not present (X^2 = 1.42, df = 2, p = 0.49) or related to whether wind speed was <4 m/s or ≥4 m/s (X^2 = 5.31, df = 2, p = 0.07). However, there was a statistically significant association between whether or not vocalizations were made and the flock size categories (X^2 = 25.15, df = 3, p < 0.001) and vocalizations and temperature when temperatures of ≤0°C and >0°C were compared with the vocalization categories (X^2 = 6.23, df = 3, p = 0.04). Large flocks represented both the greatest percentage of vocalizations (36.3%) and the lowest percentage of no recorded vocalization (17.6%). The lowest percentage of vocalizations occurred when individuals were not in a flock (9.7%). Medium flocks had the highest percentage (30.4%) of no recorded vocalizations, followed by small flocks (28.7%), and then not being in a flock (23.3%). 60.7% of vocalizations were observed when temperatures were above freezing. Of these vocalizations, 89.0% of vocalizations were calls and the other 11% were buzzes (4 instances) and songs (5 instances). When temperatures were at or below freezing, 100% of vocalizations were calls. The first call of 2016 was recorded on February 18.

Flocks and Associated Species

The proportion of male Towhees in flock with tagged individuals was 81.7% and the proportion for female Towhees was 18.3%. 77.8% of tagged individuals were male and 22.2% were female.

Of the 420 flock descriptions, the most common flock size was medium (31.7%), followed by small (25.95%), large (23.1%), and not in flock (19.3%). The relationship between flock size and temperature was ($X^2 = 12.44$, df = 3, p = 0.000006). Flock size differed according to if snow cover was present or not present ($X^2 = 12.01$, df = 3, p = 0.007). The general trend of flocks above freezing and without snow was similar, but the trend of flocks at or below freezing differed from the trend of flocks when snow was present (Table 4). Flock size did not vary significantly between wind speeds of <4 m/s or ≥4 m/s ($X^2 = 2.71$, df = 3, p = 0.438).

Whether foraging occurred differed according to the flock size ($X^2 = 20.97$, df = 3, p = 0.0001). 33.3% of foraging took place when the individual was in a large flock, 30.6% took place in a medium flock, 21.3% in a small flock, and 14.8% took place when the individual was not in a flock. 33.3% of observations of individuals not in a flock, 35.8% of small flocks, 42.1% of medium flocks, and

62.9% of large flocks involved a foraging observation. About two-thirds of all foraging occurred in large (33.3%) and medium flocks (30.6%). The majority of large flocks involved a foraging observation (62.9%). For medium flocks, 42.1% involved a foraging observation, but 57.9% did not.

The relationship between flock size and habitat type were statistically significant when flock size was divided into flocks with 10 or fewer individuals and flocks with more than 10 individuals ($X^2 = 15.33$, df = 3, p = 0.002). 60.0% of recorded locations in mowed habitat and 61.4% of recorded locations in blackberry scrub habitat involved flocks of 10 or fewer individuals, while only 38.3% of recorded locations in wooded habitat and 40.8% of recorded locations in woody shrub habitat involved flocks of the same size. 39.5% of flock locations with 10 or fewer individuals occurred in woody shrub habitat, 28.4% occurred in blackberry scrub habitat, 25.8% occurred in wooded habitat, and 6.3% occurred in mowed habitat. 47.4% of flock locations with more than 10 individuals occurred in woody shrub habitat, 34.8% occurred in mowed habitat, 34.3% occurred in wooded habitat, and 14.8% occurred in blackberry scrub habitat.

The top five species that were spotted with the Towhees each represented at least 10.0% of the 292 locations listing one or more associated species (Figure 5). Three of those species were each recorded for at least 50% of the associated species observations. The 20 species outside of the top five each composed 10% of locations or less (17 each composed 5% of locations). As for the Towhees themselves, out of all sighting of Towhees, both tagged and in flock, 81.7% of observed Towhees were male (note that this is slightly above the percentage of tagged male Towhees, which was 77.8%)

Discussion

Home Ranges, Core Areas, and Habitat

Overall, habitat usage did not completely follow habitat availability. The ArcGIS supervised image classification of TFEA showed that blackberry scrub habitat was most available. However, woody shrub habitat was utilized most by Eastern Towhees. This suggests there could be a preference for woody shrub habitat over blackberry scrub habitat. The preference for woody shrub in winter is supported by a study of McClure et al. (2013), which showed that Eastern Towhees wintering in the Tuskegee National Forest preferred dense vegetation. Also, a study by Pearson (1993) found that Eastern Towhees preferred shrubby habitats over grassy or mowed habitats, due to their need for cover. Zuckerberg and Vickery (2006) found that Towhees tend to avoid mowed habitat.

The percent usage of wooded habitat increased with the presence of snow. The increased attraction of wooded habitat is supported by Zuckerberg and Vickery's (2006) study on Nantucket Island, which indicated that Eastern Towhees tend to prefer habitat with leafy detritus. Leafy detritus is valuable to Eastern Towhees in the winter, since it is the primary substrate through which they forage (Whalen and Watts 2000).

The average home range sizes were skewed slightly by the lower home ranges from 2014−2015. The greatest differences were between mowed habitat and woody shrub habitat in the core area. The birds tracked in 2014−2015 had fewer locations (47 locations/bird in 2014−2015, compared to 58.7 locations/bird in 2015−2016). Kernel utilization distribution estimates are known to increase in area with increasing location sample size (Seaman et al. 1999).

As for the habitat use, fewer observations would not necessarily show significant differences, since I chose to use a percentage to reflect usage of each type. Differences in the percent use of each habitat type within the core areas were minimal. The percent use of each habitat type within the home ranges differed. The home ranges from 2014−2015 were composed of a greater percentage of woody shrub habitat and a lower percentage of mowed habitat. These differences could be attributed to the lower number of observations or perhaps a change in the landscape since 2014, the year of the imagery used in the image classification. Some honeysuckle has been removed since then, so it is possible that this image classification would differ if taken from 2015 data, and differ even more if taken from 2016 data. The borders of the four habitat types could have shifted since the 2014 image. None of the differences between the two studies were over eight percent, and most were under four percent. The general trend remains the same.

Foraging & Weather

Weather patterns had a definite effect on Towhee behavior. The only exception was wind speed, which had no bearing whatsoever on foraging method, habitat, flock size, or vocalizations. Temperature and snow cover were found to influence foraging methods in statistically significant ways. As is typical for wintering Eastern Towhees (Greenlaw 2015), foraging on the ground was the most common method utilized above freezing. Eastern Towhees utilize a ground-foraging technique known as bilateral scratching, in which they use both of their feet to swipe away leaves or other substrate to reveal seeds or insects underneath (Greenlaw 1977). Frozen ground and snow cover would probably make this technique more tedious. The ground foraging percentage likely decreased with freezing temperatures and snow cover for this reason. In turn, feeding off seed heads increased slightly. However, Eastern Towhees have exceptional scratching abilities (Whalen and Watts 2000), so ground foraging still remained the most widely used method.

However, Eastern Towhees also seem to respond very well to supplemental feeding. I saw evidence of this when a neighboring farmer put out corn to attract a cow that had escaped into the study area. Two or three Eastern Towhees would eat from the pile at a time. In addition, Eastern Towhees were one of three bird species that appeared most often to eat from white-tailed deer food plots at multiple sites across the eastern U.S. (Ricks et al. 2016).

Flocking Behavior

The proportion of tagged male Towhees appears to accurately represent the total proportion of males Towhees at the site, as the proportions were very similar. Barbour (1941) also recorded a similar proportion of females in his Kentucky winter study. Latitudinal segregation of the sexes is not uncommon. This behavior, whereby males tend to remain closer to their breeding grounds has been described elsewhere (Cristol et al. 1999). Males of eight species in a winter study in Mexico were concentrated north of the average female distribution (Komar et al. 2005). This phenomenon probably explains why males were more common at the study area, since Kentucky is located in the northern section of the Eastern Towhee's winter range (Greenlaw 2015).

Both temperature and snow cover influenced flock size. Medium flocks were the most common above freezing, with snow, without snow, and overall. Most notably, large flocks were the most common when temperatures were below freezing and the least common above freezing. This demonstrates that temperature was a component in determining flock size and that large flocks are associated with low temperatures. Also consistent with this idea were those not in a flock, which were the least common flock size in freezing temperatures. Eastern Towhees tended to gather in larger groups when temperatures dropped. They probably flocked together according to resource availability, as the majority of large flocks had a foraging observation of some kind, while the majority of each of the other flock sizes did not. Sridhar et al. (2009) compared almost 200 scientific papers about mixed-species flocks and found that individuals in flocks foraged more than those not in a flock. I observed the largest flock size at the corn pile mentioned in the previous section. Twenty to thirty Eastern Towhees gathered in the vicinity. This occurred in late January when the temperatures were below freezing and there was snow on the ground.

Flock size tended to increase with freezing temperatures and snow cover. Large flocks were the most common below freezing, and medium flocks were the most common with snowfall. It is possible that the size of flocks in the snow could have been underestimated. One of the cues I used to estimate the number of birds was the sound of foraging. Noises that are made as Towhees dig for food probably were not as clear with a layer of snow on the ground. In such cases, I may have marked a flock as “medium,” when it was actually “large.”

Small flocks and those not in a flock spent more time in mowed habitat and blackberry scrub habitat, while medium and large flocks spent more time in woody shrub and forest. Since there was no significant relationship between foraging and habitat use, these associations cannot be explained with foraging trends. Shrub was the most common habitat and medium flocks were the most common flock size, so it is not surprising that the two are related. A connection is also not surprising for those not in a flock and mowed habitat. Woody shrub was the most common habitat for those not in a flock and small flocks and the most common habitat for medium and large flocks. While it may seem odd for woody shrub to hold both positions, woody shrub habitat accounted for the most locations overall. This is why it is possible for the majority of flocks in woody shrub habitat to have more than ten individuals, but also for woody shrub habitat to have the highest percentage of flocks with ten or fewer individuals. The least common habitat for those not in a flock and small flocks was mowed habitat and the least common habitat for medium and large flocks was blackberry scrub habitat. Mowed habitat presented this way because it had only 20 locations out of 420. Mowed habitat was the least common habitat for flocks of ten or fewer individuals, yet the majority of the locations in mowed habitat were of flocks of this size.

As for the flock associates, Barbour (1941) noted that flocks of Eastern Towhees almost always included Northern Cardinals (*Cardinalis cardinalis*), Song Sparrows (*Melospiza melodia*), and White-throated Sparrows (*Zonotrichia albicollis*) and frequently included Carolina Chickadees (*Poecile carolinensis*). These four species were some of the most common associated species that I observed as well. Barbour (1941) also recorded many occurrences of Dark-eyed Juncos (*Junco hyemalis*), Field Sparrows (*Spizella pusilla*), Tufted Titmice (*Baeolophus bicolor*), and Winter Wrens (*Troglodytes hiemalis*) in Towhee flocks. I did not see Field Sparrows or Tufted Titmice often and I never observed Dark-eyed Juncos or Winter Wrens.

Vocalizations

As one would expect, the greatest percentage of vocalizations occurred in large flocks, while the lowest percentage occurred when individuals were not in a flock. However, the large flocks' percentage composed just over a third of all of the vocalizations. No one habitat type was associated with a significant majority. The patterns differed slightly when considering no recorded vocalizations. While it should follow that the highest percentage of no recorded vocalization occurred when individuals were not in a flock, medium flocks actually had the highest percentage, followed by small flocks, and then not being in a flock. The majority of vocalizations were observed above freezing. All vocalizations were calls at or below freezing.

Limitations and Conclusions

One limitation of this study is the small sample size (N= 9), as well as the singular, relatively small study area (24 hectares). There may also have been a greater margin of error in the beginning of the study, since I had virtually no telemetry experience and had to develop the skill over the course of the study. Also, the sex ratio was skewed toward males (7:2). I did not test for differences among the sexes, but it is possible that there are some differences between variables. For example, habitat use has been shown to vary between the sexes in other species (Marra 2000).

Similar to the results found by (Weinkam et al. *in press*.), in a winter study of Eastern Bluebirds, the snow and freezing temperatures of winter prompted Eastern Towhees gather in larger flocks. In response to snow, Towhees increased seed head use and shifted use of blackberry scrub to wooded habitat. Towhees also increased seed head use in response to freezing temperatures. Even with the change in seed head use, ground foraging remained a preference in all circumstances in the winter. The underlying implication of that is that Towhees must prefer habitat that allows for plenty of ground foraging. Such habitat should have a good layer of leafy detritus (Zuckerberg and Vickery 2006) and dense vegetation (McClure et al. 2013). According to Greenlaw (2015), high quality Towhee habitat should not be too densely vegetated and should have a layer of leafy detritus. Eastern Towhees have also been shown to respond well to supplemental feeding (Greenlaw 2015, Ricks et al. 2016).

This study will fit in among other research that details the condition of birds that wintered in poor temperate habitat, as a description of certain winter habitats and the resulting winter behavior. If winter is indeed a limiting time period (Sherry and Holmes 1996, Rappole et al. 2003, Brown and Sherry 2006), then it is crucial that we know what it means for a species and ideally multiple species to have quality winter habitat and that we understand what winter circumstances tend to increase likelihood of mortality during the winter or in subsequent seasons. This knowledge could be especially important in the conservation of many songbird species that could be in decline due to poor winter habitat. A variety of studies have been published in recent years that seek to expand our comprehension of the winter ecology of avian species (e.g., Weinkam et al. *in press*., McClure et al. 2012, Rockwell et al. 2012, Hargitai et al. 2014). However, there is still much we do not know.

Research Priorities

For Eastern Towhees specifically, a future study should test habitat types across Kentucky or even across multiple states in winter, but also in spring, summer, and fall. A significant study should follow Eastern Towhees from their arrival to the non-breeding habitat through the end of the breeding season and assess their body condition throughout. Such a study could determine how much of a connection there is between the quality of winter habitat and breeding success and survival. Further studies are needed to understand how habitat and weather conditions are related to overwinter survival.

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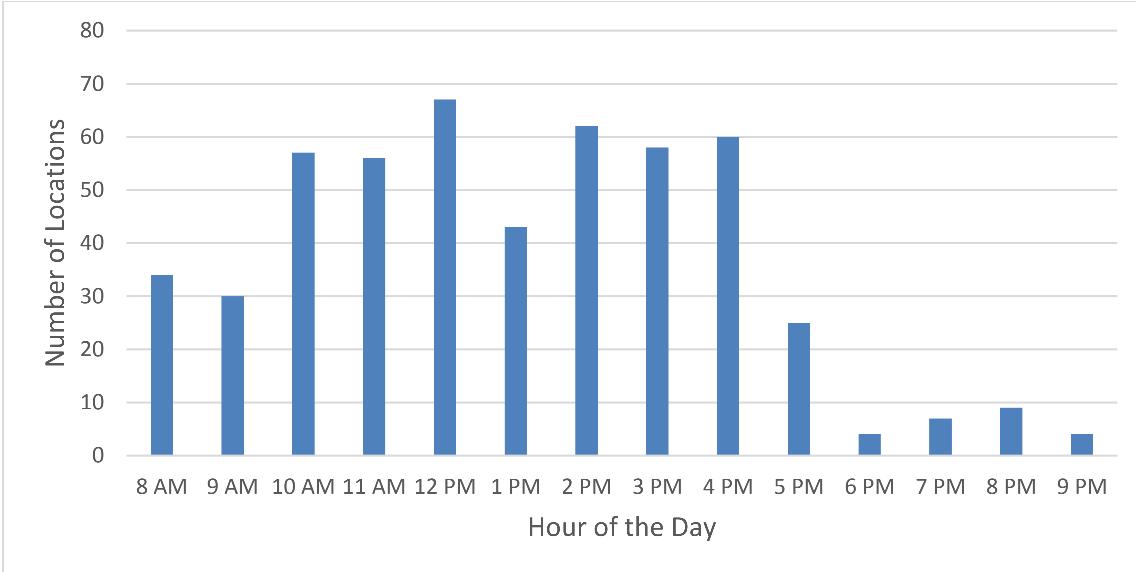

Figure 1: Distribution of total number of Eastern Towhee locations by hour of the day. Eastern Towhees were radio-tracked in winter 2015−2016 at Taylor Fork Ecological Area, Richmond, Kentucky.

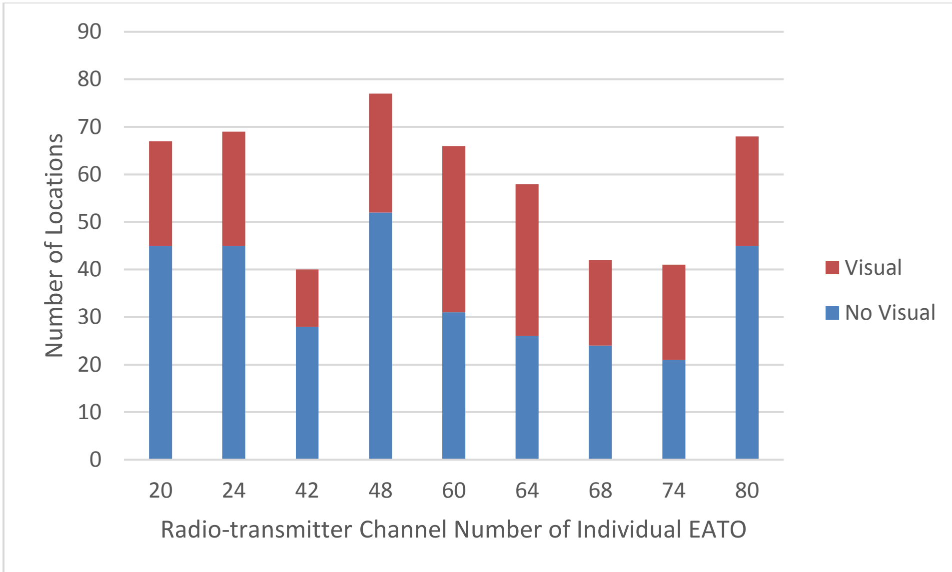

Figure 2: Total number of observed locations compared to the number of visual sightings of tagged individual Eastern Towhees radio-tracked in winter 2015−2016 at Taylor Fork Ecological Area, Richmond, Kentucky

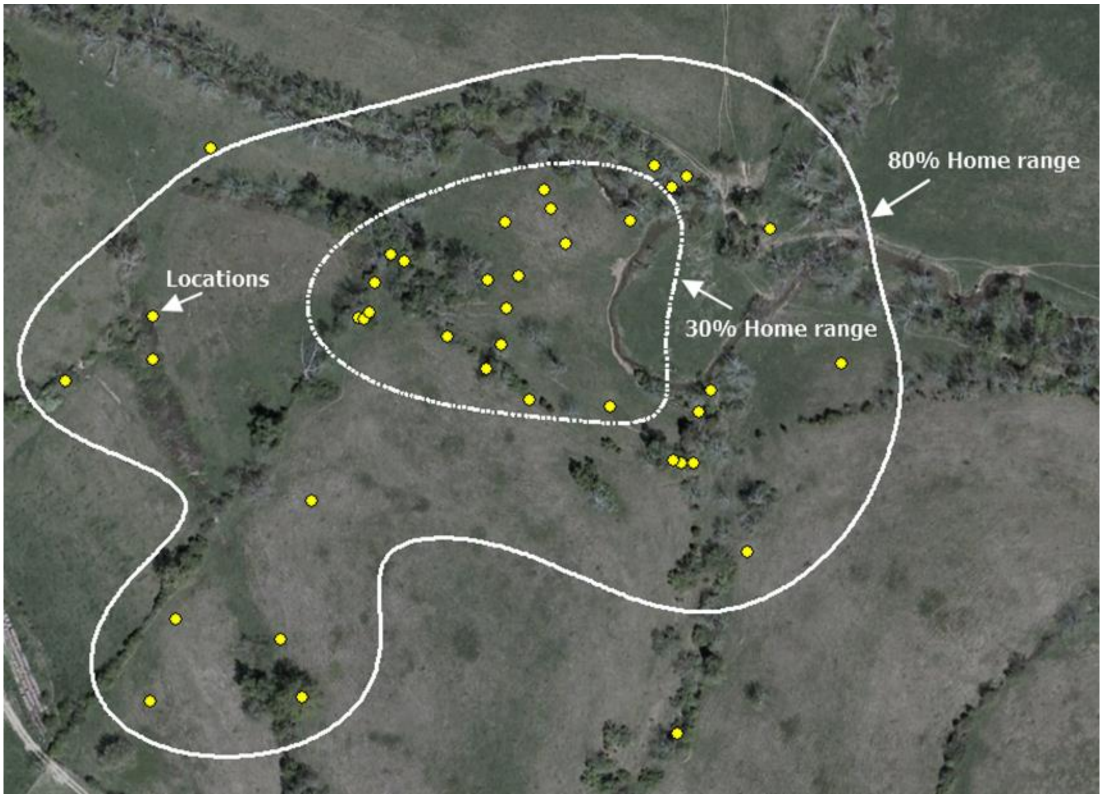

Figure 3: Example of a home range and core area of an individual Eastern Towhee tracked at Taylor Fork Ecological Area, winter 2015−2016, generated with ArcMap, Geospatial Modelling Environment, and Program R

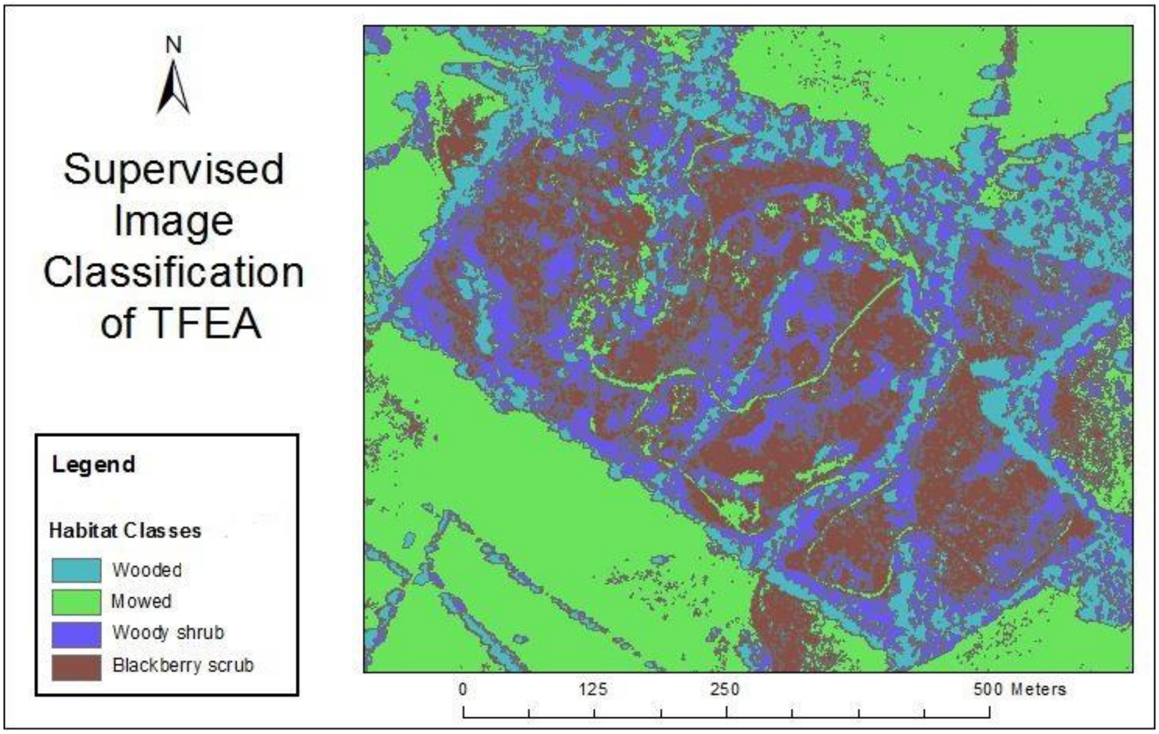

Figure 4: Four habitat types (wooded, blackberry scrub, mowed, woody shrub) generated with an ArcGIS supervised image classification of 2014 National Agriculture Imagery Program imagery of Taylor Fork Ecological Area, Richmond, Kentucky

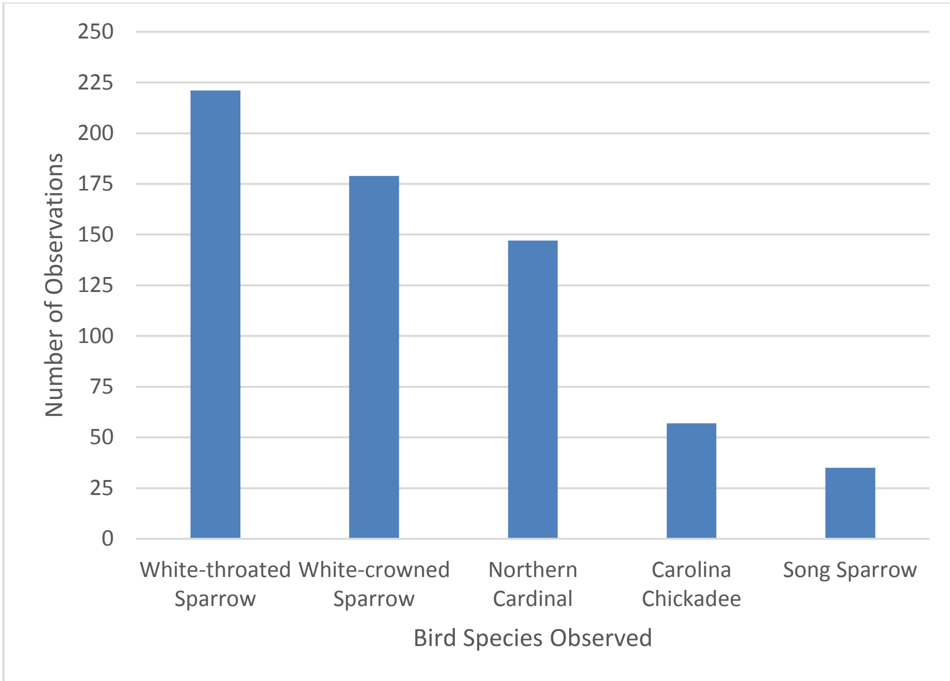

Figure 5: Graph of the five most common species associated with Eastern Towhees wintering at Taylor Fork Ecological Area, Richmond, Kentucky, 2015−2016.

Table 1: Comparison of the average core area and home range sizes (in hectares) of 12 Eastern Towhees at Taylor Fork Ecological Area, Richmond, Kentucky, tracked in winters of 2014−2015 and 2015−2016

	Core Area Avg. (ha)	Core Area SE (ha)	Home Range Avg.(ha)	Home Range SE (ha)
2014-2015	0.80	0.19	3.69	0.69
2015-2016	1.76	0.23	8.52	0.93
Both	1.52	0.22	7.31	0.94

Table 2: Patch sizes of four habitat types found at Taylor Fork Ecological Area, Richmond, Kentucky based on an ArcGIS supervised image classification of 2014 National Agriculture Imagery Program imagery of Taylor Fork Ecological Area, Richmond, Kentucky

	Wooded	Mowed	Woody Shrub	Blackberry Scrub
Number of Patches	2216	1318	3065	3124
Average Size (ha)	0.02	0.001	0.03	0.03
Standard Deviation	0.16	0.001	0.30	0.49
Frequency > 5 ha	0	0	3	5
Frequency < 0.003 ha	1596	1165	2254	2415

Table 3: Comparison of the habitat composition percentages of the home ranges and core areas of 12 Eastern Towhees from winters 2014−2015 and 2015−2016 with the percentages of four habitat types available at Taylor Fork Ecological Area, Richmond, Kentucky

	Hab. Type	Avg. %	% Available
Home Range	Wooded	24.39	18.64
	Mowed	9.73	6.89
	Woody Shrub	37.79	35.44
	Blackberry scrub	28.10	39.04
Core Area	Wooded	21.63	18.64
	Mowed	16.46	6.89
	Woody Shrub	32.43	35.44
	Blackberry scrub	29.48	39.04

Table 4: Percentage of locations by flock size of Eastern Towhees based on temperature and snow cover at Taylor Fork Ecological Area, Richmond, Kentucky, winter 2015−2016

	% not in flock (1 individual)	% small (2-10 individuals)	% medium (11-25 individuals)	% large (>25 individuals)
>0°C	19.69	30.89	34.36	15.06
≤0°C	18.63	18.01	27.33	36.02
0 in. snow cover	22.59	28.52	29.63	19.26
>0 in. snow cover	13.33	21.33	35.33	30.00