Habitat use of Henslow's Sparrows (Centronyx henslowii) in Southern Ohio

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# Abstract

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Habitat use of Henslow's Sparrows (Centronyx henslowii) in Southern Ohio

Director of Thesis: Dr. Kelly A. Williams

Grassland birds have narrow habitat requirements that are influenced by food availability, habitat composition, and habitat structure. Because survival is influenced by habitat quality and availability, understanding habitat requirements is critical for conservation. I determined how Henslow's Sparrows (Centronyx henslowii) use grassland habitat in the breeding season. In the past 10 years, technology advancements have allowed researchers to study the habitat use and movement ecology of understudied birds, such as grassland birds. I deployed nanotags on 47 adult Henslow's Sparrows at two sites in southern Ohio to determine home range size and habitat use in relation to distance to edge and shrub, as well as the post-breeding dispersal and migratory timing.

I predicted that Henslow's Sparrows would use core grassland habitat and avoid edge and shrubs. I found no difference in 95 % home range size between female (0.10 ± 0.03 ha) and male (0.32 ± 0.18 ha) Henslow's Sparrows. Henslow's Sparrows used shrubs when available and edge habitat as refugia after disturbance. I also found that Henslow's Sparrows use fields into August, past dates typically recommended for disturbance (e.g., mid to late July), which suggests the need to leave corridors and patches for refugia after management such as mowing or burning. I determined the fall migratory departure timing of 13 Henslow's Sparrows. I found that Henslow's Sparrows are at risk for entanglement which resulted in mortality of two birds. A third bird found entangled was found alive, entangled in vegetation, and was released after I removed the nanotag. I also found that 24 Henslow's Sparrows were able to remove nanotags and several damaged their nanotags. While I do not recommend the use of nanotags on this species in future studies, my study did result in determining fall migratory departure timing of Henslow's Sparrows in Ohio which was previously unknown.

**Key Words**

Conservation, edge, entanglement, grassland birds, habitat use, Henslow's Sparrow, home range, management, migration, radio tag

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## Chapter 1 Introduction

Birds in North America have faced dramatic declines in the past 70 years (Rosenberg et al. 2019). Across all biomes, 57% of species have exhibited declines, resulting in a loss of almost three billion birds (Rosenberg et al. 2019). Population declines are not limited to a single group: 64% of forest bird species and 74% of grassland bird species have faced significant declines (Rosenberg et al. 2019). The most significant and widespread declines occur in grassland birds (Vickery et al. 2000, With et al. 2008).

Human disturbance is responsible for numerous major drivers of avian declines, including habitat loss and degradation, fragmentation, climate change, and pollution (Dong et al. 2022). Land use changes and habitat loss create unsuitable habitats for birds and destroy resources. For example, Perlut and Strong (2011) found that hayfields can act as an ecological trap for grassland birds, and Bowler et al. (2019) found grassland conversion into agriculture negatively affected insect abundance, resulting in declines in aerial insectivores in Europe. Fragmentation in grasslands and forests increases edge, resulting in greater nest parasitism and predation by avian and mammalian predators (Robinson et al. 1995, Winter et al. 2000). Climate change has led to decreased avian populations and lower breeding success of migratory birds due to phenological mismatch. Periods of peak insect abundance are advancing due to temperature increase, while migratory birds have not advanced their arrival time resulting in decreased breeding productivity (Koleček et al. 2020). Both chemical (pesticides, heavy metals, oils) and physical (light and noise) pollution harm migratory and resident bird populations (Richard et al. 2021).

To implement effective conservation strategies, we must understand how birds use habitats throughout the full annual cycle. Nesting habitat and success has been studied across numerous bird species and habitats (Best et al. 1995, Ingold 2002, Reinking et al. 2015, Williams et al. 2023a). However, most studies only tell us the proportion of young fledged from the nest and nest success. Post-fledging and post-breeding habitat use is less understood. Understanding habitat use during this critical period will provide key data for land management and conservation decisions.

As technology has advanced, studies of avian habitat use have increased. Miniaturization of VHF-emitting radio transmitters (nanotags) has allowed more studies using telemetry with nanotags for very small species (≥6 grams; McKinnon et al. 2013, McKinnon and Love 2018, Dossman et al. 2023). Telemetry has a wide variety of applications across almost all groups of animals including fish (Thorstad et al. 2013), insects (Kissling et al. 2014), and mammals (Wallace et al. 2022). In birds, telemetry has been used to study many aspects of life, including stopover habitat use, winter habitat use, breeding habitat use, migratory pathways, flight speed, activity patterns, survival, social behavior, and more (Balph 1977, Taylor et al. 2011, Mitchell et al. 2015, Syartinilia et al. 2015, Schofield et al. 2018, Bégin-Marchand et al. 2021, Morales et al. 2022). Telemetry can be manual (tracking by researchers) or automated (arrays of towers that detect animals within range). Manual telemetry requires more time and individual effort but can be used to understand fine-scale habitat use by individual animals. Automated telemetry is conducted passively by a VHF-receiver tower. Automated radio telemetry towers are useful in that they can detect every pulse from individual nanotags when the nanotag is within range of the tower (0.3-1.1 km2) without the need of manual tracking (Crewe et al. 2019). For many applications of automated telemetry, scientists engage in the Motus Wildlife Tracking System (Motus). Motus is a network of receiving tower stations across the world that detect the radio signals emitted from nanotagged animals (Birds Canada and the Motus Community 2022). Data collected by the automated telemetry network includes the individual identification of the organism detected, location, the time and date (Taylor et al. 2017). Data from Motus towers are uploaded to a centralized database housed by Birds Canada. Much of this data is then available for public access on motus.org. Motus tallows us to understand migratory departure decisions, daily activity patterns, migratory connectivity, and more (Cooper et al. 2018, Packmor et al. 2020, Morales et al. 2022). The expansion of the Motus network and nanotags for small birds has increased by 300% since 2016 and allowed for significantly more flexibility in study species and accuracy in data collection (Birds Canada and the Motus Community 2022).

**Value of Birds**

Biodiversity is essential for maintaining healthy and functioning ecosystems. Birds are a critical part of global biodiversity with over 10,000 species and an estimated 200-400 billion individuals (Gaston and Blackburn 1997). Many birds serve as keystone species and are necessary for ecosystem function (Schulze 1994, Whelan et al. 2015). For example, the Dovekie (*Alle alle*) alters terrestrial and freshwater ecosystems through nutrient addition, promoting primary and secondary production (González-Bergonzoni et al. 2017); the Red-cockaded Woodpecker (*Leuconotopicus borealis*) in the Southeastern United States is a cavity nesting species whose nests are used by over 20 other species of secondary cavity nesters, mammals, and insects (Conner et al. 1997); and the Southern Cassowary (*Casuarius casuarius*) predominately consume only the flesh of fallen fruits and is the only disperser of 100 rainforest plants within Queensland, Australia forests (Moore 2007). Birds are also responsible for numerous other ecosystem functions, many of which benefit humans. In the Neotropics, hummingbirds (*Trochilidae*), honeyeaters (*Meliphagidae*), and sunbirds (*Nectariniidae*) are important pollinators of trees, vines, flowers, and other flora (Michel et al. 2020). Across the world, insectivores and raptors serve as pest control in agricultural settings (Montoya et al. 2021, Mayne et al. 2023). Seed eating birds are also important plant dispersers (Michel et al. 2020). These services, classified as "economic ornithology", serve human economic and agricultural systems (Whelan et al. 2015). Birds also serve humans outside of ecosystem services. Numerous cultures across the world recognize birds as messengers, communicators, or signs (Wyndham and Park 2018). Other ways humans enjoy birds include birdwatching, art and photography, religious symbols, and bird-based tourism, which generates over 8 billion dollars per year in the United States alone (Sekercioglu 2002, Michel et al. 2020).

**Conservation of Birds**

Bird conservation in North America began with the founding of the American Ornithologists' Union in 1883 as the Passenger Pigeon (*Ectopistes migratorius*) went extinct and numerous other species were quickly declining (Fitzpatrick, 2002). Policies were then passed by the US Fish and Wildlife service to conserve and protect declining species. The Lacey Act (1900) was passed to prevent the selling and importation of poached animals, including birds, across state lines. In 1918, the Migratory Bird Treaty Act (1918) was passed, and international treaties were entered with Canada (International Conservation Treaty with Canada, 1916), Mexico (International Conservation Treaty with Mexico, 1936), Japan in 1972 (International Conservation Treaty with Japan, 1972), and Russia in 1976 (International Conservation Treaty with Russia, 1976). The Migratory Bird Treaty Act (1918) prohibited the take of any parts of protected migratory bird species. The Bald and Golden Eagle Protection Act (1940) was passed and prohibited anyone from taking any parts of the Bald Eagle (*Haliaeetus leucocephalus*) or Golden Eagle (*Aquila chrysaetos*). Finally, the Endangered Species Act (1973) was passed to protect fish, wildlife, and plants listed as threatened and endangered. The Migratory Bird Treaty Act species list was updated in 2023 and protects over 1,000 species in North America.

There are numerous international, national, and regional organizations focused on the conservation of birds. BirdLife International (birdlife.org) is an international organization of birders and scientists that study birds across all parts of the world and publishes the bi-annual State of the World's Birds (BirdLife International). The American Bird Conservancy (abcbirds.org) and Partners in Flight (partnersinflight.org) are international organizations in North America that focus on conserving wild birds and their habitats throughout the Americas (American Bird Conservancy) and working to "keep common birds common" across the United States and Canada (Partners in Flight). The National Audubon Society (audubon.org) and the US North American Bird Conservation Initiative (nabci.org) are national organizations that focus on protecting birds and their habitats (Audubon Society) and facilitate collaborative partnerships that advance priorities for North American avian conservation (NABCI). Two regional conservation organizations, the Upper Mississippi River and Great Lakes Joint Venture (umgljv.org) and the Appalachian Mountains Joint Venture (amjv.org), identify priority species and provide resources for conservation planning in Ohio.

**Grassland Habitats**

Grassland ecosystems are defined by their lack of woody vegetation and disturbance regimen (Gibson, 2009). These ecosystems have evolved with frequent disturbances such as drought, grazing, and fire (P. Vickery et al., 2000). Grass dominance is influenced by numerous factors, including climate (precipitation and temperature), soil type, and disturbance (Strömberg, 2011).

Since the 1800's, 80% of grassland ecosystems in North America have been lost due to agriculture, silviculture, development, and fragmentation (Brennan & Kuvlesky, 2005). Other threats to grassland communities include range management, unnatural grazing, exotic grasses and other invasive species, and succession from grassland to shrubland (P. Vickery et al., 2000). Most remaining grassland habitats have been highly modified from their original state. Some grasslands are considered artificial habitats, which includes airports and airfields, military bases, and reclaimed mine land.

In Ohio, we lie at the intersection of two types of grassland habitats. The Midwestern Tallgrass Prairie, which historically extends from the Great Plains region to the Midwest, is characterized by tall grass, deep soil, and more precipitation than short grass habitats and grasses such as big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), indian grass (*Sorghastrum nutans*), and cord grass (*Spartina pectinate*; (P. Vickery et al., 2000). Tallgrass prarie was historically maintained by fire but has been widely replaced by agriculture and agricultural grasslands. The Eastern Grassland, which historically extends North-South from New England to the southeast and East-West from the Appalachian Mountains to coastal Texas, is maintained by fire and is characterized by two primary grass species, little bluestem and poverty grass (*Danthonia spicata*; Vickery et al. 2000). Prior to widespread settlement in the 1800's approximately 5% of Ohio's vegetation was grassland or prairie (Figure 1.1). Ohio is now composed of less than 1% grassland which is distributed primarily in Western Ohio (Ohio Plants, 2023; Figure 1.2).

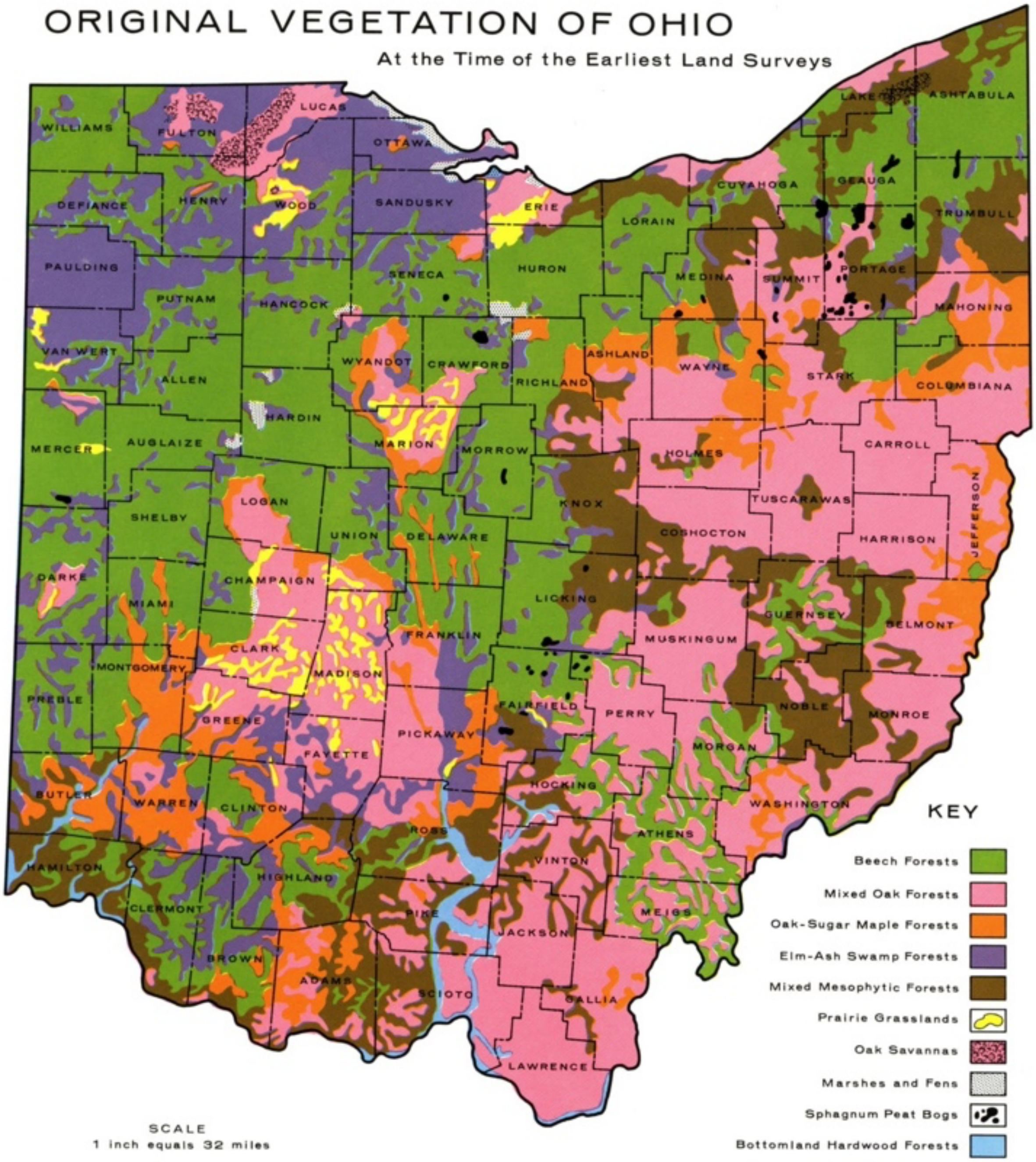



**Figure 1.1. Landcover of Ohio prior to European settlement from Gordon & Flint (1966).**

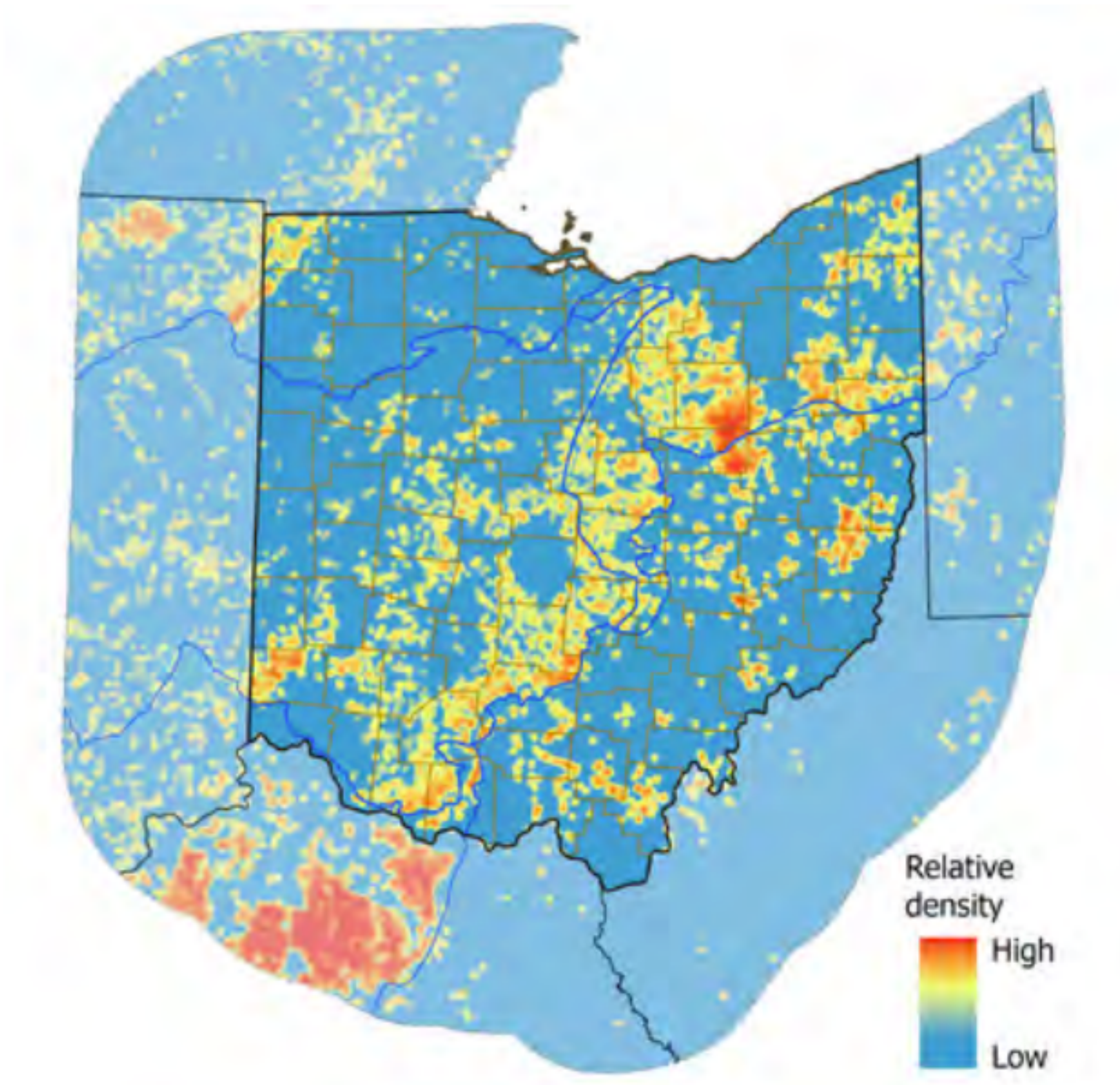



**Figure 1.2. Grassland cover in Ohio in 2021 from Williams et al. (2023).**

## Grassland Birds

Many grassland birds require and occupy sites with specific habitat features and are affected by size, edge, patch shape, and vegetation composition (Herse et al., 2020; Lockhart & Koper, 2018; P. Vickery et al., 2000). Obligate grassland birds are specialists that depend on grassland habitats and include Henslow's Sparrow (*Centronyx henslowii*), Grasshopper Sparrow

(*Ammodramus savannarum*), Bobolink (*Dolichonyx oryzivorus*), and Eastern Meadowlark (*Sturnella magna*; Vickery and Herkert 1995). Facultative grassland birds are not entirely dependent on grassland habitats but use grassland regularly for nesting and foraging, and include Red-winged Blackbird (*Agelaius phoeniceus*), Brown-headed Cowbird (*Molothrus ater*), and Common Yellowthroat (*Geothlypis trichas*; Vickery and Herkert 1995). Obligate grassland birds are impacted by landscape shape (i.e., amount of edge, patch shape, patch size) and species abundance and richness both decrease with greater fragmentation and decreased native plant species composition (Lockhart & Koper, 2018). Because humans have increased fragmentation and invasive species across habitats, anthropogenic disturbance negatively impacts grassland birds even when grassland habitat is available. Many grassland species now occupy artificial grassland habitats created by modern practices (Vickery and Herkert 1995). While these human modified artificial habitats provide important habitat for numerous threatened grassland species such as Henslow's Sparrows and Upland Sandpipers (*Bartamia longicauda*), species with large range requirements and those intolerant of human disturbance continue to decline (Ingold, 2002; P. Vickery & Herkert, 1995).

**Focal Species**

Henslow's Sparrows are small, inconspicuous birds that inhabit grasslands across eastern and central United States. The type specimen for this species was collected in 1820 "amongst tall grass" in Kentucky by John James Audubon and was named for John Stevens Henslow, a Professor of Botany at the University of Cambridge (Hyde, 1939). Henslow's Sparrows are in the family Passerellidae, also known as the New World Sparrows (J. R. Herkert et al., 2020). Henslow's Sparrows were originally placed in the Ammodramus group of sparrows which characterized by large heads, short tails, and drab but patterned plumages (Reinking, 2002) but was changed to the Centronyx group in 2018 to resolve the *Ammodramus* paraphyletic group (Chesser et al., 2018; Klicka et al., 2014).

Henslow's Sparrows are ground nesting birds and build deep cup nests with arched grass roofs at the base of thick clumps of grass (Hyde, 1939). Across their range, nesting beings in late May and ends in August on average (Hyde, 1939). Eggs are incubated for 10-12 days and young fledge 8-10 days after hatching (Hyde, 1939). Henslow's Sparrows have multiple broods per season (Peterjohn, 2001). Adults and juveniles both feed primarily on Orthopteran insects, with crickets and grasshoppers composing most of the diet (Hyde, 1939). Both males and females sing an insect-like song throughout the breeding season while perching on tall stalks of vegetation (Hyde, 1939). While nesting territories of male Henslow's Sparrows are small (0.18-1.0 hectare), this species is more common in large grasslands with high densities of individuals (J. R. Herkert, 2019).

Henslow's Sparrows are an obligate grassland bird that requires appropriate grassland habitat (P. Vickery & Herkert, 1995). Henslow's Sparrows occupy a wide variety of habitats across their breeding and overwintering range, including coastal marshes, swamps, dry fields, wet meadows, weedy hayfields or pastures, and reclaimed surface mines (J. R. Herkert et al., 2020). In the past 50 years populations have decreased 1.5% as they are threatened by habitat loss (Sauer et al., 2019). The Appalachian Mountains Joint Venture, Upper Mississippi River and Great Lakes Joint Venture, and the Ohio Bird Conservation Initiative have identified the Henslow's Sparrow as the highest priority for conservation attention and is included in numerous international, national, and state conservation plans. Henslow's Sparrows have benefitted from the establishment of habitat through programs like the Conservation Reserve Program, a US federal program to set aside farmland with grass and forb cover for at least 10 years (P. D. Vickery & Herkert, 2001). Henslow's Sparrows will also use reclaimed mine land with suitable habitat (Bajema et al., 2001; Ingold, 2002; Ingold et al., 2009; Ingold, 2022).

Studies focusing on the full annual cycle are lacking for many species of grassland birds. Henslow's Sparrow research has focused primarily on nestling and post-fledging birds (Stauffer et al., 2011; Winter, 1999; Young et al., 2019). During the breeding season Henslow's Sparrows use habitats dominated by grasses with a well-developed litter layer, tall and dense vegetation, and low woody density throughout the Midwest (Chandler & Woodrey, 1995; J. R. Herkert, 2019; Young et al., 2019). Areas not occupied by Henslow's Sparrows had 70% greater shrub cover compared to areas occupied by Henslow's Sparrows and fledgling survival was higher in patches with reduced shrub density (J. R. Herkert & Glass, 1999; Young et al., 2019). However, (J. Herkert, 1994) found no relationship between species occurrence and woody stem density. Therefore, Henslow's Sparrows tolerance to woody shrubs is unclear, but they tend to nest in open grassland (Young et al., 2019). Henslow's Sparrows overwinter along the Atlantic and Gulf coasts in the Southeastern United States using fire-maintained pine savannas and open woodlands (Chandler & Woodrey, 1995).

**Figure 1.3. A nanotagged Henslow's Sparrow.**

**Henslow's Sparrows in Ohio**

Henslow's Sparrows were first documented in Ohio in 1872 at Buckeye Lake in Licking County (Rodewald et al., 2016). Henslow's Sparrows were abundant in Ohio until the 1930's, when they were found in 46 counties (Peterjohn, 2001). By the 1960's, population declines were high in glaciated northern and central Ohio, but the population had greatly expanded in unglaciated southern Ohio where there was suitable habitat (Peterjohn, 2001). Henslow's Sparrows are still found across the state, but primarily in southern Ohio (Rodewald et al., 2016).

Henslow's Sparrows start to arrive in Ohio in mid-April with most individuals returned to breeding grounds by mid-May. In Ohio, nesting begins in May and continues through August, sometimes having multiple broods per season (Peterjohn, 2001). Between broods, some individuals will move to different fields due to habitat disturbance (e.g., haying; Peterjohn 2001). Henslow's Sparrows depart their breeding grounds beginning in August through October to migrate to their overwintering grounds in the Southeastern United States (Peterjohn, 2001). Henslow's Sparrows begin to arrive on their overwinter grounds in mid-October and stay until March (E. Johnson et al., 2009). Because Henslow's Sparrows prefer recently burned (3-5 years) overwintering habitat they have low side fidelity between years (Keating et al., 2023; Plentovich et al., 1998).

Henslow's Sparrows distribution, life history, and song were widely studied in Ohio in the early to mid-1900's (Borror & Reese, 1954; Henninger, 1910; Vickers, 1908). Since then, they have been subject to some studies, but remain a mostly unknown and overlooked species. The knowledge gap in previous studies include fine-scale habitat use and dispersal during the post-breeding and fledging period. Because Henslow's Sparrows are in decline in Ohio and are an obligate grassland species with specific habitat requirements, they are an ideal species to serve as a model organism for understanding habitat use and migratory departure timing for grassland birds.

Understanding how Henslow's Sparrows use grassland habitats post-breeding could be useful to prevent further population declines in both Henslow's Sparrows and other grassland species. Further, understanding how Henslow's Sparrows respond to mid-season disturbance, such as mowing, during the post-breeding and fledging period will provide insight into best management practices for the grasslands they inhabit. Using radio transmitters to track the precise habitat used by individuals will provide an accurate idea of Henslow's Sparrows habitat use during this time period.

**Thesis Outline**

The overall goals of my thesis research were to understand how Henslow's Sparrows use grassland habitat in the post-breeding period, to identify post-breeding dispersal to nearby fields, and to understand fall migratory departure timing. In Chapter 2, I determined how Henslow's Sparrows use grassland habitat in relation to the distance to edge and distance to shrub and the home range size of individual birds. My findings will be useful for conservation and management. In Chapter 3, I discuss issues with nanotag application on Henslow's Sparrows which limited my ability to study post-breeding dispersal and fall migratory departure timing. I discovered that Henslow's Sparrows are not a good target species to use leg loop harnesses to fit nanotags. Birds removed harnesses, damaged nanotags, and some birds became entangled in the grass resulting in injury or mortality.

## Chapter 2 Habitat Use of Henslow's Sparrows (*Centronyx henslowii*) in Southern Ohio

### Introduction

In the last 50 years, birds associated with grasslands have experienced greater population declines than birds in other habitat guilds (Rosenberg et al., 2019) due to habitat loss, fragmentation, and degradation (Vickery et al. 2000). Many grassland species have narrow habitat requirements related to patch size (Davis, 2004; J. Herkert, 1994), composition (Cunningham & Johnson, 2019; Hovick et al., 2015; Lockhart & Koper, 2018), and distance to edge (Davis, 2004; Keyel et al., 2013; Sliwinski & Koper, 2012). Habitat use and home range size are influenced by food availability, habitat composition, and habitat structure (Rolando, 2002). Because distance to shrubs, woody vegetation, edge, and home range size influence predation and survival (Benson et al., 2013), brood parasitism, and nest success of birds (Klug et al., 2010; Pietz et al., 2009), evaluating how birds use patches of habitat within the landscape is a high priority in conservation science.

The home range is the area an animal uses to survive and reproduce, which includes the defended territory (Börger et al., 2008). Because grassland species have different home range requirements, understanding home range size allows land managers to provide areas large enough for to sustain bird populations. Home range size of adult grassland birds varies by species and season. In fire-managed savannas, overwintering Henslow's Sparrows (*Centronyx henslowii*) had a home range size of 0.09 – 1.50 ha (Bechtoldt & Stouffer, 2005). In the breeding season, Henslow's Sparrows had a territory size of 0.32 ha (Wiens 1969) and 0.61 ha (Robins 1971) while Savannah Sparrows had a home range size of 0.02 – 0.51 ha (Swanson et al., 2020). Understanding the minimum home range size required by birds allows land managers to preserve patches of adequate size for birds in the breeding season.

A patch is the area of landscape defined by specific characteristics, i.e., a grassland (Clark, 2010). Patch size impacts occupancy, population density, and reproductive success of grassland species such as Henslow's Sparrows, whose population density was negatively affected by smaller patch size in a fragmented habitat (Winter & Faaborg, 1999). Johnson (2001) also suggested that birds may use habitat outside of their established home range, and patches must be larger than the territory size.

Patch size and shape influence the amount of edge and the severity of edge effects on grassland birds (J. Herkert, 1994). Increased edge relative to the shape of the patch decreased richness and abundance of obligate grassland species (Lockhart & Koper, 2018). Other edge effects include an increased risk of brood parasitism (Pietz et al., 2009; Winter et al., 2000), decreased nest density (Ellison et al., 2013; Keyel et al., 2013; Renfrew et al., 2005), and decreased species occurrence (Ellison et al., 2013; Sliwinski & Koper, 2012). Within a patch, species occurrence is affected by density of woody and shrubby vegetation (Grant et al., 2004). Eastern Meadowlark (*Sturnella magna*), Grasshopper Sparrow (*Ammodramus savannarum*), and Clay-colored Sparrow (*Spizella pallida*) use shrubs and other woody vegetation as cover or song perches (Ribic & Sample, 2001; Wiens, 1969). Species density of other grassland species, such as Savannah Sparrow and LeConte's Sparrow, decreases when woody cover reaches 10-25% (Grant et al., 2004).

The Henslow's Sparrow is a ground-dwelling bird that inhabits grasslands across the eastern and central United States (J. R. Herkert et al., 2020). Henslow's Sparrow populations have declined 2.3% per year since 1966 (Sauer et al., 2019) and the species is listed as a bird of conservation concern by national and state organizations (North American Bird Conservation Initiative, 2022; Rosenberg et al., 2016; U.S. Fish and Wildlife Service, 2021; Williams et al., 2023). Henslow's Sparrows' most prominent threats are habitat loss and degradation due to urbanization, agriculture, and loss of successional habitat (P. D. Vickery et al., 1999).

In this study, I aimed to determine how Henslow's Sparrows use grassland habitat in the breeding season. I deployed nanotags on adult Henslow's Sparrows in two grasslands in southern Ohio to determine home range size and habitat use in relation to distance to edge and shrub. Henslow's Sparrows tolerance of woody vegetation is unclear; some studies have found shrub tolerance (Cully & Michaels, 2000; Hill & Diefenbach, 2013), while others have found Henslow's Sparrows occurrence decreases with increasing shrub cover (Crimmins et al., 2016; Jacobs et al., 2012). I predicted that Henslow's Sparrows would use core grassland habitat and avoid edge and shrub. Because male grassland birds use woody vegetation as song perches when available (Johnsgard & Rickard, 1957; Wiens, 1969), I also predicted that there would be a difference in habitat use between males and females.

## Methods

### *Study Area*

This study was conducted June-November 2023 at two field sites in southern Ohio: the Edge of Appalachia Preserve (EOA; 38°45'35"N, 83°27'35"W) in Adams County, owned and managed by both the Conservancy and the Cincinnati Museum Center, and The Wilds (39°49'12"N, 81°43'48"W) in Muskingum County, a partner of the Columbus Zoo and Aquarium. The Edge of Appalachia is a 20,000 acre preserve system that is one of the most biologically diverse natural systems in the midwestern U.S. (The Nature Conservancy). The site was used as agricultural cropland 1930-1980 but has since been hayed annually in late July or early August (R. McCarty, The Nature Conservancy, personal communication). The total area monitored for nanotagged Henslow's Sparrows was 47.1 ha (purple in Figure 2.1a) while our banding site encompassed 23.3 ha (yellow in Figure 2.1a). The field was surrounded by a patchwork of forests and agricultural lands and was bisected by a red cedar (*Juniperus virginiana*) hedgerow. Common vegetation in the field included goldenrod (*Solidago* spp.), common milkweed (*Asclepias syriaca*), ironweed (*Vernonia* sp.), and big bluestem (*Andropogon gerardi*). The center of the field was 64 – 138 m from edge habitat.

The Wilds is a 10,000-acre conservation facility situated on reclaimed surface mine land (The Wilds.org). In 1947, reclamation efforts began in the area through planting trees, autumn olive (*Elaeagnus umbellata*), and grasses; contouring the land to remove highwalls; and building lakes (Swift, 2022). The landscape at this site is heavily eroded due to previous mining activities. The total area monitored for nanotagged Henslow's Sparrows was 255.0 ha (purple in Figure 2.1b) while our banding site encompassed 29.0 hectares (yellow in Figure 2.1b). Our study field was bordered by grassland on three sides, with scattered wooded patches, and a small lake drainage basin on one side. From the center of our study field, the nearest edge was 140.0 m away. Common vegetation in the field included grasses (*Poaceae* spp.), ironweed (*Vernonia* sp.), milkweeds (*Asclepias* sp.), yellow sweetclover (*Melilotus officinalis*), teasel (*Dipsacus fullonum*), thistle (*Cirsium* sp.), and scattered autumn olive shrubs (Ingold 2022).

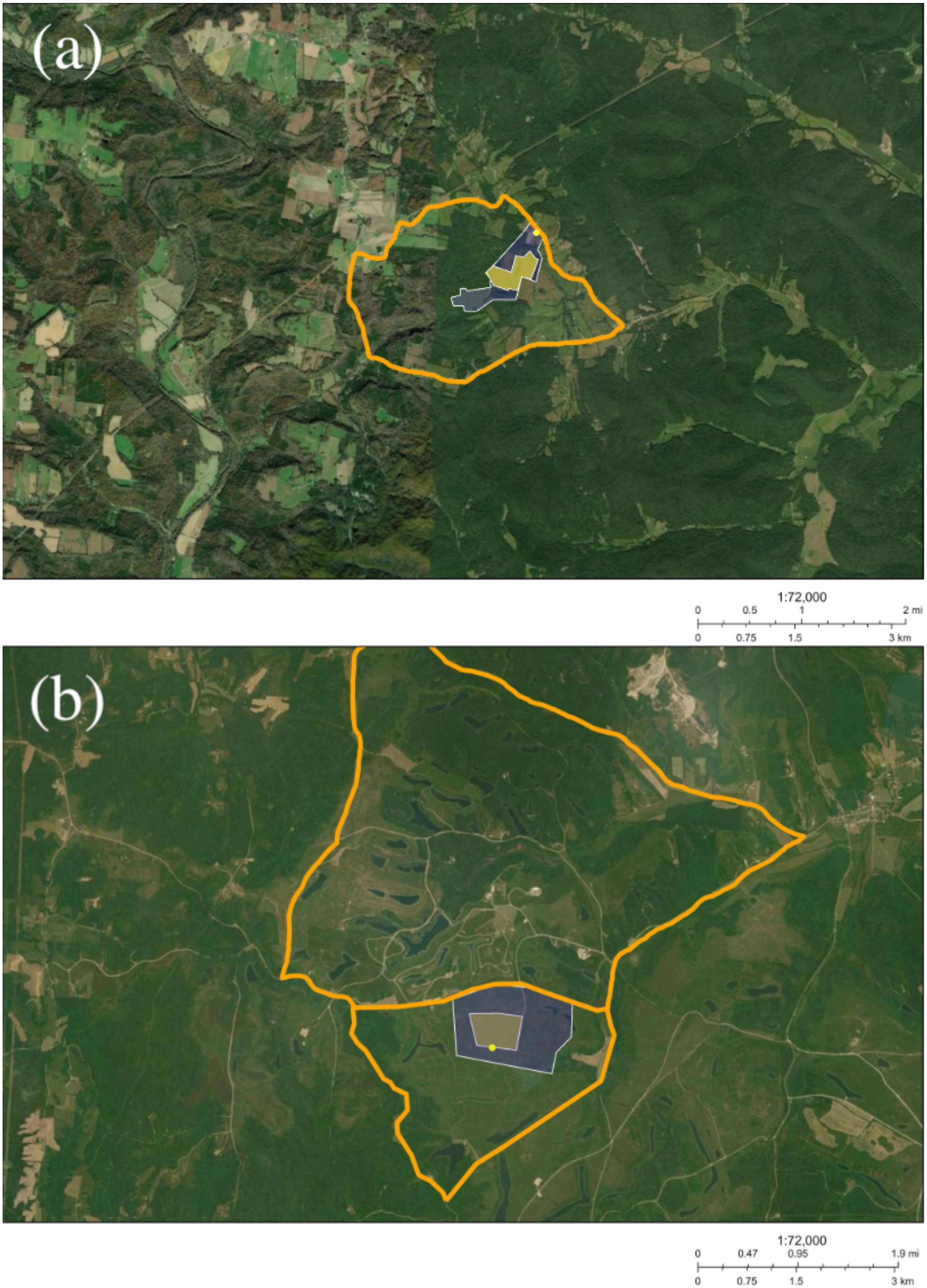

(a)
1:72,000
0 0.5 1 2 mi
0 0.75 1.5 3 km
(b)
1:72,000
0 0.47 0.95 1.9 mi
0 0.75 1.5 3 km

**Figure 2.1. The landscape matrix around our study sites at The Edge of Appalachia (a) and The Wilds (b). The fields where I captured and tagged birds are delineated in yellow, the portion of the field where I manually tracked and searched for birds are delineated in orange. The Motus tower is indicated by a yellow circle. The landscape around the EOA study site is mostly woodland with few residential homes and crop fields, while the landscape around The Wilds study site is the conservation preserve graze lands, woodland, grassland, and some crop fields.**

The Motus Wildlife Tracking System (Motus; motus.org) is a global network of collaborating researchers managing arrays of receiving towers. All data is housed in a centralized database managed by Birds Canada, and nanotags registered with Motus can be detected by any receiver in the network (Taylor et al., 2017). My study sites were within range of a Motus tower and radio transmitters were deployed under project 406 (Ohio University Avian Movement Ecology).

The Motus tower at the EOA was located ~800 m from the study site. The tower was a CTT SensorStation with four 8-element 166.38 MHz Yagi antennas. The expected coverage of the SensorStation is 20 km. The Motus tower at The Wilds was damaged in a lightning strike prior to our field work, so we installed a SensorGnome with an omnidirectional antenna in the field on 8 July 2023. The expected coverage of the SensorGnome is a 500 – 1000 m radius.

***Field Methods***

I, as part of a larger research team, captured birds in mist nets during four tagging events: 22 – 23 June 2023 and 3 – 4 August 2023 at The Wilds and 6 – 7 July 2023 and 31 July – 1 August 2023 at the Edge of Appalachia. I fitted each adult bird with a numbered USGS aluminum leg band and a unique combination of 1-3 color bands to aid in visual identification, following USGS permit #23434 and Ohio University IACUC 21-H-021. In June and July, I fitted hatch year birds with USGS aluminum leg bands and released them. I nanotagged hatch year birds captured in August (n = 6) if flight feather growth was complete and weight was greater than 11 grams. As standard practice, I aged birds based on molt limits following Pyle (1997) and sexed birds as male (cloacal protuberance) or female (brood patch). I weighed (g) and measured wing chord (mm) for all birds. I tagged adult birds that weighed >10 grams with a Lotek Avian Nanotag (model NTQB2-1 at 166.38 MHz) with a burst interval of 21.1 seconds and an estimated total lifespan of 86 days (buffered total lifespan = 129 days). I used a figure-eight leg loop harness (34-38 mm; Rappole & Tipton, 1991; Figure 2.2). The weight of all markers and tags did not exceed 3% of body mass.

I deployed 29 nanotags during the first deployment (The Wilds, 22 – 23 June, n = 15; EOA, 6 – 7 July, n = 14). After the first deployment, I recovered 15 nanotags that were removed by the birds (EOA: n = 6; The Wilds: n = 9). I deployed 27 nanotags during the second deployment (The Wilds, 31 July – 1 August, n = 12; EOA, 3 – 4 August, n = 15). I recaptured 10 of the birds that had removed their first nanotag tag (EOA: n = 5; The Wilds: n = 5) and redeployed a tag. I adjusted leg loop harness size to provide a snugger fit when possible, resulting in harness sizes 0–3 mm smaller. After the second deployment, I recovered 6 nanotags in the field that had been removed by the birds (EOA: n = 2; The Wilds: n = 4). I found three birds entangled in vegetation. Two entangled birds were found dead at The Wilds. One entangled bird was found alive at EOA, so I removed the nanotag and released the bird. One other mortality occurred for unknown reasons; the nanotag was still on the bird and was found by manual telemetry. In total, I deployed 42 nanotags on 47 birds (EOA: n = 21 birds; The Wilds: n = 26 birds).

I used a Lotek SRX1200 M2 receiver and 3-element Yagi antenna for manual telemetry and resighting of color banded birds every 6–14-days from 29 June 2023 to 23 October 2023. I mapped detections of all birds within 255 ha at The Wilds and 47.1 ha at EOA, and assigned territories following Bibby et al (2000; Supplemental Figure 2.3).

The EOA study site was mowed for hay on 21 August 2023. Therefore, I separated data into two time periods for comparisons: early (22 June – 21 August) and late (22 August – 16 October) even though there was no disturbance at The Wilds.

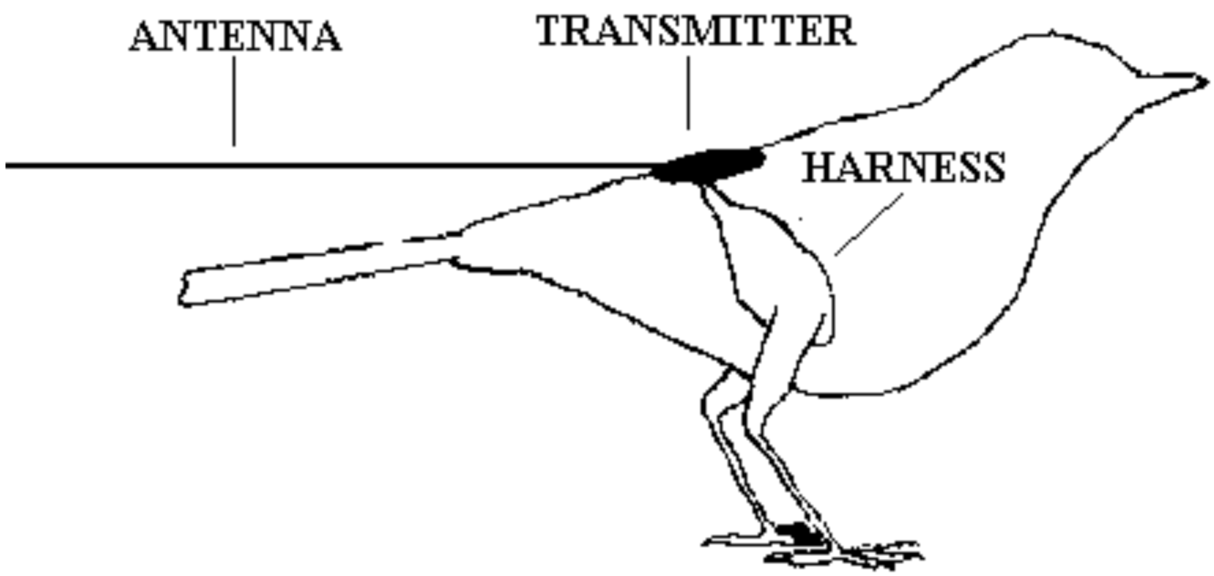



**Figure 2.2. Lateral view of a bird showing placement of the figure-8 harness and transmitter from Rappole & Tipton (1991).**

### *Statistical Analyses*

All analyses were performed in the statistical program R (v4.2.1; R Core Team 2021). We mapped all detections from manual telemetry in ArcGIS to calculate distance to edge and distance to shrub using the measure tool. I used the package *adehabitatHR* (Fortmann-Roe 2023) to calculate 50% and 95% minimum convex polygons of birds with 5 or more detections throughout the season to determine home range size.

Of the 38 Henslow's Sparrows detected, 6 were detected in the field only one time during the season so I could not use individual as a random effect. Instead, I calculated mean distance to edge or shrub to use as response variables in my analyses. I used a general linear model to test the hypothesis that site, sex, Julian day, and time period explained variation in 50% and 95% home range size, and that site, sex, Julian day, time period, and the interaction between site and sex explained variation in mean distance to shrub and edge. Because I used sex as a covariate, hatch year birds in which the sex was unknown (n = 6) were removed from analyses. I used AICc to select the most supported model selection in the package *MuMIn* (Kamil Bartoń, 2023). Model selection tables are included as Supplemental Tables 2.1-2.4.

**Results**

At the two study sites, 38 of the 47 nanotagged individuals were detected by manual telemetry (Supplemental Table 2.1), and 39 of the 47 birds were detected by the Motus tower (EOA: n = 21; The Wilds: n = 18). Four birds were not detected by automated telemetry or manual telemetry after tag deployment, and 5 birds were detected by the automated telemetry tower but not manual telemetry. Within the search area (blue in figure 2.1), territory size of adult Henslow's Sparrows (n = 25) was 0.32 ± 0.06 ha and ranged 0.002 – 0.81 ha. At The Wilds, there were 0.4 birds per ha (females = 0.12 per ha, n = 9; males = 0.28 per ha, n = 8). At EOA, there were 0.53 birds per ha (females = 0.12 per ha, n = 5; males = 0.35 per ha, n = 13).

### *Home Range Size*

Of the 47 nanotagged Henslow's Sparrows, I detected 13 adult birds >5 times throughout the breeding season and could be included in home range analysis (females: n = 5, males: n = 8; Figure 2.3). On the morning of 21 August 2023 prior to mowing at EOA, I detected 15 birds in the field by colorband sighting or telemetry. During mowing (09:00-18:00 H), Henslow's Sparrows moved into smaller patches until no patches remained. Then birds flushed to wooded edge. During mowing, I detected 11 Henslow's Sparrows in the field by telemetry, including one bird that was not detected earlier in the day. After mowing was completed on 21 August 2023 (17:30 H), I detected 4 Henslow's Sparrows in wooded edge adjacent to the field. On 22 August 2023, I detected 7 Henslow's Sparrows in wooded edge and found one in the center of the mowed field. Nine days after mowing, I did not detect any colorbanded or nanotagged birds except one female (purple home range in Figure 2.2a) who remained in an adjoining forest patch. This bird remained in the field and adjoining forest patch with young into November (tag expired on 8 November 2023; life of tag extended beyond 129 day buffer life span). Because this bird had a large home range compared to other birds (likely due to mowing), I removed her from analyses. One male and one female were found at The Wilds beyond 31 Aug.

I found no difference in 95% home range size by site (EOA: 0.15 ± 0.19 ha; The Wilds: 0.37 ± 0.19 ha; Table 2.1) or sex (female: 0.10 ± 0.03 ha; male: 0.32 ± 0.18 ha; $F_{2,10}$ = 1.67, $P$ = 0.24, $R^2_{adj}$ = 0.10). I also found no difference in 50% home range size by site (EOA: 0.025 ± 0.007 ha; The Wilds: 0.032 ± 0.007 ha; Table 2.1) or sex (female: 0.03 ± 0.02 ha; male: 0.03 ± 0.005 ha; Table 2.1) and site and sex did not explain variation ($F_{2,10}$ = 0.25, $P$ = 0.79, $R^2_{adj}$ = -0.14; Supplemental Table 2.2).

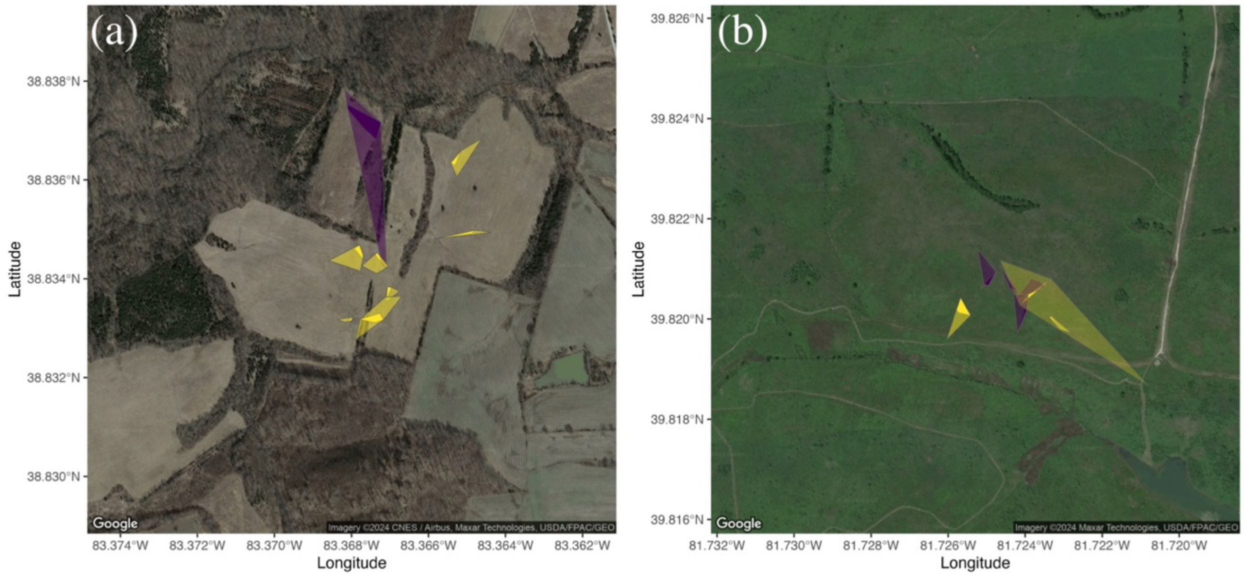



**Figure 2.3. The home range of females (purple) and males (yellow) at The Edge of Appalachia (a) and The Wilds (b). The 50% home range size is mapped (solid) under the 95% home range size (transparent).**

**Table 2.1. Henslow's Sparrow mean ± SE and range 50% and 95% home range size (ha) by Edge of Appalachia (EOA) and The Wilds and sex (female and male). Number of individuals detected per site and sex shown.**

| Site | Sex | n | 50% home range size mean ± SE | 50% home range size range | 95% home range size mean ± SE | 95% home range size range |
|---|---|---|---|---|---|---|
| EOA | F | 1 | 0.21 | 0.21 | 1.50 | 1.50 |
| EOA | M | 7 | 0.03 ± 0.01 | 0.005 – 0.06 | 0.15 ± 0.04 | 0.02 – 0.35 |
| The Wilds | F | 4 | 0.03 ± 0.01 | 0.02 – 0.07 | 0.12 ± 0.03 | 0.05 – 0.17 |
| The Wilds | M | 3 | 0.03 ± 0.01 | 0.01 – 0.06 | 0.71 ± 0.61 | 0.04 – 1.93 |

### *Mean Distance to Shrub*

My AICc selected model of mean distance to shrub included sex, site, and Julian day (AICc = 1172.4, $F_{3,141} = 37.44$, $P < 0.001$, $R^2_{adj} = 0.43$; Supplemental Table 2.3). Females were observed closer to shrubs (21.1 m ± 1.8; Table 2.2) compared to males (26.0 m ± 1.5; $t = -2.04$, $P = 0.04$; Figure 2.4) and Henslow's Sparrows at The Wilds were observed closer to shrubs (12.4 m ± 1.7) compared to EOA (34.8 m ± 1.6; $t = 9.67$, $P < 0.001$; Figure 2.4). Distance to shrub decreased with Julian day ($t = 3.05$, $P = 0.003$; Figure 2.4); however, I only observed 3 individuals after 31 August.

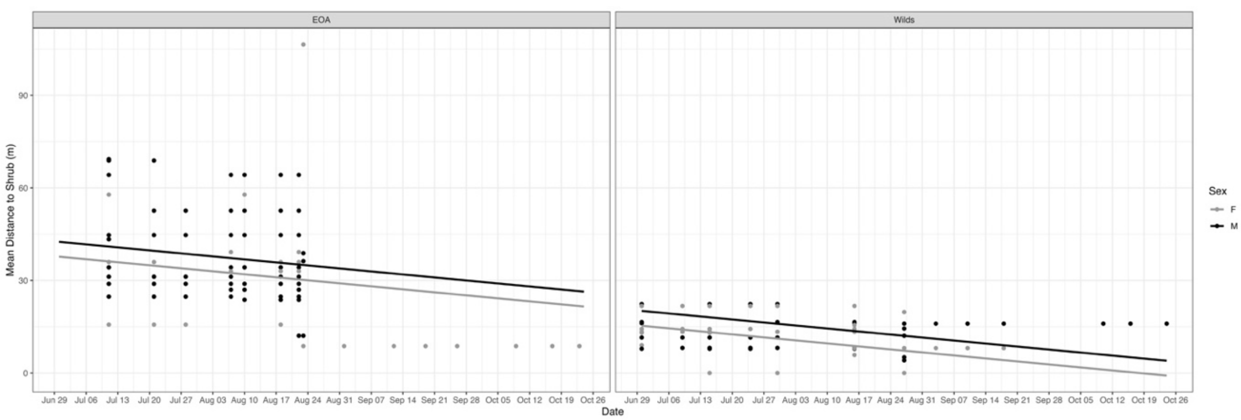



**Figure 2.4. Henslow's Sparrows mean distance to shrub (m) for male and females (female = gray and male = black) at the Edge of Appalachia and The Wilds.**

**Table 2.2. Henslow's Sparrow minimum, maximum, and mean ± SE distance to shrub (m) at the Edge of Appalachia (EOA) and The Wilds, time period (pre-21 August and post-21 August), and sex (female and male) and number of individuals (n).**

| Site | Time Period | Sex | n | Mean | Range |
|---|---|---|---|---|---|
| EOA | Early | F | 5 | 33.3 ± 6.0 | 4.2 – 90.9 |
| | | M | 12 | 39.4 ± 3.0 | 0 – 96.1 |
| EOA | Late | F | 2 | 19.6 ± 11.6 | 0 – 106.5 |
| | | M | 3 | 24.8 ± 8.9 | 0 – 38.8 |
| The Wilds | Early | F | 9 | 13.9 ± 2.0 | 0 – 34.0 |
| | | M | 6 | 13.1 ± 1.9 | 0 – 35.5 |
| The Wilds | Late | F | 3 | 8.7 ± 3.1 | 0 – 19.8 |
| | | M | 5 | 13.4 ± 2.5 | 0 – 28.5 |

***Mean Distance to Edge***

My AICc selected model of mean distance to edge included the interaction between site and sex (AICc = 1335.7, $F_{3,141}$ = 64.94, $P$ < 0.001, $R^2_{adj}$ = 0.57; Supplemental Table 2.4). Females at The Wilds had a greater distance to edge (100.4 m ± 8.0; Table 2.3) compared to males (60.2 m ± 7.1; $t$ = 6.77, $P$ < 0.001; Figure 2.5) while there was no difference with distance to edge between males (33.4 m ± 3.2) and females (25.3 m ± 6.0) at EOA ($t$ = -1.40, $P$ = 0.16; interaction: $F_1$ = 33.98, $P$ < 0.001; Figure 2.5). As expected, distance to edge at The Wilds was greater than distance to edge at EOA ($F_1$ = 127.22, $P$ < 0.001; Figure 2.5).

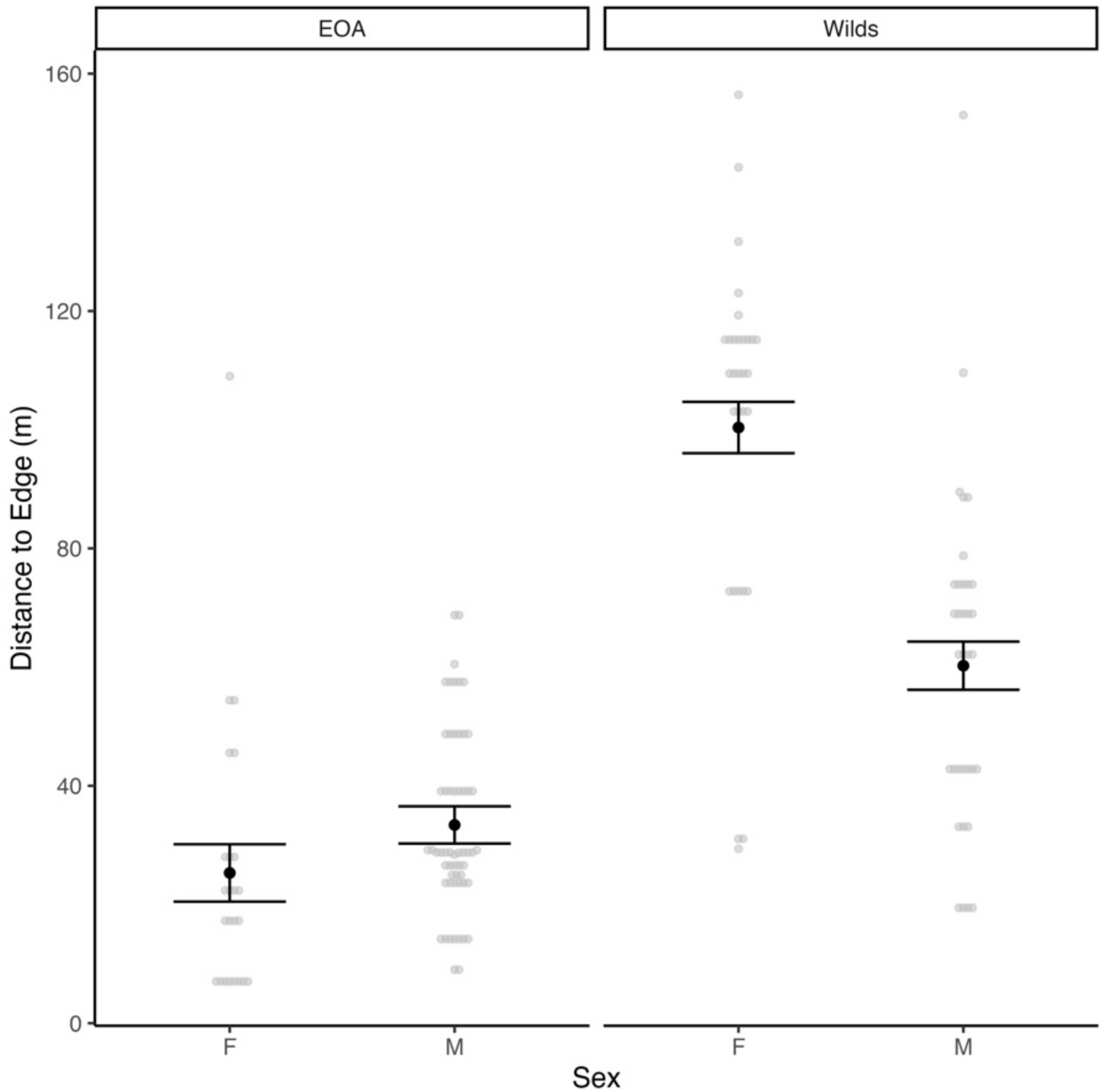



**Figure 2.5. Henslow's Sparrows distance to edge (m; mean ± SE) by sex (female and male) at the Edge of Appalachia (EOA) and The Wilds. Error bars are plotted in black over raw data.**

**Table 2.3. Henslow's Sparrow mean ± SE and range of distance to edge (m) by Edge of Appalachia (EOA) and The Wilds, time period (pre-21 August and post-21 August), and sex (female and male). Number of individuals detected per site, sex, and time period shown.**

| Site | Time Period | Sex | n | Mean | Range |
|---|---|---|---|---|---|
| EOA | Early | F | 5 | 29.5 ± 6.7 | 0.8 – 90.3 |
| | | M | 12 | 34.5 ± 3.3 | 0 – 94.8 |
| EOA | Late | F | 2 | 18.4 ± 11.6 | 0 – 109.0 |
| | | M | 3 | 18.8 ± 6.7 | 0 – 28.7 |
| The Wilds | Early | F | 9 | 96.8 ± 9.0 | 4.7 – 158.3 |
| | | M | 6 | 57.3 ± 8.4 | 2.5 – 140.0 |
| The Wilds | Late | F | 3 | 114.7 ± 17.4 | 40.5 – 156.4 |
| | | M | 5 | 66.4 ± 13.5 | 5.3 – 153.0 |

**Discussion**

I found that both male and female Henslow's Sparrows used shrubs when available. Females were observed using shrubs as cover, while males used shrubs as song perches (GAL, 2023, personal observation). I also found that Henslow's Sparrows used forest edge as refugia when responding to disturbance (e.g., fled from researchers during banding and during mowing for hay). After mowing for hay, one female Henslow's Sparrow with 3 fledged young remained near the field, using the field and forest edges.

Henslow's Sparrows use fields without recent disturbance (Bollinger, 1995; Keating et al., 2023) due to greater litter density, standing dead vegetation, and forb cover (Cully & Michaels, 2000) and potentially shrub cover. Previous studies found Henslow's Sparrows' occurrence decreases with greater shrub density (Jacobs et al., 2012; Wiens, 1969; Zimmerman, 1988). However, at The Wilds, Ingold (2022) found Henslow's Sparrow abundance was greater in cool-season grassland habitats with greater shrub encroachment than in warm-season grassland habitats with little to no shrub cover. Henslow's Sparrows distance to shrub at The Wilds was significantly less than that at the Edge of Appalachia; however, shrubs were scattered throughout the field at The Wilds while shrubs at the Edge of Appalachia were at the edge of fields.

Herse et al. (2020) found that Henslow's Sparrows avoid edge habitat, while Cully and Michaels (2000) found that Henslow's Sparrows use woodland edge, albeit much less frequently than grassland habitat. I found that Henslow's Sparrows used woodland edge as refugia when needed. When I were attempting to flush Henslow's Sparrows into mist nets, I observed birds moving to edge habitat. After mowing, birds that remained in the field used edge habitat. There were at least 11 adult Henslow's Sparrows in the field at Edge of Appalachia at the time of mowing. Five birds were observed using edge habitat during and directly after mowing (21 August), and 9 remained using edge and field habitat until departure (22 August – 6 November). While Henslow's Sparrows may be absent from or found in lower abundance in fields up to one year post-disturbance at some locations (Fuhlendorf et al., 2006; Keating et al., 2023; Reinking et al., 2015), fields at the Edge of Appalachia are mowed for hay annually in late July to mid-August and have had documented breeding Henslow's Sparrows since the mid-1990's (R. McCarty, The Nature Conservancy, personal communication). This is the first study, to our knowledge, that documented movements by Henslow's sparrows during and after disturbance within this field.

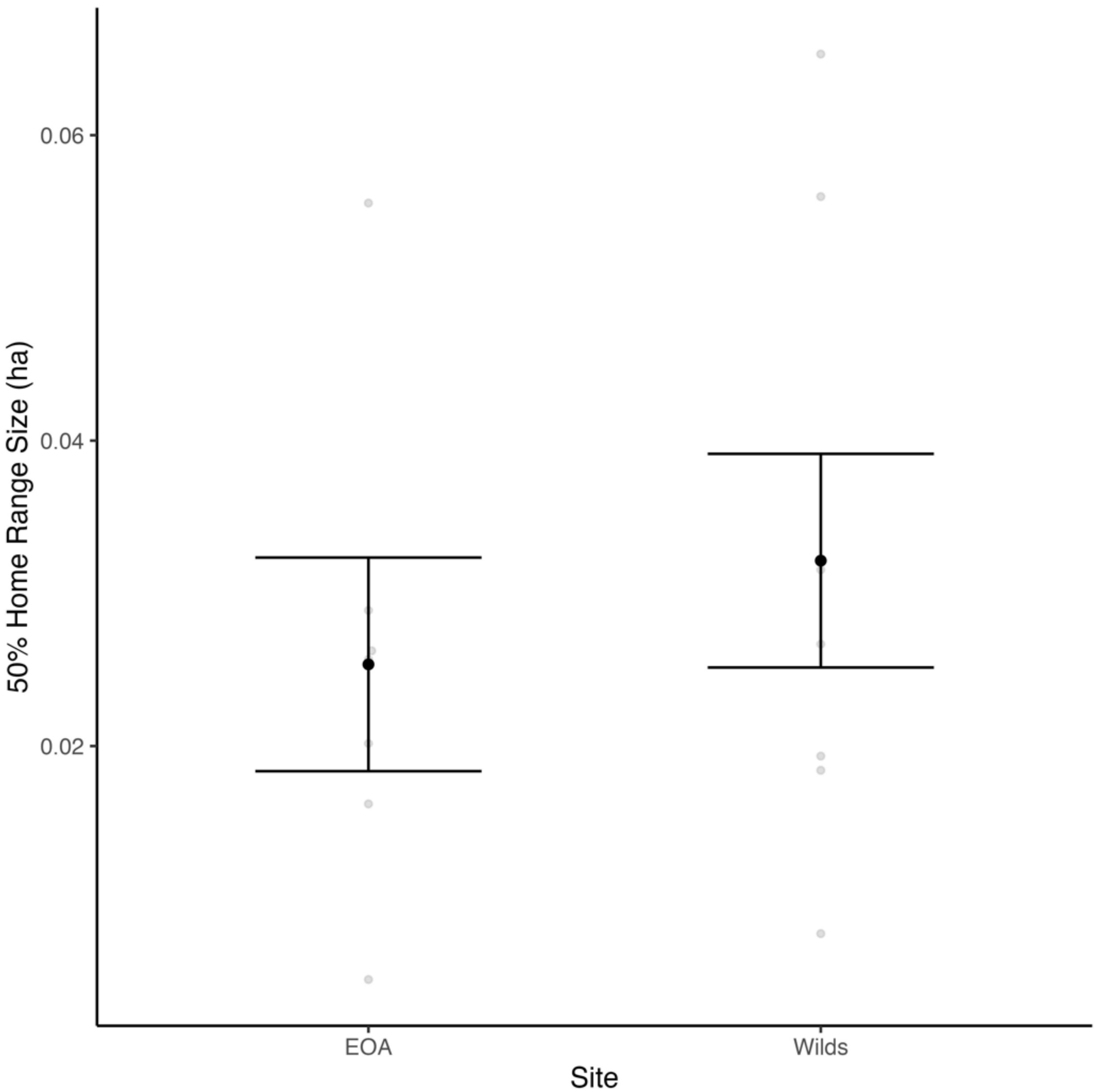
I found densities of 0.40 and 0.53 Henslow's Sparrows per hectare at The Wilds and EOA, respectively. This was comparable to (Winter & Faaborg, 1999) who found 6.34 ± 0.97, 5.56 ± 0.77, and 9.19 ± 1.48 Henslow's Sparrows per 10 hectares across three years in Missouri. I also documented Henslow's Sparrows' 95% home range size (0.02 – 1.93 ha) and 50% home range size (0 – 0.07 ha). Although my samples sizes were small, Henslow's Sparrows' home range sizes we documented were comparable to those found in other studies. For example, Bechtoldt & Stouffer (2005) found overwintering home range sizes of 0.09 – 1.50 ha in Louisiana and Wiens (1969) estimated breeding territory size of 0.32 ha in Wisconsin. Poor quality habitats with scattered resources are associated with larger home range sizes, reduced survival and greater energetic costs (Harestad & Bunnel, 1979). Although density can be an misleading predictor of habitat quality (Van Horne, 1983), density estimates and home range size estimates at multiple sites are valuable metrics for conservation and management.

### *Management Implications and Future Studies*

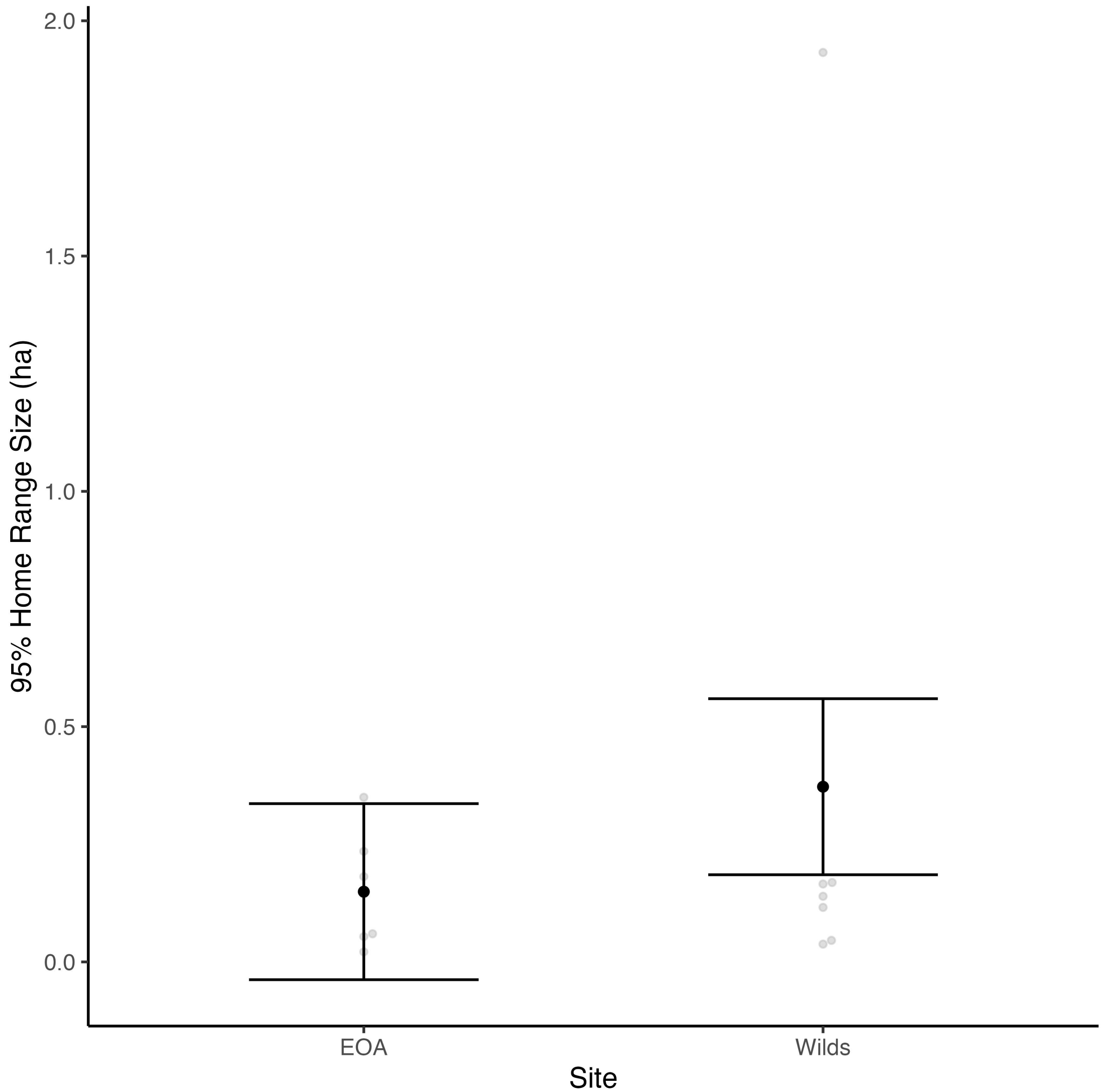
Most grasslands require periodic disturbance to maintain habitat quality and structure required by grassland birds. Mowing for hay is one management method; however, the nutritional quality of hay declines throughout the season (Brown & Nocera, 2017). Williams et al. (2023b) recommends avoiding disturbance in the nesting period (for Ohio: 15 April – 1 August). However, my study of Henslow's Sparrows suggests parental care and use of grassland habitat occurs beyond this period. Henslow's Sparrows can initiate nests until mid-July (Winter, 1999), so mowing during the current recommended time (i.e., after 1 August) could cause nest failure and may occur before young are old enough to disperse to other habitat patches.

I recommend multiple actions for management and conservation of Henslow's Sparrows. If disturbance must occur during the breeding season, I recommend leaving patches of unmowed or unburned habitat in large fields to provide a refuge for birds that cannot disperse. If a field is not large enough to leave undisturbed patches, I recommend rotating disturbance with adjoining fields so birds have less distance to travel to find new patches. I also recommend mowing fields from the center outward (instead of perimeter inward) to provide wildlife corridors for escape. Although disturbance after 1 September may better support breeding populations of Henslow's Sparrows, this timing provides little time for the vegetation to regrow into suitable habitat for migratory stopover and overwintering grassland birds of other species. A landscape approach in the application of disturbance throughout the year is needed to ensure habitat of different successional stages is available to birds throughout the full annual cycle.  Although I found that Henslow's Sparrows will use shrubs when available, I support recommendations to remove and manage woody vegetation in grasslands, especially invasive and non-native species (P. Vickery et al., 2000) to increase the quality of habitat and resources available to grassland birds on the breeding ground.

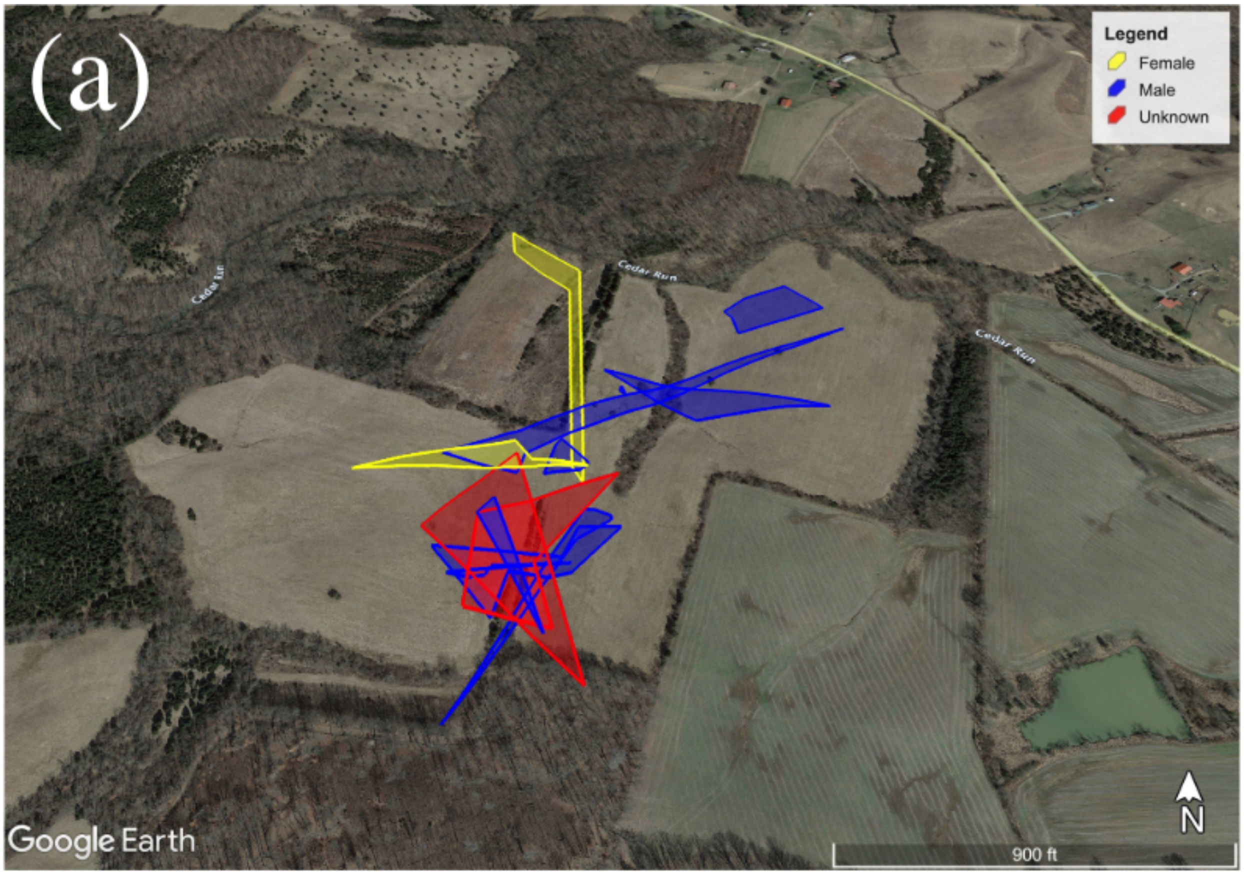
**Supplemental Materials**




**Supplemental Figure 2.1. Henslow's Sparrows 50% home range size (ha; mean ± SE) at the Edge of Appalachia (EOA) and The Wilds are plotted in black over raw data (gray).**




**Supplemental Figure 2.2. Henslow's Sparrows 95% home range size (ha; mean ± SE) at the Edge of Appalachia (EOA) and The Wilds are plotted in black over raw data plotted in gray.**


(a)
Legend
Female
Male
Unknown
Cedar Run
Cedar Run
Google Earth
900 ft
N


(b)
Legend
Female
Male
Google Earth
900 ft
N

**Supplemental Figure 2.3. Territory maps of female (yellow), male (blue) and hatch year (red) Henslow's Sparrows at the Edge of Appalachia (a) and The Wilds.**

**Supplemental Table 2.1. Model selection table of Henslow's Sparrows 95% home range size (ha) as the response variable with sex and site as explanatory variables with predictor variables, AICc, Δ AICc and the model weight. The full model included site (Edge of Appalachia and The Wilds).**

| Explanatory Variables | AICc | Δ AICc | AICc Weight |
|---|---|---|---|
| Site | 26.3 | 0 | 0.39 |
| Sex | 26.6 | 0.27 | 0.34 |
| Site + sex | 27.1 | 0.79 | 0.27 |

**Supplemental Table 2.2. Model selection table of Henslow's Sparrows 50% home range size (ha) as the response variable with sex and site as explanatory variables with predictor variables, AICc, ΔAICc and the model weight. The full model included site (Edge of Appalachia and The Wilds).**

| Explanatory Variables | AICc | Δ AICc | AICc Weight |
|---|---|---|---|
| Site | -65.7 | 0 | 0.5 |
| Sex | -65.5 | 0.29 | 0.43 |
| Site + sex | -61.7 | 4.04 | 0.07 |

**Supplemental Table 2.3. Model selection table of Henslow's Sparrows mean distance to shrub (m) as the response variable with sex, site, time period, Julian day, and the interaction between sex and site as explanatory variables with predictor variables AICc, Δ AICc and the model weight. The full model included sex (female and male), site (Edge of Appalachia and The Wilds), and Julian day.**

| Explanatory Variables | AICc | Δ AICc | AICc Weight |
|---|---|---|---|
| Julian day, sex, site | 1172.4 | 0 | 0.31 |
| Sex, site, time period | 1173.4 | 0.9 | 0.19 |
| Sex, site, time period, sex*site | 1173.6 | 1.14 | 0.18 |
| Julian day, sex, site, time period | 1173.6 | 1.16 | 0.17 |
| Julian day, sex, site, time period, sex*site | 1174.1 | 1.63 | 0.14 |
| Sex, site | 1179.6 | 7.17 | 0.01 |

**Supplemental Table 2.4. Model selection table of Henslow's Sparrows mean distance to edge (m) as the response variable with sex, site, time period, Julian day, and the interaction between sex and site as explanatory variables with predictor variables AICc, Δ AICc and the model weight. The full model included sex (female and male), site (Edge of Appalachia and The Wilds), time period (pre-21 August and post-21 August), and the interaction between sex and site.**

| Explanatory Variables | AICc | Δ AICc | Weight |
|---|---|---|---|
| Sex, site, time period, sex*site | 1337.8 | 0 | 0.75 |
| Julian day, sex, site, time period, sex*site | 1339.9 | 2.15 | 0.25 |
| Sex, site | 1364.8 | 27.08 | 0 |
| Julian day, sex, site | 1365.5 | 27.78 | 0 |
| Sex, site, time period | 1365.8 | 28.03 | 0 |
| Julian day, sex, site, time period | 1367.6 | 29.85 | 0 |

**Supplemental Table 2.5. Number of Henslow's Sparrows detected during manual telemetry (every 6-14 days, 29 June 2023 to 23 October 2023) at the Edge of Appalachia and The Wilds by sex (female and male) and time period (pre-21 August and post-21 August). Number of detections is mean ± SE and includes detections by visual sighting of colorbands or manual telemetry. Seventeen birds were detected (female = 5, male = 12) and seventeen birds were detected at The Wilds (female = 9, male = 8).**

| Site | Sex | Time period | Number of individuals | Detections (mean ± SE) |
|---|---|---|---|---|
| EOA | Female | Pre | 5 | 3.0 ± 0.71 |
| | | Post | 3 | 2.0 ± 1.52 |
| | Male | Pre | 12 | 4.0 ± 0.68 |
| | | Post | 5 | 0.46 ± 0.24 |
| The Wilds | Female | Pre | 9 | 3.11 ± 0.86 |
| | | Post | 2 | 1.67 ± 1.01 |
| | Male | Pre | 8 | 1.79 ± 0.59 |
| | | Post | 1 | 0.71 ± 0.50 |

**Supplemental Table 2.6. Henslow's Sparrow 50% and 95% home range size (ha), territory size (ha), distance to shrub (mean ± SE), distance to edge (mean ± SE), and departure date by individual. If exact departure date is unknown, the date the individual was last detected is shown. Individuals are identified by USGS band number, colorbands applied, sex, age, site, and nanotag(s).**

| Band | Colorband | Sex | Age | Site | Date tagged | Nanotag | Second date tagged | Second tag | Detections | 50% home range (ha) | 95% home range (ha) | Territory (ha) | Distance to shrub mean ± SE (m) | Distance to edge mean ± SE (m) | Depart date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 289027833 | MA | M | SY | The Wilds (ZR) | 6/7/23 | 230 | | | 0 | | | | | | >6/23/23 |
| 301032802 | OA | F | SY | The Wilds | 6/22/23 | 231 | | | 2 | | | | 13.06 ± 8.21 | 31.07 ± 26.37 | 10/26/23 |
| 301032808 | MOA | M | SY | The Wilds | 6/22/23 | 233 | 8/4/23 | 242 | 4 | | | 0.02 | 14.79 ± 3.72 | 95.61 ± 28.25 | |
| 301032810 | MYA | M | SY | The Wilds | 6/22/23 | 228 | | | 0 | | | | | | |

| Band | Colorband | Sex | Age | Site | Date tagged | Nanotag | Second date tagged | Second tag | Detections | 50% home range (ha) | 95% home range (ha) | Territory (ha) | Distance to shrub mean ± SE (m) | Distance to edge mean ± SE (m) | Depart date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 301032811 | WGA | M | AHY | The Wilds | 6/22/23 | 232 | | | 6 | 0.01 | 0.04 | 0.19 | 11.50 ± 1.30 | 73.94 ± 17.66 | 10/19/23 |
| 301032812 | RA | F | AHY | The Wilds | 6/22/23 | 236 | | | 2 | | | | 0.00 ± 0.00 | 115.17 ± 43.14 | |
| 301032815 | MGA | M | ASY | The Wilds | 6/23/23 | 250 | | | 4 | | | 0.02 | 22.36 ± 4.47 | 19.46 ± 8.06 | |
| 301032816 | OBA | M | SY | The Wilds | 6/23/23 | 245 | 8/4/23 | 433 | 4 | | | 0.37 | 16.51 ± 9.58 | 33.10 ± 3.85 | >8/15/23 |

| Band | Colorband | Sex | Age | Site | Date tagged | Nanotag | Second date tagged | Second tag | Detections | 50% home range (ha) | 95% home range (ha) | Territory (ha) | Distance to shrub mean ± SE (m) | Distance to edge mean ± SE (m) | Depart date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 301032823 | WBA | F | SY | The Wilds | 6/23/23 | 418 | 8/3/23 | 434 | 5 | 0.03 | 0.17 | 0.56 | 14.27 ± 4.58 | 72.79 ± 16.25 | >8/24/23 |
| 301032826 | OGA | M | SY | The Wilds | 6/23/23 | 234 | 8/3/23 | 250 | 6 | 0.03 | 1.93 | 0.78 | 7.63 ± 2.42 | 82.99 ± 21.60 | |
| 301032827 | MRA | M | SY | The Wilds | 6/23/23 | 249 | | | 0 | | | | | | |
| 301032828 | WA | F | AHY | The Wilds | 6/23/23 | 248 | | | 8 | 0.07 | 0.12 | 0.47 | 13.352 ± 5.04 | 109.47 ± 20.86 | |

| Band | Colorband | Sex | Age | Site | Date tagged | Nanotag | Second date tagged | Second tag | Detections | 50% home range (ha) | 95% home range (ha) | Territory (ha) | Distance to shrub mean ± SE (m) | Distance to edge mean ± SE (m) | Depart date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 301032829 | SA | F | AHY | The Wilds | 6/23/23 | 247 | | | 1 | | | | 9.01 | 29.4 | |
| 301032830 | OOA | M | SY | The Wilds | 6/23/23 | 237 | 8/3/23 | 426 | 4 | | | 0.03 | 7.86 ± 3.70 | 62.13 ± 16.62 | |
| 301032831 | RA | F | SY | The Wilds | 6/23/23 | 251 | | | 7 | 0.02 | 0.05 | 0.1 | 17.61 ± 4.07 | 109.27 ± 8.91 | >8/26/23 |
| 301032832 | ORA | M | SY | The Wilds | 6/23/23 | 238 | | | 0 | | | | | | |

| Band | Colorband | Sex | Age | Site | Date tagged | Nanotag | Second date tagged | Second tag | Detections | 50% home range (ha) | 95% home range (ha) | Territory (ha) | Distance to shrub mean ± SE (m) | Distance to edge mean ± SE (m) | Depart date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 288080273 | ABO | M | AHY | EOA | 7/6/23 | 428 | | | 6 | 0.02 | 0.05 | 0.19 | 31.21 ± 2.87 | 23.65 ± 1.39 | |
| 301032833 | WA | M | SY | EOA | 7/6/23 | 235 | 8/1/23 | 243 | 5 | 0.00 | 0.02 | 0.009 | 34.24 ± 6.18 | 26.6 ± 7.19 | |
| 301032834 | RA | M | ASY | EOA | 7/6/23 | 239 | 8/1/23 | 252 | 10 | 0.06 | 0.35 | 0.47 | 21.92 ± 4.67 | 24.38 ± 6.73 | >8/28/23 |
| 301032837 | OA | F | AHY | EOA | 7/6/23 | 430 | 8/1/23 | 418 | 13 | 0.21 | 1.50 | 0.67 | 17.81 ± 4.99 | 12.15 ± 3.18 | >11/6/23 |

| Band | Colorband | Sex | Age | Site | Date tagged | Nanotag | Second date tagged | Second tag | Detections | 50% home range (ha) | 95% home range (ha) | Territory (ha) | Distance to shrub mean ± SE (m) | Distance to edge mean ± SE (m) | Depart date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 301032838 | BMA | M | SY | EOA | 7/6/23 | 240 | 7/31/23 | 246 | 9 | 0.03 | 0.24 | 0.81 | 44.71 ± 9.38 | 39.11 ± 11.42 | >8/21/23 |
| 301032839 | BWA | M | SY | EOA | 7/6/23 | 429 | | | 1 | | | | 69.3 | 60.5 | >7/20/23 |
| 301032840 | MRA | M | AHY | EOA | 7/7/23 | 427 | | | 1 | | | | 43.35 | 39.05 | |
| 301032843 | WRA | M | AHY | EOA | 7/7/23 | 417 | | | 9 | 0.03 | 0.14 | 0.1 | 29.83 ± 2.90 | 15.96 ± 4.68 | >8/23/23 |

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| Band | Colorband | Sex | Age | Site | Date tagged | Nanotag | Second date tagged | Second tag | Detections | 50% home range (ha) | 95% home range (ha) | Territory (ha) | Distance to shrub mean ± SE (m) | Distance to edge mean ± SE (m) | Depart date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 301032844 | RRA | M | AHY | EOA | 7/7/23 | 419 | 8/1/23 | 244 | 5 | 0.03 | 0.06 | 0.49 | 64.21 ± 16.41 | 57.50 ± 17.95 | |
| 301032845 | OMA | M | SY | EOA | 7/7/23 | 421 | | | 1 | | | | | | >7/7/23 |
| 301032852 | WYA | M | AHY | EOA | 7/7/23 | 431 | | | 7 | 0.02 | 0.18 | 0.47 | 52.63 ± 7.73 | 48.73 ± 8.12 | >8/23/23 |
| 301032856 | MA | F | AHY | EOA | 7/7/23 | 229 | | | 4 | | | 0.8 | 15.68 ± 3.70 | 17.26 ± 7.06 | >7/12/23 |

| Band | Colorband | Sex | Age | Site | Date tagged | Nanotag | Second date tagged | Second tag | Detections | 50% home range (ha) | 95% home range (ha) | Territory (ha) | Distance to shrub mean ± SE (m) | Distance to edge mean ± SE (m) | Depart date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 301032859 | BA | F | AHY | EOA | 7/7/23 | 424 | | | 2 | | | | 57.81 ± 33.06 | 54.41 ± 31.70 | >7/13/23 |
| 301032861 | YMA | M | SY | EOA | 7/7/23 | 241 | | | 2 | | | | 68.85 ± 8.76 | 68.76 ± 10.75 | |
| 301032866 | | U | HY | EOA | 7/31/23 | 231 | | | 4 | | | 1.29 | 19.49 ± 13.68 | 50.17 ± 14.37 | |
| 301032869 | | U | HY | EOA | 7/31/23 | 233 | | | 7 | 0.20 | 0.68 | 0.95 | 18.50 ± 5.48 | 15.18 ± 5.75 | >8/24/23 |
| 301032836 | | U | HY | EOA | 8/1/23 | 419 | | | 1 | | | | 46.25 | 34.05 | |

| Band | Colorband | Sex | Age | Site | Date tagged | Nanotag | Second date tagged | Second tag | Detections | 50% home range (ha) | 95% home range (ha) | Territory (ha) | Distance to shrub mean ± SE (m) | Distance to edge mean ± SE (m) | Depart date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 301032873 | MMA | F | ASY | EOA | 8/1/23 | 234 | | | 4 | | | 0.34 | 51.39 ± 18.42 | 48.26 ± 20.28 | >8/23/23 |
| 301032878 | MWA | M | SY | EOA | 8/1/23 | 423 | | | 4 | | | 0.15 | 29.95 ± 8.04 | 25.93 ± 9.24 | >8/23/23 |
| 301032880 | OYA | M | SY | EOA | 8/1/23 | 247 | | | 4 | | | 0.002 | 23.72 ± 1.01 | 29.17 ± 2.67 | >8/22/23 |
| 301032887 | BRA | F | AHY | EOA | 8/1/23 | 420 | | | 2 | | | | 39.19 ± 34.96 | 45.55 ± 44.80 | >8/23/23 |
| 301032892 | | U | HY | The Wilds | 8/3/23 | 232 | | | 1 | | | | | | |

| Band | Colorband | Sex | Age | Site | Date tagged | Nanotag | Second date tagged | Second tag | Detections | 50% home range (ha) | 95% home range (ha) | Territory (ha) | Distance to shrub mean ± SE (m) | Distance to edge mean ± SE (m) | Depart date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 301032893 | MBA | F | SY | The Wilds | 8/3/23 | 235 | | | 2 | | | | 12.81 ± 6.95 | 139.73 ± 16.71 | |
| 301032895 | WOA | F | SY | The Wilds | 8/3/23 | 425 | | | 1 | | | | 8 | 131.8 | 10/7/23 |
| 301032896 | OWA | M | SY | The Wilds | 8/3/23 | 427 | | | 0 | | | | 4.1 | 78.78 | |
| 301032900 | BYA | M | SY | The Wilds | 8/4/23 | 236 | | | 0 | | | | | | >8/4/23 |
| 301061902 | YMA | M | SY | The Wilds | 8/4/23 | 428 | | | 8 | 0.06 | 0.17 | 0.26 | 16.00 ± 3.30 | 42.81 ±12.16 | 10/31/23 |

| Band | Colorband | Sex | Age | Site | Date tagged | Nanotag | Second date tagged | Second tag | Detections | 50% home range (ha) | 95% home range (ha) | Territory (ha) | Distance to shrub mean ± SE (m) | Distance to edge mean ± SE (m) | Depart date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 301061907 | WMA | M | SY | The Wilds | 8/4/23 | 240 | | | 1 | | | | 14.4 | 89.5 | |
| 301061908 | YOA | F | AHY | The Wilds | 8/4/23 | 237 | | | 5 | 0.02 | 0.14 | 0.17 | 9.57±2.57 | 111.30 ± 20.16 | |
| 301061909 | | U | HY | The Wilds | 8/4/23 | 245 | | | 0 | | | | | | 10/22/23 |
| 301061910 | | U | HY | The Wilds | 8/4/23 | 432 | | | 0 | | | | | | >8/9/23 |

## Chapter 3 Negative Impacts of Transmitter Use in a Grassland Passerine

### Introduction

In the last 50 years, birds associated with grasslands have experienced greater population declines than birds in other habitat guilds (Rosenberg et al., 2019). Understanding the post-breeding dispersal and migratory timing of grassland species allows us to manage and maintain grasslands while reducing negative impacts on populations (Williams et al., 2023). Additionally, understanding the migratory timing of grassland birds allows us to protect migratory pathways during critical migration periods (Faaborg et al., 2010). Radio transmitters and automated radio telemetry are useful tools that provide data about the presence and absence of birds in an area, as well as migratory movements that can better inform how birds use habitats throughout the full annual cycle.

In the past 10 years, technology has advanced so we can apply transmitters to smaller birds (Taylor et al., 2017; Williamson & Witt, 2021). Small radio transmitters can be affixed to birds in three ways: glue, backpack harness, and leg-loop harness (Mackenzie et al., 2024). Harness styles require a proper fit to the individual bird; harnesses must be snug enough to remain on the bird but loose enough to not restrict movement or growth (Naef-Daenzer, 2007). Transmitters plus all other auxiliary markers should not exceed 3% of the individuals body weight (Barron et al., 2010). We used figure-eight leg loop harnesses (Rappole & Tipton, 1991). Harness sizing can be guided by weight (Naef-Daenzer et al., 2001) and experience of other researchers (e.g., tag harness size; https://docs.motus.org/en/tags/tag-deployment), but should be fitted to the individual bird. Studies using this technology provide valuable information on movement patterns of birds (Taylor et al., 2017); however, researchers should be aware of potential problems and negative impacts of transmitters on birds (Barron et al., 2010; Jones et al., 2024).

Numerous challenges can arise when using transmitters and radio telemetry on birds (Barron et al., 2010; Jones et al., 2024). A meta-analysis found energy expenditure was greater in tagged birds than non-tagged birds (Barron et al., 2010; Godfrey et al., 2003). Survival of Barn Swallows (*Hirundo rustica*) was also negatively impacted by transmitter deployment (Scandolara et al., 2014). Hill and Elphick (2011) conducted a survey of 60 researchers that used transmitters and found that entanglement within vegetation was reported for 19% of grassland species, including Henslow's Sparrows. Risk of entanglement may be age related (van Vliet & Stutchbury, 2018) as fledglings have less mobility and tend to hide under vegetation (Suedkamp Wells et al., 2007). Entanglement is a risk in non-grassland species as well. Dougill et al. (2000) found Palila (*Loxioides bailleui*) entangled in trees 8 times. In juvenile Louisiana Waterthrushes (*Parkesia motacilla*) and Sprague's Pipits (*Anthus spragueii*), adults were observed removing transmitters from nestlings (Fisher et al., 2010; Mattsson et al., 2006). Within species, transmitters can have different effects based on age, sex or the part of the annual cycle the bird is in (Barron et al., 2010). For example, female Barn Swallows had decreased survival and greater transmitter loss rates compared to males (Scandolara et al., 2014). In addition, transmitter failure may occur due to electronic failure or because of damage inflicted by birds (Naef-Daenzer et al., 2001).

I deployed nanotags on Henslow's Sparrows in two grasslands in southern Ohio to determine post-breeding dispersal and fall migratory departure timing. However, because of tag loss, tag damage and entanglement, I was unable to obtain sufficient sample sizes to meet our goals. Problems with nanotag deployment are rarely reported or published (Jones et al., 2024). Researchers should both be aware of, and willing to report these problems to the community. Here, I report findings of habitat use during post breeding period from my limited sample size but focus on reporting problems encountered in using nanotags in Henslow's Sparrows with the aim of raising awareness of negative consequences of nanotag use in this, and likely other, grassland species.

**Methods**

I, as part of a larger research team, captured birds in mist nets during four banding events during summer 2023. I conducted bird banding using mist nets during two periods (early and late) to ensure battery life lasted through mid-October so I could obtain data on post-breeding dispersal and fall migration. Early season banding occurred on 22 – 23 June 2023 and 3 – 4 August 2023 at The Wilds and 6 – 7 July 2023. Late season banding occurred on 31 July – 1 August 2023 at the Edge of Appalachia.  The Edge of Appalachia Preserve site (EOA; 38°45'35"N, 83°27'35"W) was in Adams County, owned and managed by both the Conservancy and the Cincinnati Museum Center. The site was used as agricultural cropland 1930-1980 but has since been hayed annually in late July or early August (R. McCarty, The Nature Conservancy, personal communication). The Wilds site (39°49'12"N, 81°43'48"W) was in Muskingum County, a partner of the Columbus Zoo and Aquarium. The landscape at this site is heavily eroded due to previous mining activities and had a high density of non-native vegetation.

During banding, I fitted each adult bird with a numbered USGS aluminum leg band and a unique combination of 1-3 color bands to aid in visual identification, following USGS permit

#23434 and Ohio University IACUC 21-H-021. I aged birds based on molt limits following Pyle (1997) and sexed birds as male (cloacal protuberance) or female (brood patch). I weighed (g) and measured wing chord (mm) for all birds. I tagged adult birds that weighed >10 grams with a Lotek Avian Nanotag (model NTQB2-1 at 166.38 MHz) with a 180 mm whip-style antenna. In June and July, I fitted hatch year birds with USGS aluminum leg bands and released them without transmitters. In August, I nanotagged hatch year (HY) birds captured if flight feather growth was complete and weight was greater than 11 grams (n = 6 HY birds). The weight of all markers and tags did not exceed 3% of body mass.

The nanotags had a burst interval of 21.1 seconds and an estimated total lifespan of 86 days (buffered total lifespan = 129 days). I used a figure-eight leg loop harness (34 – 38 mm) following Rappole & Tipton (1991). We used the Naef-Daenzer (2007) equation to estimate harness sizing with adjustments (Table 3.1); however I adjusted harness size smaller by 3 – 7 mm to better fit Henslow's Sparrows based on my and another researcher's experience in the field (E. Nastase, University of North Carolina, personal communication). I checked that nanotags remained in position on the center of the back by tugging gently (tag moved less than 2 mm caudally) and used the "flip test" in which I flipped the tag toward the bird's head and ensured the tag returned to the appropriate position. I ensured that leg loops remained in place and were not too snug. I also placed birds in the weighing cone again to ensure that the tag remained in place as the bird moved in the cone. If the tag shifted caudally toward the synsacrum during any of these checks, I removed the tag and repeated this process with a 1 – 2 mm smaller leg loop harness.

**Table 3.1. The (Naef-Daenzer, 2007) estimated size for figure-eight leg loop harnesses versus the actual size deployed (Deployed Size). The Naef-Daenzer equation for estimating harness size is 14.16 + 8.34 * bird mass$^{0.437}$. Wing chord, sex, and if the tag was recovered is also shown.**

| Naef-Daenzer Size | Body Mass | Wing Chord | Sex | Tag Number | Deployed Size | Recovered | Comments |
|---|---|---|---|---|---|---|---|
| 40.2 | 13.5 | 51 | M | 228 | 34 | N | never detected |
| 40.9 | 14.4 | 49 | F | 229 | 34 | N | |
| 38.9 | 12 | 59 | M | 230 | 38 | N | never detected |
| 40.1 | 13.4 | 49 | F | 231 | 38 | Y | |
| 39.6 | 12.8 | 52 | M | 232 | 38 | Y | |
| 40.4 | 13.8 | 51 | M | 233 | 38 | Y | |
| 39.7 | 13 | 53 | M | 234 | 38 | Y | |
| 39.9 | 13.2 | 51 | M | 235 | 38 | Y | |
| 40.3 | 13.6 | 49 | F | 236 | 38 | Y | |
| 39.7 | 13 | 54 | M | 237 | 38 | Y | |
| 38.6 | 11.7 | 52 | M | 238 | 38 | N | never detected |
| 40.6 | 14 | 53 | M | 239 | 38 | N | |
| 40.4 | 13.8 | 52 | M | 240 | 38 | Y | |

| Naef-Daenzer Size | Body Mass | Wing Chord | Sex | Tag Number | Deployed Size | Recovered | Comments |
|---|---|---|---|---|---|---|---|
| 39.4 | 12.6 | 54 | M | 241 | 38 | Y | |
| 40.0 | 13.3 | 56 | M | 245 | 36 | Y | |
| 39.3 | 12.5 | 51 | F | 247 | 38 | Y | |
| 40.3 | 13.7 | 49 | F | 248 | 36 | Y | |
| 39.2 | 12.4 | 50 | M | 249 | 36 | N | never detected |
| 39.4 | 12.6 | 52 | M | 250 | 36 | Y | |
| 40.2 | 13.5 | 50 | F | 251 | 36 | N | |
| 39.0 | 12.1 | 52 | M | 417 | 36 | N | |
| 40.7 | 14.2 | 51 | F | 418 | 34 | Y | |
| 39.5 | 12.7 | 53 | M | 419 | 36 | Y | |
| 40.2 | 13.5 | 53 | M | 421 | 34 | N | never detected |
| 40.0 | 13.3 | 50 | F | 424 | 34 | N | |
| 39.4 | 12.6 | 53 | M | 427 | 36 | Y | |
| 39.9 | 13.2 | 52 | M | 428 | 36 | Y | |
| 40.8 | 14.3 | 52 | M | 429 | 36 | N | |

| Naef-Daenzer Size | Body Mass | Wing Chord | Sex | Tag Number | Deployed Size | Recovered | Comments |
|---|---|---|---|---|---|---|---|
| 43.3 | 17.5 | 49 | F | 430 | 36 | Y | high mass due to egg in oviduct |
| 39.8 | 13.1 | 52 | M | 431 | 36 | N | |
| 40.2 | 13.5 | 50 | U | 231 | 34 | N | |
| 38.8 | 11.9 | 47 | U | 232 | 35 | N | |
| 39.9 | 13.2 | 51 | U | 233 | 34 | N | |
| 38.8 | 11.9 | 51 | F | 234 | 34 | N | |
| 39.9 | 13.2 | 50 | F | 235 | 34 | Y | |
| 38.6 | 11.7 | 53 | M | 236 | 34 | N | |
| 39.3 | 12.5 | 49 | F | 237 | 34 | Y | |
| 39.9 | 13.2 | 51 | M | 240 | 36 | Y | |
| 39.7 | 12.9 | 51 | M | 242 | 35 | Y | |
| 39.9 | 13.2 | 52 | M | 243 | 36 | Y | |
| 39.6 | 12.8 | 52 | M | 244 | 35 | Y | |
| 39.6 | 12.8 | 50 | U | 245 | 34 | N | |
| 41.1 | 14.6 | 52 | M | 246 | 35 | N | |
| 38.7 | 11.8 | 50 | M | 247 | 35 | N | |
| 39.9 | 13.2 | 52 | M | 250 | 35 | Y | |

| Naef-Daenzer Size | Body Mass | Wing Chord | Sex | Tag Number | Deployed Size | Recovered | Comments |
|---|---|---|---|---|---|---|---|
| 39.1 | 12.3 | 52 | M | 252 | 35 | N | |
| 40.1 | 13.4 | 49 | F | 418 | 34 | N | |
| 39.0 | 12.2 | 49 | U | 419 | 34 | Y | |
| 40.1 | 13.4 | 52 | F | 420 | 34 | N | |
| 40.0 | 13.3 | 51 | M | 423 | 35 | N | |
| 40.4 | 13.8 | 49 | F | 425 | 35 | N | |
| 40.7 | 14.1 | 52 | M | 426 | 36 | Y | |
| 40.5 | 13.9 | 52 | M | 427 | 35 | Y | |
| | | 51 | M | 428 | 35 | N | no weight |
| 39.0 | 12.1 | 50 | U | 432 | 35 | N | |
| 40.5 | 13.9 | 52 | M | 433 | 35 | N | |
| 39.6 | 12.8 | 49 | F | 434 | 34 | N | |

I used manual radio telemetry to relocate and map birds at each study site once every 10-14 day period until 16 October 2023 as part of another study (Chapter 2). Between 23 June and 31 July, I recovered 15 nanotags during manual telemetry (Table 3.2). The tags were removed by the birds (EOA = 6, The Wilds = 9) and leg loop harnesses were intact. During the late season banding sessions, I reassessed fit and deployed nanotags using 34, 35, or 36 mm leg loop harnesses. During this banding session, I recaptured 10 of the birds that had removed their first nanotag tag (EOA = 5, W = 5) and redeployed tags on these birds. I used the same size loop size on one bird (34 mm) because we did not feel it appropriate to use a smaller size. I used smaller harnesses on 9 birds (Table 3.3). After the second banding session, I continued manual telemetry and I recovered 6 nanotags in the field that had been removed by the birds (Table 3.4; EOA = 2, W = 4).

**Table 3.2. The mean (± SE and range) number of days VHF nanotags applied to Henslow's Sparrows were active and detected by either the Motus Tower (Edge of Appalachia: EOA or the mini station at The Wilds) or by manual radio telemetry during the first deployment. Note: the tower at The Wilds malfunctioned and we did not add a mini station (sensor gnome with Omni directional antenna) until 8 July 2023. Birds that were tagged in June at The Wilds but never detected on the tower are indicated by The Wilds). Tag fate included destroyed, entangled, removed, or retained. Tags were considered destroyed by the Henslow's Sparrow if the bird was recaptured but the nanotag was still in place and was not detectable by the receiver due to damage caused by the bird's beak. Three birds were found entangled by the nanotag and antenna in the vegetation during manual telemetry (three birds were found dead, one bird was found alive. We cut the leg-loop harness to remove the nanotag and released the alive bird without a nanotag). We classified the tag as removed if the tag was found by manual telemetry but there was no evidence that the bird had died. We classified retained tags when we were able to detect birds in different locations during manual telemetry on different days until they were no longer detected in our study area.**

| Tag Fate | Site | n | Mean ± SE | Range |
|---|---|---|---|---|
| destroyed | EOA | 1 | 26.00 | 26 – 26 |
| entangled | EOA | 1 | 5.00 | 5 – 5 |
| malfunction | EOA | 1 | 6.68 | 6.68 – 6.68 |
| removed | EOA | 7 | 4.71 ± 2.79 | 0 – 21 |
| retained | EOA | 11 | 35.68 ± 6.64 | 4 – 87.11 |

| Tag Fate | Site | n | Mean ± SE | Range |
|---|---|---|---|---|
| unknown | EOA | 0 | | |
| destroyed | The Wilds mini | 0 | | |
| entangled | The Wilds mini | 3 | 8.81 ± 2.88 | 3.1 – 12.33 |
| malfunction | The Wilds mini | 0 | | |
| removed | The Wilds mini | 7 | 22.90 ± 4.82 | 9.82 -44.47 |
| retained | The Wilds mini | 7 | 58.25 ± 11.6 | 8.74 – 88.05 |
| unknown | The Wilds mini | 1 | 0.62 | 0.62 – 0.62 |
| destroyed | The Wilds | 0 | | |
| entangled | The Wilds | 0 | | |
| malfunction | The Wilds | 0 | | |
| removed | The Wilds | 7 | 8.57 ± 2.2 | 6 – 22 |
| retained | The Wilds | 0 | | |
| unknown | The Wilds | 5 | 0 | 0 |

**Table 3.3. Fate of second nanotag deployment on birds that removed or destroyed their first nanotag with leg loop harness size (mm) on the first and second deployment. Entangled mortality are birds that we recovered during manual telemetry that were entangled in vegetation and had died.**

| | Harness size (mm) on first and second deployment | | | | |
|---|---|---|---|---|---|
| Fate | 38 to 36 | 38 to 35 | 36 to 35 | 36 to 34 | 34 to 34 |
| Retained | | 2 | 1 | 1 | 1 |
| Removed | 1 | | 2 | | |

| | | |
|---|---|---|
| Entangled Mortality | 1 | 1 |

**Table 3.4. The mean (± SE and range) number of days VHF nanotags applied to Henslow's Sparrows were active and detected by either the Motus Tower at the study site or manual radio telemetry during the second deployment. Tag fate included destroyed, entangled, removed, or retained.**

| Tag Fate | Site | n | Mean ± SE | Range |
|---|---|---|---|---|
| removed | EOA | 2 | 17.51 ± 0.02 | 17.49 – 17.52 |
| retained | EOA | 3 | 73.79 ± 25.32 | 23.20 – 101.16 |
| removed | The Wilds mini | 0 | | |
| retained | The Wilds mini | 1 | 21.07 | 21.07 |

**Results**

I deployed 47 nanotags on 42 birds during the summer of 2023. Eighteen nanotags were retained by birds and were detected by manual and automated telemetry until departure from the study site. I was unable to determine post breeding dispersal due to complications with using nanotags on Henslow's Sparrows. However, I was able to determine migratory departure timing for 13 birds (22 August – 5 November; Supplemental Table 3.1). One Henslow's Sparrow was detected during fall migration at the Caesars Head State Park Motus Tower in Cleveland, South Carolina.

Birds that lost nanotags were able to destroy or remove the nanotag. Removed nanotags had harnesses that were 38 mm (n = 10), 36 mm (n = 10), 35 mm (n = 4), and 34 mm (n = 3). Henslow's Sparrows were observed in the field and in the hand pulling on the antenna and body of the transmitter. Upon nanotag recovery, I found numerous nanotags were damaged including damage to the battery casing (Figure 3.1). Three birds (EOA = 2, The Wilds = 1) were observed via color band resighting but the tag was not detected, indicating that the tags were removed or malfunctioned. On 1 August, I recaptured one female that had destroyed the nanotag by removing the antenna and the coating which reveal the battery. I were able to detect this tag using the manual receiver when the tag was within a few feet of the receiver but the tag was not detectable during telemetry since date. Six birds with nanotags were not detected by manual or automated radio telemetry after tagging in early season. I were unable to determine if I did not detect these birds due to tag damage, tag malfunction, or if the birds left our study site after tagging.

I found three birds entangled in vegetation and two of the entangled birds were found dead. The other entangled bird was found alive, so I removed the nanotag, checked the bird for injuries then released the bird. While the bird had red skin from the harness, no injuries were detected. Nanotags that became entangled had harnesses that were 36 mm (n =1), 35 mm (n = 1), and 34 mm (n = 1). One other mortality occurred at The Wilds for unknown reasons; the bird was found during manual telemetry with the nanotag intact but was not entangled in vegetation.

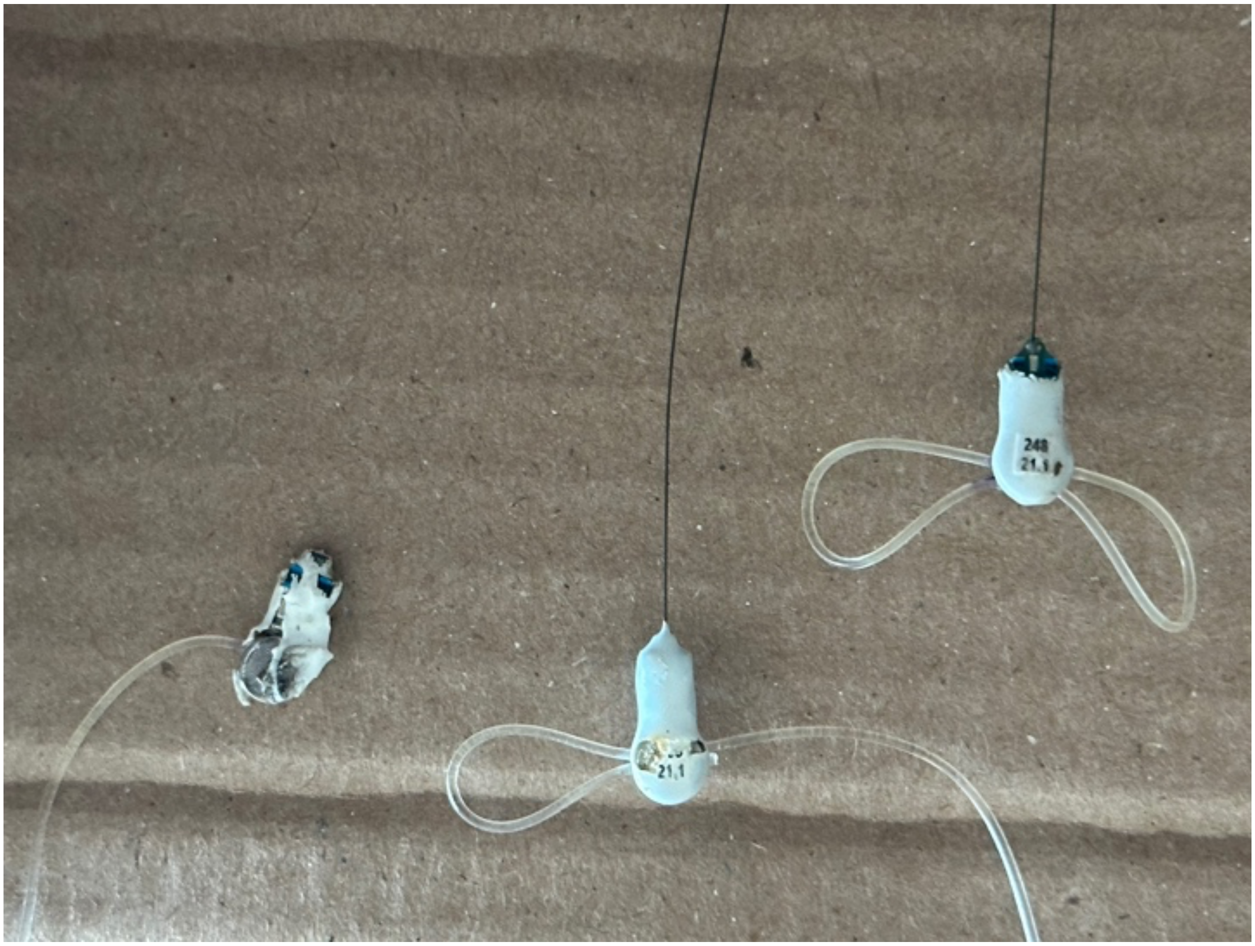


**Figure 3.1. Three examples of nanotags damaged by Henslow's Sparrows. Damage was observed to the battery casing, the leg-loop harness, and the antenna.**

## Discussion

I was unable to determine post breeding dispersal for most individuals because of nanotag loss and damage. While I ensured proper leg loop harness size by tugging the tag caudally (tag moved less than 2 mm) and using the flip test, I found that if birds pulled the tag caudally to the synsacrum, birds were still able to flip the tail above the nanotag and remove the harness despite my best efforts. However, tighter harnesses can result in the birds are not able to get out of the harnesses when they became entangled resulting in fatalities. Therefore, I found there is a need for balance of nanotag sizing as harnesses must be snug enough to avoid loss but loose enough to avoid fatal entanglement or injury to the bird. Entanglement has been reported in grassland birds previously (Hill & Elphick, 2011; van Vliet & Stutchbury, 2018; Young et al., 2019), particularly Henslow's Sparrows (Thatcher et al., 2006; Young et al., 2019).

Reducing antenna length is suggested in some cases to reduce or prevent entanglement (Streby et al., 2015). However, the birds that I found entangled had the nanotag and base of the antenna entangled in vegetation. In areas of dense vegetation, such as my study sites, shorter antennas would still become entangled. Longer antenna length is also associated with a greater detection distance (Jones et al., 2024). Therefore, researchers must balance entanglement risk and detectability of study species.

My study highlights the need for redetection of nanotagged birds after tagging to ensure safe and best practices for each study species. I used manual and automated telemetry, color band resighting, and recapture to determine the fate of our birds. However due to time constraints and study design, many researchers rely on automated telemetry to detect birds after tagging and do not use manual telemetry to ensure birds are moving within the landscape, especially when studying long-term movements (González et al., 2020; Herbert et al., 2022).

Researchers should ensure proper fit for each species to avoid injury and reduce the risk of tag loss. I recommend using a larger harness size when necessary. While tag recovery will be required if birds remove the harness and tag, the risk of fatal entanglement is decreased. When working with a species, I strongly recommend the use of manual telemetry, color band resighting, or recapture to determine if there is damage to nanotags or injury to birds. If birds are not detected, we don’t know if the bird left the study area or if damage to the tag caused malfunction resulting in non-detects. If damage to tags, entanglement and mortality occur, methods other than the use of nanotags may be more appropriate for the species. At this time, I cannot recommend the use of nanotags and leg-loop harnesses for Henslow’s Sparrows, nor other grassland birds that run through thick grasses (Hill & Elphick, 2011; van Vliet & Stutchbury, 2018).

# Chapter 4 Discussion

Because grassland birds are declining drastically, the need for additional studies to understand how birds use and survive in the landscape are critical to make and implement conservation actions. The goal of my thesis was to determine habitat use (distance to shrub, distance to edge, and home range size), post-breeding dispersal, and migratory departure timing of Henslow's Sparrows in Southern Ohio.

In chapter 2, I found that Henslow's Sparrows used shrubs as song perches by males and for cover by females. Shrub usage is not well documented in Henslow's Sparrows, as previous studies (Jacobs et al., 2012; Wiens, 1969; Zimmerman, 1988) found that Henslow's Sparrows' occurrence decreases with shrub density. I also found that Henslow's Sparrows use edge habitat as refugia during disturbance by researchers and management such as mowing for hay. Edge use was also not well documented in Henslow's Sparrows, as previous studies (Herse et al. 2020) found that Henslow's Sparrows avoid edge habitats. Finally, I found that Henslow's Sparrows may remain using grassland habitat much later in the season than we previously thought. Many management recommendations recommend delaying haying until mid to late July (Williams et al., 2023); however, I found that birds continued to use fields past these dates. Very little is known about Henslow's Sparrow migration, especially fall migratory departure timing (J. R. Herkert et al., 2020). Johnson et al. (2009) found that Henslow's Sparrows begin arriving on the wintering grounds in Louisiana in October. However, a number of the birds at my study sites remained through the end of October.

In chapter 3, I found that the use of nanotags and radio telemetry was less effective in Henslow's Sparrows than with other species due to tag loss, tag damage and mortality resulting from tag entangelement in vegetation. While using radio telemetry on secretive birds like Henslow's Sparrows provides us with critical life history data, this is not an appropriate method to use on this species at this time due to the risk of entanglement in grass resulting in mortality and damage to tags. For future research on this species, I suggest the use of colorband resighting to evaluate habitat use. While understanding the migratory patterns of Henslow's Sparrows will fill a critical knowledge gap, nanotag technology must advance further prior to doing this research again. Additionally, development of the Motus Network in the Southern United States is necessary for this research.

**Implications**

Understanding the habitat use and migratory patterns of secretive grassland species is critical to conserving habitat for these species. Henslow's Sparrows served as an appropriate model for this research because of their presence on a variety of grassland types. Because Henslow's Sparrows are an understudied species, I was able to contribute to our knowledge base of avian interactions with disturbance as well as the knowledge of Henslow's Sparrows as a species. My recommendations for management will be reported to the Edge of Appalachia to preserve breeding habitat for Henslow's Sparrows and other grassland birds. Finally, my findings of the negative effects of nanotags on Henslow's Sparrows will be reported to the USGS Bird Banding Laboratory for the welfare of all birds.

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