



Grassland Bird and Raptor Inventory of Harpers Ferry National Historical Park, 2022



Harpers Ferry NHP Schoolhouse Ridge North grassland bird habitat, 22 September 2022.
NPS / L. RUDGE

Grassland bird and raptor inventory of Harpers Ferry National Historical Park, 2022

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Abstract

Harpers Ferry National Historical Park (NHP) includes grassland habitats that are maintained for the interpretation of historic Civil War battles. In 2022, as part of the National Park Service Inventory and Monitoring program, the University of Delaware conducted a grassland bird and raptor inventory in the park. The goals of this inventory were to determine the grassland bird use of Harpers Ferry grasslands during Spring and Fall migration, estimate the abundance and daily nest survival for focal breeding species, and determine the raptor use during migration. We established and used multiple avian sampling techniques to address these goals including distance sampling using line transects, mist-netting to capture passerine birds, point counts, hawk watching, and nest searching and monitoring. We conducted this inventory during the annual cycle starting in March 2022 and completed the sampling in October 2022. During the course of this effort, we detected 111 species using the Harpers Ferry grasslands at some time during the year. We found that the park is supporting migrating and breeding grassland birds and that the avian species composition changes over the course of the annual cycle. During migration, we detected focal grassland bird species including Bobolink, Savannah Sparrow, Grasshopper Sparrow, and Eastern Meadowlark. During the breeding season, we located and monitored Eastern Meadowlark and Grasshopper Sparrow nests with adequate sample sizes to estimate daily nest survival. We found that Eastern Meadowlark daily nest survival was relatively high (99%) and was influenced by the proximity of the nest to a forested edge. We recommend the park focus on Eastern Meadowlark and Grasshopper Sparrows as these two species used the park during both Spring and Fall migrations and successfully fledged young during the breeding season. The park could attempt to maintain or enhance Eastern Meadowlark and Grasshopper Sparrow use of the park during all stages of the annual cycle but especially during the breeding season. This could be achieved by continuing to keep the existing breeding areas intact through delayed mowing (no mowing from 15 May – 15 July), removing tree lines and woody or non-native vegetation to increase the perceived openness and grassland patch size, and continuing to monitor the effects of any management actions that may influence grassland bird use of Harpers Ferry NHP. Grassland birds are a national conservation priority so any sites that have the capacity to maintain or enhance these declining habitat specialists should do so. Grassland birds provide an opportunity to integrate cultural and natural resources as these birds were most certainly present prior to, during, and after the Civil War Battles that Harpers Ferry was established to commemorate.

Acknowledgements

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Introduction

North American grasslands have been altered extensively with over 95% of the original grassland extent lost with the remaining grassland habitat occurring in fragmented patches (Knopf 1994, Askins et al. 2007). In the eastern United States, prior to European settlement, there were extensive grassland habitats including the Hempstead Plains on Long Island, beaver meadows, and open areas created by Native Americans through agricultural practices and burning (Askins 1999, Norment 2002). In the late 1800s and early 1900s forest clearing increased grassland and early successional habitats in eastern North America allowing for range expansions and population growth of grassland birds in the region (Hurley and Franks 1976). Currently, grasslands in the Northeast occur in managed landscapes associated with pastures, airports, and hay or fallow fields (Shriver et al. 2005, Vickery et al. 2005, Zuckerberg et al. 2018). The majority of grassland bird populations in the Northeast occur on managed grasslands that provide important habitat for this suite of habitat specialists grassland birds (Bollinger 2001). Protected areas that include grassland habitats in Eastern North America can serve as critical habitat for grassland bird conservation if these areas are managed with the specific objectives of maintaining or increasing grassland bird populations (Bollinger 2001, Norment 2002, Shriver et al. 2005, Vickery et al. 2005).

A suite of bird species in the Mid-Atlantic Region including Horned Lark (*Eremophila alpestris*), Vesper Sparrow (*Pooecetes gramineus*), Grasshopper Sparrow (*Ammodramus savannarum*), Henslow's Sparrow (*A. henslowii*), Savannah Sparrow (*Passerculus sandwichensis*), Eastern Meadowlark (*Sturnella magna*), Bobolink (*Dolichonyx oryzivorus*), Northern Harrier (*Circus cyaneus*), Short-eared Owl (*Asio flammeus*), and Upland Sandpiper (*Bartramia longicauda*) are dependent on grasslands during the annual cycle, and as a group, these species have experienced steeper, more consistent, and widespread declines than any behavioral or ecological guild in the past 40 years (Rosenberg et al. 2019). Widespread conversion of native grasslands for agricultural and urban development are primary causes for these declines, in addition to other factors such as habitat fragmentation (Askins et al. 2007), succession to shrublands or forests (Vickery et al. 2005), and climate change (Zuckerberg et al. 2018). Most grassland ecosystems in North America have been altered or completely developed with total habitat loss exceeding 80%, with only 0.1% of the area making up native prairie (Vickery et al. 1999). Currently, Northeastern grasslands are largely composed of private lands with agricultural lands and hayfields, making up over half of the grassland habitat in the region (Norment 2002). In the Northeast, 14 of 19 species of grassland birds have declined in the past 30 years with Grasshopper Sparrow declining at an estimated rate of 6% annually (Askins 1999, Peterjohn and Sauer 1999). Breeding bird survey trends indicate that Eastern Meadowlark and Grasshopper Sparrow, once relatively common in the Mid-Atlantic, have declined precipitously since the late 1960's (Figure 1).

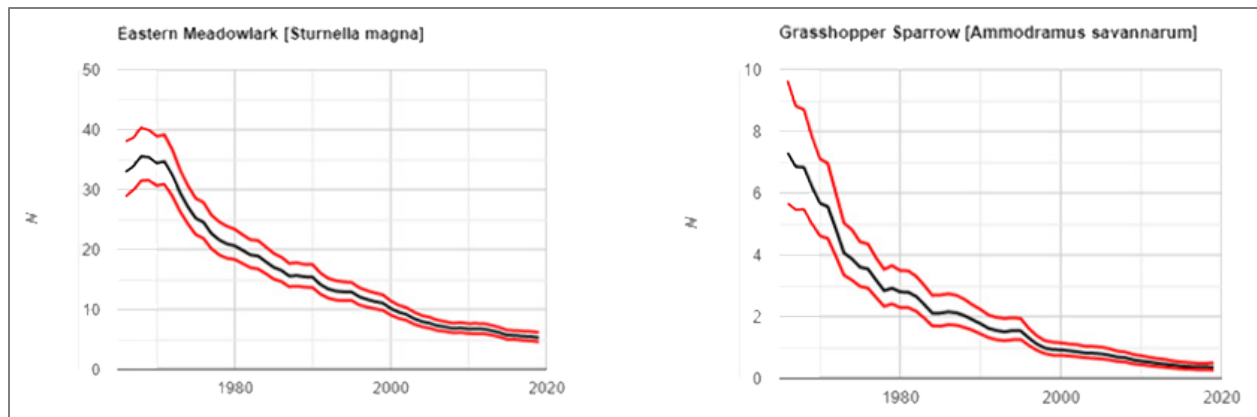


Figure 1. Breeding Bird Survey (BBS) trends (+/- CI) for Eastern Meadowlark and Grasshopper Sparrow in the Appalachian Bird Conservation Region where Harpers Ferry NHP is located. Index of abundance estimates (N y-axis) are from 1966 to 2020 (x-axis). Accessed from <https://eesc.usgs.gov/MBR/>

Public lands (national and state parks and national forests and grasslands) where habitats are relatively intact and protected from conversion to degraded uses or development are fundamental to protecting biodiversity (Lovejoy 2006, Wilson 2016). Protecting biodiversity in protected areas has been shown to not only maintain biodiversity (Saout et al. 2013) but also increase the protected areas perceived value to visitors (Siikamäki et al. 2015). Public lands managed by the National Park Service (NPS) support significant biodiversity nationally and have become increasingly important in this role as habitat loss and fragmentation continue outside park boundaries (Beissinger et al. 2017). In the NPS National Capital Region, several civil war battlefield parks provide habitat for grassland birds within the increasingly urbanized matrix of the Mid-Atlantic region (Peterjohn 2006, Sexton et al. 2013, Massa et al. 2023). These primarily cultural parks maintain grassland areas that replicate their historical appearance and provide important habitat for grassland dependent species, including birds. Additional grasslands that remain in the Mid-Atlantic region include federal, state, and municipal lands (Ruth 2015).

Harpers Ferry National Historical Park (NHP) includes grassland habitats that are maintained for the interpretation of historic Civil War battles (Fig. 1). Situated halfway between the northern and southern forests along the east coast, Harpers Ferry NHP includes a rich diversity of woodland plants, including white and red oak, hickory, black walnut, black locust, and hackberry (*Celtis occidentalis*). Several invasives grow along the fence rows, threatening to encroach upon the fields. These include tree-of-heaven (*Ailanthus altissima*) and Russian olive (*Elaeagnus angustifolia*), among others. Some specimens of osage orange (*Maclura pomifera*) and hackberry still mark the historic fence lines. The farmland is still cultivated with the same crops that grew there during the Civil War, such as hay, corn, and wheat. Thus, vegetation on School House Ridge North has changed little since the historic period of significance, and the site retains a high level of integrity with respect to this aspect of the landscape.

Park Resource Management Issues

Harpers Ferry NHP grasslands include semi-natural plant communities considered successional meadows/grasslands and managed hay fields. Additionally, there are several power line cuts

supporting grasslands. Most of these open areas are bordered by successional forests and various degrees of human development. Park staff at Harpers Ferry NHP are developing a grassland management plan to protect these threatened ecosystems and several of the semi-natural grasslands are currently under consideration for intensive restoration.

Permits

We requested and received a Scientific Collecting Permit from Harpers Ferry NHP and we banded birds under the PI's Master Banding Permit (W. Gregory Shriver #23475).

Project Goals

The primary goal of this project was to provide an inventory of the birds currently using the park grassland habitats throughout the annual cycle. We designed and implemented a grassland bird survey including raptors of Harpers Ferry NHP to estimate species richness, occupancy, abundance, and density during Spring and Fall migrations and during the breeding season. Here, grassland birds are defined as any species that has become adapted to and reliant on some variety of grassland habitat for part or all of its life cycle (Vickery et al. 1999).

Methods

Sample Design

Study Area

Harpers Ferry NHP is a 1,516 ha (3,745 acre) park at the confluence of the Potomac and Shenandoah Rivers, where the borders of West Virginia, Virginia, and Maryland meet. Harpers Ferry NHP was established primarily to preserve historic resources and to commemorate the historic events that occurred at and around Harpers Ferry. Harpers Ferry NHP contains varied habitats such as rivers, riparian areas, agricultural fields, historical towns, ridgelines, and forests. The geographical scope of this project was limited to six distinct grassland sites located in Jefferson County, West Virginia: Schoolhouse Ridge North (including Ott Farm), Lower Bolivar (star), Bolivar Heights, Murphy Farm, Nash Farm (not shown), and Schoolhouse Ridge South (Figure 2).

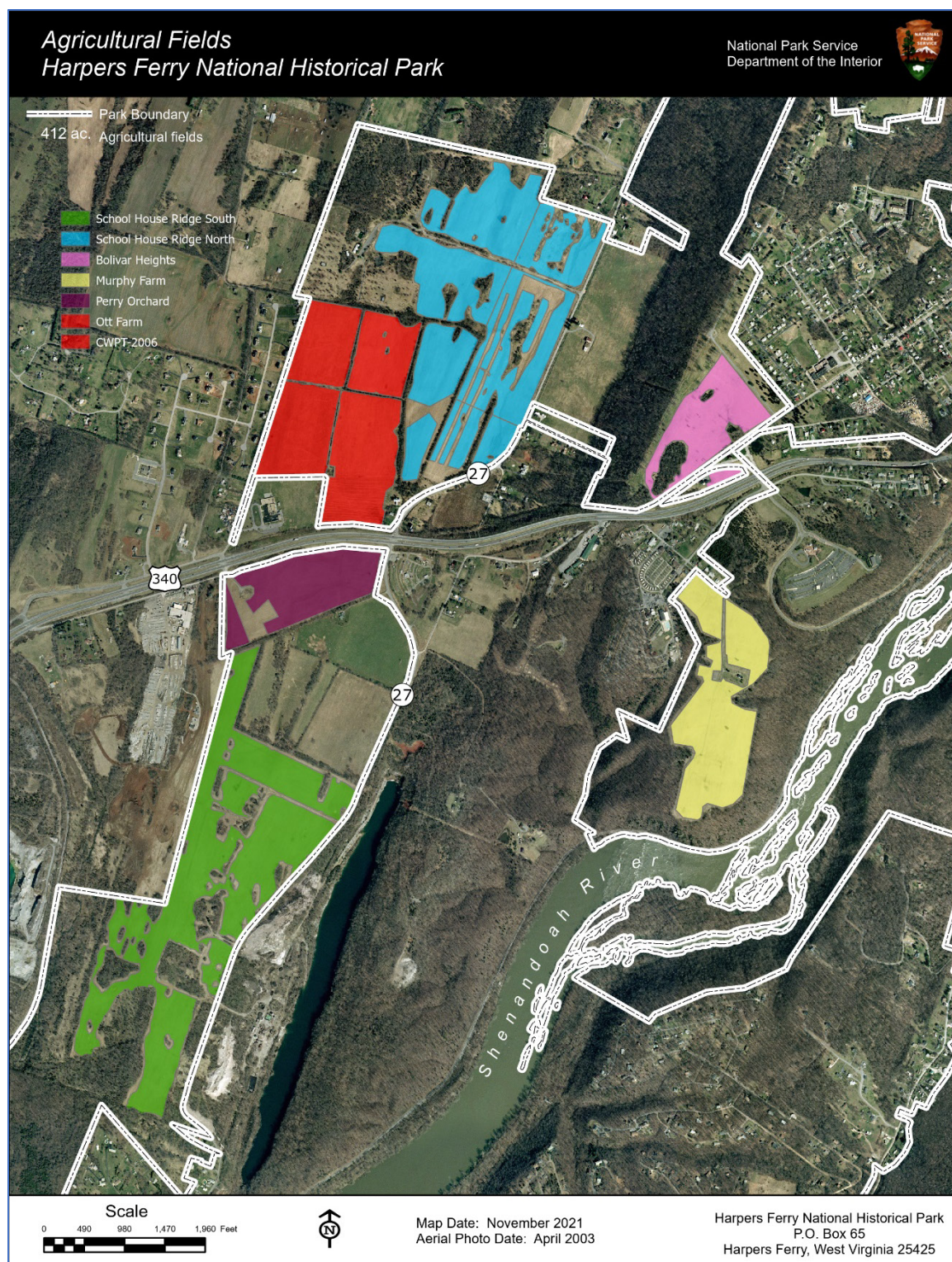


Figure 2. Grassland units sampled for grassland birds at Harpers Ferry NHP, 2022. The 'star' indicates the Lower Bolivar site that is not in an agricultural permit.

There are varying management strategies in place for each grassland site within Harpers Ferry NHP. Lower Bolivar and Nash Farm are not hayed and are managed by the park. In the remaining four grasslands there are currently 408 acres in agricultural permit (personal communication Andrew Lee). A haying restriction for fields in agricultural permit is in place annually from May 15- July 15 but each area is cut at various times at the farmers' discretion throughout the rest of the year. All Harpers Ferry NHP grassland sites share a history of being agricultural fields, so their vegetative makeup is often predominantly cool season grass. There are extensive invasive plants in some fields, especially in the areas that are not hayed or are less frequently hayed/mowed.

Survey Methods

We used multiple avian sampling techniques to quantify the avian community use of Harpers Ferry NHP grassland habitats. We sampled the bird community during Spring and Fall migrations (March – April) as well as during the breeding season (May – August).

- Spring and Fall Migration
 - We established line-transects within the six distinct grassland units of the park to estimate avian species richness and population density by species using distance sampling.
 - We used mist-nets to capture and identify the migratory species using the park grasslands and we used these data to augment estimates of species richness and diversity as well as to estimate timing of migration arrival and departure.
 - We surveyed migratory raptors at designated 'hawk watch sites'
- Breeding Season
 - We used the National Capital Region I&M Landbird monitoring point count surveys to estimate breeding bird species richness and abundance (Dawson and Efford 2014).
 - We established demographic study plots in the different grassland types within the park to locate and monitor breeding bird nests and then estimated daily nest survival for Grasshopper Sparrow and Eastern Meadowlark.

Spring and Fall Migration

Distance Sampling Transects

We established 19 distance sampling transects within each grassland site to cover as much area as possible. To mitigate for edge effect, we used a buffer of at least 50 m from the transect line to the forest edge on either side, so transects were limited to grassland areas with widths greater than 100 m. Due to the heterogeneous composition of grasslands and forested areas in the park, each transect had a unique perimeter, area, and length (Table 1; Figure 3).

Table 1. Line transects surveyed during spring and fall migration at Harpers Ferry NHP. Coordinates are in decimal degrees (Datum = WGS-84)

Site ID	Transect ID	Start Point Latitude	Start Point Longitude	End Point Latitude	End Point Longitude	Length (m)	Visits in Spring	Visits in Fall
Schoolhouse Ridge North	SRNO-01	39.32772502	-77.76583040	39.32043771	-77.77037212	1029	12	15
	SRNO-02	39.31911102	-77.77311041	39.32602511	-77.76902738	842	12	15
	SRNO-03	39.32708235	-77.76824153	39.32837072	-77.77196123	349	12	15
	SRNO-04	39.32728501	-77.77527159	39.32619500	-77.77100800	386	12	15
	SRNO-05	39.32328400	-77.77234800	39.32059324	-77.77355470	521	11	15
	SRNO-06	39.31771198	-77.77679840	39.32460440	-77.77479773	784	12	15
	SRNO-07	39.32500098	-77.77721724	39.31933902	-77.77934970	651	11	15
Lower Bolivar Heights	LOBO-01	39.32115310	-77.76729403	39.32662832	-77.76420644	664	13	15
Bolivar Heights	BOHE-01	39.32274692	-77.76096505	39.32088952	-77.75883006	270	13	15
	BOHE-02	39.31976389	-77.76109167	39.32091389	-77.76241389	171	13	15
Murphy Farm	MUFA-01	39.30757837	-77.76240220	39.31153300	-77.76093300	522	13	15
	MUFA-02	39.31262937	-77.75896112	39.31536978	-77.76217977	412	13	15
Nash Farm	NAFA-01	39.33123207	-77.75388228	39.33167979	-77.75169046	195	13	15
Schoolhouse Ridge South	SRSO-01	39.30754200	-77.77850200	39.30701388	-77.78157799	319	13	15
	SRSO-02	39.30395046	-77.78486710	39.30821900	-77.78310600	498	13	15
	SRSO-03	39.30223047	-77.78441397	39.29827274	-77.78612774	459	13	15
	SRSO-04	39.31487235	-77.78201277	39.31604648	-77.77562856	577	13	15
	SRSO-05	39.31031300	-77.78220800	39.30886589	-77.77835146	375	13	15
	SRSO-06	39.30660624	-77.78093962	39.30402391	-77.78237925	311	13	15



Grassland Bird Survey 2022 - Transect Lines Spring/Fall Migration

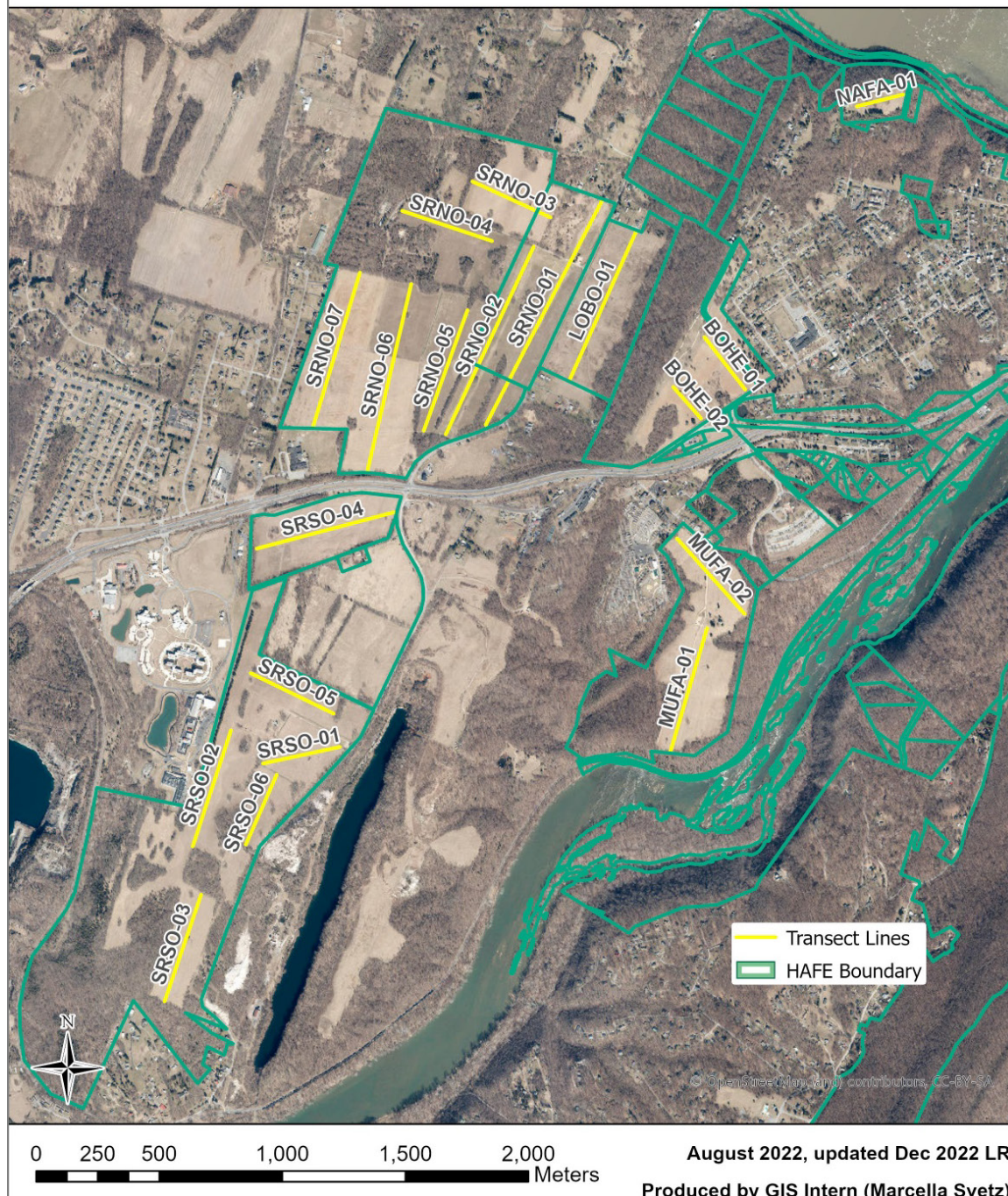


Figure 3. Line transect locations used for surveying birds at Harpers Ferry NHP during spring and fall migration, 2022. HAFE = Harpers Ferry NHP.

In spring, we conducted weekly distance sampling surveys from March 14 until May 3, 2022 on each transect to estimate migratory grassland bird use migrants over time. Due to the unique size and length of each transect line, we could not control for time surveyed at each transect. Therefore, we created consistency by walking the same exact line and walking at a maximum walking speed at each transect. Each technician used features on their handheld Garmin GPS units to walk consistent paths at consistent speeds. After navigating to the start point of the transect, technicians selected the end point of the transect and changed their view to the “Trip Computer” screen to continuously refer to the “Off-Course” function (to identify how far off transect they might be) and the “Speed” function (to keep their walking speed below 2.5 km/h) and correct accordingly.

Technicians conducted distance sampling surveys on each transect between 20 minutes before sunrise until 5 hours after sunrise. During transect surveys, technicians recorded all aural and visual detections of birds using each transect area. The transect area included the edge of the forest, as a bird could pop in and out to forage, seek cover, or use it as a singing perch. Each detection was identified to species and distance perpendicular to the transect line the bird(s) was first observed was measured using Vortex rangefinders (Figure 4). We also collected information on the number of individuals detected at each observation, whether the bird was using the habitat or not (flyover), singing, if a good visual identification could be made, and any notes.

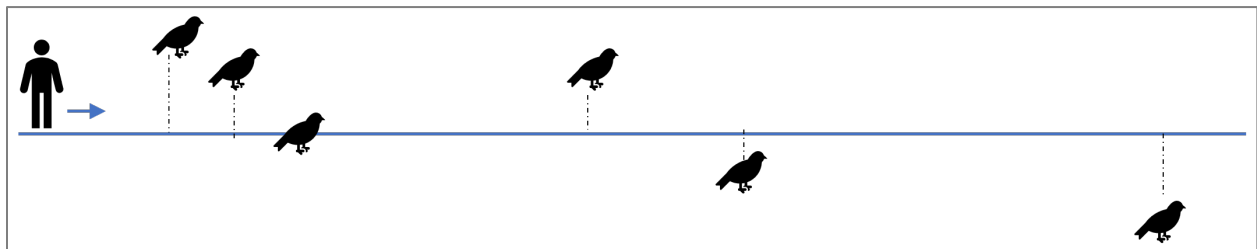


Figure 4. A simple depiction of line-transect distance sampling. The transect line is shown as a solid line, and the distance of each detection along the line (shown by a dotted line) is measured perpendicular to the transect line.

Daily weather variables were collected at each survey including temperature (° F), wind (0 – 12 using the Beaufort scale; <https://www.weather.gov/pqr/beaufort>), and cloud cover following National Weather Bureau codes (ranging from 0 – clear to 8 – snow; https://www.pwrc.usgs.gov/BBS/help/Weather_Codes.txt) Weather Bureau codes). At each transect, measures of human influence such as the level of background noise (0 - 4 scale where 0 = no noise and 4 = probably cannot hear birds beyond 25 m), number of humans, number of leashed and unleashed dogs, and number of feral cats were observed. Other notable observations, such as other wildlife (deer and potential wild predators), park maintenance or interpretation activities, or farming activities were also recorded.

Hawkwatch

We located a hawkwatch site at Harpers Cemetery, with a nearly clear view of north to south ridgeline and of the confluence of the Shenandoah and Potomac Rivers. Observers positioned themselves at the

top of the hill in the Harper cemetery, directly under a dogwood tree near William Broadus's grave marker (Figure 5).

The ridge system is part of the Appalachian portion of the Atlantic flyway, where there are several other hawkwatch sites to the north and south along the ridge line. The Washington Monument State Park hawkwatch near Boonsboro, MD has conducted spring and fall hawk counts since 2003 and is located approximately 27 km (17 miles) northeast of the Harpers Cemetery hawkwatch. The Snickers Gap hawkwatch near Leesburg, VA has conducted fall hawk migration counts since 1992 and is approximately 25 km (16 miles) to the southwest (Figure 5).

At Harpers Cemetery, spring hawkwatch occurred from April 8 to May 12, 2022 following protocols at <https://www.hmana.org/>. Daily counts began after morning operations were completed (~10:00 am) and ended no later than one hour before sunset. Each hour, wind speed (mph) and direction were measured using a Kestrel weather meter, temperature ($^{\circ}$ F), humidity, barometric pressure, visibility (miles) and a second wind speed and direction were measured using the NOAA mobile weather app, and percent cloud cover was estimated by observers. Since it was a pilot year, counts were conducted in all wind and weather conditions as long as visibility allowed observers a high confidence of detecting migrating birds. We counted raptor species common to the Eastern US except Turkey vultures (*Cathartes aura*) and Black vultures (*Coragyps atratus*). Both vulture species are found year-round in this area and were seen flying in often unclear and indecisive flight patterns making it too difficult to determine if the vultures were migrating.

In spring, birds flew northbound over the Blue Ridge/Loudon Heights ridgeline, sometimes kettling over the Loudon Heights overlook area, and then either flew across the confluence over Maryland Heights, or further east over the South Mountain ridgeline. If birds made confident and direct flights from the Blue Ridge to either of these locations, they were considered a migrant. If their flight pattern was less direct, they were followed more closely to determine their status as a migrant or not. Eagles were identified to age class if possible and were always closely followed; they were counted as migrants only if they continued north (as opposed to flying downriver, which was common) and were not seen again for the rest of the hour.

A minimum of two counters faced south towards Blue Ridge and scanned the skies along the ridgeline. Once a raptor was detected, it was identified to species using standard field identification techniques such as shape, color, wing beat cadence, behavior, etc. If it was not possible to identify the bird to species, it was either identified to genus or as an unidentified raptor. Often unidentified raptors happened when the bird was extremely far away from the counters, if the sky conditions were poor i.e., bright clear blue skies with no eye relief, and often a mix of these two difficulties.

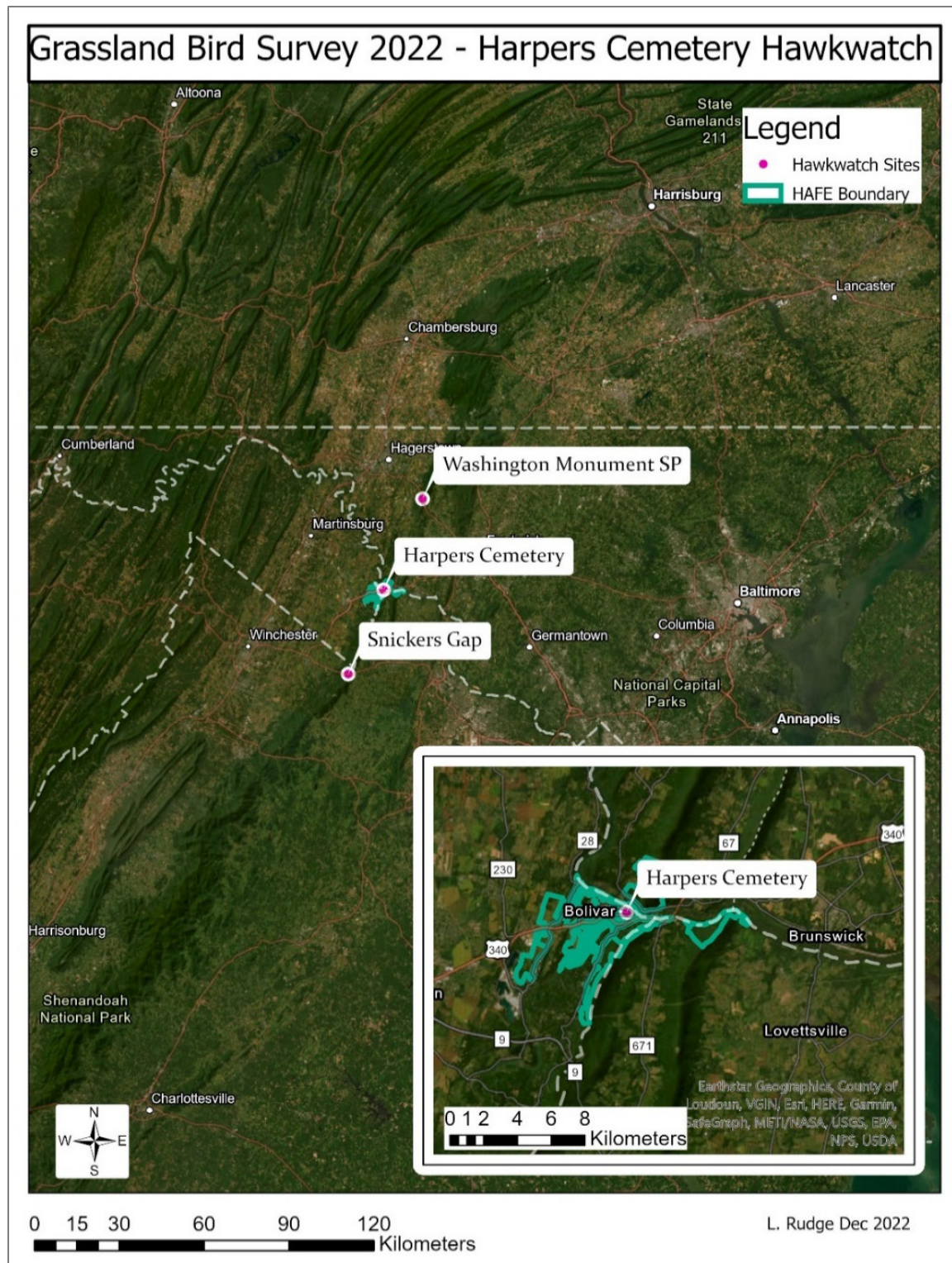


Figure 5. Hawkwatch was conducted during spring and fall migration, 2022, at the Harpers Cemetery hawkwatch site. Two other nearby hawkwatches, Snickers Gap and Washington Monument SP are also shown.

Migration Banding

Using behavioral observations from transect surveys, net locations were opportunistically placed where bird activity had recently been concentrated to increase capture efficiency (Table 2). Up to nine 12 m x 2.5 m x 36 mm mesh songbird mist nets were set depending on the vegetation, topography, and target area. At least two qualified personnel were present at all times. Nets were checked and cleared throughout the morning at 20 - 40 minute intervals. Captured songbirds were placed in holding bags and immediately taken to a centralized banding location for processing.

Table 2. Grassland bird migration banding locations at Harpers Ferry NHP, 2022. Coordinates in decimal degrees; datum = WGS-84.

Season	Site	Transect ID	Latitude	Longitude
Spring	Schoolhouse Ridge North	SRNO-01	39.32584	-77.7674
	Schoolhouse Ridge South	SRSO-01	39.30818	-77.7784
	Murphy Farm	MUFA-01	39.31376	-77.7606
Fall	Schoolhouse Ridge North	SRNO-01	39.32259	-77.7698
	Schoolhouse Ridge North	SRSO-01	39.30775	-77.7811
	Schoolhouse Ridge North	SRSO-01	39.30775	-77.7811
	Schoolhouse Ridge North	SRNO-04	39.32693	-77.7753
	Schoolhouse Ridge North	SRNO-04	39.32244	-77.7753
	Schoolhouse Ridge North	SRNO-06	39.32261	-77.7751
	Schoolhouse Ridge North	SRNO-06	39.32213	-77.7769
	Schoolhouse Ridge North	SRNO-06	39.32244	-77.7753
	Schoolhouse Ridge North	SRNO-06	39.32212	-77.7767
	Schoolhouse Ridge North	SRNO-06	39.32212	-77.7767
	Schoolhouse Ridge North	SRNO-07	39.32261	-77.7751
	Bolivar Heights	BOHE-01	39.32159	-77.7615
	Bolivar Heights	BOHE-02	39.32114	-77.761
	Murphy Farm	MUFA-01	39.31092	-77.7607
	Schoolhouse Ridge South	SRSO-01	39.30833	-77.7786
	Schoolhouse Ridge South	SRSO-01	39.30765	-77.7811
	Schoolhouse Ridge South	SRSO-05	39.30888	-77.7804
	Schoolhouse Ridge South	SRNO-06	39.32244	-77.7753
	Schoolhouse Ridge South	SRNO-06	39.32200	-77.7766

Each captured bird was identified to species and fit with a uniquely numbered aluminum leg band provided by the USGS Bird Banding Lab. Morphometric measurements were collected to determine age, sex, and body condition including length of unflattened wing chord (mm), mass (g), fat score, muscle score, and flight feather molt. Age was determined by degree of skull ossification or plumage characteristics, and sex was determined, when possible, by plumage, wing chord, and presence of breeding condition such as cloacal protuberance or brood patch (Pyle 1997). Mass was measured

using an electronic scale. We scored subcutaneous fat scores (Helms and Drury 1960, Desante and Burton 1997). We determine flight feather molt by examining wing and tail for growing feathers, and was classified as symmetric, adventitious, juvenile, or none. For recaptured individuals, their band number, mass, and body condition (fat and muscle scores) were recorded to estimate daily weight gain or loss and duration of stopover at Harpers Ferry NHP grassland habitats.

Breeding Season

Point counts

We used the National Capital Region Network's (NCRN) grassland point count surveys to estimate breeding bird species richness, diversity, and abundance for a subset of birds present in Harpers Ferry grasslands. NCRN grassland sampling points were randomly located along a grid within each grassland unit and spaced at least 250 m apart to ensure spatial independence (Figure 6). Trained technicians ($n = 3$) surveyed points for breeding birds between early May and July 2022. Technicians conducted surveys between 20 minutes before sunrise until 5 hours after sunrise. At each point, surveys lasted for 10 minutes with observers recording all individuals detected aurally and visually within a 100 m radius of the plot center. To provide information on detection probability, each site was sampled twice per season with observers recording the level of disturbance (e.g., road noise, construction noise, etc.) at each sampling occasion. As we were interested only in individuals occupying the local habitat, flyovers detected during surveys were not considered for this analysis.

Harpers Ferry National Historic Park

Harpers Ferry, WV

National
Park
Service



Figure 6. Breeding grassland bird survey point locations from the National Capital Region I&M Program used for sampling in 2022.

Nest Monitoring

We established demographic study plots in the different grassland sites within the park to locate and monitor breeding bird nests to estimate daily nest survival. Nests were located using behavioral

observation, systematic walking, rope dragging, and haphazard walking survey methods (Winter et al. 2003). Eastern Meadowlark and Grasshopper Sparrow nests were targeted as these species are the most common grassland birds breeding in the park, but all nests of all passerine species located were monitored; Red-winged blackbird (*Agelaius phoeniceus*) and Field sparrow (*Spizella pusilla*) nests were found incidentally. One to three observers searched for behavioral indication of breeding activity in each site at least once per week. When behavioral evidence was found, a more thorough nest search was conducted using the various walking survey types mentioned above based on the size of search area covered and vegetation height and type. Nests were mapped in the field with handheld Garmin GPS units, flagged with pin flags, and monitored every 2-3 days to determine their ultimate nest fate—success, depredated, or abandoned. Nests were considered successful if at least one nestling fledged i.e., if fledgling activity was found in the immediate area or if parents continued to show protective behavior at nest sites after the nest was found empty indicating that fledging was successful.

We recorded vegetation characteristics at nest sites within the week that they became inactive. At all nests, we measured the average vegetation height with a Robel pole. At ground-nester sites (Eastern Meadowlark and Grasshopper Sparrow), we also measured litter depth (cm). At non-ground nester sites (Red-winged Blackbird and Field Sparrow), we also measured nest height with a Robel pole. We also measured vegetation height (Robel) and litter depth (cm) at 60 random points on July 14 and 15, 2022 before the haying period began.

Breeding Season Banding

Banding at nests entailed setting (typically) two nets in a “V” shape surrounding the nest and flushing the brooding female off the nest and into the net in the early morning hours. We aimed to spend ~15 minutes or less at each nest site. If we were not initially successful with our capture, we either attempted to call in the male using playback while the nets were still set up, or we left the nest site for that day. Depending on the nesting stage and observed behavior of the birds, we either returned the next day for nests that were close to fledging young to repeat our capture methods or waited one or two days to return to re-try for nests that were being incubated or had young nestlings. Playback was used only to target grassland obligate species: Eastern Meadowlark, Grasshopper Sparrow, and Bobolink. Playback was not repeated multiple days in a row and was never played for more than one hour at a time.

We attempted to capture both the male and female parents/caretakers at each nest. If we could not capture the male during the nesting cycle, we attempted to call him into the nets using playback after the nest was inactive. This occurred in grasslands cut off from other areas (by significant boundaries such as tree lines) where there was only one singing male to avoid catching males un-related to the nest.

Analysis Methods

Distance Sampling

We used hierarchical models (Royle and Nichols 2003, Chandler et al. 2011) that account for imperfect detection to estimate abundance and density. Specifically, we used the functions ‘distsampOpen’ and ‘pcount’ in the R package ‘unmarked’ for the migration distance sampling

transect and for the breeding season point count data respectively (Fiske and Chandler 2011). Both modeling frameworks provide detection adjusted estimates. We included detection covariates (observer, date, wind, temp, and cloud cover) and observation covariates (grassland type, vegetation cover, openness, and distance to edge) in models for species with adequate detections for model convergence. For infrequently detected species, we provide summary statistics and naïve estimates. We estimated species density of the full range of species present in Harper Ferry NHP across all six grasslands surveyed and for individual fields. We excluded flyovers from our analyses and set a cut-off distance of 100 meters, only including detections within this distance. We only included species with at least 10 detections across all fields.

For each species we fit a series of five pre-selected detection function models to the distribution of distances observed:

- 1) Uniform function with cosine series adjustments,
- 2) Half normal key function with no adjustments,
- 3) Half normal key function with cosine series adjustments,
- 4) Half normal key function with "observer" as a covariate, and
- 5) Hazard rate key function with cosine series adjustments

We ranked models using Akaike's Information Criterion (AICc), selecting the top model as the most parsimonious detection function for each species (Burnham and Anderson 2002). We used the top detection function for each species to estimate density.

Breeding Season Abundance

We estimated the abundance (mean number of birds per sampling location) within Harpers Ferry NHP for four focal species (Field Sparrow, Grasshopper Sparrow, Eastern Meadowlark, and Red-winged Blackbird) based on the point count data from NCRN. Our analysis included data with detections from within a 0-100 m distance band, and analyzed count data from two repeated visits using N-mixture models with the `pcount()` function (Royle 2004, Chandler 2012) in the R package 'unmarked' (Fiske and Chandler 2011).

Nest Survival

We used MCEstimate (Etterson et al. 2007) to estimate daily survival probability for each species and to determine the influence of distance to an edge and type of edge (treeline, hiking trail, public road) on daily nest survival. We used nesting periods of 29 days for Eastern Meadowlark, 27 days for Red-winged Blackbird, and 25 days for Grasshopper Sparrow to determine nest period success (Yasukawa and Searcy 2019, Vickery 2020, Jaster et al. 2022).

Edge effect measurements for nest survival analyses

We used ArcGIS Pro to measure distances (m) between the observed nests and their proximity to the forest edge / tree line, hiking trails, and public roads. To help remove human error, National Park Service GIS layers were used for determining the appropriate locations for the distance variables. However, in some special cases human judgment was required, in which case high resolution (typically 6") imagery was used to raise confidence. Nest coordinates were collected with a handheld

Garmin GPS unit using the WGS 1984 coordinate system. The coordinate system was later projected to NAD 1983 (2011) State Plane Maryland FIPS 1900 (US Feet) to stay consistent with the Harpers Ferry NHP GIS database.

We used a one-way T-test to compare the distance from a nest to edges (tree lines, hiking trails, and public roads) between random locations ($n = 46$) and nest sites ($n = 46$). We used an MCMC model using the software MCEstimate with AICc model selection (Burnham and Anderson 2002) to distinguish among a set of possible models describing the relationship between distance to edges (tree line, hiking trail, public road) and nest failure. For each species (except Field Sparrow), we ran all univariate models ($n = 3$ models), a global model ($n = 1$ model), a null model ($n = 1$ model), distance only ($n = 1$ model) and vegetation only ($n = 1$ model) models.

Results

Spring and Fall Migration

Line Transects – Species Richness

During Spring migration, we sampled line transects using distance sampling from March 14 – May 3, 2022; during that 51-day period, we spent 98 hours surveying Harpers Ferry NHP grassland habitats (Table 3; Figure 3). Schoolhouse Ridge North and Schoolhouse Ridge South were the largest contiguous patches of grassland habitat at Harpers Ferry NHP and therefore have the most transect area compared to the other sites (Table 3). Due to the unique shape of each grassland site, the amount of time spent surveying each location depended on the number, size, and length of transects. Average time spent surveying in smaller areas was less than one hour, while at larger sites average survey times were about two hours in Schoolhouse Ridge South and nearly four hours in Schoolhouse Ridge North.

Table 3. Harpers Ferry NHP grassland bird survey line transect effort, 2022.

Site ID	Length (m)	Hours Surveyed	Times Surveyed	Hours/Survey
Schoolhouse Ridge North	4562	46	12	3.84
Lower Bolivar	664	6	13	0.49
Bolivar Heights	441	5	13	0.40
Murphy Farm	934	10	13	0.75
Nash Farm	195	3	13	0.22
Schoolhouse Ridge South	2858	28	13	2.14
Total	9654	98	–	7.85

During Fall migration, we sampled line transects using distance sampling from September 1 until October 27, 2022 (57 days); over that period, we spent 111 hours surveying Harpers Ferry NHP grassland habitats (Table 3). Due to the unique shape of each transect, the amount of time spent surveying each location depended on size, length, and bird activity; maximum speed was controlled. The most survey effort was conducted in Schoolhouse Ridge North, and the least in Nash Farm. Average time spent surveying in smaller areas was less than one hour, while at larger sites average survey times were nearly two hours in Schoolhouse Ridge South and over three hours in Schoolhouse Ridge North.

Species Richness During Spring Migration

We observed 87 avian species using Harpers Ferry NHP grassland habitats in spring 2022 (Table 4). Schoolhouse Ridge North had the greatest species richness of all sites with 72 species observed and Lower Bolivar had the lowest species richness with 32 species (Table 4). A complete list of species observed at each site, frequency they were detected, and average counts can be found in Appendix A.

Table 4. Number of species detected on line transects during spring migration at Harpers Ferry NHP, 2022.

Site ID	Total # Species	% of all species
Schoolhouse Ridge North	72	83
Lower Bolivar	32	37
Bolivar Heights	37	43
Murphy Farm	53	61
Nash Farm	39	45
Schoolhouse Ridge South	61	70
Total	87	100

The following grassland bird species were detected during our sampling;

Schoolhouse Ridge North - Eastern Meadowlark, Grasshopper Sparrow, Bobolink, Savannah Sparrow, Vesper Sparrow

Schoolhouse Ridge South - Eastern Meadowlark, Grasshopper Sparrow, Savannah Sparrow, Vesper Sparrow

Murphy Farm - Eastern Meadowlark, Grasshopper Sparrow, Savannah Sparrow, Vesper Sparrow

Lower Bolivar - Eastern Meadowlark, Grasshopper Sparrow

Bolivar Heights - Eastern Meadowlark, Savannah Sparrow

Frequently detected species across all grassland sites included American Goldfinch (*Spinus tristis*), Eastern Bluebird (*Sialia sialis*), Eastern Meadowlark, European Starling (*Sturnus vulgaris*), Field Sparrow, Northern Cardinal (*Cardinalis cardinalis*), and Red-winged Blackbird. Northern Cardinal was among the most frequently detected species at all six grassland sites. Eastern Bluebird, Eastern Meadowlark, and Field Sparrow were frequently detected species at five grassland sites. Eastern Bluebirds were never detected on a transect survey in Bolivar Heights in spring but were observed there year-round. Eastern Meadowlarks were detected in every site except for Nash Farm; their average count in Schoolhouse North was 23 birds (± 1.53) and they were found on all 12 surveys in spring. Field Sparrows were detected in all sites except for Murphy Farm. American Goldfinch, European Starling, and Red-winged Blackbird were frequently detected at four of the grassland sites. European Starlings and Red-winged Blackbirds were detected in high numbers in Schoolhouse Ridge North ($n = 96 \pm 22.13$ and 117 ± 16.05 , respectively) and were found at all 12 surveys. As with many species, average counts tended to be higher in larger grassland sites; species with average counts over 20 individuals (including American Robin (*Turdus migratorius*), Eastern Meadowlark, European Starling, and Red-winged Blackbird) were all detected in Schoolhouse Ridge North and Schoolhouse Ridge South. Nash Farm lacked grassland obligate species during spring migration; its species composition was more generalist species.

Species Richness During Fall Migration

We observed 96 avian species using Harpers Ferry grasslands and adjacent habitats in Fall 2022. Schoolhouse Ridge North had the highest species richness of all sites with 79 avian species observed there and Lower Bolivar had the lowest species richness with 32 species (Table 5). A complete list of species observed at each site, frequency they were detected, and average counts can be found in Appendix A.

Table 5. Number of species detected on line transects during fall migration at Harpers Ferry NHP, 2022.

Site ID	Total # Species	% of all species
Schoolhouse Ridge North	79	82
Lower Bolivar	32	33
Bolivar Heights	44	46
Murphy Farm	56	58
Nash Farm	49	51
Schoolhouse Ridge South	69	72
ALL	96	100

Frequently detected species across all grassland sites in fall included American Crow (*Corvus brachyrhynchos*), American Goldfinch, Blue Jay (*Cyanocitta cristata*), Carolina Wren (*Thryothorus ludovicianus*), Cedar Waxwing (*Bombycilla cedrorum*), Eastern Bluebird, European Starling, Northern Cardinal, and Northern Flicker (*Colaptes auratus*; Appendix A). Eastern Bluebirds were found throughout the park, and since haying operations were still active into the fall, we noticed that they were especially active in an area right after it had been hayed and baled. American Goldfinch was frequently detected at five grassland sites. Cedar Waxwing, European Starling, and Northern Flicker were frequently detected at four of the grassland sites (Appendix A; Appendix B). Cedar Waxwings were often seen in large flocks as well; average counts range from a high of 44 ± 11.09 individuals at Schoolhouse Ridge South to 16 ± 6.05 at Bolivar Heights. European Starlings (117 ± 22.97) were detected in high numbers in Schoolhouse Ridge North. As with many species, average counts tended to be higher in larger grassland sites; species with average counts over 20 individuals (including Blue Jay, Cedar Waxwing, Eastern Bluebird, Eastern Meadowlark, and European Starling) were detected in Schoolhouse Ridge North and Schoolhouse Ridge South.

Line Transects – Density Estimates

Harpers Ferry Grasslands Combined

Density estimates for grassland bird species from line transects varied between Spring and Fall across all grassland habitat at Harpers Ferry NHP (Table 6; Figure 7). American Kestrel, Barn Swallow, and Bobolink were only detected during the Fall migrations (Table 6; Figure 7). Eastern Meadowlark, Field Sparrow, Grasshopper Sparrow and Savannah Sparrow had the greatest estimated density across all Harpers Ferry grasslands during Spring and Fall migrations with greater densities in the Spring for these four species (Table 6; Figure 7).

Table 6. Model estimated density (number/km²± standard error) of grassland birds using Harpers Ferry NHP during Fall and Spring migration 2022.

Species	Fall	Spring
American Kestrel	0.50 (0.19)	0.00 (0.00)
Barn Swallow	1.49 (0.55)	0.00 (0.00)
Bobolink	0.56 (0.49)	0.00 (0.00)
Eastern Bluebird	11.01 (1.66)	8.30 (1.08)
Eastern Meadowlark	10.04 (3.10)	17.93 (2.63)
Field Sparrow	3.09 (1.34)	11.42 (2.15)
Grasshopper Sparrow	8.80 (5.33)	11.33 (4.15)
Savannah Sparrow	11.62 (4.86)	14.36 (4.51)

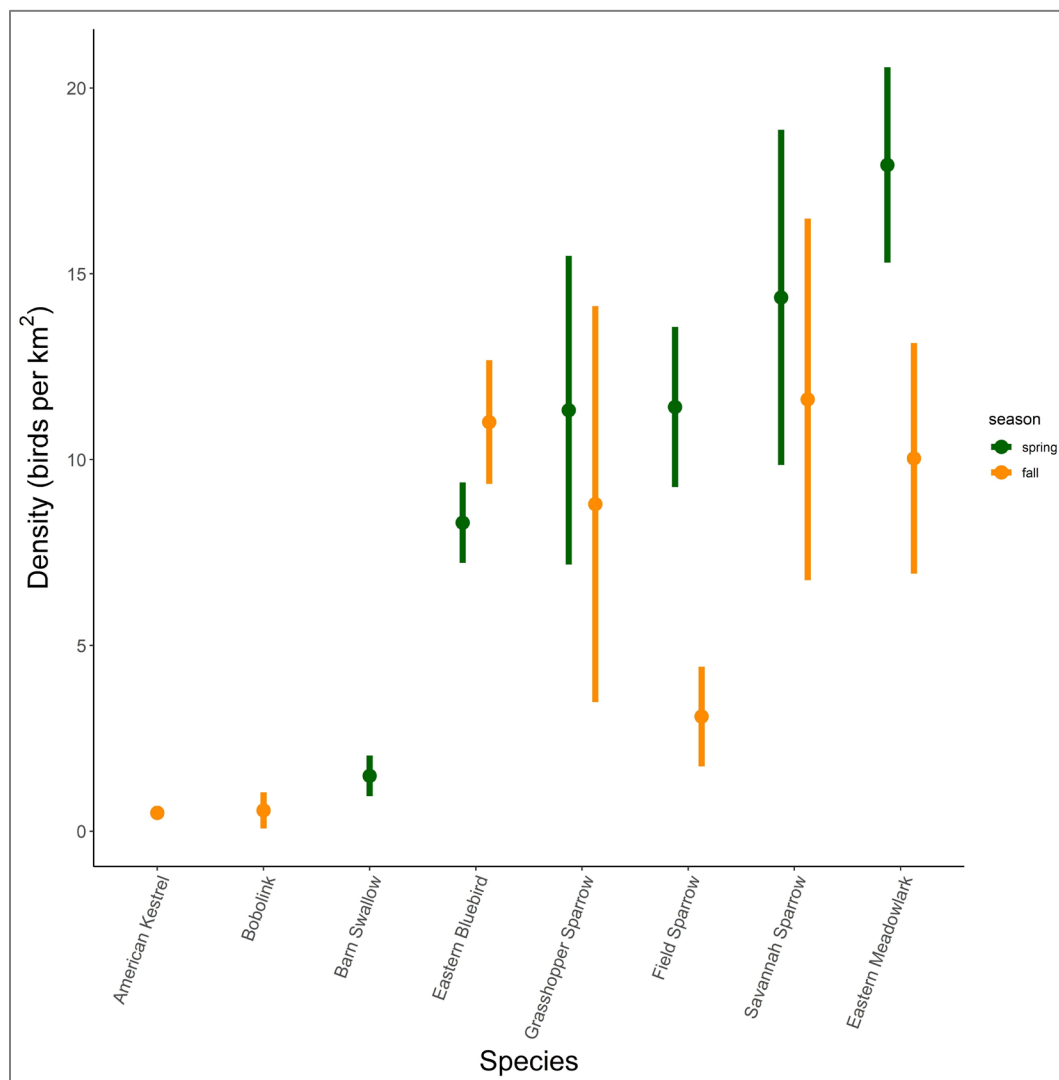


Figure 7. Grassland bird density (number/km² ± standard error) during Spring (green) and Fall (orange) migration across all grassland habitat at Harpers Ferry NHP, 2022.

Schoolhouse Ridge North

Density estimates for grassland bird species from line transects varied between Spring and Fall at Schoolhouse Ridge North (Table 7, Figure 8). Grasshopper Sparrow, Savannah Sparrow, and Eastern Meadowlark had the greatest estimated density during both Spring and Fall migrations at Schoolhouse Ridge North (Table 7, Figure 8). We estimated a greater density of Field Sparrows using Schoolhouse Ridge North during the Spring migration compared to Fall migration (Table 7; Figure 8). American Kestrel and Bobolink occurred at low densities at Schoolhouse Ridge North during the Fall migration only, while Barn Swallow density could only be estimated during the Spring migration (Table 7; Figure 8).

Table 7. Model estimated density (number/km² ± standard error) of grassland birds using Schoolhouse Ridge North at Harpers Ferry NHP during Fall and Spring migration in 2022.

Species	Fall	Spring
American Kestrel	0.86 (0.30)	0.00 (0.00)
Barn Swallow	2.04 (0.86)	0.00 (0.00)
Bobolink	1.14 (0.98)	0.00 (0.00)
Eastern Bluebird	8.00 (1.44)	8.08 (1.86)
Eastern Meadowlark	17.33 (4.94)	23.34 (3.66)
Field Sparrow	2.09 (0.96)	10.23 (3.01)
Grasshopper Sparrow	16.69 (13.83)	17.20 (7.96)
Savannah Sparrow	15.06 (9.17)	18.34 (9.00)

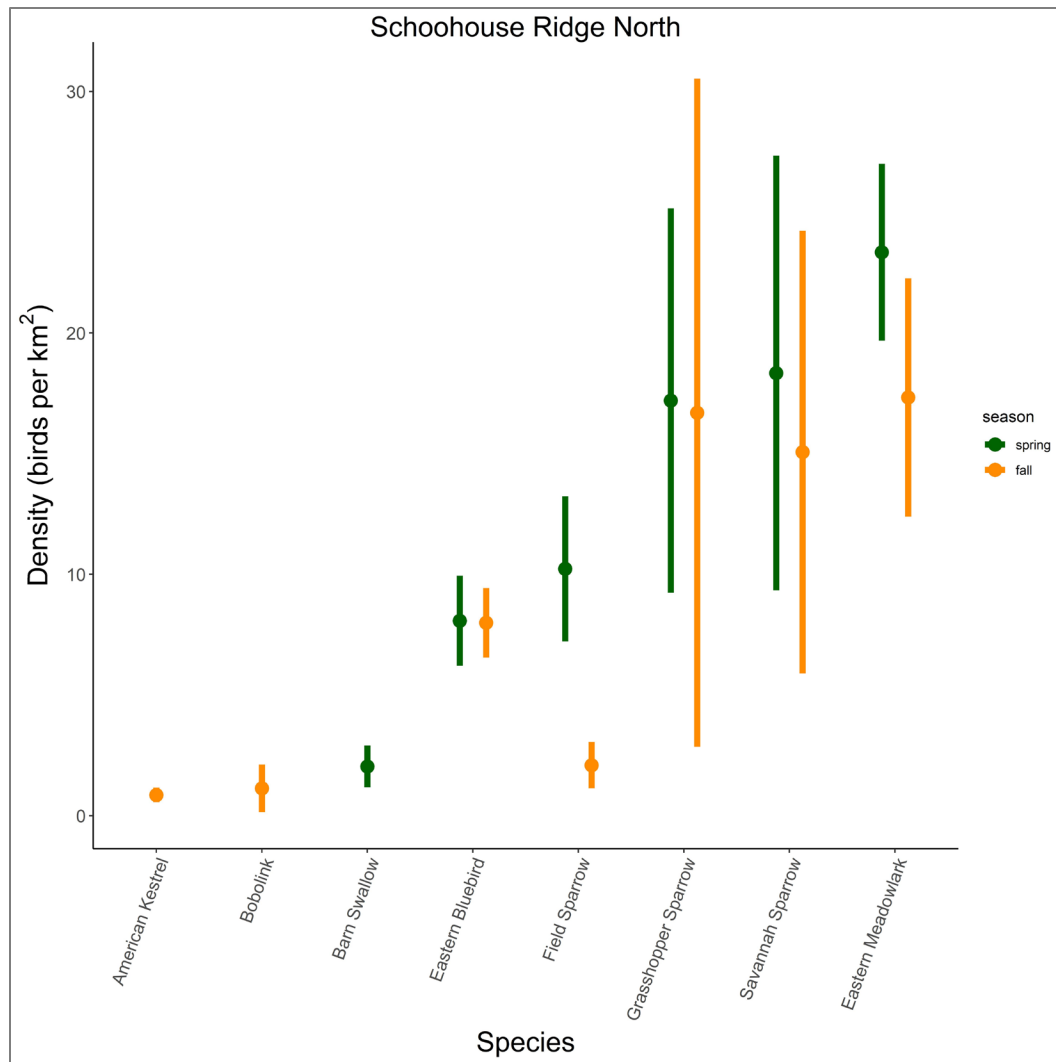


Figure 8. Model estimated density (number/km² ± standard error) of grassland birds using Schoolhouse Ridge North at Harpers Ferry NHP during Fall (orange) and Spring (green) migration in 2022.

Lower Bolivar

Density estimates for grassland bird species from line transects were limited at Lower Bolivar (Table 8, Figure 9). We estimated similar densities of Field Sparrows using Lower Bolivar during the Fall and Spring migrations and Eastern Bluebird only during the Spring migration (Table 8; Figure 9).

Table 8. Model estimated density (number/km² ± standard error) of grassland birds using Lower Bolivar at Harpers Ferry NHP during Fall and Spring migration 2022.

Species	Fall	Spring
Eastern Bluebird	–	10.21 (3.57)
Field Sparrow	23.51 (4.07)	20.27 (5.70)

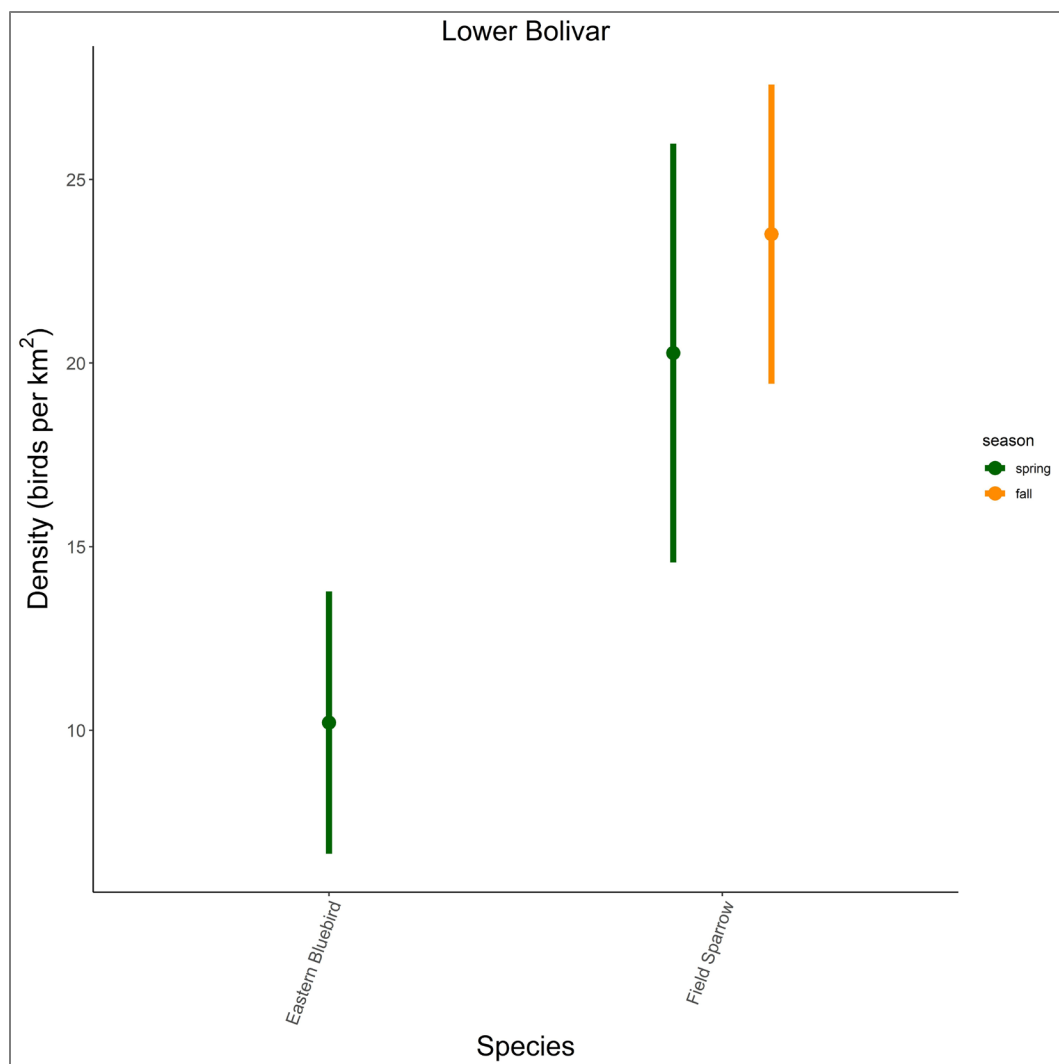


Figure 9. Model estimated density (number/km² ± standard error) of grassland birds using Lower Bolivar at Harpers Ferry NHP during Fall (orange) and Spring (green) migration in 2022.

Bolivar Heights

Density estimates for grassland bird species from line transects at Bolivar Heights indicated this site was used by Field Sparrow and Eastern Meadowlark during Spring migration and Eastern Bluebird during Fall migration (Table 9, Figure 10).

Table 9. Model estimated density (number/km² ± standard error) of grassland birds using Bolivar Heights at Harpers Ferry NHP during Fall and Spring migration in 2022.

Species	Fall	Spring
Eastern Bluebird	58.76 (23.87)	–
Eastern Meadowlark	–	22.68 (18.55)
Field Sparrow	–	20.33 (21.08)

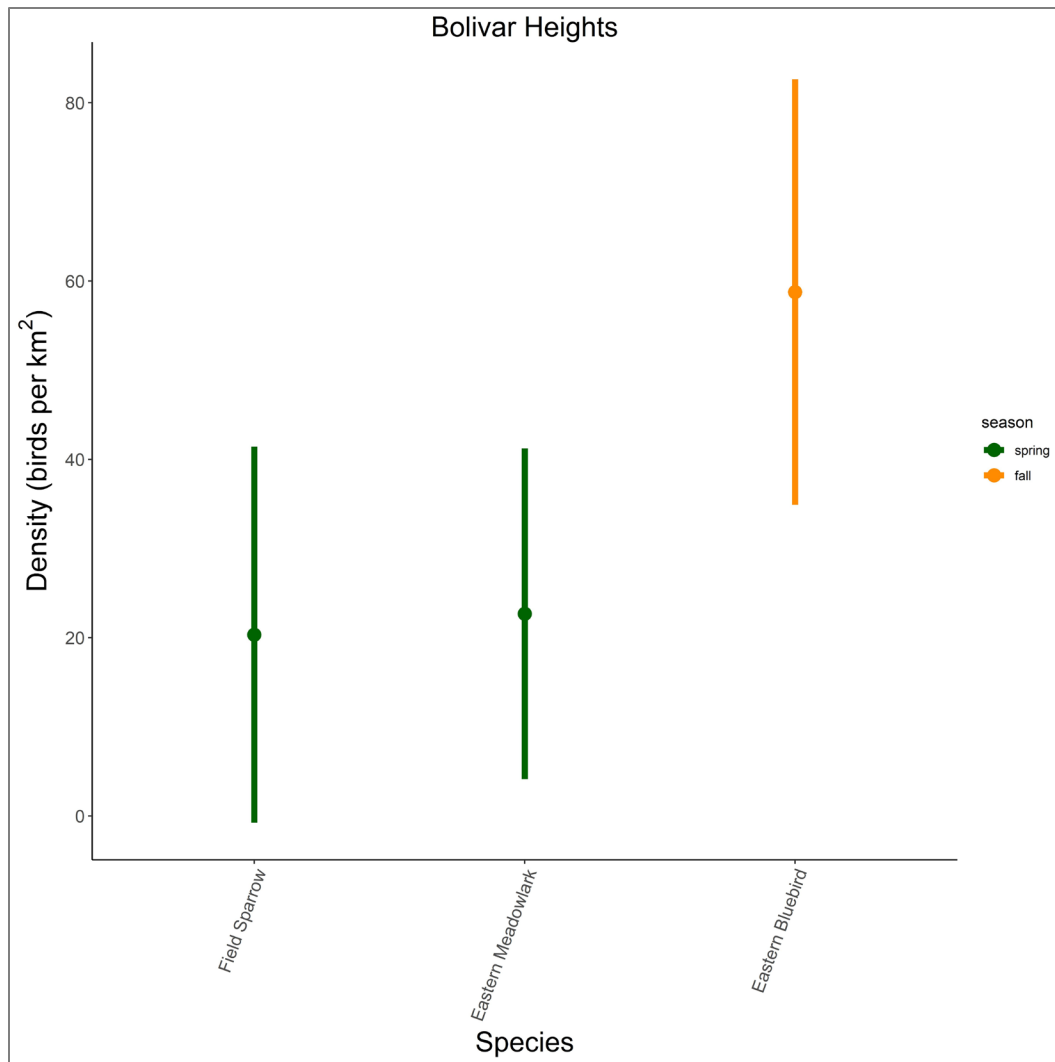


Figure 10. Model estimated density (number/km² ± standard error) of grassland birds using Bolivar Heights at Harpers Ferry NHP during Fall (orange) and Spring (green) migration in 2022.

Murphy Farm

Density estimates for grassland bird species from line transects at Murphy Farm included Eastern Bluebird, Eastern Meadowlark, and Savannah Sparrow (Table 10; Figure 11). We estimated greater density of Eastern Bluebird using Murphy Farm during Fall migration compared to Spring migration; Eastern Meadowlark density was similar between Fall and Spring migration; and Savannah Sparrow used Murphy Farm during Fall migration (Table 10; Figure 11).

Table 10. Model estimated density (number/km² ± standard error) of grassland birds using Murphy Farm at Harpers Ferry NHP during Fall and Spring migration in 2022.

Species	Fall	Spring
Eastern Bluebird	20.07 (5.53)	6.18 (2.16)
Eastern Meadowlark	16.03 (8.31)	21.18 (2.07)
Savannah Sparrow	28.53 (15.76)	–

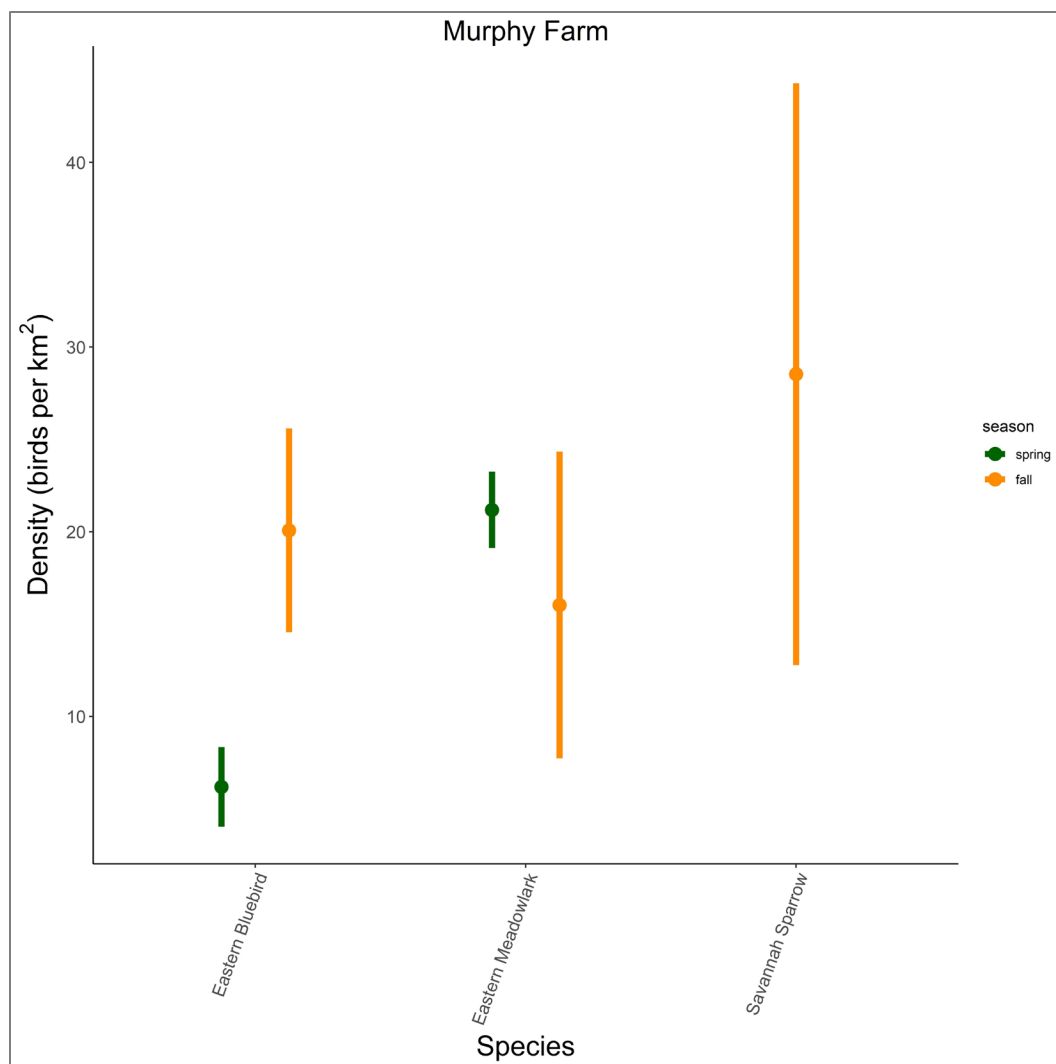


Figure 11. Model estimated Density (number/km² ± standard error) of grassland birds using Murphy Farm at Harpers Ferry NHP during Fall (orange) and Spring (green) migration in 2022.

Schoolhouse Ridge South

Density estimates for grassland bird species from line transects at Schoolhouse Ridge South included Grasshopper Sparrow, Eastern Bluebird, Field Sparrow, Eastern Meadowlark, and Savannah Sparrow (Table 11; Figure 12). We estimated similar Eastern Bluebird and Savannah Sparrow densities in both Spring and Fall migrations and Grasshopper Sparrow, Field Sparrow, and Eastern Meadowlark primarily during Spring migration at Schoolhouse Ridge South (Table 11; Figure 12).

Table 11. Model estimated density (number/km² ± standard error) of grassland birds using Schoolhouse Ridge South at Harpers Ferry NHP during Fall and Spring migration in 2022.

Species	Fall	Spring
Eastern Bluebird	13.03 (3.40)	9.12 (1.89)
Eastern Meadowlark	1.92 (0.91)	13.70 (3.90)
Field Sparrow	–	12.72 (3.85)
Grasshopper Sparrow	–	8.52 (7.22)
Savannah Sparrow	18.68 (18.23)	18.11 (9.78)

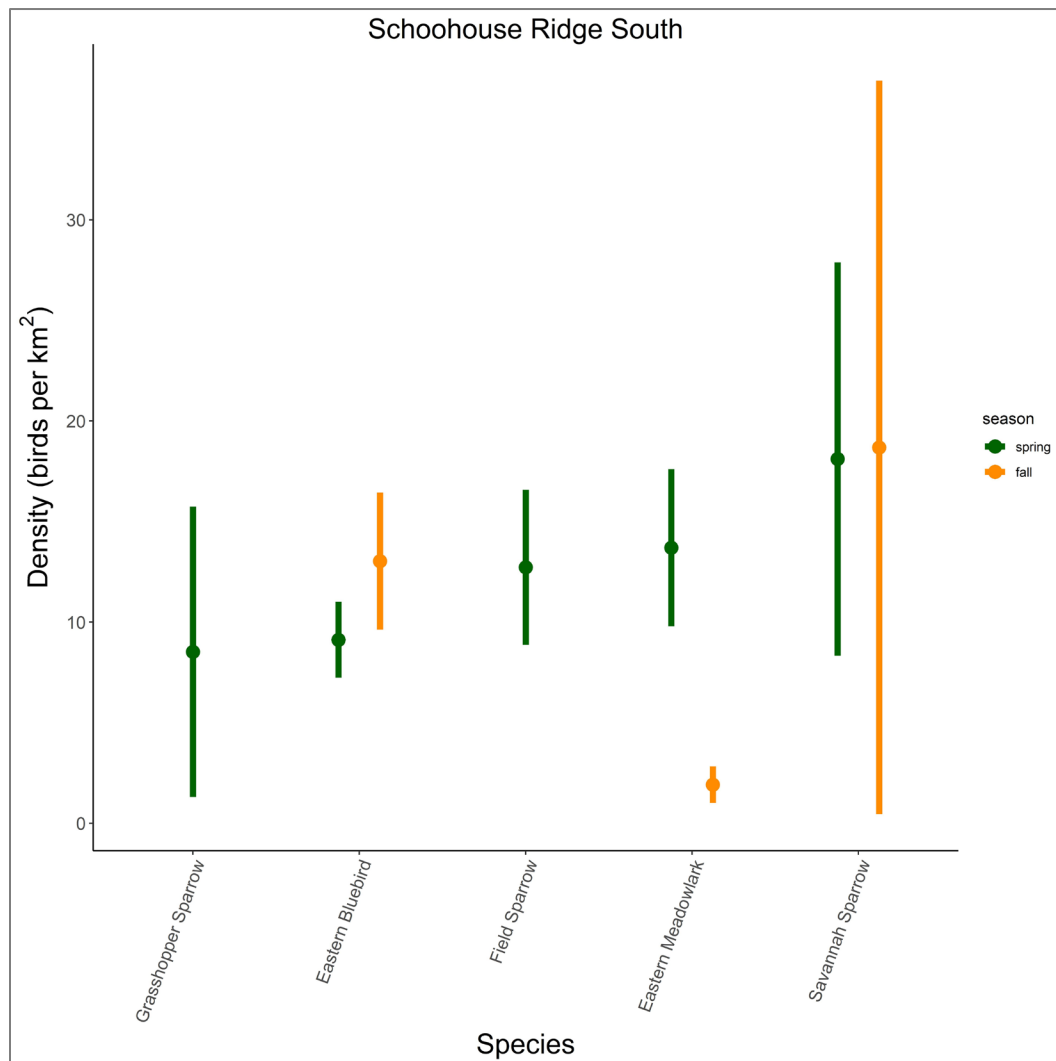


Figure 12. Model estimated density (number/km² ± standard error) of grassland birds using Schoolhouse Ridge South at Harpers Ferry NHP during Fall (orange) and Spring (green) migration in 2022.

Hawkwatch

Spring hawkwatch occurred at Harpers Cemetery between April 8 and May 12, 2022; we counted on 21 days for a total of 81 hours. We identified nine species of migrating diurnal raptors at Harpers Cemetery (Table 12). The most counted species was Broad-winged Hawk ($n = 685$), and the least counted species was Red-shouldered Hawk (Figures 13 and 14). The biggest observed migration day in spring was on April 22 with 262 birds (204 of which were Broad-winged Hawks). We did not observe any migrating Northern Goshawks, Golden Eagles, Merlin, or Peregrine Falcons during spring migration. From our hawkwatch site we were able to observe the nesting Peregrine Falcons on Maryland Heights. On the week of April 11, we began noticing more activity from the adult Peregrine. On the week of April 18, we were able to see at least two chicks being fed by the parent. We were also able to interact with 94 park visitors during the spring hawkwatch to share information about this inventory to the public.

Table 12. Counts of migrating diurnal raptors at Harpers Cemetery hawkwatch and neighboring hawkwatch site Washington Monument State Park (MD) during spring migration, 2022.

Common Name	Scientific Name	Harpers Cemetery	Washington Monument State Park (Boonesboro, MD)
Osprey	<i>Pandion haliaetus</i>	56	2
Bald Eagle	<i>Haliaeetus leucocephalus</i>	4	0
Northern Harrier	<i>Circus hudsonius</i>	22	2
Sharp-shinned Hawk	<i>Accipiter striatus</i>	47	21
Cooper's Hawk	<i>Accipiter cooperii</i>	20	2
Northern Goshawk	<i>Accipiter gentilis</i>	0	0
Red-shouldered Hawk	<i>Buteo lineatus</i>	1	0
Broad-winged Hawk	<i>Buteo platypterus</i>	685	32
Red-tailed Hawk	<i>Buteo jamaicensis</i>	13	7
Golden Eagle	<i>Aquila chrysaetos</i>	0	0
American Kestrel	<i>Falco sparverius</i>	6	2
Merlin	<i>Falco columbarius</i>	0	0
Peregrine Falcon	<i>Falco peregrinus</i>	0	0
Unid. Accipiter	—	8	0
Unid. Buteo	—	7	0
Unid. Eagle	—	0	0
Unid. Falcon	—	0	0
Unid. Raptor	—	31	1
Total Raptors	—	900	79
Total Hours	—	81	12

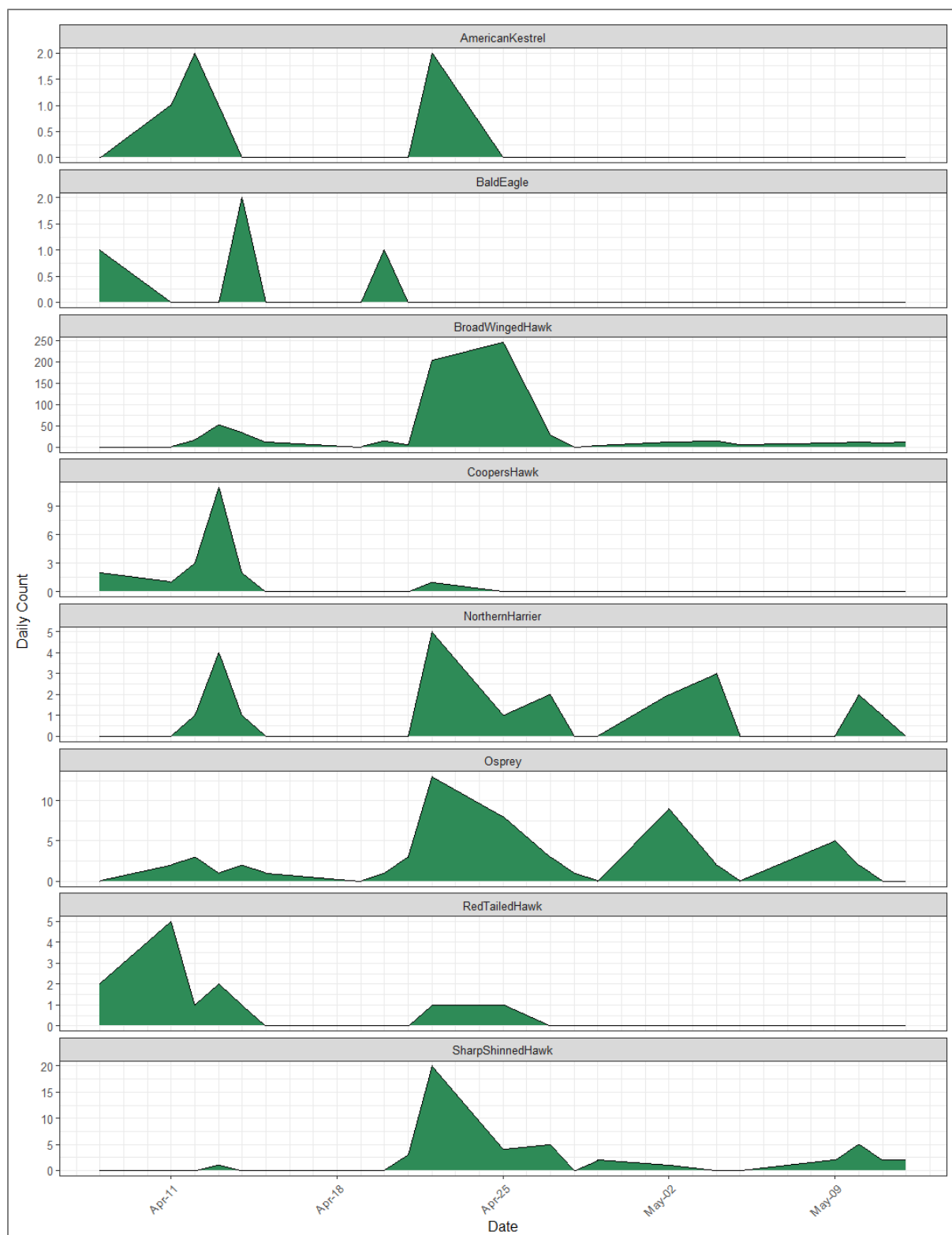


Figure 13. Spring migration phenology of diurnal raptors at Harpers Cemetery hawkwatch site, 2022.

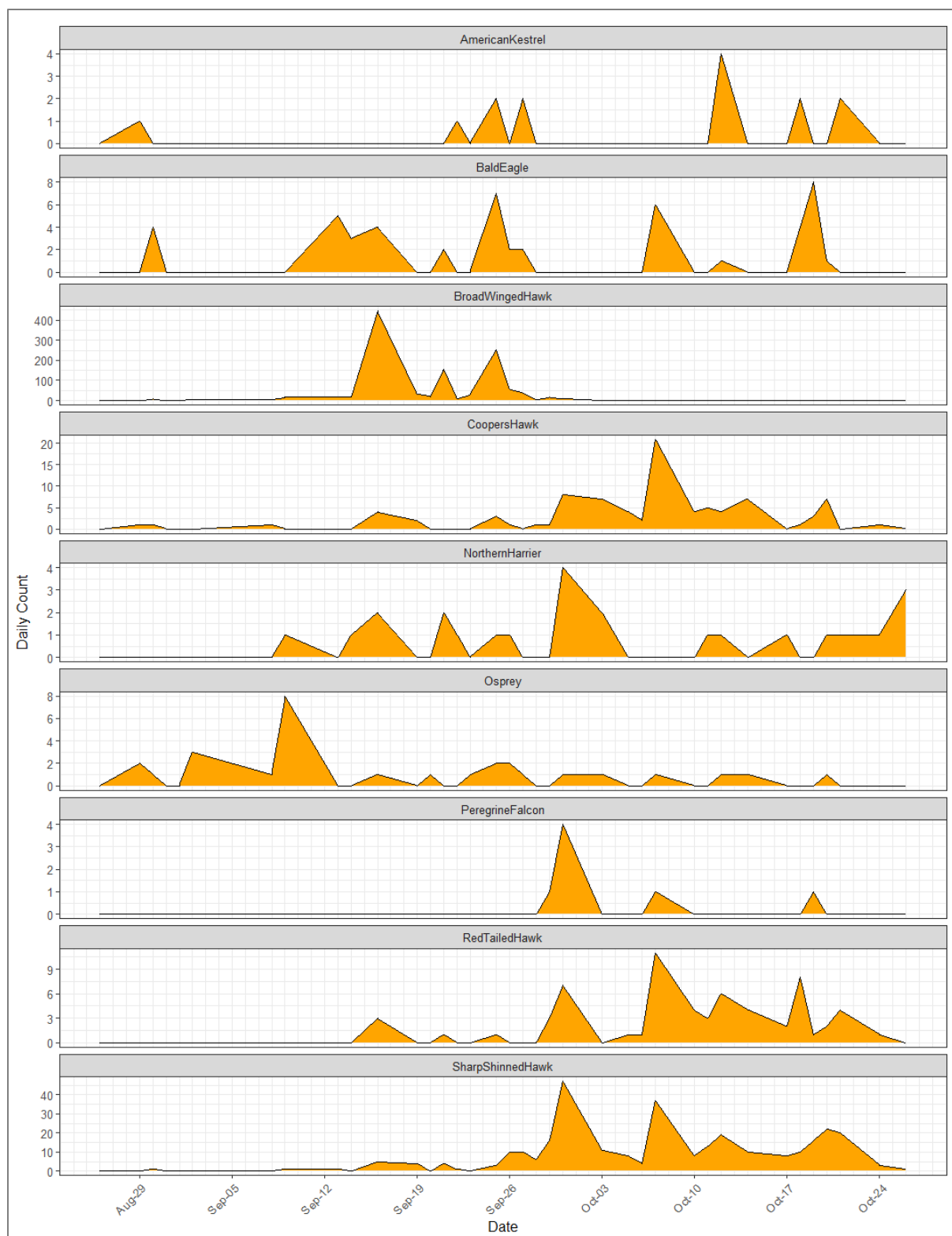


Figure 14. Fall migration phenology of diurnal raptors at Harpers Cemetery hawkwatch site, 2022.

The neighboring hawkwatch near Boonesboro, MD only counted on 4 days for a total of 12 hours in spring. Their count days were in mid-April which were likely timed to capture peak Broad-winged Hawk migration. Their mid-April count days were on the 13th and 16th, which were moderate days, missing the significant migration numbers we saw on the 22nd and 25th. Despite the difference in effort, both hawkwatch sites counted the same species (although they counted both vulture species). Count numbers from the Boonesboro site are available here:

https://www.hawkcount.org/month_summary.php?rsite=279.

Migration Banding

Spring banding operations occurred on May 4 and 5, 2022. We caught 16 birds of eight species (Table 13). We spent 27 net hours capturing birds in Schoolhouse Ridge North (n = 10), Schoolhouse Ridge South (n = 9), and Murphy Farm (n = 8).

Table 13. Species captured during spring migration banding at Harpers Ferry NHP, 2022.

Species	# Captured
American Robin	1
Chipping Sparrow	1
Grasshopper Sparrow*	2
Northern Mockingbird	1
Northern Rough-winged Swallow	1
Red-winged Blackbird*	2
Savannah Sparrow*	7
Song Sparrow	1
Total	16

*Grassland birds and focal species (also shown in **bold font**).

Fall banding operations occurred from September 1 to October 27, 2022. We spent 406 net hours (number of hours multiplied by the number of standard 12 m mist nets set up) banding in the grasslands. We banded a total of 219 new captures of 27 species in Harpers Ferry NHP grasslands (Table 14). The most frequently captured species included Savannah Sparrow, Eastern Bluebird, Palm Warbler (*Setophaga palmarum*), Song Sparrow (*Melospiza melodia*), Chipping Sparrow (*Spizella passerina*), and Tree Swallow (*Tachycineta bicolor*). We caught 126 juvenile (hatch year) birds, 80 adult birds, and 13 birds whose age was unknown. We caught 29 females, 33 males, and 157 birds that could not be sexed (mostly sparrows) (Table 15). We had the most captures and the most net hours in Schoolhouse Ridge North (189 net hours, 123 captures), and the least in Bolivar Heights (19 net hours, 7 captures).

Table 14. Banding effort during fall migration at Harpers Ferry NHP, 2022.

Site ID	Transect ID	Total Net Hours	Total Captures
Schoolhouse Ridge North	SRNO-01	11	1
	SRNO-02	6	0
	SRNO-04	34	18
	SRNO-06	130	102
	SRNO-07	15	2
	Total	189	123
Bolivar Heights	BOHE-01	12	1
	BOHE-02	7	6
	Total	19	7
Murphy Farm	MUFA-01	30	18
Schoolhouse Ridge South	SRSO-01	66	35
	SRSO-05	22	11
	SRSO-06	13	3
	Total	107	71
TOTAL	–	345	219

Table 15. Summary of fall migration banding captures by age and sex class at Harpers Ferry NHP, 2022.

Common Name	# inds.	Age			Sex		
		Unknown	Juvenile	Adult	Female	Male	Unknown
Savannah Sparrow*	66	2	30	34	–	–	66
Eastern Bluebird*	37	4	15	18	18	13	6
Palm Warbler	21	1	16	4	–	–	21
Song Sparrow	19	1	13	5	–	–	19
Chipping Sparrow	9	1	6	2	–	–	9
Tree Swallow	9	–	7	2	1	8	–
American Goldfinch	8	–	4	4	2	6	–
Field Sparrow*	7	1	6	–	–	–	7
Cedar Waxwing	5	–	5	–	3	–	2
Eastern Meadowlark*	5	–	1	4	–	–	5
Eastern Phoebe	5	–	4	1	–	–	5
Grasshopper Sparrow*	4	–	4	–	–	–	4
Yellow-rumped Warbler	4	1	3	–	–	3	1
Northern Flicker	3	1	1	1	2	1	–
House Wren	2	1	1	–	–	–	2
Nelson's Sparrow	2	–	2	–	–	–	2
Swamp Sparrow	2	–	1	1	–	–	2
White-throated Sparrow	2	–	–	2	–	–	2
Clay-colored Sparrow	1	–	1	–	–	–	1
Cape May Warbler	1	–	–	1	1	–	–
Common Yellowthroat	1	–	1	–	–	–	1
Downy Woodpecker	1	–	1	–	–	1	–
Eastern Wood-Pewee	1	–	1	–	–	–	1
Gray Catbird	1	–	1	–	–	–	1

*Grassland birds and focal species (also shown in **bold font**).

Table 15 (continued). Summary of fall migration banding captures by age and sex class at Harpers Ferry NHP, 2022.

Common Name	# inds.	Age			Sex		
		Unknown	Juvenile	Adult	Female	Male	Unknown
Indigo Bunting	1	–	1	–	1	–	–
Northern Cardinal	1	–	–	1	–	1	–
N. Rough-winged Swallow	1	–	1	–	1	–	–
Total	219	13	126	80	29	33	157

*Grassland birds and focal species (also shown in **bold font**).

Breeding Season

Abundance from Point Counts

We estimated park-wide abundance for focal grassland breeding birds at Harpers Ferry NHP, 2022, using the NPS NCRN I&M Landbird Monitoring programs point count data (Table 16). We found that Harpers Ferry NHP supports relatively abundant populations of breeding Field Sparrows, Grasshopper Sparrows, and Eastern Meadowlarks and based on the 95% CIs our detection adjusted estimates were reasonable for these species (Table 16). Alternatively, our detection adjusted estimates for Red-winged Blackbird ranged from 3.59 to 82.54 / point, likely due to substantial variation in counts among points and visits (Table 16.)

Table 16. Park-wide abundance per monitoring point estimates for four grassland breeding birds at Harpers Ferry NHP, 2022. The predicted abundance, Standard Error (SE), 95% Confidence Interval (CI), and range are provided.

Common Name	Predicted	SE	Lower CI	Upper CI	Range
Field Sparrow	1.64	0.38	1.05	2.58	1.54
Grasshopper Sparrow	1.07	0.51	0.42	2.72	2.31
Eastern Meadowlark	2.17	0.70	1.15	4.10	2.95
Red-winged Blackbird	17.21	13.77	3.59	82.54	78.95

Nest Monitoring

We spent 558 hours conducting nest monitoring activities including behavioral observations, nest searching and monitoring nests (Table 17). We spent the greatest effort in Schoolhouse Ridge North (n = 290 hours) and the least time in Nash Farm (n = 3 hours). We found nests at all grassland sites other than Nash Farm. Nash Farm lacked any grassland obligate species, so search effort was limited.

Table 17. Nest monitoring effort including behavioral observations, nest searching, and nest monitoring during breeding season 2022.

Site ID	Hours
Schoolhouse Ridge North	290
Lower Bolivar	28
Bolivar Heights	34
Murphy Farm	78
Nash Farm	3
Schoolhouse Ridge South	124
Total	558

We found 46 nests in Harpers Ferry NHP grasslands during the 2022 breeding season (Table 18, Figure 15). Nearly half of the nests we found belonged to grassland obligate species (n = 21) such as Eastern Meadowlark (n = 15; Figure 16) and Grasshopper Sparrow (n = 6; Figure 17). The remaining

nests belonged to generalist species Red-winged Blackbird ($n = 23$; Figure 18) and shrubland species Field Sparrow ($n = 2$).

Table 18. Summary of nests found in Harpers Ferry NHP grasslands during breeding season, 2022.

Site ID	Transect ID	Eastern Meadowlark			Field Sparrow		Grasshopper Sparrow			Red-winged Blackbird		
		Fledged	Failed	Total	Failed	Total	Fledged	Failed	Total	Fledged	Failed	Total
Schoolhouse Ridge North	SRNO-01	–	–	–	–	–	–	–	–	1	2	3
	SRNO-02	–	1	1	–	–	–	–	–	3	–	3
	SRNO-03	–	–	–	–	–	–	–	–	1	–	1
	SRNO-04	1	–	1	–	–	1	–	1	–	–	–
	SRNO-05	–	–	–	–	–	–	–	–	7	3	10
	SRNO-06	2	–	2	–	–	1	1	2	–	–	–
	SRNO-07	4	–	4	–	–	1	2	3	–	–	–
	TOTAL	7	1	8	–	–	3	3	6	12	5	17
Lower Bolivar	LOBO-01	–	–	–	1	1	–	–	–	–	–	–
	TOTAL	–	–	–	1	1	–	–	–	–	–	–
Bolivar Heights	BOHE-01	2	–	2	–	–	–	–	–	–	–	–
	TOTAL	2	–	2	–	–	–	–	–	–	–	–
Murphy Farm	MUFA-01	1	1	2	–	–	–	–	–	–	–	–
	MUFA-02	1	–	1	–	–	–	–	–	–	–	–
	TOTAL	2	1	3	–	–	–	–	–	–	–	–
Schoolhouse Ridge South	SRSO-01	–	1	1	–	–	–	–	–	–	–	–
	SRSO-03	–	–	–	1	1	–	–	–	–	–	–
	SRSO-04	–	–	–	–	–	–	–	–	1	–	1
	SRSO-05	1	–	1	–	–	–	–	–	4	1	5
	TOTAL	1	1	2	1	1	–	–	–	5	1	6
Total Nests per Species	–	12	3	15	2	2	3	3	6	17	6	23



Grassland Bird Nests - Overview of Mapped Areas

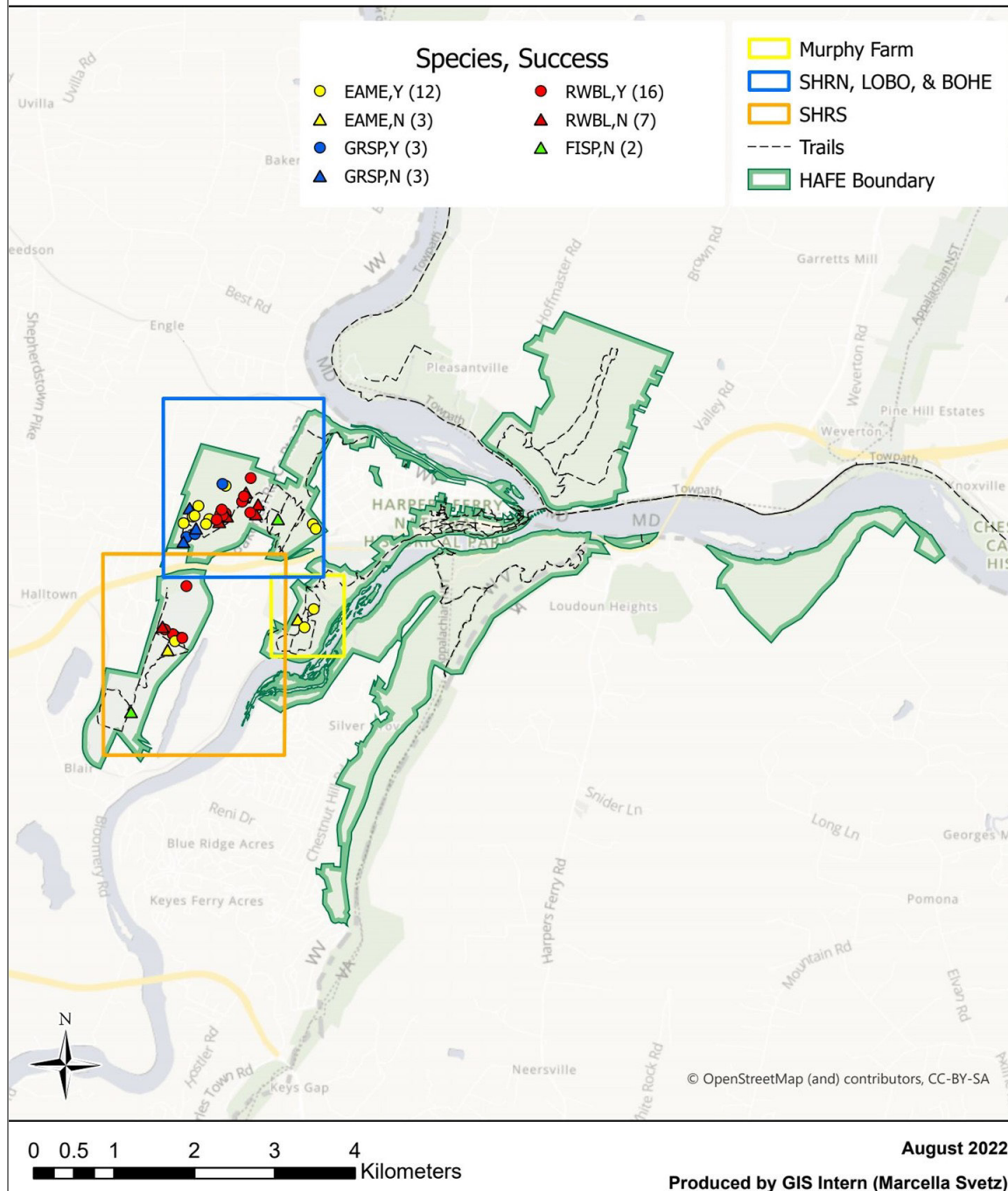


Figure 15. Grassland bird nest locations at Harpers Ferry NHP, 2022. EAME = Eastern Meadowlark, GRSP = Grasshopper Sparrow, RWBL = Red-winged Blackbird, FISP = Field Sparrow, SHRN = Schoolhouse Ridge North, LOBO = Lower Bolivar, BOHE = Bolivar Heights, SHRS = Schoolhouse Ridge South. "Y" indicates a successful nest; "N" indicates a failed nest.



Figure 16. Adult Eastern Meadowlark (top), a nest with eggs (bottom left), and with nestlings (bottom right).



Figure 17. Adult Grasshopper Sparrow (top), a nest with eggs (bottom left), and with nestlings (bottom right)



Figure 18. Adult Red-winged Blackbird (top), a nest with eggs (bottom left), and with nestlings (bottom right).

Schoolhouse Ridge North

We found the most nests at Schoolhouse Ridge North ($n = 31$), and over all species 71% of nests fledged there (Table 18). In Schoolhouse Ridge North 88% of Eastern Meadowlark nests fledged, 50% of Grasshopper nests fledged, and 71% of Red-winged Blackbird nests fledged. We estimated that there were at least 5 Eastern Meadowlark groups, 8 Grasshopper Sparrow groups, 32 Red-winged Black-bird groups, and 1 group of Bobolinks.

Lower Bolivar

In Lower Bolivar, we found one Field Sparrow nest that was depredated. We also searched for a Grasshopper Sparrow nest in this location but are unsure if a nesting attempt was made. We also observed high evidence of breeding for the following species in the area: Chipping Sparrow (*Spizella passerina*), Common Yellowthroat (*Geothlypis trichas*), and Red-winged Blackbird.

Bolivar Heights

At Bolivar Heights, we observed one polygynous family group of Eastern Meadowlark (male = 1, female = 2) who fledged two successful nests. Interestingly, after both nests fledged an intruder male arrived (first noted sighting of intruder was 6/29) and there was some territorial defense/singing by the native male. We caught and banded both females and we suspect we banded the male. This Eastern Meadowlark family group (including the intruder) left Bolivar Heights around 7/29/22 and no meadowlark were seen there again. We found all nests of target species here. Other breeding observations at this site include Common Yellowthroat, Blue Grosbeak (*Passerina caerulea*), Field Sparrow, Gray Catbird (*Dumetella carolinensis*), and European Starling.

Murphy Farm

Eastern Meadowlark nests were the only nests found at Murphy Farm, where there was a similar polygynous family group of one male and likely three females. Out of the 3 nests we detected, 67% of Eastern Meadowlark nests at Murphy Farm fledged. We banded and targeted both nests that were active at the same time simultaneously, so we know there were at least two females. We suspected there was a third female whose nest was not located. This was supported by the observation of at least 9 (6/7/22) meadowlark with at least ~4 fledglings before MUFA-2 nest had fledged, and repeated observations of 4 meadowlarks on distance sampling surveys in spring. We banded one female and one male here. There were no other target species nesting here, but other breeding evidence in the area included Eastern Bluebird, European Starling, Northern Mockingbird, Northern Cardinal, and House Finch.

Schoolhouse Ridge South

In Schoolhouse Ridge South we found nine nests with 67% of nests over all species fledging. The Field Sparrow nest ($n = 1$) did not fledge, 50% of Eastern Meadowlark nests ($n = 2$) fledged, and 83% of Red-winged Blackbird nests ($n = 6$) fledged. In Schoolhouse Ridge South, we discovered evidence of at least one successful nest as we observed and banded young Grasshopper Sparrows in SRNO-04. Throughout the summer, two males were singing simultaneously, so there may have been more Grasshopper Sparrow nests we did not find. We observed strong evidence of breeding for several other species, including Brown-headed Cowbird, European Starling, Eastern Bluebird, Northern Mockingbird, Northern Cardinal, Wild Turkey.

Nest survival

Using the ultimate nest fate determined upon nest completion or failure, we estimated the daily and period survival probability for each species found nesting in Harpers Ferry NHP grasslands with adequate sample sizes. Due to the low sample size of Field Sparrow nests, and lack of any successful nesting attempts, nest survival could not be estimated for this species. We estimated a daily survival probability for Eastern Meadowlark (0.99 ± 0.01), Grasshopper Sparrow (0.93 ± 0.04), and Red-winged Blackbird (0.97 ± 0.01 ; Table 19). We used the daily survival probability to determine the total nesting period survival probability (number of days from egg laying to fledging). Eastern Meadowlark total survival probability (over a 29-day nesting period) was 75%, Grasshopper Sparrow total survival probability (25 days) was 16%, and Red-winged Blackbird total survival probability of 45% (27 days; Table 19).

Table 19. Nest survival probability for species breeding in Harpers Ferry grasslands, 2022.

Species	Daily Nest Survival (DNS)		Total Nesting Period # Days	Nesting Period Survival Probability (DNS ^ # Days)
	Probability of Success	Standard Error		
Eastern Meadowlark	0.99	0.01	29	0.75
Grasshopper Sparrow	0.93	0.04	25	0.16
Red-winged Blackbird	0.97	0.01	27	0.45

Edge effects on nest site selection

Distances from nests to edge habitats were investigated to determine if there was an effect on nest success. The average distance from Eastern Meadowlark nests ($n = 15$) to the tree line was 122.5 m (Table 20). Eastern Meadowlarks nested 1.8 times farther from the tree line than random points ($t = 2.78, p < 0.05$). The average distance between Grasshopper Sparrow nests ($n = 6$) and the tree line was 163.7 m. Compared to random points, Grasshopper Sparrows nested 2.4 times farther away from the tree line ($t = 3.12, p < 0.05$). On average, Grasshopper Sparrow nested further away from public roads ($t = 1.83, p = 0.06$) and trails than random points.

Table 20. Measures of distance from nests found in Harpers Ferry NHP grasslands to different types of edge habitat: tree line, public road, and hiking trail.

Covariate	Metric	Eastern Meadowlark (n=15)	Field Sparrow (n=2)	Grasshopper Sparrow (n=6)	Red-winged Blackbird (n=23)	Random Points (n=46)
Distance to Tree line (m)	Min	36.09	7.39	61.22	27.43	4.36
	Max	267.76	16.78	259.63	159.63	249.45
	Avg	122.50	12.09	163.71	80.26	67.83
	p	0.01	–	0.01	0.15	–
	t	2.78	–	3.11	1.03	–
Distance to Public Road (m)	Min	24.29	140.93	191.05	20.25	50.49
	Max	509.21	211.95	555.05	439.63	469.04
	Avg	231.47	176.44	314.16	297.48	211.29
	p	0.50	–	0.06	0.00	–
	t	0.31	–	1.83	2.75	–
Distance to Hiking Trail (m)	Min	8.88	10.42	4.52	23.06	0.61
	Max	304.84	42.02	344.48	241.60	428.27
	Avg	114.49	26.22	126.29	94.98	117.08
	p	0.46	–	0.43	0.03	–
	t	-0.09	–	0.17	-1.98	–

Red-winged Blackbird nested further from public roads ($t = 2.75$, $p < 0.05$) and the tree line than random points, but closer to trails on average. Generally, Field Sparrows nested closer to the tree line, public roads, and trails than random points but with only two nests we were unable to provide a statistical test for this pattern (Table 20).

Edge effects on nest survival

Using MCEstimate, we modeled whether distance to an edge habitat type would influence nest failure using AIC model selection. The best model for Eastern Meadowlark indicated that distance from the nest to tree line positively affected nest survival (Table 21). The null model was the best model for Grasshopper Sparrow and Red-winged Blackbird indicating no relationship between distance to an edge and nest survival (Table 21).

Table 21. Model selection results on the effects of grassland bird nest failure in Harpers Ferry NHP grasslands related to distance to different types of edge habitats (tree line, public road, and hiking trails), 2022. Models are ordered by AICc (low to high). NLL = natural log-likelihood; AICc = Aikikee's information criterion for small sample sizes; Δ AICc = change in AICc from top model; Weight = relative likelihood of a model; K = number of parameters.

Species	Model Name	NLL	AICc	Δ AICc	Weight	K
Eastern Meadowlark	Distance to Tree line	10.08	24.25	0.00	0.78	2
	Global	9.72	27.73	3.49	0.14	4
	Distance to Hiking Trail	12.93	29.95	5.70	0.05	2
	Null	14.50	31.02	6.78	0.03	1
	Distance to Public Road	14.17	32.43	8.19	0.01	2
Grasshopper Sparrow	Null	8.07	18.24	0.00	0.34	1
	Global	4.97	19.08	0.84	0.22	4
	Distance to Tree line	7.62	19.56	1.32	0.17	2
	Distance to Hiking Trail	7.78	19.88	1.64	0.15	2
	Distance to Public Road	7.99	20.31	2.07	0.12	2
Red-winged Blackbird	Null	23.15	48.32	0.00	0.38	1
	Distance to Hiking Trail	22.52	49.10	0.78	0.25	2
	Distance to Public Road	22.94	49.94	1.62	0.17	2
	Distance to Tree line	23.09	50.23	1.91	0.14	2
	Global	21.92	52.03	3.70	0.06	4

As distance between an Eastern Meadowlark nest and a tree line increased, nests were more likely to fledge (Figure 19). For example, at a distance of approximately 25 m from a forest edge, an Eastern Meadowlark nest has a roughly 25% probability of failure. As the distance of the nest from the tree line increased to 100 m, the probability of nest failure approaches 0%.

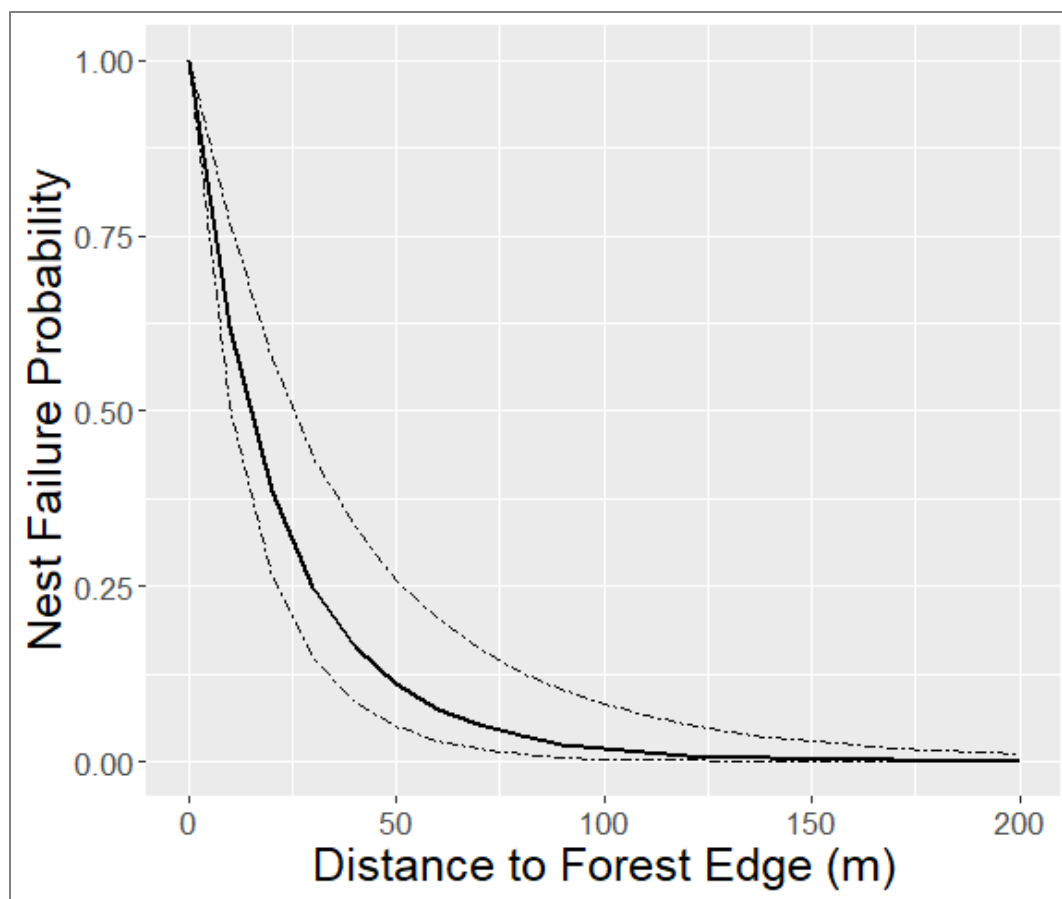


Figure 19. Logistic model showing that the probability of nest failure increases as the distance from Eastern Meadowlark nests to the forest edge decreases. Solid line = model estimate of nest failure; dashed line = 95% CI of the modeled estimate.

Breeding Season Banding

Summer banding operations occurred from May 15 to August 25, 2022. We spent a total of 460 net hours (number of hours multiplied by the number of standard 12 m mist nets set up) banding in the grasslands; the majority of those net hours (439 hours) was spent in net arrays (Table 22). We had the most captures and the most net hours in Schoolhouse Ridge North (112 captures, 317 net hours), and the least in Lower Bolivar (1 capture, 20 net hours).

We banded 141 new captures of 26 species of birds in the Harpers Ferry NHP grasslands (Table 23). The top five species captured included Grasshopper Sparrow, Eastern Meadowlark, Field Sparrow, Gray Catbird, and American Goldfinch (Table 23). We caught 43 birds who hatched in summer 2022, 87 adult birds, and one bird whose age was unknown. We caught 50 females, 44 males, and 46 birds that could not be sexed (mostly young birds).

We held a banding demonstration for the Harpers Ferry NHP staff on July 12, 2022. We set up eight nets for 2.5 hours (20 net hours) and caught 17 birds (including 1 un-banded hummingbird). We estimated that 12 park staff were in attendance. Our goal was to educate and inspire park staff from all divisions about the project.

Table 22. Banding effort in Harpers Ferry NHP grasslands during summer 2022. Net hours and captures include targeted banding at nests and randomly set net arrays.

Site ID	Transect ID	Net Hours			Total Captures
		Net Arrays	Target Netting at Nest	Total	
Schoolhouse Ridge North	SRNO-01	20	–	20	16
	SRNO-02	23	1	24	10
	SRNO-03	6	–	6	4
	SRNO-04	16	1	17	5
	SRNO-05	38	–	38	7
	SRNO-06	69	9	77	35
	SRNO-07	131	4	135	35
	TOTAL	303	14	317	112
Lower Bolivar	LOBO-01	20	–	20	1
	TOTAL	20	–	20	1
Bolivar Heights	BOHE-01	23	1	24	1
	BOHE-02	7	–	7	12
	TOTAL	30	1	31	13
Murphy Farm	MUFA-01	12	5	16	1
	MUFA-02	11	1	12	4
	TOTAL	23	5	28	12
Schoolhouse Ridge South	SRSO-01	29	–	29	3
	SRSO-04	8	–	8	11
	SRSO-05	27	1	28	1
	TOTAL	64	1	65	1
TOTAL	–	439	21	460	141

Table 23. Summary of summer banding captures by age and sex class at Harpers Ferry NHP, 2022.

Species	# Captured	Age			Sex		
		Unknown	Juvenile	Adult	Female	Male	Unknown
Grasshopper Sparrow	38	–	10	28	11	17	10
Eastern Meadowlark	19	–	6	13	12	4	3
Field Sparrow	12	–	3	9	2	7	3
Gray Catbird	12	–	3	9	4	1	7
American Goldfinch	9	–	–	9	3	6	–
Bobolink	7	1	2	4	5	–	2
Eastern Bluebird	7	–	4	3	2	1	4
Red-winged Blackbird	5	–	2	3	4	1	–
Song Sparrow	5	–	0	5	1	4	–
Barn Swallow	4	–	4	0	–	–	4
Carolina Wren	4	–	1	3	1	–	3
Chipping Sparrow	3	–	0	3	1	2	–
Blue Grosbeak	2	–	1	1	1	–	1
Indigo Bunting	2	–	0	2	2	–	–
Baltimore Oriole	1	–	1	0	–	–	1
Brown-headed Cowbird	1	–	1	0	–	–	1
Brown Thrasher	1	–	0	1	–	–	1
Downy Woodpecker	1	–	1	0	–	–	1
Eastern Kingbird	1	–	0	1	–	1	–
Eastern Wood-Pewee	1	–	0	1	–	–	1
House Finch	1	–	1	0	–	–	1
House Wren	1	–	1	0	–	–	1
Northern Mockingbird	1	–	0	1	1	–	–
Northern Rough-winged Swallow	1	–	1	0	–	–	1

Table 23 (continued). Summary of summer banding captures by age and sex class at Harpers Ferry NHP, 2022.

Species	# Captured	Age			Sex		
		Unknown	Juvenile	Adult	Female	Male	Unknown
Tree Swallow	1	–	0	1	–	–	1
Tufted Titmouse	1	–	1	0	–	–	1
Total Captures	141	1	43	97	50	44	47

Banding at nests

We spent 21 net hours doing targeted captures of breeding adults at the nest. We captured 19 adult grassland obligate species nesting in the Harpers Ferry NHP grasslands: Eastern Meadowlark (n = 10) and Grasshopper Sparrows (n = 9; Table 24). Female Eastern Meadowlark 1422-11908 presented our only documented case of a second brood. Her first brood fledged on June 16 in SRNO-06 (nest name SRNO-06-EAME-2) and her second brood fledged on July 27 in SRNO-07 (nest name SRNO-07-EAME-4); both her broods fledged successfully. Male Grasshopper Sparrow 2391-92124 from nest SRNO-07-GRSP-2 was originally caught at the cannons in May unrelated to a nest. Later, he was called into a net surrounding a nest downhill from the cannons.

Two polygynous nesting families were documented in summer 2022 in Bolivar Heights and Murphy Farm. Through observation we are sure that there was only one male at each of these sites that could have copulated to produce the nests. Male meadowlark 1873-51205 in Bolivar Heights had two females associated with him (1873-51201 and 1422-11905) and both had successful broods. We suspect that male meadowlark 1873-51202 had three females associated with him, but we were only able to successfully capture female 1422-11904, who had a successful brood. We can confirm that he had at least two females, because we found two concurrently active nests.

Table 24. Captures during targeted mist-netting at Eastern Meadowlark and Grasshopper Sparrow nests breeding at Harpers Ferry NHP, 2022.

Site ID	Transect ID	Species	Nest ID	Male band#	Female band#
Schoolhouse Ridge North	SRNO-02	Eastern Meadowlark	SRNO-02-EAME-1	–	–
	SRNO-04	Eastern Meadowlark	SRNO-04-EAME-1	–	1422-11907
	SRNO-06	Eastern Meadowlark	SRNO-06-EAME-1	–	–
	SRNO-06	Eastern Meadowlark	SRNO-06-EAME-2	–	1422-11908
	SRNO-07	Eastern Meadowlark	SRNO-07-EAME-1	–	1422-11909
	SRNO-07	Eastern Meadowlark	SRNO-07-EAME-2	–	1422-11912
	SRNO-07	Eastern Meadowlark	SRNO-07-EAME-3	–	1422-11913
	SRNO-07	Eastern Meadowlark	SRNO-07-EAME-4	–	1422-11908
	SRNO-06	Grasshopper Sparrow	SRNO-06-GRSP-1	2391-92155	2391-92153
	SRNO-06	Grasshopper Sparrow	SRNO-06-GRSP-2	–	2391-92144
	SRNO-07	Grasshopper Sparrow	SRNO-07-GRSP-1	2391-92136	2391-92130
	SRNO-07	Grasshopper Sparrow	SRNO-07-GRSP-2	2391-92124	–
	SRNO-07	Grasshopper Sparrow	SRNO-07-GRSP-3	2391-92157	2391-92156
	SRNO-04	Grasshopper Sparrow	SRNO-04-GRSP-1	–	–
Bolivar Heights	BOHE-01	Eastern Meadowlark	BOHE-01-EAME-1	1873-51205	1873-51201
	BOHE-01	Eastern Meadowlark	BOHE-01-EAME-2	1873-51205	1422-11905
Murphy Farm	MUFA-02	Eastern Meadowlark	MUFA-02-EAME-1	1873-51202	1422-11904
	MUFA-01	Eastern Meadowlark	MUFA-01-EAME-1	1873-51202	–
	MUFA-01	Eastern Meadowlark	MUFA-01-EAME-2	1873-51202	–
Schoolhouse Ridge South	SRSO-01	Eastern Meadowlark	SRSO-01-EAME-1	–	–
	SRSO-05	Eastern Meadowlark	SRSO-05-EAME-1	–	1422-11903

Discussion

Across all sampling methodologies and seasons it is clear that Harpers Ferry NHP grassland habitats provide critical habitat for grassland birds. Bird communities using the Harpers Ferry NHP grassland habitats changed throughout the seasons indicating these habitats are supporting different species during both the Spring and Fall migrations and the breeding season. We had more species and greater abundance of individuals using the Harpers Ferry NHP grassland units during the migration periods than we did during the breeding season further supporting the importance of these grasslands to birds throughout the annual cycle.

Spring and Fall Migrations

Our line transect sampling during the spring and fall migrations provided robust estimates of the bird species using each of the six grassland units at Harpers Ferry NHP and indicated differences in bird community structure. For example, we detected 87 and 96 species using the Harpers Ferry grasslands during the Spring and Fall migrations respectively. Eastern Meadowlarks were detected using all six of the grassland units during both Spring and Fall migrations and Grasshopper Sparrows were detected using all units except Bolivar heights. Most of the breeding season use of the Harpers Ferry NHP grassland units were from Eastern Meadowlarks and Grasshopper Sparrows; therefore, we think these two species should be the focal species for the park to target in any grassland restoration or management planning.

Eastern Meadowlarks utilize a variety of grassland types from highly disturbed sites such as airports or roadsides to sites with a smaller amount of disturbance like tallgrass prairies (Hull 2002). Eastern Meadowlarks use meadows, pastures, hayfields, and croplands as breeding habitat and have been shown to be positively associated with grasslands with high vegetation density and species richness. Suitable habitat for the Eastern Meadowlark includes meadows with a mixture of warm and cool season grasses that are maintained by way of disturbance (mowing or burning) after the breeding season (Hull 2002). Grasshopper Sparrows can occupy a variety of grassland habitats but tend to prefer grasslands with limited woody vegetation and exposed bare ground (Vickery 2020). Mixed-grass areas with higher percent grass cover and litter depth are positively associated with Grasshopper Sparrow density (Dechant et al. 2002.). Additionally, Grasshopper Sparrows prefer grasslands with intermediate grass height and density (Ruth 2015). Grasshopper Sparrows rarely use cropland and tend to breed in grassland habitats with greater vegetation heterogeneity (Dechant et al. 2002). Our results support the findings of other studies where the Grasshopper Sparrows were most abundant in meadows. The low abundance in pasture and row crop may be due to their preference for grassland habitat of greater heterogeneity (Dechant et al. 2002).

We detected Bobolink using one of the larger grassland units, Schoolhouse Ridge North, during the fall migration, indicating that this grassland unit is providing critical stop-over habitat for Bobolinks on their southward migration to South America. Harpers Ferry NHP is on the southern extent of the Bobolink breeding range, so it is not surprising that we only detected this species during migration. There are Bobolink breeding sites in West Virginia, so it is possible to attract Bobolinks to Harpers Ferry NHP during the breeding season, but currently this species occurs primarily during the fall

migration. Bobolinks are long-distance Nearctic-Neotropical migrants that begin to depart the breeding grounds in July – early August and congregate in grassland habitats where they complete a pre-basic molt (Renfrew et al. 2020). Having access to habitat during a pre-migration molt is especially important to increase the survival probability for long-distance migrants like the Bobolink. Harpers Ferry NHP grassland units seem to be providing Bobolinks access to habitats during this critical period of the annual cycle. The Bobolink migration is transequatorial, spans approximately 20,000 km between breeding and overwintering areas and is one of the longest annual migrations of any New World passerine species (Renfrew et al. 2020). For species like the Bobolink, migration is by far the greatest source of mortality during the annual cycle (Silllett and Holmes 2002, Newton 2006, Bayly et al. 2018); therefore, providing access to migratory stop-over habitats is critical for their conservation (Sheehy et al. 2011). Bobolinks are known to perform transoceanic flights during fall migration which can range in length from 1,700 – 3,400 km (Perlut 2018), further emphasizing the need to provide stop-over habitats like Harpers Ferry NHP grassland where individuals can molt, rest, and refuel.

Savannah Sparrow was also detected only during the migration sampling periods and occurred in all Harpers Ferry NHP grassland units except Lower Bolivar. Similar to Bobolink, the Harpers Ferry NHP grasslands are near the southern extent of the Savannah Sparrow breeding range (Wheelwright and Rising 2020). Savannah Sparrows breed in open, grassy habitats and avoid areas with extensive tree cover similar to their non-breeding habitats (Wheelwright and Rising 2020). The frequency of detection on line transects and the relatively high Savannah Sparrow density estimates based on distance sampling suggest that this species may be using Harpers Ferry grasslands as both migratory stop-over habitat and a wintering area depending on local weather conditions. Savannah Sparrows will over-winter in West Virginia; therefore, Harpers Ferry NHP grasslands are supporting this species during both Spring and Fall migrations and likely some individuals during the non-breeding season.

Using distance sampling on the grassland line transects we were able to estimate species densities during the Spring and Fall migrations. We had adequate detections to estimate density for American Kestrel that primarily used the grassland habitat provided at Schoolhouse Ridge North during the Fall migrations. American Kestrel populations are showing ongoing population declines especially along the Atlantic Coast and eastern Appalachian Mountains (Farmer and Smith 2009, Smallwood and Bird 2020). Not only did we have the number of detections to estimate American Kestrel density from line transects, we also detected American Kestrels during both Spring and Fall migration at our hawkwatch site. Currently, the American Kestrel Partnership (<https://kestrel.peregrinefund.org/home>) provides an opportunity to participate in American Kestrel conservation by deploying and monitoring Kestrel boxes which could be an option to enhance Kestrel use of Harpers Ferry NHP grasslands.

We also estimated densities for Eastern Meadowlark, Grasshopper Sparrow, and Savannah Sparrow, all of which showed relatively high densities in Harpers Ferry NHP grassland units during both Spring and Fall migrations. Schoolhouse Ridge North supported the greatest densities for Eastern Meadowlark, Grasshopper Sparrow, and Savannah Sparrow with Schoolhouse Ridge South support lower densities for all three species. Murphy Farm supported Eastern Meadowlark during both Spring and Fall migration and Savannah Sparrow during Fall migration.

Using mist-netting to capture individuals during Spring and Fall migrations supported the information from the distance sampling transects that the Harpers Ferry NHP grassland units are providing critical migratory stopover habitat for Savannah Sparrow. By using mist-netting techniques we were able to age the captured individuals which is not possible with line transect sampling. Aging the individuals can provide an assessment of the annual productivity for the species as well as determine if different age classes are selecting different habitats. During migration banding at Harpers Ferry NHP grasslands, we captured 66 Savannah Sparrows and 30 of these individuals (45%) were juveniles indicating that Harpers Ferry is providing habitat for grassland bird species in different age classes. Our hawkwatch surveys indicated that the diurnal raptor species moving through and potentially using Harpers Ferry NHP habitats were similar to estimates provided by nearby hawkwatch sites. We detected nine raptor species with Broad-winged Hawk the most frequently detected species.

Breeding Season

We used point counts to estimate abundance, nest searching to estimate daily nest survival rates, and mist-netting to age individuals and associate adults with specific nesting attempts at Harpers Ferry NHP grassland units in 2022. Our point count information supported the idea that the Harpers Ferry NHP grassland unit focal species during the breeding season are Eastern Meadowlark and Grasshopper Sparrow. These two species had the greatest estimated abundances park-wide and we recommend that given there were successful breeding individuals in 2022, the park should focus any management or restoration on maintaining and enhancing the breeding options for Eastern Meadowlark and Grasshopper Sparrow.

Our nest search efforts indicated that the Harpers Ferry NHP grasslands supports breeding populations of Eastern Meadowlarks and Grasshopper Sparrows as well as Red-winged Blackbird and Field Sparrow nesting. Our estimate of Eastern Meadowlark daily nest survival probability (0.99) was high and these adults were able to fledge young. Similarly, our estimate of Grasshopper Sparrow daily nest survival probability (0.93), although not as high as Eastern Meadowlark, showed that Grasshopper Sparrow adults were still able to fledge young. Given the steep population declines for these species regionally and nationally, anywhere we have breeding populations, no matter how small the area, are important to maintain or enhance. Schoolhouse Ridge North supported the most Eastern Meadowlark and Grasshopper Sparrow nests with Schoolhouse Ridge South supporting the second most nesting for Eastern Meadowlark.

We found a clear and positive pattern between distance to forested edge and Eastern Meadowlark nest survival. Habitat openness has been shown to be an important aspect of avian habitat selection (Hildén 1965) with the angle to the horizon from within the habitat patch providing an estimate of habitat openness (Bakker et al. 2002, Grant et al. 2006, Keyel et al. 2012). Perceived habitat openness has been shown to be as strong or stronger of a predictor for open species occupancy and abundance than patch size (Keyel et al. 2013, Marshall et al. 2020). Harpers Ferry NHP has opportunities to increase the perceived patch size for grassland breeding birds by removing primarily non-native trees within or adjacent to the grassland management units (see management recommendations).

Our breeding season banding efforts further support an initial focus on Eastern Meadowlark and Grasshopper Sparrow breeding in Harpers Ferry NHP grasslands. We captured 19 Eastern

Meadowlarks (13 adults:6 juveniles) and 38 Grasshopper Sparrows (28 adults:10 juveniles) for 0.46 and 0.35 adult:juvenile ratios for each species, respectively. These banding efforts coupled with the nest monitoring efforts provide better information than point count abundance estimates related to the importance of Harpers Ferry NHP grassland to grassland bird conservation.

Conclusion

General Management Recommendations

Patch Size

Grassland patch size, openness, and perimeter area ratios have all been shown to influence the breeding ecology for grassland birds (Keyel et al. 2012, Zuckerberg et al. 2018). The probability of occurrence for grassland bird species has been shown to be inversely correlated with perimeter–area ratio and occupancy was also correlated with grassland area (Helzer and Jelinski 1999). Generally, larger and more open grasslands tend to support greater grassland bird densities, but smaller grasslands have been shown to be important for these specialist species (Walk et al. 2010). Walk et al. (2010) also indicated that the loss of small grassland patches would have a direct negative effect on grassland bird population fecundity, supporting the idea that maximizing overall habitat quality within a landscape of grassland management units, like Harpers Ferry NHP, would benefit grassland birds.

The grassland units at Harpers Ferry NHP are interspersed with tree lines and small patches of trees that limit the perceived grassland unit size. Strategically removing specific tree lines, single trees, or small patches of trees would increase the perceived patch size, reduce the perimeter area ratio, and increase the openness measure thereby enhancing overall grassland bird habitat quality (see below for specific unit specific suggestions).

Non-native Plants

Non-native and invasive species are relatively common in many of the Harpers Ferry grassland management units. Specifically, Johnson Grass (*Sorghum halepense*) can be found in Schoolhouse Ridge North, Bolivar Heights, and Schoolhouse Ridge South; Chinese Bushclover (*Sericea lespedeza*) was observed in all sites except for Bolivar Heights, and it is very common in Murphy Farm. Vetch species (*Vicia spp*) were found most noticeably in Schoolhouse Ridge North, where they create a dense layer of vegetation over most of the western half of the grassland unit making this area unsuitable for grassland birds. Autumn Olive (*Elaeagnus umbellata*) was detected in all sites except Murphy Farm and is a small tree / shrub species that could reduce the perceived openness of a grassland patch. Reducing and controlling non-native invasive species within and adjacent to the Harpers Ferry grassland units could extend the amount of usable grassland bird habitat. Maximizing the overall grassland habitat quality for grassland birds would benefit these specialist species that are already using the park and could increase occupancy (more species may perceive the park as habitat; i.e., Bobolink and Savannah Sparrows during breeding), abundance, and / or fecundity (Eastern Meadowlark and Grasshopper Sparrow). Currently, the breeding Eastern Meadowlarks and Grasshopper Sparrows are patchily distributed primarily in Schoolhouse Ridge North. Managing vegetation structure and the perceived openness of the Harpers Ferry NHP grassland units could increase the number of breeding territories for Eastern Meadowlark and Grasshopper Sparrow and may attract other species that are currently not breeding in the park.

Timing of haying or disturbance

Timing of disturbance is likely the most critical aspect of managing grasslands for grassland birds. Limiting disturbance during the breeding season (1 May – 15 July) is certainly an appropriate first

step as this will remove the potential for nest destruction and reproductive failure. Maintaining Eastern Meadowlarks and Grasshopper Sparrow in their current densities could be an initial objective of a Harpers Ferry Grassland Bird Management Plan. Grassland birds have strong philopatry (they tend to return to the same area, especially if they successfully bred there the previous season); therefore, negatively altering the habitat could cause the species that are currently using the Harpers Ferry NHP grasslands to seek alternative areas. The lack of disturbance could cause the grassland habitat to transition to a more woody-plant dominated shrubland. Alternatively, too frequent disturbance could limit vegetation structure thereby reducing cover during migration stop-overs or breeding.

Human Disturbance

Harpers Ferry NHP provides public access to grassland units via mowed hiking trails which is a positive way for the public to experience the park's cultural and natural resources. However, during many days in the field while conducting this inventory, off-leash dogs were frequently observed running off trails into the grasslands during both Spring and Fall migration and during the breeding season. These disturbances can have negative impacts on migrating and breeding birds thereby reducing the overall habitat quality. We realize that enforcing leash law policies is a challenge but keeping dogs on leashes and constrained to designated trails would benefit the bird and other species using the park's grassland habitats.

Unit Specific Management Recommendations

Schoolhouse Ridge North

Schoolhouse Ridge North is the largest grassland unit that supports the most species and greatest densities of grassland birds throughout the year. We think Schoolhouse Ridge North should be considered the central unit within the park for grassland bird conservation. The Ott Farm portion of Schoolhouse Ridge North should be left in the 2022 condition with 75% of the unit hayed and the remaining 25% in forb meadow and left unmown during growing season. Timing of haying is critical to maintain or enhance the grassland bird use of Schoolhouse Ridge North. During our 2022 inventory, we observed that Schoolhouse Ridge North was hayed in Spring which delayed nesting start dates by approximately one month while the vegetation recovered. It would be best to avoid late Spring mowing in the future.

The lower portion of Schoolhouse Ridge North has been invaded by Johnson grass and vetch and we did not detect grassland birds using this area. Restoring the lower portion of Schoolhouse Ridge North to reduce the density of Johnson grass and vetch could expand the overall usable extent of Schoolhouse Ridge North which may allow for more grassland birds to consider this area potential habitat. In the current state, the lower portion of Schoolhouse Ridge North is not grassland bird habitat.

Removing tree lines wherever possible without damaging cultural resources should be considered a management option to benefit grassland birds using Harpers Ferry NHP. In 2012, tree line around the unhayed 25% of Ott Farm was removed. By way of example of what tree line removal could do at Schoolhouse Ridge South to create the perception of a larger contiguous grassland we provide a hypothetical 'before' (Figure 20) and 'after' (Figure 21).



Figure 20. Existing grassland patches divided by tree lines at Schoolhouse Ridge North, Harpers Ferry NHP, 2022.



Figure 21. Potential grassland habitat at Schoolhouse Ridge North if tree lines were removed, Harpers Ferry NHP, 2022.

Schoolhouse Ridge South

Based on our experience and inventory surveys at Schoolhouse Ridge South, we recommend maintaining this grassland unit in the same management regime and state it was in during the 2022

surveys. If the land transfer with the neighbor to the North (ICE) is successful then there would be an opportunity to create a larger contiguous grassland area by cutting tree lines to provide more open areas.

Transects SRSO-01 and SRSO-05 were productive for breeding Eastern Meadowlark in 2022 so we would recommend ensuring that species continues to breed there. We did detect singing Grasshopper Sparrows and captured them in mist-nets during our Spring sampling at Schoolhouse Ridge South, but they did not stay to breed. Schoolhouse Ride South (Transect SRSO-03) had extensive cover of dead standing native *Andropogon spp* when we initiated the inventory surveys in March, 2022. It would be worth considering mowing the standing dead vegetation in late March to reduce the thick cover and limit woody vegetation.

Lower Bolivar

Lower Bolivar is currently managed entirely by Harpers Ferry NHP (there are not agricultural permits) and should be maintained as a grassland with limited woody vegetation. Possibly, transition from mowing to a prescribed fire rotation. Also, reduce the *Rubus spp.* and other woody vegetation that reduce the habitat quality for grassland birds. We detected greater grassland bird use of Lower Bolivar during the Spring migration than during the breeding season and we observed limited use during the Fall migration. We recommend managing Lower Bolivar as part of the “Greater Schoolhouse Ridge North” grasslands and consider leaving standing, dead vegetation on this site throughout the winter to benefit any overwintering birds (Johnson et al. 2019).

Bolivar Heights

We think the current management and the 2022 condition of Bolivar heights was appropriate for grassland birds. We recommend controlling the Johnson grass to limit any further spread within this grassland unit. We detected Eastern Meadowlark breeding in Bolivar Heights which is a relatively small grassland unit but still provides important breeding opportunities and should be consider a productive area for grassland birds (Walk et al. 2010). Bolivar Heights had extensive cover of dead standing native *Andropogon spp* when we initiated this inventory in March, 2022. It might be worth considering mowing the standing dead vegetation in late March to reduce cover and limit woody vegetation.

Murphy Farm

We think the current management and the 2022 condition of Murphy Farm was appropriate for grassland birds. We detected Grasshopper Sparrow at Murphy Farm during the Spring migration and a male singing in early May indicating the potential for this site to provide breeding opportunities for Grasshopper Sparrows. Removing non-native and invasive plant species like Chinese Bush Clover (*Lespedeza cuneata*) would benefit grassland birds at Murphy Farm.

Nash Farm

Nash Farm was not in grassland habitat during the 2022 inventory and we did not detect grassland birds using this site.

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Appendix A: Species detected on line transects during spring and fall migration

Table 25 shows the species detected on line transects.

Table 25. Species detected on line transects during spring and fall migration at Harpers Ferry NHP, 2022.

Site ID	Common Name	Scientific Name	% Freq. Detect	Avg Count (SE)
Schoolhouse Ridge North	American Crow	<i>Corvus brachyrhynchos</i>	100	4 (0.90)
Schoolhouse Ridge North	American Goldfinch	<i>Spinus tristis</i>	100	6 (1.63)
Schoolhouse Ridge North	Carolina Chickadee	<i>Poecile carolinensis</i>	100	3 (0.55)
Schoolhouse Ridge North	Eastern Bluebird	<i>Sialia sialis</i>	100	6 (1.08)
Schoolhouse Ridge North	Eastern Meadowlark	<i>Sturnella magna</i>	100	23 (1.53)
Schoolhouse Ridge North	European Starling	<i>Sturnus vulgaris</i>	100	96 (22.13)
Schoolhouse Ridge North	Field Sparrow	<i>Spizella pusilla</i>	100	9 (1.64)
Schoolhouse Ridge North	Mourning Dove	<i>Zenaidura macroura</i>	100	5 (1.07)
Schoolhouse Ridge North	Northern Cardinal	<i>Cardinalis cardinalis</i>	100	13 (1.56)
Schoolhouse Ridge North	Rock Pigeon	<i>Columba livia</i>	100	4 (0.68)
Schoolhouse Ridge North	Red-winged Blackbird	<i>Agelaius phoeniceus</i>	100	117 (16.05)
Schoolhouse Ridge North	Song Sparrow	<i>Melospiza melodia</i>	100	6 (0.70)
Schoolhouse Ridge North	American Robin	<i>Turdus migratorius</i>	92	22 (12.96)
Schoolhouse Ridge North	Brown-headed Cowbird	<i>Molothrus ater</i>	92	4 (0.82)
Schoolhouse Ridge North	Blue Jay	<i>Cyanocitta cristata</i>	92	10 (6.32)
Schoolhouse Ridge North	Carolina Wren	<i>Thryothorus ludovicianus</i>	92	2 (0.47)
Schoolhouse Ridge North	Northern Mockingbird	<i>Mimus polyglottos</i>	92	2 (0.38)
Schoolhouse Ridge North	Tree Swallow	<i>Tachycineta bicolor</i>	92	3 (0.87)
Schoolhouse Ridge North	Common Grackle	<i>Quiscalus quiscula</i>	83	3 (0.73)
Schoolhouse Ridge North	Savannah Sparrow	<i>Passerculus sandwichensis</i>	83	10 (2.91)
Schoolhouse Ridge North	Brown Thrasher	<i>Toxostoma rufum</i>	75	4 (0.87)

Table 25 (continued). Species detected on line transects during spring and fall migration at Harpers Ferry NHP, 2022.

Site ID	Common Name	Scientific Name	% Freq. Detect	Avg Count (SE)
Schoolhouse Ridge North	Chipping Sparrow	<i>Spizella passerina</i>	75	3 (1.21)
Schoolhouse Ridge North	Northern Flicker	<i>Colaptes auratus</i>	75	2 (0.69)
Schoolhouse Ridge North	White-throated Sparrow	<i>Zonotrichia albicollis</i>	75	2 (0.38)
Schoolhouse Ridge North	Canada Goose	<i>Branta canadensis</i>	67	3 (1.26)
Schoolhouse Ridge North	Downy Woodpecker	<i>Dryobates pubescens</i>	67	1 (0.26)
Schoolhouse Ridge North	Red-bellied Woodpecker	<i>Melanerpes carolinus</i>	67	2 (0.56)
Schoolhouse Ridge North	Tufted Titmouse	<i>Baeolophus bicolor</i>	67	2 (0.45)
Schoolhouse Ridge North	Barn Swallow	<i>Hirundo rustica</i>	58	2 (0.91)
Schoolhouse Ridge North	Grasshopper Sparrow	<i>Ammodramus savannarum</i>	58	6 (2.87)
Schoolhouse Ridge North	House Finch	<i>Haemorhous mexicanus</i>	58	1 (0.48)
Schoolhouse Ridge North	Turkey Vulture	<i>Cathartes aura</i>	58	1 (0.24)
Schoolhouse Ridge North	Fish Crow	<i>Corvus ossifragus</i>	50	1 (0.46)
Schoolhouse Ridge North	Yellow-rumped Warbler	<i>Setophaga coronata</i>	50	1 (0.42)
Schoolhouse Ridge North	Common Raven	<i>Corvus corax</i>	42	1 (0.28)
Schoolhouse Ridge North	Eastern Towhee	<i>Pipilo erythrophthalmus</i>	42	1 (0.33)
Schoolhouse Ridge North	House Wren	<i>Troglodytes aedon</i>	42	1 (0.64)
Schoolhouse Ridge North	Red-Shouldered Hawk	<i>Buteo lineatus</i>	42	1 (0.26)
Schoolhouse Ridge North	Cedar Waxwing	<i>Bombycilla cedrorum</i>	33	9 (5.90)
Schoolhouse Ridge North	Cooper's Hawk	<i>Accipiter cooperii</i>	33	1 (0.23)
Schoolhouse Ridge North	Pileated Woodpecker	<i>Dryocopus pileatus</i>	33	0 (0.19)
Schoolhouse Ridge North	Sharp-shinned Hawk	<i>Accipiter striatus</i>	33	0 (0.19)
Schoolhouse Ridge North	Black Vulture	<i>Coragyps atratus</i>	25	0 (0.13)
Schoolhouse Ridge North	Bobolink	<i>Dolichonyx oryzivorus</i>	25	0 (0.23)
Schoolhouse Ridge North	Eastern Kingbird	<i>Tyrannus tyrannus</i>	25	1 (0.34)
Schoolhouse Ridge North	Gray Catbird	<i>Dumetella carolinensis</i>	25	1 (0.61)

Table 25 (continued). Species detected on line transects during spring and fall migration at Harpers Ferry NHP, 2022.

Site ID	Common Name	Scientific Name	% Freq. Detect	Avg Count (SE)
Schoolhouse Ridge North	N. Rough-winged Swallow	<i>Stelgidopteryx serripennis</i>	25	0 (0.19)
Schoolhouse Ridge North	Orchard Oriole	<i>Icterus spurius</i>	25	1 (0.51)
Schoolhouse Ridge North	Yellow Warbler	<i>Setophaga petechia</i>	25	1 (0.36)
Schoolhouse Ridge North	Bald Eagle	<i>Haliaeetus leucocephalus</i>	17	0 (0.18)
Schoolhouse Ridge North	Baltimore Oriole	<i>Icterus galbula</i>	17	0 (0.34)
Schoolhouse Ridge North	Blue-gray Gnatcatcher	<i>Poliophtila caerulea</i>	17	0 (0.11)
Schoolhouse Ridge North	Eastern Phoebe	<i>Sayornis phoebe</i>	17	0 (0.11)
Schoolhouse Ridge North	House Sparrow	<i>Passer domesticus</i>	17	0 (0.22)
Schoolhouse Ridge North	Red-tailed Hawk	<i>Buteo jamaicensis</i>	17	0 (0.11)
Schoolhouse Ridge North	American Kestrel	<i>Falco sparverius</i>	8	0 (0.08)
Schoolhouse Ridge North	American Pipit	<i>Anthus rubescens</i>	8	0 (0.08)
Schoolhouse Ridge North	Broad-winged Hawk	<i>Buteo platypterus</i>	8	0 (0.08)
Schoolhouse Ridge North	Double-crested Cormorant	<i>Nannopterum auritum</i>	8	0 (0.08)
Schoolhouse Ridge North	Dark-eyed Junco	<i>Junco hyemalis</i>	8	0 (0.17)
Schoolhouse Ridge North	Horned Lark	<i>Eremophila alpestris</i>	8	1 (0.50)
Schoolhouse Ridge North	Indigo Bunting	<i>Passerina cyanea</i>	8	0 (0.33)
Schoolhouse Ridge North	Killdeer	<i>Charadrius vociferus</i>	8	0 (0.08)
Schoolhouse Ridge North	Osprey	<i>Pandion haliaetus</i>	8	0 (0.08)
Schoolhouse Ridge North	Ruby-crowned Kinglet	<i>Corthylio calendula</i>	8	0 (0.08)
Schoolhouse Ridge North	Red-headed Woodpecker	<i>Melanerpes erythrocephalus</i>	8	0 (0.08)
Schoolhouse Ridge North	Scarlet Tanager	<i>Piranga olivacea</i>	8	0 (0.08)
Schoolhouse Ridge North	Vesper Sparrow	<i>Pooecetes gramineus</i>	8	3 (2.92)
Schoolhouse Ridge North	White-eyed Vireo	<i>Vireo griseus</i>	8	0 (0.08)
Schoolhouse Ridge North	Wood Duck	<i>Aix sponsa</i>	8	0 (0.17)
Lower Bolivar	Field Sparrow	<i>Spizella pusilla</i>	100	4 (0.74)

Table 25 (continued). Species detected on line transects during spring and fall migration at Harpers Ferry NHP, 2022.

Site ID	Common Name	Scientific Name	% Freq. Detect	Avg Count (SE)
Lower Bolivar	Red-winged Blackbird	<i>Agelaius phoeniceus</i>	92	8 (2.10)
Lower Bolivar	American Goldfinch	<i>Spinus tristis</i>	67	2 (0.51)
Lower Bolivar	Blue Jay	<i>Cyanocitta cristata</i>	50	1 (0.21)
Lower Bolivar	Tree Swallow	<i>Tachycineta bicolor</i>	50	1 (0.26)
Lower Bolivar	Eastern Bluebird	<i>Sialia sialis</i>	42	1 (0.32)
Lower Bolivar	Carolina Wren	<i>Thryothorus ludovicianus</i>	33	0 (0.13)
Lower Bolivar	Eastern Meadowlark	<i>Sturnella magna</i>	33	1 (0.27)
Lower Bolivar	Northern Cardinal	<i>Cardinalis cardinalis</i>	33	0 (0.18)
Lower Bolivar	American Crow	<i>Corvus brachyrhynchos</i>	25	0 (0.24)
Lower Bolivar	American Robin	<i>Turdus migratorius</i>	25	0 (0.12)
Lower Bolivar	Brown Thrasher	<i>Toxostoma rufum</i>	25	0 (0.12)
Lower Bolivar	Carolina Chickadee	<i>Poecile carolinensis</i>	25	0 (0.12)
Lower Bolivar	Eastern Phoebe	<i>Sayornis phoebe</i>	25	0 (0.17)
Lower Bolivar	Chipping Sparrow	<i>Spizella passerina</i>	17	0 (0.17)
Lower Bolivar	Common Raven	<i>Corvus corax</i>	17	0 (0.10)
Lower Bolivar	European Starling	<i>Sturnus vulgaris</i>	17	5 (5.30)
Lower Bolivar	Fish Crow	<i>Corvus ossifragus</i>	17	0 (0.33)
Lower Bolivar	Song Sparrow	<i>Melospiza melodia</i>	17	0 (0.21)
Lower Bolivar	Tufted Titmouse	<i>Baeolophus bicolor</i>	17	0 (0.10)
Lower Bolivar	Brown-headed Cowbird	<i>Molothrus ater</i>	8	0 (0.08)
Lower Bolivar	Canada Goose	<i>Branta canadensis</i>	8	0 (0.23)
Lower Bolivar	Cedar Waxwing	<i>Bombycilla cedrorum</i>	8	2 (1.69)
Lower Bolivar	Common Grackle	<i>Quiscalus quiscula</i>	8	0 (0.08)
Lower Bolivar	Grasshopper Sparrow	<i>Ammodramus savannarum</i>	8	0 (0.08)
Lower Bolivar	House Sparrow	<i>Passer domesticus</i>	8	0 (0.15)

Table 25 (continued). Species detected on line transects during spring and fall migration at Harpers Ferry NHP, 2022.

Site ID	Common Name	Scientific Name	% Freq. Detect	Avg Count (SE)
Lower Bolivar	Indigo Bunting	<i>Passerina cyanea</i>	8	0 (0.08)
Lower Bolivar	Mourning Dove	<i>Zenaida macroura</i>	8	0 (0.08)
Lower Bolivar	Northern Mockingbird	<i>Mimus polyglottos</i>	8	0 (0.23)
Lower Bolivar	Pileated Woodpecker	<i>Dryocopus pileatus</i>	8	0 (0.08)
Lower Bolivar	Turkey Vulture	<i>Cathartes aura</i>	8	0 (0.08)
Lower Bolivar	Wood Thrush	<i>Hylocichla mustelina</i>	8	0 (0.08)
Bolivar Heights	European Starling	<i>Sturnus vulgaris</i>	92	7 (1.86)
Bolivar Heights	Red-winged Blackbird	<i>Agelaius phoeniceus</i>	85	2 (0.54)
Bolivar Heights	Field Sparrow	<i>Spizella pusilla</i>	69	1 (0.39)
Bolivar Heights	Eastern Meadowlark	<i>Sturnella magna</i>	62	1 (0.28)
Bolivar Heights	Northern Cardinal	<i>Cardinalis cardinalis</i>	62	1 (0.26)
Bolivar Heights	Common Grackle	<i>Quiscalus quiscula</i>	54	1 (0.61)
Bolivar Heights	Blue Jay	<i>Cyanocitta cristata</i>	46	1 (0.45)
Bolivar Heights	Chipping Sparrow	<i>Spizella passerina</i>	46	1 (0.24)
Bolivar Heights	Song Sparrow	<i>Melospiza melodia</i>	46	1 (0.18)
Bolivar Heights	American Crow	<i>Corvus brachyrhynchos</i>	38	1 (0.33)
Bolivar Heights	Brown Thrasher	<i>Toxostoma rufum</i>	38	0 (0.18)
Bolivar Heights	Eastern Bluebird	<i>Sialia sialis</i>	38	1 (0.29)
Bolivar Heights	American Goldfinch	<i>Spinus tristis</i>	31	0 (0.22)
Bolivar Heights	American Robin	<i>Turdus migratorius</i>	31	0 (0.18)
Bolivar Heights	Brown-headed Cowbird	<i>Molothrus ater</i>	31	0 (0.13)
Bolivar Heights	Savannah Sparrow	<i>Passerculus sandwichensis</i>	23	0 (0.12)
Bolivar Heights	Carolina Chickadee	<i>Poecile carolinensis</i>	15	0 (0.17)
Bolivar Heights	Gray Catbird	<i>Dumetella carolinensis</i>	15	0 (0.24)
Bolivar Heights	Mourning Dove	<i>Zenaida macroura</i>	15	0 (0.08)

Table 25 (continued). Species detected on line transects during spring and fall migration at Harpers Ferry NHP, 2022.

Site ID	Common Name	Scientific Name	% Freq. Detect	Avg Count (SE)
Bolivar Heights	Northern Mockingbird	<i>Mimus polyglottos</i>	15	0 (0.10)
Bolivar Heights	Ruby-crowned Kinglet	<i>Corthylio calendula</i>	15	0 (0.10)
Bolivar Heights	Tree Swallow	<i>Tachycineta bicolor</i>	15	0 (0.10)
Bolivar Heights	Yellow-rumped Warbler	<i>Setophaga coronata</i>	15	0 (0.10)
Bolivar Heights	Barn Swallow	<i>Hirundo rustica</i>	8	0 (0.08)
Bolivar Heights	Carolina Wren	<i>Thryothorus ludovicianus</i>	8	0 (0.08)
Bolivar Heights	Eastern Phoebe	<i>Sayornis phoebe</i>	8	0 (0.08)
Bolivar Heights	Fish Crow	<i>Corvus ossifragus</i>	8	0 (0.08)
Bolivar Heights	House Finch	<i>Haemorhous mexicanus</i>	8	0 (0.08)
Bolivar Heights	N. Rough-winged Swallow	<i>Stelgidopteryx serripennis</i>	8	0 (0.08)
Bolivar Heights	Pileated Woodpecker	<i>Dryocopus pileatus</i>	8	0 (0.08)
Bolivar Heights	Red-bellied Woodpecker	<i>Melanerpes carolinus</i>	8	0 (0.08)
Bolivar Heights	Red-Shouldered Hawk	<i>Buteo lineatus</i>	8	0 (0.08)
Bolivar Heights	Tufted Titmouse	<i>Baeolophus bicolor</i>	8	0 (0.08)
Bolivar Heights	Turkey Vulture	<i>Cathartes aura</i>	8	0 (0.08)
Bolivar Heights	White-throated Sparrow	<i>Zonotrichia albicollis</i>	8	0 (0.08)
Bolivar Heights	Yellow Warbler	<i>Setophaga petechia</i>	8	0 (0.08)
Murphy Farm	American Robin	<i>Turdus migratorius</i>	100	4 (1.47)
Murphy Farm	Northern Mockingbird	<i>Mimus polyglottos</i>	100	2 (0.33)
Murphy Farm	Eastern Meadowlark	<i>Sturnella magna</i>	92	3 (0.67)
Murphy Farm	European Starling	<i>Sturnus vulgaris</i>	77	4 (1.45)
Murphy Farm	Northern Cardinal	<i>Cardinalis cardinalis</i>	77	2 (0.41)
Murphy Farm	Chipping Sparrow	<i>Spizella passerina</i>	69	3 (0.85)
Murphy Farm	Eastern Bluebird	<i>Sialia sialis</i>	69	1 (0.43)
Murphy Farm	Northern Flicker	<i>Colaptes auratus</i>	62	3 (1.53)

Table 25 (continued). Species detected on line transects during spring and fall migration at Harpers Ferry NHP, 2022.

Site ID	Common Name	Scientific Name	% Freq. Detect	Avg Count (SE)
Murphy Farm	Yellow-rumped Warbler	<i>Setophaga coronata</i>	62	1 (0.36)
Murphy Farm	American Crow	<i>Corvus brachyrhynchos</i>	54	1 (0.26)
Murphy Farm	Brown-headed Cowbird	<i>Molothrus ater</i>	54	1 (0.51)
Murphy Farm	Blue Jay	<i>Cyanocitta cristata</i>	54	1 (0.37)
Murphy Farm	Brown Thrasher	<i>Toxostoma rufum</i>	46	1 (0.40)
Murphy Farm	Carolina Chickadee	<i>Poecile carolinensis</i>	46	1 (0.40)
Murphy Farm	Common Grackle	<i>Quiscalus quiscula</i>	46	1 (0.42)
Murphy Farm	Tree Swallow	<i>Tachycineta bicolor</i>	46	1 (0.30)
Murphy Farm	Tufted Titmouse	<i>Baeolophus bicolor</i>	46	1 (0.26)
Murphy Farm	Field Sparrow	<i>Spizella pusilla</i>	38	1 (0.24)
Murphy Farm	Savannah Sparrow	<i>Passerculus sandwichensis</i>	38	1 (0.30)
Murphy Farm	American Goldfinch	<i>Spinus tristis</i>	31	0 (0.13)
Murphy Farm	Carolina Wren	<i>Thryothorus ludovicianus</i>	31	1 (0.27)
Murphy Farm	Cedar Waxwing	<i>Bombycilla cedrorum</i>	31	2 (1.23)
Murphy Farm	Eastern Towhee	<i>Pipilo erythrophthalmus</i>	31	0 (0.18)
Murphy Farm	Mourning Dove	<i>Zenaida macroura</i>	31	0 (0.22)
Murphy Farm	N. Rough-winged Swallow	<i>Stelgidopteryx serripennis</i>	31	0 (0.22)
Murphy Farm	Song Sparrow	<i>Melospiza melodia</i>	31	1 (0.48)
Murphy Farm	Bald Eagle	<i>Haliaeetus leucocephalus</i>	23	0 (0.12)
Murphy Farm	Black Vulture	<i>Coragyps atratus</i>	23	0 (0.12)
Murphy Farm	Grasshopper Sparrow	<i>Ammodramus savannarum</i>	23	1 (0.33)
Murphy Farm	Red-bellied Woodpecker	<i>Melanerpes carolinus</i>	23	0 (0.31)
Murphy Farm	Red-winged Blackbird	<i>Agelaius phoeniceus</i>	23	1 (0.78)
Murphy Farm	Turkey Vulture	<i>Cathartes aura</i>	23	1 (0.54)
Murphy Farm	Canada Goose	<i>Branta canadensis</i>	15	0 (0.21)

Table 25 (continued). Species detected on line transects during spring and fall migration at Harpers Ferry NHP, 2022.

Site ID	Common Name	Scientific Name	% Freq. Detect	Avg Count (SE)
Murphy Farm	Chimney Swift	<i>Chaetura pelagica</i>	15	1 (0.71)
Murphy Farm	Double-crested Cormorant	<i>Nannopterum auritum</i>	15	0 (0.31)
Murphy Farm	Dark-eyed Junco	<i>Junco hyemalis</i>	15	1 (0.46)
Murphy Farm	Downy Woodpecker	<i>Dryobates pubescens</i>	15	0 (0.10)
Murphy Farm	Fish Crow	<i>Corvus ossifragus</i>	15	0 (0.31)
Ourphy Farm	Hermit Thrush	<i>Catharus guttatus</i>	15	0 (0.10)
Murphy Farm	Pileated Woodpecker	<i>Dryocopus pileatus</i>	15	0 (0.10)
Murphy Farm	Ruby-crowned Kinglet	<i>Corthylio calendula</i>	15	0 (0.10)
Murphy Farm	White-breasted Nuthatch	<i>Sitta carolinensis</i>	15	0 (0.10)
Murphy Farm	Blue-gray Gnatcatcher	<i>Poliophtila caerulea</i>	8	0 (0.08)
Murphy Farm	Common Raven	<i>Corvus corax</i>	8	0 (0.15)
Murphy Farm	House Finch	<i>Haemorhous mexicanus</i>	8	0 (0.08)
Murphy Farm	House Sparrow	<i>Passer domesticus</i>	8	0 (0.08)
Murphy Farm	Purple Martin	<i>Progne subis</i>	8	0 (0.08)
Murphy Farm	Vesper Sparrow	<i>Poocetes gramineus</i>	8	0 (0.15)
Murphy Farm	White-throated Sparrow	<i>Zonotrichia albicollis</i>	8	0 (0.08)
Murphy Farm	Palm Warbler	<i>Setophaga palmarum</i>	8	0 (0.15)
Nash Farm	Northern Cardinal	<i>Cardinalis cardinalis</i>	77	3 (0.58)
Nash Farm	American Goldfinch	<i>Spinus tristis</i>	62	1 (0.25)
Nash Farm	Brown-headed Cowbird	<i>Molothrus ater</i>	46	1 (0.51)
Nash Farm	Carolina Wren	<i>Thryothorus ludovicianus</i>	38	1 (0.22)
Nash Farm	Field Sparrow	<i>Spizella pusilla</i>	38	1 (0.29)
Nash Farm	Tufted Titmouse	<i>Baeolophus bicolor</i>	38	0 (0.14)
Nash Farm	White-throated Sparrow	<i>Zonotrichia albicollis</i>	38	1 (0.68)
Nash Farm	American Crow	<i>Corvus brachyrhynchos</i>	31	1 (0.52)

Table 25 (continued). Species detected on line transects during spring and fall migration at Harpers Ferry NHP, 2022.

Site ID	Common Name	Scientific Name	% Freq. Detect	Avg Count (SE)
Nash Farm	Eastern Bluebird	<i>Sialia sialis</i>	31	0 (0.18)
Nash Farm	Ruby-crowned Kinglet	<i>Corthylio calendula</i>	31	0 (0.13)
Nash Farm	Song Sparrow	<i>Melospiza melodia</i>	31	1 (0.27)
Nash Farm	Carolina Chickadee	<i>Poecile carolinensis</i>	23	0 (0.12)
Nash Farm	Chipping Sparrow	<i>Spizella passerina</i>	23	0 (0.12)
Nash Farm	Red-bellied Woodpecker	<i>Melanerpes carolinus</i>	23	0 (0.27)
Nash Farm	Tree Swallow	<i>Tachycineta bicolor</i>	23	0 (0.17)
Nash Farm	American Robin	<i>Turdus migratorius</i>	15	2 (2.15)
Nash Farm	Blue Jay	<i>Cyanocitta cristata</i>	15	0 (0.10)
Nash Farm	Common Grackle	<i>Quiscalus quiscula</i>	15	0 (0.31)
Nash Farm	Common Raven	<i>Corvus corax</i>	15	0 (0.10)
Nash Farm	Dark-eyed Junco	<i>Junco hyemalis</i>	15	0 (0.10)
Nash Farm	Red-winged Blackbird	<i>Agelaius phoeniceus</i>	15	0 (0.31)
Nash Farm	Yellow-rumped Warbler	<i>Setophaga coronata</i>	15	1 (0.69)
Nash Farm	Black-and-white Warbler	<i>Mniotilta varia</i>	8	0 (0.08)
Nash Farm	Brown Thrasher	<i>Toxostoma rufum</i>	8	0 (0.15)
Nash Farm	Downy Woodpecker	<i>Dryobates pubescens</i>	8	0 (0.15)
Nash Farm	Eastern Kingbird	<i>Tyrannus tyrannus</i>	8	0 (0.08)
Nash Farm	Eastern Towhee	<i>Pipilo erythrophthalmus</i>	8	0 (0.08)
Nash Farm	Fish Crow	<i>Corvus ossifragus</i>	8	0 (0.23)
Nash Farm	Golden-crowned Kinglet	<i>Regulus satrapa</i>	8	0 (0.08)
Nash Farm	House Wren	<i>Troglodytes aedon</i>	8	0 (0.08)
Nash Farm	Indigo Bunting	<i>Passerina cyanea</i>	8	0 (0.15)
Nash Farm	Magnolia Warbler	<i>Setophaga magnolia</i>	8	0 (0.08)
Nash Farm	Red-eyed Vireo	<i>Vireo brevipennis</i>	8	0 (0.08)

Table 25 (continued). Species detected on line transects during spring and fall migration at Harpers Ferry NHP, 2022.

Site ID	Common Name	Scientific Name	% Freq. Detect	Avg Count (SE)
Nash Farm	Rock Pigeon	<i>Columba livia</i>	8	0 (0.15)
Nash Farm	Swamp Sparrow	<i>Melospiza georgiana</i>	8	0 (0.08)
Nash Farm	Turkey Vulture	<i>Cathartes aura</i>	8	0 (0.08)
Nash Farm	White-breasted Nuthatch	<i>Sitta carolinensis</i>	8	0 (0.08)
Schoolhouse Ridge South	Eastern Bluebird	<i>Sialia sialis</i>	100	5 (0.78)
Schoolhouse Ridge South	Eastern Meadowlark	<i>Sturnella magna</i>	100	8 (0.89)
Schoolhouse Ridge South	European Starling	<i>Sturnus vulgaris</i>	100	20 (2.55)
Schoolhouse Ridge South	Field Sparrow	<i>Spizella pusilla</i>	100	8 (0.96)
Schoolhouse Ridge South	Northern Cardinal	<i>Cardinalis cardinalis</i>	100	7 (1.03)
Schoolhouse Ridge South	Northern Mockingbird	<i>Mimus polyglottos</i>	100	3 (0.54)
Schoolhouse Ridge South	Red-winged Blackbird	<i>Agelaius phoeniceus</i>	100	26 (5.71)
Schoolhouse Ridge South	American Goldfinch	<i>Spinus tristis</i>	92	4 (0.69)
Schoolhouse Ridge South	American Robin	<i>Turdus migratorius</i>	92	13 (4.34)
Schoolhouse Ridge South	Brown-headed Cowbird	<i>Molothrus ater</i>	92	5 (0.81)
Schoolhouse Ridge South	Carolina Chickadee	<i>Poecile carolinensis</i>	92	4 (0.91)
Schoolhouse Ridge South	Common Grackle	<i>Quiscalus quiscula</i>	92	6 (1.61)
Schoolhouse Ridge South	House Finch	<i>Haemorrhous mexicanus</i>	92	3 (0.91)
Schoolhouse Ridge South	Carolina Wren	<i>Thryothorus ludovicianus</i>	85	4 (0.89)
Schoolhouse Ridge South	Mourning Dove	<i>Zenaida macroura</i>	85	3 (0.70)
Schoolhouse Ridge South	Savannah Sparrow	<i>Passerculus sandwichensis</i>	85	3 (1.05)
Schoolhouse Ridge South	American Crow	<i>Corvus brachyrhynchos</i>	69	1 (0.45)
Schoolhouse Ridge South	Eastern Phoebe	<i>Sayornis phoebe</i>	69	2 (0.50)
Schoolhouse Ridge South	Northern Flicker	<i>Colaptes auratus</i>	69	2 (0.69)
Schoolhouse Ridge South	Tufted Titmouse	<i>Baeolophus bicolor</i>	69	2 (0.45)
Schoolhouse Ridge South	Red-bellied Woodpecker	<i>Melanerpes carolinus</i>	62	1 (0.36)

Table 25 (continued). Species detected on line transects during spring and fall migration at Harpers Ferry NHP, 2022.

Site ID	Common Name	Scientific Name	% Freq. Detect	Avg Count (SE)
Schoolhouse Ridge South	Song Sparrow	<i>Melospiza melodia</i>	62	2 (0.50)
Schoolhouse Ridge South	Tree Swallow	<i>Tachycineta bicolor</i>	62	2 (0.63)
Schoolhouse Ridge South	Turkey Vulture	<i>Cathartes aura</i>	62	1 (0.57)
Schoolhouse Ridge South	Brown Thrasher	<i>Toxostoma rufum</i>	54	1 (0.39)
Schoolhouse Ridge South	Canada Goose	<i>Branta canadensis</i>	54	2 (0.68)
Schoolhouse Ridge South	Fish Crow	<i>Corvus ossifragus</i>	54	1 (0.33)
Schoolhouse Ridge South	Barn Swallow	<i>Hirundo rustica</i>	46	1 (0.38)
Schoolhouse Ridge South	Downy Woodpecker	<i>Dryobates pubescens</i>	46	1 (0.24)
Schoolhouse Ridge South	Grasshopper Sparrow	<i>Ammodramus savannarum</i>	46	2 (0.95)
Schoolhouse Ridge South	Rock Pigeon	<i>Columba livia</i>	46	1 (0.31)
Schoolhouse Ridge South	Blue Jay	<i>Cyanocitta cristata</i>	38	15 (14.41)
Schoolhouse Ridge South	Cedar Waxwing	<i>Bombycilla cedrorum</i>	38	3 (1.54)
Schoolhouse Ridge South	Chipping Sparrow	<i>Spizella passerina</i>	38	3 (1.42)
Schoolhouse Ridge South	House Wren	<i>Troglodytes aedon</i>	38	1 (0.32)
Schoolhouse Ridge South	White-throated Sparrow	<i>Zonotrichia albicollis</i>	38	1 (0.52)
Schoolhouse Ridge South	Yellow-rumped Warbler	<i>Setophaga coronata</i>	38	1 (0.22)
Schoolhouse Ridge South	Blue-gray Gnatcatcher	<i>Polioptila caerulea</i>	31	0 (0.18)
Schoolhouse Ridge South	Black Vulture	<i>Coragyps atratus</i>	31	0 (0.24)
Schoolhouse Ridge South	N. Rough-winged Swallow	<i>Stelgidopteryx serripennis</i>	31	1 (0.35)
Schoolhouse Ridge South	Pileated Woodpecker	<i>Dryocopus pileatus</i>	31	0 (0.18)
Schoolhouse Ridge South	Red-Shouldered Hawk	<i>Buteo lineatus</i>	23	0 (0.12)
Schoolhouse Ridge South	White-breasted Nuthatch	<i>Sitta carolinensis</i>	23	0 (0.21)
Schoolhouse Ridge South	Baltimore Oriole	<i>Icterus galbula</i>	15	0 (0.10)
Schoolhouse Ridge South	Common Raven	<i>Corvus corax</i>	15	0 (0.17)
Schoolhouse Ridge South	Dark-eyed Junco	<i>Junco hyemalis</i>	15	0 (0.17)

Table 25 (continued). Species detected on line transects during spring and fall migration at Harpers Ferry NHP, 2022.

Site ID	Common Name	Scientific Name	% Freq. Detect	Avg Count (SE)
Schoolhouse Ridge South	Eastern Kingbird	<i>Tyrannus tyrannus</i>	15	0 (0.21)
Schoolhouse Ridge South	Eastern Towhee	<i>Pipilo erythrophthalmus</i>	15	0 (0.17)
Schoolhouse Ridge South	Vesper Sparrow	<i>Poocetes gramineus</i>	15	0 (0.31)
Schoolhouse Ridge South	American Kestrel	<i>Falco sparverius</i>	8	0 (0.08)
Schoolhouse Ridge South	Broad-winged Hawk	<i>Buteo platypterus</i>	8	0 (0.08)
Schoolhouse Ridge South	Chimney Swift	<i>Chaetura pelagica</i>	8	0 (0.31)
Schoolhouse Ridge South	Golden-crowned Kinglet	<i>Regulus satrapa</i>	8	0 (0.08)
Schoolhouse Ridge South	Gray Catbird	<i>Dumetella carolinensis</i>	8	0 (0.08)
Schoolhouse Ridge South	Killdeer	<i>Charadrius vociferus</i>	8	0 (0.08)
Schoolhouse Ridge South	Red-tailed Hawk	<i>Buteo jamaicensis</i>	8	0 (0.08)
Schoolhouse Ridge South	Warbling Vireo	<i>Vireo gilvus</i>	8	0 (0.08)
Schoolhouse Ridge South	Wild Turkey	<i>Meleagris gallopavo</i>	8	0 (0.08)
Schoolhouse Ridge South	Yellow-bellied Sapsucker	<i>Sphyrapicus varius</i>	8	0 (0.08)

Appendix B: Density estimates based on distance sampling from line transects during spring and fall migration

Tables 26 – 32 show density estimates based on distance sampling at all sites.

Table 26. Density estimates of Spring and Fall migrants across all grasslands at Harpers Ferry NHP, 2022.

Species	Season	Detection Probability	Birds/km ²	Standard Error
American Crow	fall	1.00	1.35	0.30
American Crow	spring	1.00	1.21	0.18
American Goldfinch	fall	0.64	4.63	1.24
American Goldfinch	spring	0.72	5.57	1.27
American Kestrel	fall	1.00	0.50	0.19
American Robin	fall	0.91	1.21	0.30
American Robin	spring	0.85	7.61	1.42
Barn Swallow	spring	0.52	1.49	0.55
Blue Jay	spring	0.86	2.30	0.72
Blue Jay	fall	0.74	7.73	1.54
Bobolink	fall	0.51	0.56	0.49
Brown Thrasher	spring	0.96	2.88	0.51
Brown-headed Cowbird	spring	1.00	4.20	1.06
Carolina Chickadee	spring	0.88	3.94	0.98
Carolina Chickadee	fall	0.82	2.95	0.72
Carolina Wren	fall	0.94	6.23	1.38
Carolina Wren	spring	1.00	3.29	0.65
Cedar Waxwing	spring	0.70	0.86	0.35
Cedar Waxwing	fall	0.91	3.39	0.82
Chimney Swift	fall	0.63	0.56	0.43
Chipping Sparrow	fall	0.62	2.25	0.76
Chipping Sparrow	spring	0.81	5.41	1.48
Common Grackle	spring	1.00	0.56	0.13
Common Yellowthroat	fall	0.48	0.81	0.47
Downy Woodpecker	spring	0.97	0.85	0.33
Downy Woodpecker	fall	0.87	1.30	0.40
Eastern Bluebird	fall	0.80	11.01	1.66
Eastern Bluebird	spring	0.81	8.30	1.08
Eastern Meadowlark*	fall	0.64	10.04	3.10

* Species in are considered a grassland obligate species (also in **bold font**).

Table 26 (continued). Density estimates of Spring and Fall migrants across all grasslands at Harpers Ferry NHP, 2022.

Species	Season	Detection Probability	Birds/km²	Standard Error
Eastern Meadowlark*	spring	0.84	17.93	2.63
Eastern Phoebe	fall	0.39	1.62	4.13
Eastern Phoebe	spring	0.98	0.93	0.40
Eastern Towhee	fall	0.81	0.66	0.47
Eastern Towhee	spring	0.81	0.81	0.32
Eastern Wood-Pewee	fall	0.70	0.61	0.31
European Starling	fall	0.84	4.54	0.95
European Starling	spring	0.85	11.03	1.56
Field Sparrow*	fall	0.68	3.09	1.34
Field Sparrow*	spring	0.91	11.42	2.15
Fish Crow	spring	0.83	0.58	0.23
Grasshopper Sparrow*	fall	0.10	8.80	5.33
Grasshopper Sparrow*	spring	0.40	11.33	4.15
Gray Catbird	spring	0.82	0.85	0.35
Gray Catbird	fall	0.76	1.79	0.73
House Finch	spring	1.00	1.34	0.46
House Finch	fall	0.75	1.76	0.46
House Wren	spring	0.71	1.47	0.46
Indigo Bunting	fall	0.50	0.71	0.46
Mourning Dove	fall	0.60	0.77	0.32
Mourning Dove	spring	1.00	2.64	0.53
Northern Cardinal	fall	0.76	11.27	2.56
Northern Cardinal	spring	0.78	15.39	3.16
Northern Flicker	spring	0.96	2.70	0.58
Northern Flicker	fall	0.83	3.79	0.76
Northern Mockingbird	spring	0.60	5.93	1.78
Northern Mockingbird	fall	0.64	4.20	1.16
Northern Rough-winged Swallow	fall	0.50	0.71	0.52
Palm Warbler	fall	0.41	1.20	0.61
Pileated Woodpecker	spring	1.00	0.26	0.13
Pileated Woodpecker	fall	0.91	0.55	0.24
Red-bellied Woodpecker	spring	1.00	2.04	0.69
Red-bellied Woodpecker	fall	0.90	4.36	0.88
Red-shouldered Hawk	fall	1.00	0.32	0.13

* Species in are considered a grassland obligate species (also in **bold font**).

Table 26 (continued). Density estimates of Spring and Fall migrants across all grasslands at Harpers Ferry NHP, 2022.

Species	Season	Detection Probability	Birds/km ²	Standard Error
Red-shouldered Hawk	spring	0.76	0.51	0.20
Red-winged Blackbird	spring	0.75	64.77	15.22
Rock Pigeon	spring	0.74	0.64	0.46
Ruby-crowned Kinglet	fall	0.73	0.83	0.39
Savannah Sparrow*	fall	0.27	11.62	4.86
Savannah Sparrow*	spring	0.28	14.36	4.51
Song Sparrow	spring	0.64	7.22	2.51
Song Sparrow	fall	0.31	11.85	3.52
Tree Swallow	fall	0.54	1.06	0.42
Tree Swallow	spring	0.54	3.07	0.86
Tufted Titmouse	fall	0.75	2.22	0.59
Tufted Titmouse	spring	1.00	1.86	0.40
Turkey Vulture	fall	0.66	0.54	0.21
White-breasted Nuthatch	fall	0.91	0.67	0.21
White-throated Sparrow	fall	0.86	1.77	0.80
White-throated Sparrow	spring	0.58	3.00	1.30
Yellow-rumped Warbler	fall	0.33	3.02	1.16

* Species in are considered a grassland obligate species (also in **bold font**).

Table 27. Density estimates of Spring and Fall migrants at Bolivar Heights, Harpers Ferry NHP, 2022.

Species	Field Code	Season	Detection Probability	Birds/km ²	Standard Error
Blue Jay	BOHE	fall	0.60	19.05	5.25
Chipping Sparrow	BOHE	fall	0.28	30.10	36.46
Eastern Bluebird	BOHE	fall	0.35	58.76	23.87
Eastern Meadowlark	BOHE	spring	0.50	22.68	18.55
European Starling	BOHE	fall	0.63	26.60	11.83
European Starling	BOHE	spring	0.54	26.04	15.21
Field Sparrow	BOHE	spring	0.77	20.33	21.08
Northern Cardinal	BOHE	fall	0.66	28.62	28.18
Northern Cardinal	BOHE	spring	0.87	11.97	18.57
Northern Mockingbird	BOHE	fall	0.63	19.35	10.36
Red-winged Blackbird	BOHE	spring	0.85	21.52	8.50

Table 28. Density estimates of Spring and Fall migrants at Lower Bolivar, Harpers Ferry NHP, 2022.

Species	Field Code	Season	Detection Probability	Birds/km²	Standard Error
American Goldfinch	LOBO	fall	0.60	15.84	3.73
American Goldfinch	LOBO	spring	0.43	13.33	5.03
Eastern Bluebird	LOBO	spring	0.51	10.21	3.57
Field Sparrow	LOBO	fall	0.53	23.51	4.07
Field Sparrow	LOBO	spring	1.00	20.27	5.70
Red-winged Blackbird	LOBO	spring	0.66	61.60	8.94
Song Sparrow	LOBO	fall	0.33	24.38	5.47

Table 29. Density estimates of Spring and Fall migrants at Murphy, Harpers Ferry NHP, 2022.

Species	Field Code	Season	Detection Probability	Birds/km²	Standard Error
American Crow	MUFA	fall	1.00	3.57	0.42
American Robin	MUFA	spring	0.77	17.18	2.34
Brown-headed Cowbird	MUFA	spring	0.62	7.34	7.15
Blue Jay	MUFA	fall	0.80	8.96	1.51
Brown Thrasher	MUFA	spring	0.81	5.62	1.31
Carolina Chickadee	MUFA	spring	1.00	3.71	2.06
Carolina Wren	MUFA	fall	0.75	6.66	4.10
Cedar Waxwing	MUFA	fall	1.00	6.42	4.33
Chipping Sparrow	MUFA	spring	0.68	21.78	3.96
Eastern Bluebird	MUFA	fall	0.57	20.07	5.53
Eastern Bluebird	MUFA	spring	1.00	6.18	2.16
Eastern Meadowlark	MUFA	fall	0.24	16.03	8.31
Eastern Meadowlark	MUFA	spring	0.70	21.18	2.07
European Starling	MUFA	spring	0.89	6.04	2.95
Northern Cardinal	MUFA	fall	1.00	4.64	1.24
Northern Cardinal	MUFA	spring	0.72	10.85	3.16
Northern Flicker	MUFA	fall	0.89	4.40	1.78
Northern Flicker	MUFA	spring	0.65	10.77	4.43
Northern Mockingbird	MUFA	fall	0.72	6.95	2.06
Northern Mockingbird	MUFA	spring	0.50	17.28	3.54
Red-bellied Woodpecker	MUFA	fall	0.81	4.87	1.14
Savannah Sparrow	MUFA	fall	0.16	28.53	15.76
Yellow-rumped Warbler	MUFA	spring	0.75	5.46	4.31

Table 30. Density estimates of Spring and Fall migrants at Nash Farm, Harpers Ferry NHP, 2022.

Species	Field Code	Season	Detection Probability	Birds/km²	Standard Error
Carolina Wren	NAFA	fall	0.58	50.10	17.13
Northern Cardinal	NAFA	fall	0.49	110.72	16.26
Northern Cardinal	NAFA	spring	0.71	99.14	14.56
Red-bellied Woodpecker	NAFA	fall	0.50	37.61	49.97
White-throated Sparrow	NAFA	spring	0.50	42.74	16.98

Table 31. Density estimates of Spring and Fall migrants at Schoolhouse Ridge North, Harpers Ferry NHP, 2022.

Species	Field Code	Season	Detection Probability	Birds/km²	Standard Error
American Crow	SRNO	fall	0.75	1.15	0.46
American Crow	SRNO	spring	0.99	1.50	0.51
American Goldfinch	SRNO	fall	0.73	3.35	1.34
American Goldfinch	SRNO	spring	0.76	5.06	2.18
American Kestrel	SRNO	fall	1.00	0.86	0.30
American Robin	SRNO	spring	0.74	6.94	2.65
Barn Swallow	SRNO	spring	0.59	2.05	0.86
Blue Jay	SRNO	fall	0.81	8.07	1.42
Blue Jay	SRNO	spring	0.82	3.18	1.49
Bobolink	SRNO	fall	0.51	1.14	0.98
Brown Thrasher	SRNO	spring	0.87	3.65	1.25
Carolina Chickadee	SRNO	fall	0.72	2.81	0.90
Carolina Chickadee	SRNO	spring	0.67	4.18	3.15
Carolina Wren	SRNO	fall	0.86	5.26	1.63
Carolina Wren	SRNO	spring	0.87	2.67	0.78
Cedar Waxwing	SRNO	fall	0.77	2.89	0.86
Chipping Sparrow	SRNO	fall	0.64	1.12	0.65
Chipping Sparrow	SRNO	spring	0.66	3.54	1.75
Downy Woodpecker	SRNO	fall	0.75	1.06	0.56
Downy Woodpecker	SRNO	spring	0.72	1.43	0.50
Eastern Bluebird	SRNO	fall	0.79	8.00	1.44
Eastern Bluebird	SRNO	spring	0.76	8.08	1.86
Eastern Meadowlark	SRNO	fall	0.66	17.33	4.94
Eastern Meadowlark	SRNO	spring	0.83	23.34	3.66
Eastern Towhee	SRNO	fall	0.68	1.38	1.18

Table 31 (continued). Density estimates of Spring and Fall migrants at Schoolhouse Ridge North, Harpers Ferry NHP, 2022.

Species	Field Code	Season	Detection Probability	Birds/km²	Standard Error
European Starling	SRNO	fall	0.82	5.20	1.23
European Starling	SRNO	spring	0.84	12.73	1.97
Field Sparrow	SRNO	fall	0.69	2.10	0.96
Field Sparrow	SRNO	spring	0.82	10.23	3.01
Gray Catbird	SRNO	fall	0.70	2.57	1.37
Gray Catbird	SRNO	spring	0.71	1.44	0.66
Grasshopper Sparrow	SRNO	fall	0.07	16.69	13.83
Grasshopper Sparrow	SRNO	spring	0.39	17.20	7.96
House Finch	SRNO	fall	0.72	1.41	0.59
House Finch	SRNO	spring	0.51	1.46	0.93
House Wren	SRNO	spring	0.64	2.20	0.95
Mourning Dove	SRNO	spring	1.00	3.45	0.87
Northern Cardinal	SRNO	fall	0.73	11.00	3.58
Northern Cardinal	SRNO	spring	0.71	18.09	4.90
Northern Flicker	SRNO	fall	0.73	3.75	1.99
Northern Flicker	SRNO	spring	1.00	2.15	0.48
Northern Mockingbird	SRNO	fall	0.45	3.50	1.69
Northern Mockingbird	SRNO	spring	0.48	4.10	2.88
Red-bellied Woodpecker	SRNO	fall	0.86	4.12	1.31
Red-bellied Woodpecker	SRNO	spring	0.94	1.79	0.87
Rock Pigeon	SRNO	spring	0.74	1.39	0.96
Red-winged Blackbird	SRNO	spring	0.71	113.51	23.97
Savannah Sparrow	SRNO	fall	0.27	15.06	9.17
Savannah Sparrow	SRNO	spring	0.26	18.34	9.00
Song Sparrow	SRNO	fall	0.52	9.19	2.25
Tree Swallow	SRNO	fall	0.54	1.98	0.80
Tree Swallow	SRNO	spring	0.43	4.53	1.83
Tufted Titmouse	SRNO	fall	0.66	1.41	0.53
Tufted Titmouse	SRNO	spring	0.84	1.67	0.67
Unidentified Sparrow	SRNO	fall	0.18	5.96	6.88
Unidentified Sparrow	SRNO	spring	0.50	1.85	0.72
White-throated Sparrow	SRNO	fall	0.74	2.25	1.66
White-throated Sparrow	SRNO	spring	0.68	2.05	1.24
Yellow-rumped Warbler	SRNO	fall	0.37	2.91	1.85

Table 32. Density estimates of Spring and Fall migrants at Schoolhouse Ridge South, Harpers Ferry NHP, 2022.

Species	Field Code	Season	Detection Probability	Birds/km²	Standard Error
American Crow	SRSO	fall	1.00	1.32	0.45
American Goldfinch	SRSO	fall	0.68	2.92	0.68
American Goldfinch	SRSO	spring	0.75	6.03	1.51
American Robin	SRSO	fall	0.86	1.69	2.37
American Robin	SRSO	spring	0.90	9.27	1.91
Brown-headed Cowbird	SRSO	spring	1.00	7.27	1.68
Blue Jay	SRSO	fall	1.00	3.57	1.70
Brown Thrasher	SRSO	spring	0.82	2.04	0.83
Carolina Chickadee	SRSO	fall	0.78	3.41	1.86
Carolina Chickadee	SRSO	spring	1.00	5.45	2.00
Carolina Wren	SRSO	fall	0.96	8.93	3.32
Carolina Wren	SRSO	spring	1.00	5.45	1.25
Cedar Waxwing	SRSO	fall	1.00	3.84	1.47
Chipping Sparrow	SRSO	spring	0.95	4.16	1.59
Downy Woodpecker	SRSO	fall	1.00	1.32	1.01
Eastern Bluebird	SRSO	fall	0.90	13.03	3.40
Eastern Bluebird	SRSO	spring	0.86	9.12	1.89
Eastern Meadowlark	SRSO	fall	0.69	1.92	0.91
Eastern Meadowlark	SRSO	spring	0.92	13.70	3.90
Eastern Phoebe	SRSO	spring	1.00	2.42	0.63
European Starling	SRSO	fall	1.00	2.52	1.07
European Starling	SRSO	spring	0.90	12.26	2.51
Field Sparrow	SRSO	spring	1.00	12.72	3.85
Grasshopper Sparrow	SRSO	spring	0.44	8.52	7.22
House Finch	SRSO	fall	0.82	2.25	1.08
House Finch	SRSO	spring	1.00	3.18	1.31
House Wren	SRSO	spring	0.78	1.56	0.40
Mourning Dove	SRSO	spring	1.00	3.33	1.14
Northern Cardinal	SRSO	fall	0.90	8.52	2.51
Northern Cardinal	SRSO	spring	0.85	13.16	4.56
Northern Flicker	SRSO	fall	1.00	4.10	1.46
Northern Flicker	SRSO	spring	1.00	3.03	1.33
Northern Mockingbird	SRSO	fall	0.79	3.86	2.02
Northern Mockingbird	SRSO	spring	0.71	7.69	3.83
Red-bellied Woodpecker	SRSO	fall	0.91	5.25	2.06

Table 32 (continued). Density estimates of Spring and Fall migrants at Schoolhouse Ridge South, Harpers Ferry NHP, 2022.

Species	Field Code	Season	Detection Probability	Birds/km²	Standard Error
Red-bellied Woodpecker	SRSO	spring	1.00	2.58	1.22
Red-winged Blackbird	SRSO	spring	0.99	25.52	9.51
Savannah Sparrow	SRSO	fall	0.10	18.68	18.23
Savannah Sparrow	SRSO	spring	0.25	18.11	9.78
Song Sparrow	SRSO	fall	0.46	4.30	2.25
Tufted Titmouse	SRSO	fall	0.91	2.32	1.00
Tufted Titmouse	SRSO	spring	0.94	2.75	0.68
White-throated Sparrow	SRSO	spring	0.35	5.57	4.08

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