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Long-term Changes in Avian Capture Rates During Twelve Years of Active Grassland and Savannah Restoration

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LONG-TERM CHANGES IN AVIAN CAPTURE RATES DURING TWELVE YEARS OF ACTIVE GRASSLAND AND SAVANNAH RESTORATION

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ABSTRACT

The decline of grassland ecosystems throughout the United States has caused population declines of many bird species, especially grassland specialists, which has led to greater interest in restoring these dwindling habitats with a combination of natural fire regimes and the replanting of native vegetation. In the southeastern United States, several species of birds use grassland habitats at critical points throughout the annual cycle, as breeding or wintering grounds or as migration stopover sites. Since April 2007, we have operated 9–11 mist nets at Panola Mountain State Park, in Rockdale County, Georgia, in an area that is being actively restored to native warm-season grasses. We captured 6,786 birds of 90 species between April 2007 and April 2019. Monthly capture rates overall increased significantly during critical times of the year—spring migration (March, $F = 6.62$, $P = 0.03$) and fall migration (August, $F = 18.06$, $P = 0.003$ and September, $F = 6.31$, $P = 0.03$). Capture rates of Indigo Buntings (*Passerina cyanea*) increased significantly from 2007 to 2019 ($F = 7.75$, $P = 0.006$) during fall migration ($F = 16.44$, $P = 0.0007$) and in August ($F = 17.97$, $P = 0.003$). Capture rates of Field Sparrows (*Spizella pusilla*) increased significantly during the breeding season ($F = 4.90$, $P = 0.03$), fall migration ($F = 13.30$, $P = 0.001$), April ($F = 6.03$, $P = 0.03$), August ($F = 9.68$, $P = 0.01$), and September ($F = 15.18$, $P = 0.003$). Given that the increases include wintering season, breeding season, and year-round resident species, we conclude that the restoration efforts at Panola Mountain State Park have had positive impacts on the avian community that uses this habitat throughout all portions of the year. Increases during fall migration (and August and September) and during March when some species are migrating north indicate that changes in habitat have resulted in Panola being an important site for migrating birds, potentially being used as a migratory stopover site. While a breeding analysis would reveal more concrete trends, the increases in grassland residents like Field Sparrows and grassland breeders like Indigo Buntings certainly suggest that breeding habitat has improved with the restoration of this site.

Keywords: avian ecology, mist netting, grasslands, grassland restoration, banding, conservation, Indigo Bunting, Field Sparrow

INTRODUCTION

Grassland ecosystems have declined throughout the United States in the last hundred years primarily from habitat conversion to agriculture and vegetation changes from fire suppression (Askins et al. 2007; Samson et al. 2004). Because of this, grassland bird populations have declined more than birds of any other major habitat type in North America (Cassidy and Kleppel 2017; Brennan and Kuvlesky 2005; Peterjohn and Sauer 1999). In fact, conservation of grassland bird species has become a major concern nationwide because of the implications of these drastic population changes on long-term population trends (North American Bird Conservation Initiative 2009), and retired agriculture fields are being restored to warm-season grasslands by the U.S. Department of Agriculture's Conservation Reserve Program (Byers et al. 2017). With increasing attention on grassland birds, grassland restoration efforts have become more common throughout the United States (Ruiz-Jaen and Aide 2005; Fletcher and Koford 2002) on both public and private lands (Heard et al. 2000).

Fire is the most important ecological driver in maintaining grasslands in the southeastern United States because it stops the otherwise rapid succession into shrub-scrub and forest habitat. Therefore, a major component of grassland restoration is the introduction of regular small-scale fires (Askins et al. 2000). The use of an appropriate fire regime in grassland habitats provides the necessary structural heterogeneity as well as plant species composition to maintain a diverse avian community (Byers et al. 2017). In the southeastern United States, pine savannas were the dominant vegetation for centuries and, like other grasslands, are fire-dependent ecosystems that require burns on a one to five-year time scale (Askins et al. 2007). Grassland obligate species use the grassy component of pine savannah ecosystems, therefore these ecosystems remain an important native habitat for many declining grassland birds of eastern North America, such as Bachman's Sparrows and Eastern Meadowlarks (Askins et al. 2007) as well as many "edge species" such as Indigo Bunting, Prairie Warbler and Eastern Towhee. Prescribed burns coupled with native revegetation also minimize the spread of invasive species such as water oak (*Quercus nigra*) and sweetgum (*Liquidamber styraciflua*), species which can reduce food variety, alter nest-site selection, and lead to reduced nest success or higher predation rates (Borgman and Rodewald 2004) with long-term effects on bird populations (Schmidt et al. 2005).

Restoring grasslands that birds use for their breeding grounds has been a major focus of many recent studies. In the southeastern United States, different bird species use these grasslands at various times in their annual cycle, so examining population trends throughout the annual cycle is an important assessment tool for restoration efforts. Many grassland species are short-distance migrants that need these often small habitats during winter, e.g., Savannah Sparrow (*Passerculus sandwichensis*), Sedge Wren (*Cistothorus platensis*), Eastern Meadowlark (*Sturnella magna*), Grasshopper Sparrow *(Ammodramus savannarum),* and Vesper Sparrow *(Pooecetes gramineus*) or as migratory stopover sites during fall or spring migration, e.g., Bobolink (*Dolichonyx oryzivorus*) and Henslow's Sparrow (*Ammodramus henslowii*). Grasslands also provide important habitat for many other species that show preference for grasslands to varying degrees throughout their life cycle (Askins et al. 2007) including Field Sparrow (*Spizella pusilla*), Yellow-breasted Chat (*Icteria virens*), Killdeer (*Charadrius vociferous*), Red-winged Blackbird (*Agelaius phoeniceus*), Swamp Sparrow (*Melospiza georgiana*), Song Sparrow (*Melospiza melodia*), and Eastern Bluebird (*Sialia sialis*). Determining the

success of restoration efforts in the context of avian ecology is complex given the variety of uses, needs, and habitat requirements of this large assemblage of species, but using several umbrella species that cover a wide range of habitat needs and functions across the annual cycle may provide a more complete picture (Block et al. 2001).

In response to declining grassland species in Georgia, the state's Department of Natural Resources initiated several small-scale grassland habitat restoration programs over the past 25 years. In cooperation with the Department of Natural Resources, the Important Bird Area Conservation Program initiated long-term bird monitoring to assess bird community responses at some of these restoration sites. Understanding how grassland bird communities respond to small-scale grassland restoration efforts is critical to conservation programs, which aim to maintain or increase current populations of grassland birds. Our objective was to examine and quantify avian community and species abundance throughout the annual cycle over 13 years in a grassland ecosystem undergoing restoration.

MATERIALS & METHODS

Panola Mountain State Park

Our study site is located in the Power of Flight region at Panola Mountain State Park in Rockdale County, Georgia, in an area covering approximately 45 ha (Figure 1). The Power of Flight area is a low-lying former wet meadow surrounded on three sides (west, north, and east) by the South River, a tributary of the Ocmulgee River. Before being acquired by the Georgia state parks system in about 1999, various parts of the Power of Flight area were dominated by hay fields used for agriculture or exotic grasses such as Johnson Grass. The habitat is fragmented by two long tree lines that grow in ditches that were previously dug to dry out the area. The Georgia Department of Natural Resources has been working to restore this area to native warm-season grassland through a combination of methods including exotic vegetation removal, revegetation with native species, girdling of trees, and seasonal prescribed fires to reconnect the previously fragmented grassland. Revegetation with native grasses and forbs, e.g., yellow indiangrass (*Sorghastrum nutans*), gammagrass (*Tripsacum* spp.), and bluestem (*Andropogon* spp.) began around 2008, initially concentrated in the southwest portion of the Power of Flight area. Reseeding with local native grasses occurred in 2010, 2013, and 2014. In addition, the Georgia Department of Natural Resources has been conducting prescribed burns on a regular schedule, alternating between burns on the eastern half (2009, 2012, 2015, and 2018), burns on the western half (2010, 2013, 2016, and 2019), and years with no burns (2011, 2014, and 2017).

Data Collection and Analysis

We operated a constant effort mist netting station approximately once a month in April and June 2007 and approximately twice a month from October 2007 through March 2008 and September 2008 through April 2019. We operated 9–10 mist nets (12 m x 2.6 m; 30-mm mesh) in the same locations from 2007 through April 2009 until a major flood event, after which we moved the nets to their current locations and added an 11th net (Figure 1). We ran the banding station from sunrise until approximately noon each day, weather permitting; nets were closed early in case of winds greater than 16 km/h or precipitation. We banded birds with United States Fish and Wildlife Service numbered

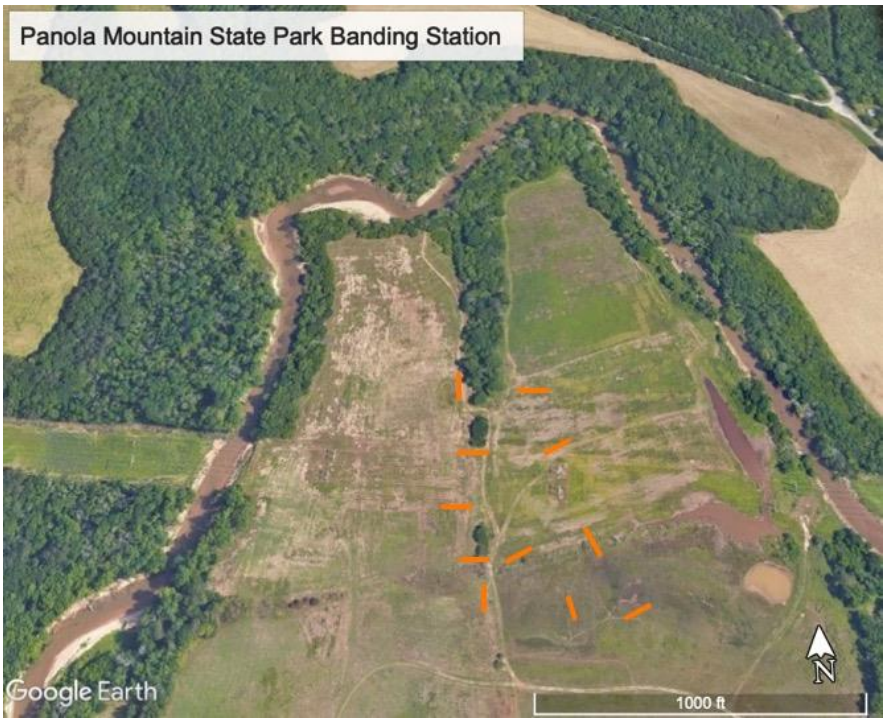

Figure 1. Eleven net lanes that we operated from April 2009 through April 2019 within the Power of Flight area at Panola Mountain State in Rockdale County, Georgia. Main map: Google, Imagery @Maxar Technologies, U.S. Geological Survey, USDA Farm Service Agency, Map data @2020.

metal leg bands and recorded age, sex, and morphometric measurements on body size and condition. We recorded effort in net hours by multiplying the number of nets by the number of hours each was open, accounting for weather-related partial-day closures and calculated capture rates by dividing the total captures by net hours and multiplying by 100 (birds/100 net hours) to account for uneven sampling effort. In cases where a bird was caught more than once in a day, we only processed and recorded that individual for the first time it was captured that date.

Temporal analysis of all species combined

We calculated annual, monthly, and seasonal (spring migration: April–May, breeding: June–July, fall migration: August–September, winter: October–March) capture rates for all species combined. To assess the change in overall capture rate, we performed an analysis of variance (ANOVA) using year, month, and season. We performed this analysis on two data sets: the full data set including all captured birds and a subset of the full data set comprising 17 focal species, which we define as species for which we captured more than five individuals per year, on average (Table I).

Temporal analysis of focal species

Next, we calculated annual, monthly, and seasonal (as above) capture rates for each of the 17 focal species. We performed an ANOVA to test the change in capture rates over time of each species during all months and seasons.

Table I. Mean annual captures and range (high–low) for 17 focal species (species for which we captured more than five individuals per year, on average) from April 2007 through April 2019 at Panola Mountain State Park in Georgia

	Average captures (range)
Swamp Sparrow	91.9 (18–156)
Song Sparrow	80.3 (52–121)
Western Palm Warbler	43.1 (13–119)
Eastern Phoebe	41.2 (3–89)
Field Sparrow	38.4 (13–74)
Indigo Bunting	33.8 (0–115)
Savannah Sparrow	31.3 (5–149)
Common Yellowthroat	29.3 (5–51)
American Goldfinch	23.3 (0–79)
Eastern Bluebird	18.0 (1–77)
Northern Mockingbird	15.6 (1–38)
Red-winged Blackbird	9.2 (0–42)
Blue Grosbeak	7.8 (0–12)
Carolina Wren	7.3 (2–16)
Northern Cardinal	6.3 (1–16)
Yellow-breasted Chat	6.2 (0–16)
Yellow-rumped Warbler	5.1 (0–12)

Temporal analysis of grassland species

Lastly, we calculated annual, monthly, and seasonal capture rates (as above) for eleven species that are typical of grassland ecosystems. Due to small sample sizes, we pooled all grassland species for this portion of the analysis (but see Table II for total captures of each species).

RESULTS

We captured and banded 6,786 birds of 90 species in 1,337 net hours from April 2007 through April 2019. Monthly totals ranged from zero to 226 captures and zero to 208 net hours. We captured 17 species at least five times per year, on average, which were those we used in the focal species analyses (Table I).

Temporal analysis of all species combined

Annual capture rate of all birds combined did not increase significantly ($F = 0.46$, $P = 0.50$), but monthly capture rates increased significantly in March ($F = 6.62$, $P = 0.03$; Figure 2), August ($F = 18.06$, $P = 0.003$; Figure 2), and September ($F = 6.31$, $P = 0.03$; Figure 2). Seasonal capture rates increased significantly during fall migration ($F = 21.37$, $P = 0.0002$; Figure 3) and showed near-significant increases during the breeding season

Table II. Total captures of grassland specialist species from April 2007 through April 2019 at Panola Mountain State Park in Georgia

	Total captures
Field Sparrow	484
Savannah Sparrow	398
Common Yellowthroat	353
Yellow-breasted Chat	75
Lincoln's Sparrow	12
Vesper Sparrow	11
Prairie Warbler	8
Bobolink	3
Grasshopper Sparrow	2
Henslow's Sparrow	1
Sedge Wren	1

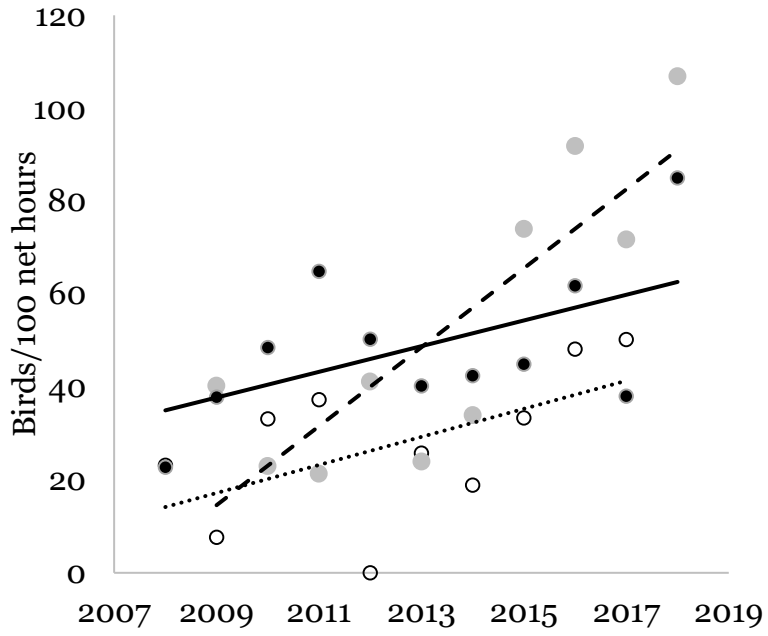

Figure 2. Increase in capture rate (number of birds captured per 100 net hours) of all species combined during March (open dots, dotted line), August (gray dots, dashed line), and September (solid dots, solid line) at Panola Mountain State Park, Georgia, between 2007 and 2019.

(F = 3.07, P = 0.09). Results using capture rates of focal species only were similar to those when using all species captured. Capture rates of focal species increased significantly during August (F = 8.84, P = 0.003) and September (F = 4.41, P = 0.03) and during fall migration (F = 8.66, P = 0.003).

Temporal analysis of focal species

Annual capture rates of Indigo Buntings (*Passerina cyanea*) increased significantly from 2007 to 2019 (F = 7.75, P = 0.006; Figure 4) and Song Sparrow capture rates decreased significantly (F = 4.56, P = 0.03; Figure 4).

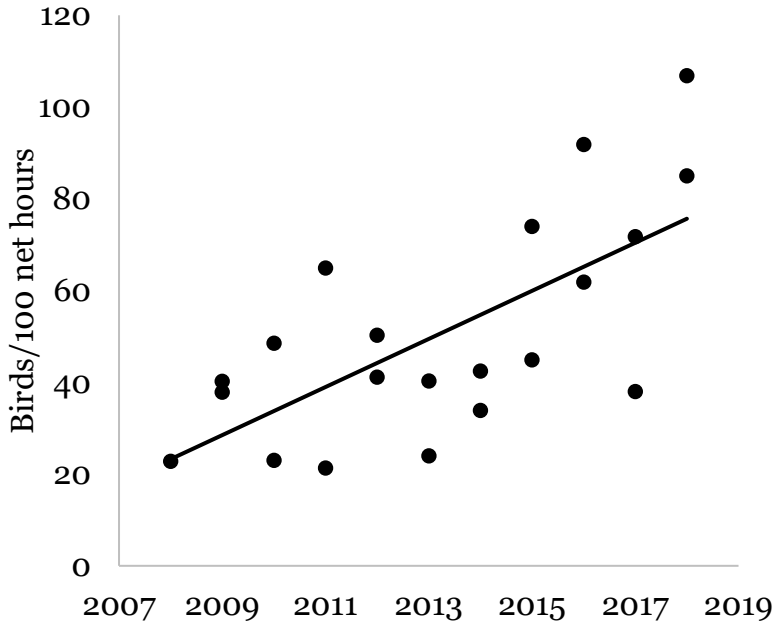

Figure 3. Increase in capture rate (number of birds captured per 100 net hours) of all species combined during fall migration (August and September) at Panola Mountain State Park, Georgia, between 2007 and 2019.

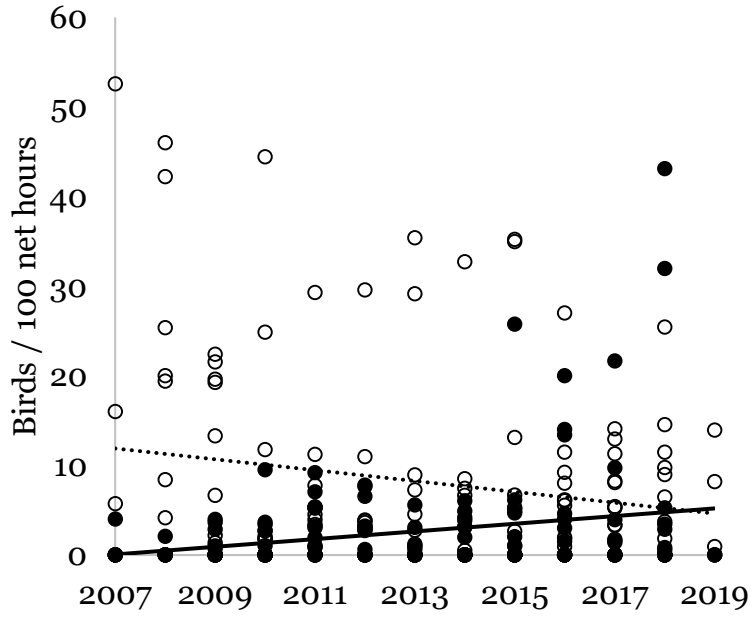

Figure 4. Change in capture rates of Indigo Buntings (solid dots, solid line) and Song Sparrows (open dots, dotted line) at Panola Mountain State Park, Georgia, between 2007 and 2019.

Capture rates significantly increased for Field Sparrows during the breeding season ($F = 4.90$, $P = 0.03$; Figure 5) and fall migration ($F = 13.30$, $P = 0.001$; Figure 5) and for Indigo Buntings during fall migration ($F = 16.44$, $P = 0.0007$; Figure 6). Capture rates significantly decreased for Northern Cardinals (*Cardinalis cardinalis*) during breeding season ($F = 7.58$, $P = 0.01$), for Carolina Wrens (*Thryothorus ludovicianus*) during winter season ($F = 5.11$, $P = 0.02$), and for Song Sparrows during winter ($F = 5.38$, $P = 0.02$). Spring migration capture rates did not significantly change for any species, however a near significant increase for Blue Grosbeaks (*Passerina caerulea*; $F = 2.97$, $P = 0.10$) during breeding season is noteworthy.

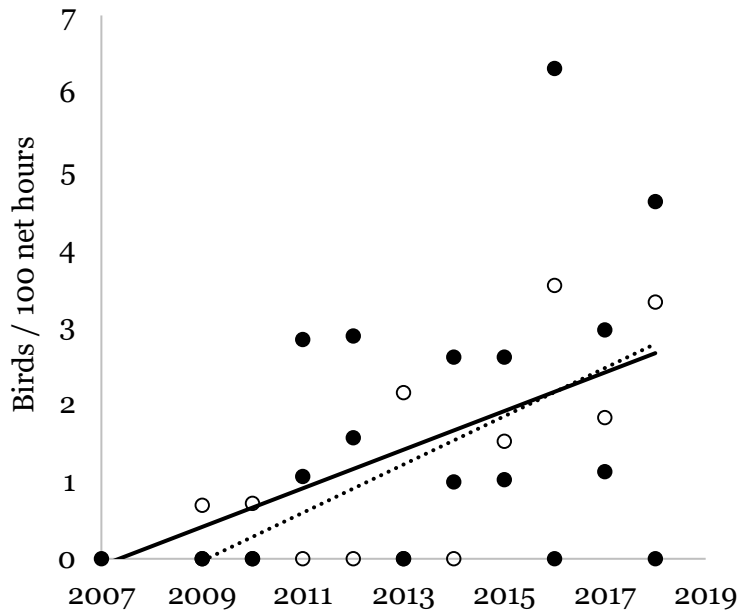

Figure 5. Increase in capture rates (number of birds captured per 100 net hours) of Field Sparrows during the breeding season (solid dots, solid line) and fall migration (open dots, dotted line) at Panola Mountain State Park, Georgia, between 2007 and 2019.

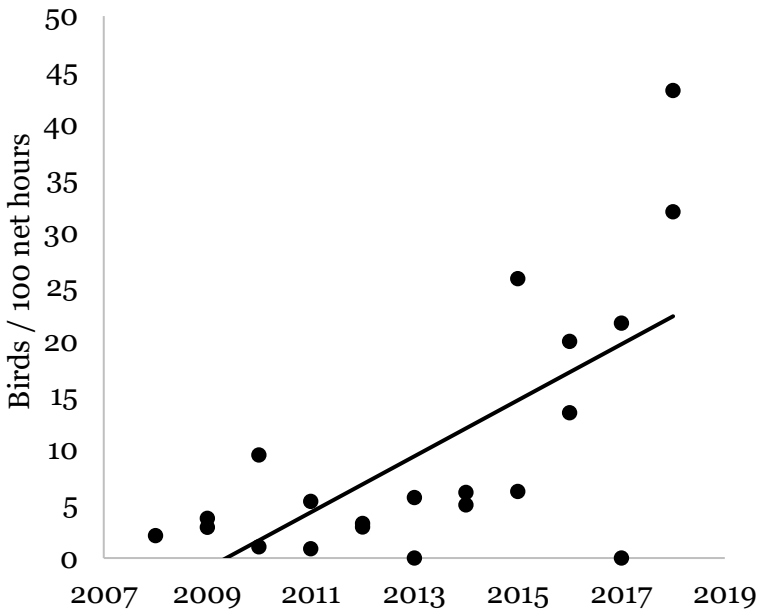

Figure 6. Increase in capture rates (number of birds captured per 100 net hours) of Indigo Buntings during fall migration at Panola Mountain State Park, Georgia, between 2007 and 2019.

Monthly capture rates significantly increased for Field Sparrows in April ($F = 6.03$, $P = 0.03$; Figure 7), August ($F = 9.68$, $P = 0.01$; Figure 7), and September ($F = 15.18$, $P = 0.003$; Figure 7); for Indigo Buntings in August ($F = 17.97$, $P = 0.003$) and Myrtle Warblers in October (*Dendroica coronate coronate*; $F = 12.11$, $P = 0.005$). Capture rates significantly decreased in in June for Northern Cardinals ($F = 11.89$, $P = 0.007$) and in October for Carolina Wrens ($F = 5.43$, $P = 0.04$).

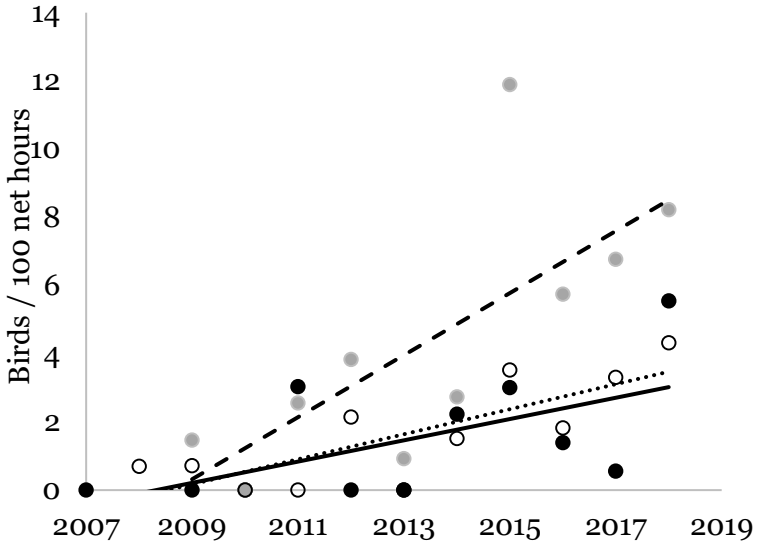

Figure 7. Capture rates (number of birds captured per 100 net hours) of Field Sparrows during April (solid dots, solid line), August (grey dots, dashed line), and September (open dots, dotted line) at Panola Mountain State Park, Georgia, between 2007 and 2019.

Temporal analysis of grassland species

Neither annual nor seasonal capture rates of grassland specialists (Table I) changed significantly between 2007 and 2019, but monthly capture rates showed a near-significant increase in March ($F = 3.25$; $P = 0.07$).

DISCUSSION

Since 2007, capture rates overall and for several species have increased throughout the annual cycle, and most of the increases have occurred during fall migration and the breeding season. Given that the increases include wintering season, breeding season, and year-round resident species, we conclude that the restoration efforts at Panola Mountain State Park have had positive impacts on the avian community that uses this habitat throughout all portions of the year. We did not expect annual capture rates of all species combined to increase, because individual species changes over time are complex and likely reflect the variability in vegetation preferences. The avian community and their temporal use patterns at Panola Mountain State Park are diverse, and some species prefer a more heterogeneous plant community while others prefer to use areas with less plant community diversity (Port and Schottler 2017). The species that showed declines, Northern Cardinals and Carolina Wrens, are not grassland species, and were thus expected to decline. Therefore, combining all of our data likely masked the trends of individual species and changes across the annual cycle when capture rates for one species may increase and offset the decreasing capture rates for others. Higher capture rates are likely due to increasing vegetation heterogeneity and complexity (Port and Schottler 2017) as a result of the restoration efforts that include both controlled burns and replanting with native vegetation. For example, some grassland obligates prefer restoration plots with low vegetative diversity while others prefer restored sites with high diversity, so planting a mosaic will be most successful at attracting and retaining the highest diversity of bird species (Port and Schottler 2017).

Migration

Capture rates at Panola Mountain State Park increased at key time periods of the year. Specifically, increases during fall migration and during August and September and during March when some species are migrating north indicate that changes in habitat have resulted in Panola Mountain State Park being an important site for migrating birds. While our sample size was too small to note any statistical changes in species that use Panola Mountain State Park only as a migratory stopover site, we did document higher capture rates for all species combined and for Field Sparrows and Indigo Buntings during fall migration or during individual months during times when fall migration is typically underway. Panola Mountain State Park lies at a special location, where many of the species we catch may be residents or may be migrating individuals. For example, Field Sparrows are year-round residents in Georgia, but some individuals that winter to the south also migrate through here on their way to more northerly breeding grounds, so some of the individuals captured during migration months could be using Panola Mountain State Park as a migratory stopover site. If patterns of use by resident species indicate that the habitat is improving and that resource availability as a result of the restoration is increasing, it follows that migrating birds will use this habitat more as restoration continues.

Breeding

It is nearly impossible to overstate the importance of increasing breeding season numbers, and we documented increases in capture rates during the breeding months. When we combined captures for all species, there were increases in March, August, and September. August may be part of the late breeding season for several species (e.g. Field Sparrows, Indigo Buntings) so those increases may reflect an increase in breeding success. In fact, capture rates of Eastern Phoebes (*Sayornis phoebe*) during August is the second highest of all focal species (behind Indigo Buntings), and more than 95% of those are hatch year birds (C. Muise, unpublished data). There were also increases in capture rates of several focal species. Capture rates of Indigo Buntings, which are not at Panola Mountain State Park in winter, have increased since 2007. We also documented increased captures of Field Sparrows during April and during the breeding months combined. Field Sparrows are a ground nesting grass-shrub species whose populations are thought to be in slow decline due to habitat loss (Birdlife 2019), so an increase at Panola Mountain State Park may be especially important and may be evidence that this is a source population for other breeding locations. It is important to note that captures in mist nets do not necessarily correlate with breeding densities (Silkey and Guepel 1999) or with increasing nesting success, which is the ultimate driver of population increases in grasslands (Vos and Ribic 2013; Renfrew et al. 2005; Herkert et al. 2003). However, capture rates are often easy data to collect and are indicative of habitat use regardless of breeding success and therefore serve as an important first step to understand population dynamics, especially in areas with a diverse avian community.

The lack of significant change of grassland specialists is not surprising. First, specialist species tend to respond slowly to improvements in habitat especially in small habitat patches simply due to the speed that specialists are able to discover new or improving habitats. Second, we catch so few of these species overall, that any changes are probably too small to detect on our relatively short time scale. However, notable recent captures in

some grassland obligate species may indicate that restoration efforts are having a positive influence and are attracting some species. For example, we captured two Sedge Wrens, the first in 2007 and the next in May 2019. This, along with increased observations in the area during banding sessions (C. Muise, unpublished data) may indicate that Sedge Wren abundance is increasing. Lastly, specialists also tend to be more patch-size specific, and the reduction of two fragmenting lines of trees has only just been completed, so continued monitoring may reveal increases in specialist species.

While capture data can reveal trends in populations, the results should be interpreted with caution for several reasons. First, while using net hours can account for some of the unequal sampling bias and effort across time, net hours can still produce spurious results, especially during months with very low hours. For example, Northern Cardinals appear to have decreasing capture rates over the time span of this study, however a single capture in 2007 coupled with few net hours can artificially inflate capture rates (e.g. one individual caught during a month with only two net hours). Second, mist nets are well-known to miss certain species and therefore should not be used as the only method to determine species composition (Dunn and Ralph 1998). For example, the small mesh in our nets are designed to capture medium sized birds, so birds larger than Northern Cardinals and smaller than Field Sparrow either bounce out or can easily fly through, so Ruby-crowned Kinglets (*Regulus calendula*), Blue-grey Gnatcatchers (*Polioptila caerulea*), Henslow's Sparrows, Winter Wrens (*Troglodytes hiemalis*), Sedge Wrens, and Marsh Wrens (*Cistothorus palustris*) are likely undersampled. While we regularly record Eastern Meadowlarks at Panola Mountain State Park during the breeding season, we have only captured one in our nets and therefore cannot assess population trends. Lastly, factors such as vertical use of vegetation, and cross species differences in age and sex can have profound impacts on the accuracy of relative abundance estimates using mist net data (Remsen and Good 1996) but these caveats generally apply to comparisons across species or habitats. Here, we are using long-term trends and the same subset of species in the same habitat to show changes in relative abundance over time.

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