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Increasing Capture Rates of Grassland Birds Over Thirteen Years Indicates Successful Restoration

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INCREASING CAPTURE RATES OF GRASSLAND BIRDS OVER THIRTEEN YEARS INDICATES SUCCESSFUL GRASSLAND RESTORATION

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Grassland bird populations are being lost at an alarming rate due to human modifications to grassland ecosystems. Grassland restoration has been shown to mitigate population declines for many species that use these habitats at some point in their annual cycles. We examined capture rates of adult, breeding, and hatch-year birds at a restored grassland site in the piedmont of central Georgia to determine whether colonization, breeding success, hatching success, and recruitment processes were impacting populations of grassland birds. We banded birds approximately twice per month from January 2009 through December 2021 at Panola Mountain State Park. Restoration efforts started in 2001, and include annual prescribed burns, control of invasives, and revegetation with native grassland plants. We documented an increase in total capture rates when all grassland species were combined ($p=0.03$, $r^2=0.37$) and for several grassland species, including Chipping Sparrows ($p=0.01$, $r^2=0.44$) and Marsh Wrens ($p=0.004$, $r^2=0.55$). Capture rates of grassland birds in breeding condition increased as well, including when grassland species were combined ($p=0.01$, $r^2=0.45$), Common Yellowthroats ($p=0.05$, $r^2=0.30$), Indigo Buntings ($p=0.04$, $r^2=0.34$), and Field Sparrows ($p=0.002$, $r^2=0.59$). Capture rates of hatch-year birds increased for Chipping Sparrows ($p=0.02$, $r^2=0.39$). Species-specific responses to restoration occur at different rates depending on habitat preferences, yet the only species that significantly declined was the Red-winged Blackbird, a bird more associated with water than grasslands. We attribute these increases and, importantly, the lack of significant declines, to successful ongoing restoration, which is providing adequate and appropriate resources for grassland birds. If managers identify target species, we recommend that restoration efforts include activities that are aimed at species-specific habitat requirements and habitat-level threats of those target species.

Keywords: grasslands, grassland restoration, mist netting, conservation, avian ecology, Passerellidae, Emberizidae, Passeriformes, Common Yellowthroat, Field Sparrow, sparrow.

INTRODUCTION

Grassland ecosystems are at risk throughout the United States, much of them having been lost or significantly altered by human actions such as conversion to agricultural lands, fire suppression, and invasion by nonnative species (Samson et al. 2004). In the southeastern

US, 97% of native grasslands have been lost because of farming practices and fire suppression (Askins et al. 2007). Because many species of both specialist and generalist passerines use these declining grasslands throughout all or some stages of their annual cycle (Askins et al. 2007), population size of grassland specialists are also sharply declining (Henderson and Davis 2014, Rosenberg et al. 2019); since 1970, about 50% (or 700 million individuals) of grassland birds have been lost across the United States (Rosenberg et al. 2019). Without significant restoration efforts of critical grassland ecosystems, this downward trend is likely to continue (Rosenberg et al. 2019).

Three of the major processes that are responsible for these population declines affect populations through different, but overlapping, mechanisms. First, conversion to agricultural land can render the habitat unsuitable for breeding and foraging, and often results in a turnover of species. Second, fire suppression often causes a shift from an herbaceous to a woody understory (Byers et al. 2017) thereby changing the vegetative structure of the habitat and removing or altering niches for many species. For example, in Florida, Bachman's Sparrow and several other passerine species disappeared from their habitat within five years of fire suppression (Brennan et al. 1998). Lastly, land conversion often exposes habitat to increased pressure from both exotic and native invasive species. Grasslands with a high percentage of cover consisting of invasive species exhibit lower avian abundance, density, and breeding success than grasslands with a higher percentage of native species (Scheiman et al. 2003, Flanders et al. 2006).

The benefits of grassland restoration on bird population size, a frequent goal of grassland restoration, are well documented. One of the most immediate benefits is colonization of the newly restored site by new individuals and/or species, resulting in an increase in abundance and/or density of breeding, overwintering, and migratory species (Hartung and Brawn 2005, Gaines et al. 2007, Rothbart and Capel 2006). While colonization is important, population size only increases if birds also successfully breed and restoration has been shown to increase nest success (Berg et al. 2002, Hoover 2009, Twedt et al. 2010). Successful breeding requires adequate resources and habitat restoration has also been shown to increase suitable breeding grounds (Seigel et al. 2005) and provide more reliable food resources (Flanders et al. 2006, Seigel et al. 2005). Nest predation is the most common cause of nest failure in passerine species (Martin 1992), and restoration can also reduce the abundance of some avian nest predators (Jones et al. 2004) potentially increasing nest success and, thus population size.

Beyond the breeding season, grassland ecosystems provide critically important habitat to migrating (Brawn 2006) and overwintering (Igl and Ballard 1999) species, many of which are not grassland specialists. Thus, the positive effects of grassland restoration extend to many other species. Even in cases where birds aren't part of the restoration goals, birds are often used as indicators of restoration success because they are early indicators of habitat changes (Chowfin and Leslie 2021, Roels et al. 2019, Rolo et al. 2017), so the presence and abundance of birds can tell us about the health of the ecosystem and the success of restoration efforts.

The ultimate goal of restoration is to recreate and maintain habitats that provide critical resources and thus ensure long-term sustainable populations of native organisms. The goal of our study was to determine whether grassland restoration at a site in central Georgia was successful in this goal. Specifically, we examined whether restoration efforts here have positively impacted the avian community by looking at capture rates of 1) all adults, 2) breeding birds, and 3) hatch-year birds using a long-term mark and recapture dataset.

MATERIALS & METHODS

Study Site

Panola Mountain banding station (PANO) is located within about 200 ha of restored grassland at Panola Mountain State Park, in the piedmont region of central Georgia (Figure 1). In 2001 The Georgia Department of Natural Resources (DNR) began restoring this area after decades of agricultural use, and the efforts are on-going. Restoration work includes girdling and cutting exotic and invasive trees, revegetating with native grasses such as yellow Indiangrass (*Sorghastrum nutans*), gammagrass (*Tripsacum* sp.), little bluestem (*Schizachyrium scoparium*), and big bluestem (*Andropogon gerardi*), controlling invasive plants, and annual prescribed burning of alternating portions of the habitat.

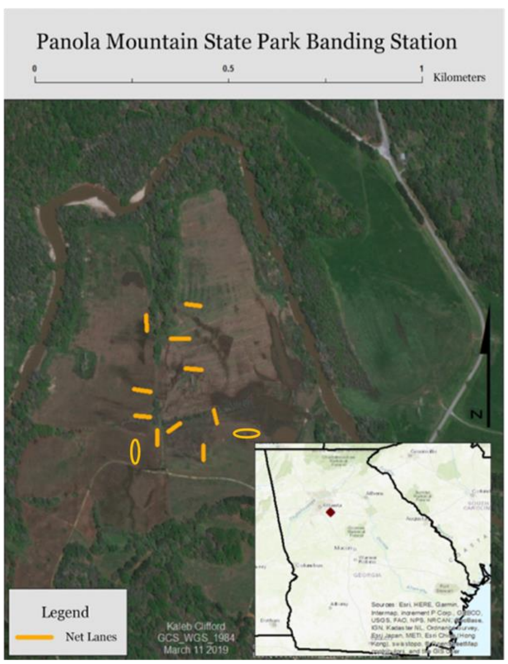

Figure 1. Twelve net lanes that we operated from 2009-2021 (orange ovals were added in 2018 and 2021) at Panola Mountain State in Rockdale County, Georgia.

Data Collection

We operated 10-12 mist-nets (12-m x 2.6 m, 30 mm mesh) at PANO approximately twice per month from January 2009 through December 2021, from dawn until 12 pm, weather permitting (Figure 1). Most nets were located in open grassland areas, though three nets are near small (2-10 trees) patches of mixed hardwood trees. The open grassland consists of approximately 1 – 1.5 meter tall grasses, depending on the season and prescribed fire. While we had to move several nets after a major flood event in April 2009 and we added 2 nets (2018 and 2021), the area covered during the study remained relatively constant. We banded all birds with a unique United States Fish and Wildlife Service numbered metal leg band and recorded age, sex, and breeding condition. We recorded net hours for each day as the number of hours nets were open multiplied by the number of nets open during those hours.

Data Analysis

We used a three-pronged approach to determine whether bird community abundance was increasing during the restoration period: 1) total captures, 2) breeding adult captures (as indicated by the presence of a brood patch or cloacal protuberance), and 3) hatch year (HY) captures. For each of the analyses (all birds, breeding adults, and HY birds, respectively) we looked at total captures per 100 net hours (hereafter, capture rate) of all species combined, of all grassland species combined (Table I), and each grassland species individually. Net hours were calculated for each analysis separately as follows: for total captures, we used total net hours for the entire year; for breeding adult captures, we summed net hours between April and November for each year (based on the earliest and latest recorded breeding season adult captured in the entire dataset); for hatch year captures we summed net hours between May and December for each year (based on earliest and latest recorded hatch year captures in the entire dataset). Individuals that were captured multiple times in the same year were only counted once to ensure we didn't overestimate abundance. We omitted birds of unknown breeding status or unknown age from breeding adult and hatch year analyses, respectively.

Oftentimes, habitat requirements of species conflict with one another so restoration efforts generally lead to increases in some species, while other species numbers decrease. Sogge et al. (2008) suggest that studies examine species-specific responses to habitat restoration. Therefore, we performed analyses for each of the grassland species (Table I) for the breeding adult and hatch year analyses using net hours based on the earliest and latest captures for each species. However, the results did not differ from the month range for the entire dataset so for simplicity we present the results using the month range above. For all analyses, we performed linear regressions using year as the independent variable and capture rate (number of captures per 100 net hours) as the dependent variable. All data analyses were performed in JMP (Version 16.2, SAS Institute, 2021).

RESULTS

Total Captures

During 316 banding sessions between January 2009 and December 2021, we captured a total of 11,350 birds (91 species) over 16,662 net hours. After removing within-year recaptures, our dataset included 9802 captures (Table I, Table II). There was no significant relationship between year and capture rate of all species or of grassland species. However, from October through December 2010, we captured 149 Savannah Sparrows (SAVS) far more than any other year (captures range from 6 to 44 in other years). SAVS prefer short grass and bare earth, so their utilization of the site is determined in part by what it looks like at the moment they fly over. For example, a lot of tractor work or a controlled burn at or near the end of growing season will likely attract them in high numbers, which we witnessed in the fall of 2010. Likewise, missing a year of fire results in heavy thatch, which they do not favor in winter. Because of these factors, we feel confident that their presence is likely not indicative of long-term restoration processes, but rather on timing of individual events in restoration, so we performed an additional analysis by removing SAVS from the grassland species analysis. Without SAVS, there was a significant increase in capture rate (p=0.03, r^2=0.37, Figure 2A). Capture rate significantly increased for three grassland species: Chipping Sparrow (p=0.01, r^2=0.44, Figure 2B), Eastern Bluebird (p=0.0007, r^2=0.66, Figure 2C), and Marsh Wren

(p=0.004, r^2=0.55, Figure 2D). No grassland species (Table I) declined significantly in capture rate over time.

Table I. Number of individuals captured for each grassland species, breeding adults, and hatch year birds at Panola Mountain State Park banding station.

Species	Number captured	Breeding adults	Hatch year birds
American Kestrel	5	-	1
American Robin	37	-	7
American Woodcock	1	-	-
Blue Grosbeak	150	57	52
Bobolink	3	-	-
Brown-headed Cowbird	14	-	8
Brown Thrasher	69	3	12
Chipping Sparrow	69	2	44
Common Yellowthroat	603	229	206
Dickcissel	1	-	-
Eastern Bluebird	476	32	138
Eastern Kingbird	14	2	1
Eastern Meadowlark	4	-	-
Eastern Phoebe	664	17	577
Field Sparrow	735	70	348
Grasshopper Sparrow	3	-	-
Henslow's Sparrow	1	-	-
Indigo Bunting	562	202	274
Killdeer	1	-	1
LeConte's Sparrow	1	-	-
Lincoln's Sparrow	18	-	11
Loggerhead Shrike	2	-	2
Marsh Wren	9	-	4
Orchard Oriole	80	45	17
Palm Warbler	714	1	426
Prairie Warbler	9	1	4
Red-winged Blackbird	97	23	51
Savannah Sparrow	485	-	241
Sedge Wren	2	-	-
Song Sparrow	1424	17	850
Sora	1	-	-
Swamp Sparrow	1719	-	743
Trail's Flycatcher	18	-	11
Vesper Sparrow	15	-	9
White-crowned Sparrow	3	-	3
Willow Flycatcher	9	-	7
Wilson's Snipe	5	-	-
White-throated Sparrow	63	-	34
Yellow-breasted Chat	104	76	10
Yellow Warbler	5	-	2

Table II. Total net hours, total captures, capture rate (birds/100 net hours), and total number of species of all birds combined for each year at Panola Mountain State Park, Georgia.

Year	Net hours	Total captures	Capture rate (birds/100 net hours)	Total # species
2009	957.34	373	38.96	36
2010	1139.47	781	68.54	41
2011	1287.80	626	48.61	43
2012	1174.74	694	59.08	47
2013	1200.86	511	42.55	42
2014	1408.84	595	42.23	47
2015	1426.13	787	55.18	48
2016	1273.46	837	65.73	63
2017	1166.33	672	57.62	45
2018	1401.46	1058	75.49	46
2019	1182.67	669	56.57	46
2020	1485.087	767	51.65	45
2021	1557.72	861	55.27	43

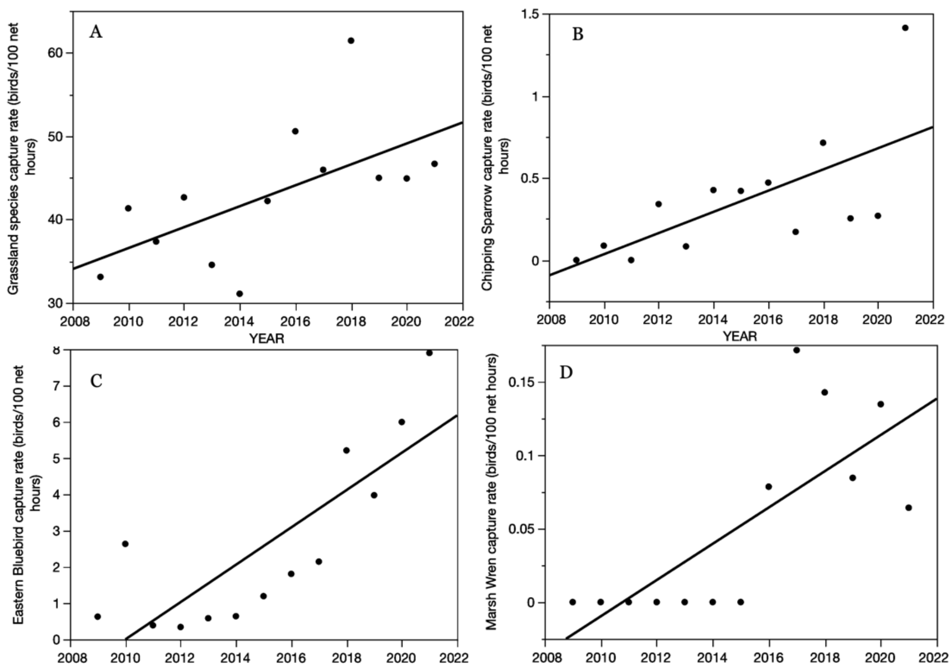

Figure 2. Capture rates (birds/100 net hours) increased significantly from 2009 to 2021 for A) grassland species (when Savannah Sparrows were removed from analysis, *see results*) combined, B) Chipping Sparrows, C) Eastern Bluebirds, and D) Marsh Wrens at Panola Mountain State Park, Georgia.

Breeding Adult Captures

We captured 979 adults (42 species) in 12,300 net hours between April-December in breeding condition (Table I, Table III). Breeding adult capture rate of all species (p=0.04, r^2=0.33, Figure 3A) and grassland species (p=0.01, r^2=0.45, Figure 3B) increased significantly. Capture rates of several grassland species also increased significantly: Common Yellowthroat (p=0.05, r^2=0.30, Figure 3C), Eastern Bluebird (p=0.03, r^2=0.35, Figure 3D), Field Sparrow (p=0.002, r^2=0.59, Figure 3E), and Indigo Bunting (p=0.04, r^2=0.34, Figure 3F). Only capture rates of Red-winged Blackbird decreased significantly (p=0.04, r^2=0.33, Figure 3G).

Table III. Total net hours, total captures, capture rate (birds/100 net hours), and total number of species of breeding adults between April – December of each year at Panola Mountain State Park, Rockdale County, Georgia.

Year	Net hours	Total captures	Capture rate (birds/100 net hours	Total # species
2009	705.43	44	6.24	15
2010	849.39	32	3.77	10
2011	931.01	77	8.27	16
2012	863.00	79	9.15	18
2013	894.34	51	5.70	14
2014	1025.70	78	7.60	16
2015	1088.76	93	8.54	16
2016	855.67	87	10.17	25
2017	886.71	79	8.91	17
2018	1132.56	76	6.71	17
2019	922.19	76	8.24	13
2020	1085.01	92	8.48	17
2021	1059.84	108	10.19	16

Hatch Year Captures

We captured 4891 hatch year birds (74 species) in 12,066 net hours between May-December (Table I, Table IV). There was no significant relationship between year and hatch year capture rate for all species nor for grassland species. Capture rates of Chipping Sparrow hatch year birds increased significantly (p=0.02, r^2=0.39, Figure 4). No species showed significant decreases over time.

DISCUSSION

Given the precipitous nationwide decline in grassland species (Rothberg et al. 2019), we would expect to see capture rates declining, yet we have documented an increase in capture rates for several species at our restored grassland site. We attribute these increases to ongoing successful restoration of the grassland ecosystem. We documented only a single significant decline in capture rates – that of breeding adult Red-winged Blackbirds (RWBL). While we consider RWBL a grassland species for our analysis, they often congregate in agricultural fields (Yasukawa and Searcy 1995), so the observed decline in capture rate could be further evidence of successful restoration from agricultural land. Importantly, we view the lack of any other significant declines as strong indication of successful restoration. So, we interpret even small significant increases in capture rates of some species as evidence of an increasing abundance of these birds.

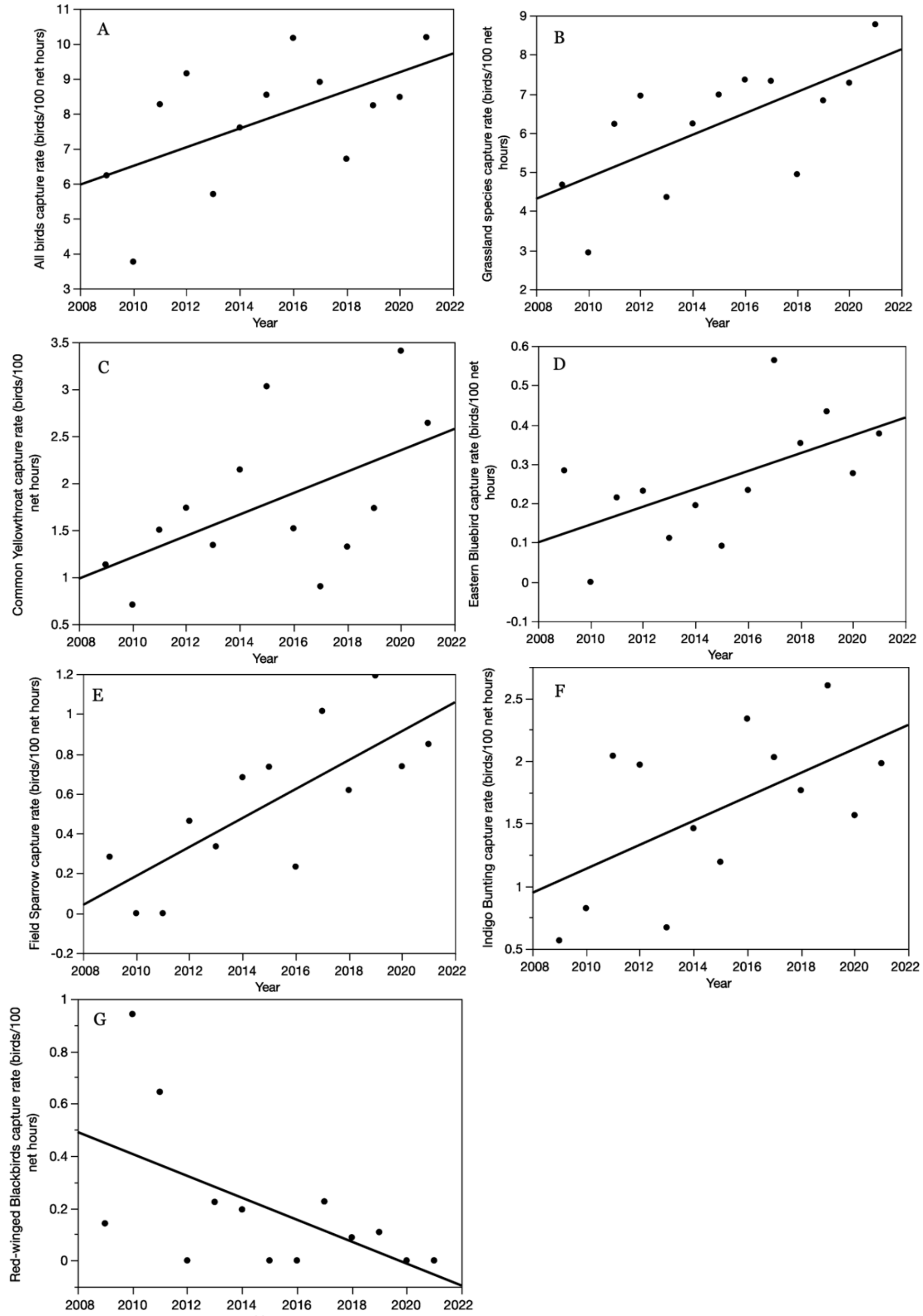

Figure 3. Capture rates (birds/100 net hours) of breeding adults increased significantly from 2009 to 2021 for A) all species combined, B) grassland species combined, C) Common Yellowthroats, D) Eastern Bluebirds, E) Field Sparrows, and F) Indigo Buntings and decreased significantly for G) Red-winged Blackbirds at Panola Mountain State Park, Georgia.

Table IV. Total net hours, total captures, capture rate (birds/100 net hours), and total number of species of hatch year birds between May – November of each year at Panola Mountain State Park, Georgia.

Year	Net hours	Total captures	Capture rate (birds/100 net hours)	Total # species
2009	721.93	192	26.60	23
2010	838.50	551	65.71	35
2011	916.74	290	31.63	35
2012	753.00	345	45.82	34
2013	906.51	271	29.89	27
2014	1076.85	255	23.68	34
2015	1097.70	445	40.54	36
2016	852.70	377	44.21	37
2017	871.58	358	41.07	31
2018	952.82	579	60.77	31
2019	814.06	293	35.99	34
2020	1145.95	274	23.91	29
2021	1117.80	419	37.48	31

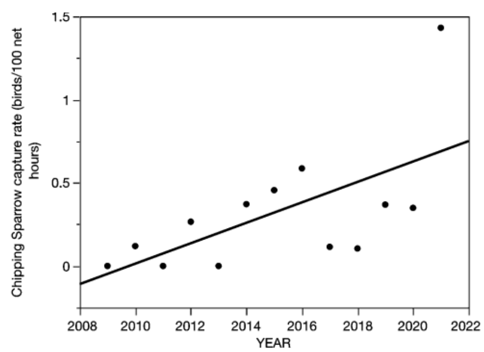

Figure 4. Capture rates (birds/100 net hours) of hatch year birds increased significantly from 2009 to 2021 for Chipping Sparrows at Panola Mountain State Park, Georgia.

Adult Birds

We documented a significant increase in grassland birds when data were pooled across species. However, when looking at individual species, we saw significant increases in capture rates for some grassland species (Eastern Bluebirds, Marsh Wrens, and Chipping Sparrows), but not others. We believe that this is due to 1) species-specific response rates to restoration, 2) surrounding landscape characteristics, and 3) effect of sample size. Species-specific responses to restored sites occurs at different rates (Paxton et al. 2018), due to many factors such as size and isolation of the restored site (Paxton et al. 2018, Hutto et al. 2014). For example, the increased capture rate of Chipping Sparrows is not surprising because they are a common grassland bird in Georgia. Some of the other grassland species (e.g. Lincoln's Sparrow, LeConte's Sparrow, see Table I) have much smaller population sizes nationwide, which may mean they will simply take longer to colonize habitat, regardless of how suitable it may be. In addition, restored sites may not always attract specialist species (Aerts et al. 2008), such as Henslow's Sparrow or Dickcissel. Again, it is worth noting that while we didn't see significant increases, all adult grassland species capture rates were trending positive and none were declining. Second, the availability of food and predator pressure in the surrounding landscape has a large effect on species' presence and abundance (Hutto et al. 2014). Our site is small (200 ha) and is bordered by both river and forest habitat, which will offer more food resources of a greater diversity but may also increase the diversity of predators as well. Paradoxically, such a heterogeneous landscape in close proximity may dissuade some specialist species from using this small restoration site, because predation risk may outweigh the benefit of food availability. Lastly, even with such a rich dataset spanning 13 years, we still have small sample sizes for several species, which makes it difficult to detect population increases. Though this long-time span is rare, it's possible we still need more time to detect increases for some of the rarer, specialist grassland species.

Breeding Adults

The only way to increase population size is to increase reproduction, and we documented significantly increasing numbers of breeding individuals on the restoration site over the course of our study. Movements of breeding birds is generally low during the breeding season, leading to lower capture rates, yet we documented an increase in the capture rates of several species (Common Yellowthroat, Eastern Bluebird, Field Sparrow, and Indigo Bunting), when all breeding birds were combined, and when grassland species were combined. The importance of this finding shouldn't be overlooked. While more birds in breeding condition doesn't always lead to increases in population sizes in subsequent years, the fact that more birds, especially of these particular species, are attempting to breed indicates that breeding habitat suitability and food availability have improved during the ongoing restoration efforts.

Breeding bird distribution, and therefore capture rates, are also strongly affected by timing of controlled burns. For example, if a prescribed fire occurs after breeding has begun, we would expect to capture fewer breeding individuals as they would move to other unburned areas to breed. In fact, Allen and Stumpf (2021) suggested that breeding bird success will be higher when prescribed burns occur earlier in the spring on grasslands. Prescribed burns at PANO were conducted pre-breeding season from 2009 until 2019, however later burns in 2020 and 2021 may have affected our capture rates in those later years for some species, resulting in a dampening of the effects we saw in other species. Still, we believe these results are conservative estimates of the actual numbers of breeding birds in the area.

Hatch Year Birds

We documented increased hatch year capture rates for only Chipping Sparrows, which is most likely because most of the hatch year birds from the restoration site dispersed to areas nearby, but outside, our net coverage (e.g. the perimeter of the grassland). Post-fledgling dispersal is common in some passerines (Ausprey and Rodewald 2013) and fledglings may disperse as much as 1600 meters from natal sites (Anthony et al. 2013). Furthermore, we documented far more species of hatch year birds than breeding adults (74 vs 41), so we either aren't adequately sampling all the breeding adult species (possibly because of better net avoidance strategies; Marques et al. 2013) or are capturing post-hatch dispersing young from adults breeding in areas outside our sampling range. In either case, the restored grassland site, while used briefly, represents a critical habitat for those fledglings, regardless of where their natal site is. An alternative explanation is that high predation rates in grassland habitats may reduce hatching and/or fledging success to the point that hatch year bird capture rates are always low. Given that we have documented increasing capture rates for adult birds coupled with the increasing recaptures we've seen with several species (C. Muise, unpubl. Data), we don't believe this is the case. Instead, it's more likely that hatch year birds are leaving the site post-fledging.

Conclusion

While capture rates in mist-nets aren't always correlated with abundance patterns (Remsen and Good 1996), we've based our interpretations on them here for two reasons. First, long-term trends can more confidently reflect population changes (Ralph et al. 2004). Second, stationary nets tend to result in decreasing capture rates over time due to net shyness (Marques et al. 2013, Ralph et al. 2004), but we observed the opposite. Thus, we interpret the increases in capture rates we have shown as an indication of increasing abundance, with the caveat that we cannot estimate true abundance with these methods. Even if, as we suspect, there are more breeding adults and more hatch year birds than we captured, any increase in productivity will not translate to increased recruitment the following year if mortality occurs on wintering or breeding grounds. Therefore, as others have suggested, we recommend that managers include activities that are aimed at species-specific habitat requirements (Stralberg et al. 2006, Wang et al. 2009, Finch 1999) and if possible, manage for habitat-level threats (Finch 1999, Leahy and Camp 2004) of target species.

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