Breeding-season Survival, Home-range Size, and Habitat Selection of Female Bachman's Sparrows

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Abstract - *Peucaea aestivalis* (Bachman's Sparrow) is a declining songbird endemic to the southeastern US, but lack of basic life-history information for females, including a description of habitat selection, limits effective management. We investigated survival, home-range size, and habitat selection of female Bachman's Sparrows during the breeding season at Fort Bragg Military Installation, NC. We attached radio-transmitters to female sparrows between April and June in 2014–2016 and recorded locations of females every 2–4 days. We estimated seasonal survival and home-range size and, in 2016, we modeled habitat selection of female sparrows within their home range. Estimated breeding-season (90 days) survival (0.941) was greater than a published estimate from South Carolina (0.794), and home-range size (1.48 ha, SE = 0.16) was similar to a published estimate for females and multiple published estimates for male sparrows (min–max = 1–5 ha). Females selected habitat patches with greater woody vegetation and intermediate grass densities than at random locations, suggesting that woody vegetation provides escape and nesting cover for female sparrows. Survival, home-range size, and habitat selection of female Bachman's Sparrows did not differ substantially from males in other studies. Therefore, management focused on male sparrows may concurrently conserve habitat requirements for females.

Introduction

Documenting avian sex-based differences is important in directing conservation efforts that provide all life-history requirements of the species (Gray et al. 2009, Marra 2000, Morton 1990, Zanette 2001). However, for species not well studied, differences in habitat selection, space use, and survival between males and females may go undetected. In North America, many conservation efforts targeting vulnerable songbirds are not informed by sex-based considerations (Bennett et al. 2019). For example, Bennett et al. (2019) suggested that conservation of *Vermivora chrysoptera* L. (Golden-winged Warbler) was limited because managers did not recognize that females were more at risk from habitat loss than males. Effective conservation planning requires research to understand sex-based differences of songbirds, especially those with declining populations (Bennett et al. 2019).

Peucaea aestivalis (Lichtenstein) (Bachman's Sparrow) is a declining songbird endemic to the southeastern US. The species' range underwent major southward retraction in the latter half of the 20th century (Watts 2015), and the range-wide population declined by 3.4% annually during this period (Sauer et al. 2017). With

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the recent extirpation of Bachman's Sparrow from Virginia (Watts 2015), North Carolina is now the northern periphery of the species' eastern range, with populations largely relegated to the south-central and southeastern portions of the state (Taillie et al. 2016). The rapid decline in Bachman's Sparrow distribution and abundance has been attributed to habitat fragmentation and loss, especially the decline in acreage of fire-maintained *Pinus palustris* Mill. (Longleaf Pine) ecosystem (Dunning et al. 2020; Taillie et al. 2015, 2016; Winiarski et al. 2017a). Fire-maintained Longleaf Pine communities are characterized by sparse overstory and midstory, and an understory dominated by forbs and grasses, such as *Aristida stricta* Michx. (Wiregrass). Bachman's Sparrows have specialized habitat requirements and will abandon sites without frequent fire (i.e., every 2–3 years) as dense woody vegetation encroaches and outcompetes herbaceous groundcover (Engstrom et al. 1984; Taillie et al. 2015; Tucker et al. 2004, 2006).

Studies of Bachman's Sparrow have focused almost exclusively on male individuals because females are difficult to monitor due to their secretive nature and tendency to remain hidden (Jones et al. 2013). Using an extensive mist-net effort (about 1500 net-hours across 3 years), Cox and Jones (2007) color-banded only 18 females, and these individuals were rarely observed during surveys for singing males. Further, Brown (2012) used playback of aggressive calls near mist nets, but was unable to capture females, which she noted were less aggressive than males. Similarly, other studies have been unable to use females in analysis due to small sample size (Cox and Jones 2007, Jones 2008) or have explicitly limited themselves to studying males because they are easier to capture and detect when singing (Cox and Jones 2010, Fish et al. 2018, Winiarski et al. 2017b). Although a few studies have examined nest-site selection (Haggerty 1995, Winiarski et al. 2017c), information is largely lacking regarding female natural history. Yet, Stober and Krementz (2000) estimated breeding-season female survival to be 0.794 (n = 14) and Stober and Krementz (2006) reported seasonal home-range size to be 2.20 ha (n = 4), but each recognized the small sample size. To our knowledge, these are the only estimates of female Bachman's Sparrow survival and home-range size, and female habitat selection has not been examined.

Our objective was to better understand female Bachman's Sparrow ecology to ensure that habitat-management recommendations informed primarily by research on male sparrows are consistent with the specific habitat requirements of female sparrows. Therefore, we estimated female breeding-season survival and home-range size and quantified habitat selection of female sparrows within their seasonal home ranges.

Field-site Description

Fort Bragg Military Installation (hereafter Fort Bragg) is a 621-km^2 property in the Sandhills physiographic region of Cumberland, Hoke, Harnett, and Moore counties, NC (Fig. 1). Characterized by rolling terrain, and well-drained, sandy soils, Fort Bragg contains the core of the largest continuous area of Longleaf Pine–

Wiregrass community in North Carolina (Sorrie et al. 2006). Longleaf Pine at Fort Bragg is mostly second-growth and is burned primarily every 3 years during the growing season (Cantrell et al. 1993). The regular fire-return interval has promoted Longleaf Pine uplands that are characterized by an open canopy, sparse midstory, and an understory dominated by Wiregrass and other herbaceous plants with isolated patches of woody shrubs and hardwood sprouts (e.g., *Quercus laevis* Walter [Turkey Oak]). Fort Bragg is dissected by a series of stream drainages that contain an understory of dense, ericaceous shrubs.

Methods

Female capture and tracking

We captured and subsequently monitored breeding female Bachman's Sparrows in 6 study sites dominated by upland Longleaf Pine community (mean site size = 754 ± 118 [SE] ha; Fig. 1). We captured sparrows using mist nets and a modified target-netting approach described by Jones and Cox (2007). We captured female sparrows between 8 April and 1 June 2014–2016 by eliciting aggressive responses using male song playback. When females failed to respond aggressively to playback, we set up an array of mist nets between individuals and presumed escape cover (e.g., lowland drainage, hillside seep, or dense vegetation cover), flushing them toward the escape cover. We determined sex by cloacal examination and the presence of a brood patch (Pyle 1997). Some females did

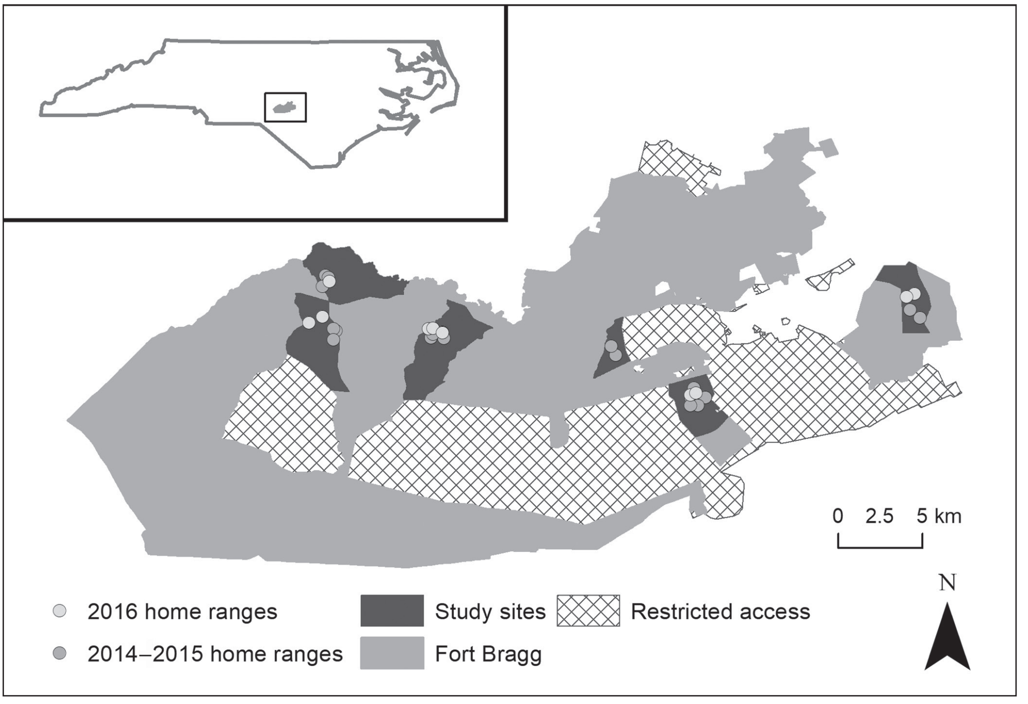

Figure 1. Study areas and female Bachman's Sparrow breeding-season home ranges at Fort Bragg Military Installation, NC, 2014–2016.

not have a brood patch early in the breeding season, but we later verified them as females during nest initiation. We attached a USGS aluminum band and a unique set of 3 plastic color bands to female sparrows in 2015 and 2016, but sparrows from 2014 were not color-banded. We attached 0.55-g backpack-style transmitters (Blackburn Custom Transmitters, Nacogdoches, TX) to each sparrow using a figure-8 thigh mounting system (2014–2015; Rappole and Tipton 1991) or a modified weak-link harness system (2015–2016; Kesler et al. 2011). We changed how we constructed attachment harnesses because the Rappole and Tipton (1991) method created a gap between the front edge of the transmitter and the sparrow's body, which entangled vegetation and caused mortality in several sparrows. No sparrows died from entanglement after switching to the modified weak-link method, which eliminated the gap between the transmitter and the sparrow's body. Transmitters did not exceed 3% of an individual sparrow's body mass. We additionally clipped the transmitter antennae to 8 cm, about 1 cm shorter than the tail length, to prevent entanglement in vegetation (Hill and Elphick 2011). We used VHF telemetry equipment to track each individual every 2–4 days and continued tracking until a mortality event or the transmitter battery died (mean = 49 days). We used homing to locate and flush sparrows and, after visual confirmation, recorded locations using a handheld GPS device.

Vegetation measurements

We measured vegetation at locations of female sparrows tracked in 2016. For each female sparrow with at least 10 telemetry locations, we created a minimum convex polygon using ArcMap (ESRI 2016). Then, within this boundary, we generated 10 random points that were at least 10 m from other random points. For each sparrow, we measured vegetation at the 10 random points and at 10 of the "used" points at which we had located a sparrow. Centered on each point, we established 2 perpendicular 10-m transects. At the center point and every 1 m in each cardinal direction along the transects (total of 21 subpoints), we recorded vegetation (i.e., grass, woody vegetation, forbs) contacts (i.e., presence/absence) on each 10-cm segment of a 2.54-cm-wide and 2-m-tall Wiens pole (Brooks and Stouffer 2010, Fish et al 2019, Wiens 1974). We recorded ground cover at each subpoint along the transects as bare ground or other. We measured total basal area from the center of each survey plot using a 10-factor prism (Avery and Burkhart 2015).

Statistical analysis

All statistical analyses were performed in R (version 4.0.2; R Core Team 2020). We calculated daily survival of females during the breeding season using the Program MARK nest-success model in the 'RMark' package (Laake 2013), which is an adaptation of known-fates analysis for radio-tracked animals that are not tracked in discrete time intervals. We extrapolated daily survival to the breeding season, defined as 90 days, as this was generally the length of the breeding seasons considered by Stober and Krementz (2000). We estimated seasonal home-range size of individuals with at least 10 telemetry locations. We calculated home-range size using the 95% fixed-kernel utilization distribution method (95FK; Worton 1989) in the 'ks' package (Duong 2020) using the 'plug-in' estimator, which is increasingly used in estimating avian home ranges and has been previously used for Bachman's Sparrows (Winiarski et al. 2017b). Also, we calculated home range using the 95% minimum convex polygon (95MCP) method in the 'sf' package (Pebesma 2018) because 95MCPs were used in many past studies, including the only study estimating home-range size for female Bachman's Sparrows. Although a threshold of 10 locations is lower than what is generally recommended for estimating home-range size (Ackerman et al. 1990, Seaman et al. 1999), other studies of Bachman's Sparrows determined that 10 (Jones et al. 2014) and 15 (Brown 2012) locations per individual were adequate.

We analyzed habitat selection of female sparrows by creating generalized linear models using the vegetation variables we measured. We calculated percent understory cover of grass, woody vegetation, and forbs as the proportion of the 21 subpoints where we measured at least 1 contact on the Wiens pole with each respective vegetation type (Fish et al. 2019). We calculated average maximum height of woody understory vegetation as the average height of the tallest woody vegetation contact across the 21 subpoints. Before analysis, we tested for highly correlated variables ($r > |0.60|$) using Pearson's correlation coefficient. Also, we computed the variance inflation factor using the 'car' package (Fox and Weisberg 2019) and a threshold value of 3 (Zuur et al. 2010); neither test revealed significant correlations. Using the 'MuMIn' package (Barton 2019), we fit 24 a priori models using the 6 vegetation covariates (Table 1), a logit link function, and a binomial response for used and random locations. Also, we included quadratic terms for grass cover and woody cover, as past studies have suggested threshold responses to grass and woody cover (Dunning and Watts 1990, Winiarski et al. 2017b). We ranked models using Akaike information criterion corrected for small

Table 1. Description and summary statistics (mean ± SD) for measured vegetation variables at random and used locations within breeding-season home ranges of female Bachman's Sparrows at Fort Bragg Military Installation, NC, in 2016.

Variable	Random	Used	Description
BA (m^2/ha)	6.25 ± 2.30	5.88 ± 3.00	Total basal area of pines and hardwoods
Forb cover (%)	11.71 ± 13.41	14.10 ± 12.63	Percent of sampling points at each location with forb cover
Grass cover (%)	71.67 ± 25.59	75.71 ± 18.75	Percent of sampling points at each location with grass cover
Woody understory cover (%)	29.29 ± 20.98	39.86 ± 21.85	Percent of sampling points at each location with woody cover
Bare ground (%)	1.43 ± 5.24	2.03 ± 5.44	Percent of sampling points at each location with bare ground
Woody understory height (m)	0.42 ± 0.22	0.45 ± 0.23	Average maximum height of woody cover at each location

sample size (AIC_C) and chose the model with the lowest AIC_C score as the most parsimonious (Burnham and Anderson 2002). However, we ignored models with non-significant parameter estimates, i.e., those with 95% confidence intervals that overlapped zero (Arnold 2010).

Results

We captured and radio-marked 19, 17, 10 female Bachman's Sparrows in 2014, 2015, and 2016, respectively. Of the 46 females captured, we censored 12 individuals from the analysis because of dispersal or failed transmitters (n = 2), dropped transmitters immediately after capture (n = 3), capture-induced mortality (n = 2), unknown dropped transmitters (n = 1), and transmitter-induced mortality (n = 4).

We tracked sparrows for a mean of 44.6 (SD = 8.9) days and 1516 total exposure days. We recorded 2 mortalities and attributed 1 to an avian predator (the transmitter was located above a raptor perch with plucked feathers) and 1 to a military training event (the intact carcass was located meters from its nest in an area of freshly trampled vegetation and spent brass). Daily survival rate was 0.999 (95% CI = 0.995–1.000), with an estimated breeding-season survival rate of 0.888 (95% CI = 0.622–0.971). Daily survival rate excluding the mortality associated with military training was 0.999 (95% CI = 0.995–1.000), with an estimated breeding-season survival rate of 0.941 (95% CI = 0.648–0.991).

We obtained 10 or more telemetry locations for 31 individuals with a mean number of 14.26 (SD = 3.40) locations per individual. We excluded 1 bird which abandoned its range after it was burned by a wildfire and later established a new home range ~0.7 km away. Mean 95MCP home-range size was 1.48 ha (SE = 0.16) and varied from 0.62 ha to 4.55 ha. Mean 95FK home-range size was 2.32 ha (SE = 0.21) and varied from 0.87 ha to 5.54 ha.

One habitat selection model was considered competitive ($\Delta AIC_C \leq 2$) and accounted for 38% of the model weight. The model included a positive linear relationship for percent woody vegetation cover and percent grass cover and a quadratic term for percent grass cover (Fig. 2). The 95% confidence intervals for parameters in the top model did not overlap zero and we considered each parameter significant (Table 2). The top model suggested that probability of female habitat use increased with increasing woody understory cover and with percent grass cover up to a threshold, at which point it declined (Table 2, Fig. 2).

Table 2. Parameter estimates and confidence interval (CI) for the top model for habitat selection within breeding-season home ranges of female Bachman's Sparrows at Fort Bragg Military Installation, NC, in 2016.

Variable	Estimate	2.5 % CI	97.5% CI
Intercept	-3.51	-6.14	-1.39
Grass cover	7.94	1.45	15.66
Grass cover^2	-5.41	-11.14	-0.37
Woody understory cover	2.45	1.06	3.93

Discussion

Our estimate (0.941) of female Bachman's Sparrow survival during the breeding season was greater than that of Stober and Krementz (2000; 0.794). Stober and Krementz (2000) suggested that female survival should be lower than that of males because females exclusively incubate the nest; however, they did not document a difference between male and female survival. Our breeding-season estimate of female survival was also greater than male estimates in other studies. Seaman and Krementz (2000) estimated male survival between April and July (97 days) to be 0.80, and Jones et al. (2014) reported a monthly survival of 0.93, suggesting that survival of female Bachman's Sparrows at Fort Bragg was slightly greater than that of Bachman's Sparrows elsewhere.

Information on causes of mortality for adult Bachman's Sparrows is limited, so our documentation of avian predation is an important addition to the literature. Predation of Bachman's Sparrows by an avian species, unknown mammal, and *Pantherophis guttatus* L. (Eastern Corn Snake) has been documented (Stober and Krementz 2000). Because females exclusively carry out nest construction, incubation, and brooding (Dunning et al. 2020), predation threats to female, as opposed to male, sparrows during the breeding season may more closely reflect nest predators. Using video surveillance, Malone et al. (2019) determined that nests were depredated most frequently by snakes, and occasionally mammals, *Solenopsis invicta* Buren (Red Imported Fire Ant), and *Cyanocitta cristata* L. (Blue Jay). The mortality of an adult female sparrow that was associated with military training has

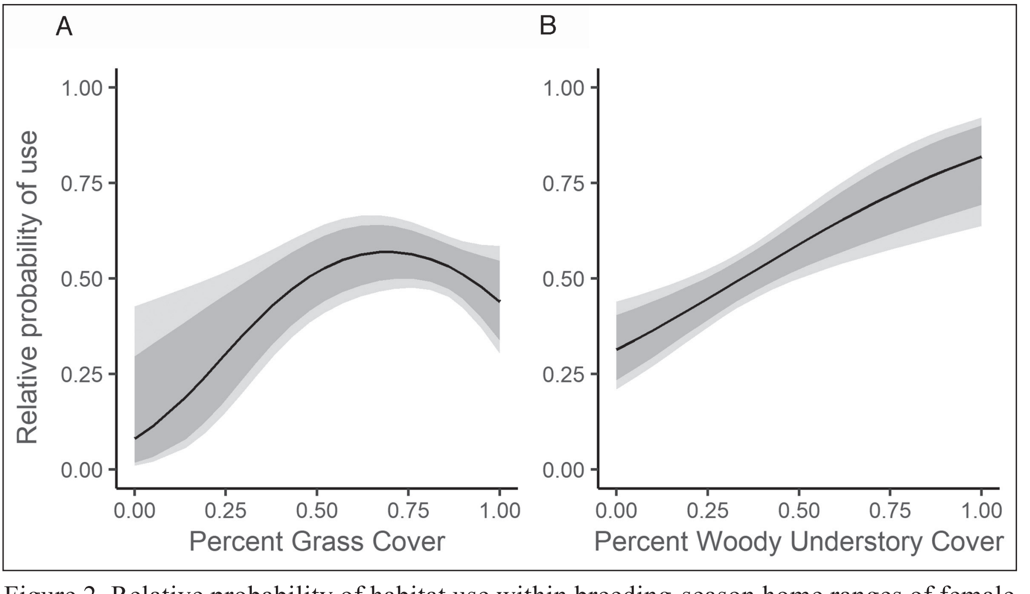

Figure 2. Relative probability of habitat use within breeding-season home ranges of female Bachman's Sparrows at Fort Bragg Military Installation, NC, in 2016, based on (a) percent grass cover (quadratic relationship) and (b) percent woody understory cover (linear relationship). The light gray and dark gray shaded regions represent the 95% and 85% confidence intervals, respectively.

not been previously reported. Fish et al. (2019) documented a Bachman's Sparrow nest trampled by military personnel, but overall reproductive output was not affected by military training. Additionally, ground-based military training was not observed as contributing to mortality of ground-nesting *Colinus virginianus* L. (Northern Bobwhite) at Fort Bragg (Rosche 2018), and we believe that adult mortality by military activity is an infrequent occurrence.

Our estimate of seasonal home-range size adds to the limited information regarding female Bachman's Sparrow natural history. Only Stober and Krementz (2006) have estimated female home-range size and reported that 95MCP seasonal home-range size of females (2.20 ha ± 0.48, n = 4) was statistically similar to that of males (3.26 ha ± 0.49 ha, n = 10). Our 95MCP (1.48 ha ± 0.16) and 95FK (2.32 ha ± 0.21) estimates were similar to that of Stober and Krementz (2006). However, estimates of male Bachman's Sparrow home ranges in other regions of the southeastern US are variable, generally varying from 1 to 5 ha (Brown 2012, Cox and Jones 2007, Haggerty 1998, McKitrick 1979, Winiarski et al. 2017b). Because female seasonal home-range size may reflect home-range size of paired males (Stober and Krementz 2006), it is likely that female Bachman's Sparrow space use is similarly variable across the range.

Female selection of intermediate densities of grass cover are consistent with several recent studies of habitat selection by male sparrows, all suggesting an upper threshold of grass density at which Bachman's Sparrow use declines (Brooks and Stouffer 2010, Tallie et al. 2015, Winiarski et al. 2017b). Although it is known that Bachman's Sparrow presence increases with grass density or cover (Allen and Burt 2014; Dunning and Watts 1990; Dunning et al. 2020; Fish et al. 2018; Plentovich et al. 1998; Tucker et al. 1998, 2004), there is an upper limit where too much grass cover impedes efficient movement (Brooks and Stouffer 2010, Haggerty 1998, Taillie et al. 2015).

On Fort Bragg, females selected for patches of woody understory vegetation, similar to males in another region of North Carolina (Winiarski et al. 2017b). Although presence of woody vegetation generally is considered detrimental to Bachman's Sparrow occupancy and reproductive success (Brooks and Stouffer 2010, Fish et al. 2019, Haggerty 1998, Taillie et al. 2015, Tucker et al. 2004), previous studies examined habitat selection at the home-range scale or larger. On a smaller scale, woody understory provides song perches for male Bachman's Sparrows (Dunning and Watts 1990, Jones et al. 2013, Winiarski et al. 2017b) and escape cover for males, females, and fledglings (Dean and Vickery 2003; Fish et al. 2018, 2020; Meanley 1959; Pulliam and Mills 1977). Additionally, Winiarski et al. (2017a) suggested that woody vegetation improved nest access for female Bachman's Sparrows, which were observed landing several meters away and moving toward nests on the ground. Hence, managers must achieve a balance in terms of restricting woody encroachment across the landscape while still retaining small, scattered patches of shrubs and woody sprouts to provide critical escape cover for Bachman's Sparrows.

Our results indicate that seasonal home-range size and survival of female Bachman's Sparrows were generally similar to males. The threshold response to grass cover and selection for woody vegetation at the home-range scale matches previously documented relationships for males. Because survival, home-range size, and habitat selection of female Bachman's Sparrows at Fort Bragg did not differ from that documented there and elsewhere for male sparrows, management based primarily on males may be adequate to conserve the species. However, we caution that female-specific natural history at Fort Bragg may vary from that in other portions of the Bachman's Sparrow range where sparrows select differing vegetation structure and species composition (e.g., use of areas with less grass [Dunning and Watts 1990] or escape cover in *Serenoa repens* (Bartram) J.K.Small [Florida Saw Palmetto; Dean and Vickery 2003]). Therefore, continued effort to understand the specific natural history of females is necessary for more successful conservation of Bachman's Sparrows.

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