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Research Article

Influence of Military Training on Breeding Ecology of Bachman's Sparrow

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ABSTRACT Anthropogenic disturbance may cause birds to flush and relocate, abandon breeding sites, experience increased nest failure, or fledge fewer young. Ground-based military activities are of particular concern for ground-nesting birds because of the increased risk of nest destruction and trampling of vegetation. We investigated how different intensities of disturbance from ground-based military training affected reproductive ecology of Bachman's sparrow (*Peucaea aestivalis*) from 2014–2016, on Fort Bragg Military Installation, North Carolina, USA. We designated 2 training intensity regimes and monitored sparrows at 6 observation areas, 3 in high-intensity training areas (i.e., foot traffic every 1–3 days) and 3 in low-intensity training (i.e., foot traffic <1 per month) areas. We compared seasonal productivity metrics and daily nest survival between training intensities. Additionally, we compared male sparrow relative abundance and micro-habitat use between high- and low-intensity training areas. We monitored 106 male territories and located 110 nests opportunistically and by tracking telemetered female sparrows. We used fixed-radius point counts to estimate relative abundance in each observation area and measured vegetation composition and structure at a subset of 10 locations in each male territory. Seasonal productivity metrics, daily nest survival, relative abundance, and vegetation composition and structure at male locations did not differ between areas with high and low military training intensity. In 2015, 1 sparrow nest was trampled by military personnel, but ≥1 nestling force-fledged and the nest was considered successful. Bachman's sparrow nesting ecology was not affected by intensity of ground-based military training activity, likely because activity was sufficiently dispersed across the landscape, even in high-intensity training areas. We recommend ground-based training attempts to minimize ground vegetation destruction by dispersing large groups and traversing variable routes when in forested uplands. © 2018 The Wildlife Society.

KEY WORDS ground disturbance, ground-nesting bird, habitat selection, longleaf pine, nest survival, *Peucaea aestivalis*, *Pinus palustris*, prescribed fire.

Anthropogenic disturbance directly and indirectly affects birds and may reduce individual fitness. Birds spend more time alert in areas with frequent pedestrian traffic (Van de Voorde et al. 2015) and reduce time allocated to foraging, which can result in a net loss of energy (Bélanger and Bédard 1990). To conserve energy and prevent flushing, birds may shift activity centers away from disturbed areas (Thiel et al. 2008). However, shifting movement may not be feasible for birds with small home ranges, occupying small habitat patches, occurring in fragmented landscapes, or during the breeding season when nests or juvenile offspring restrict movement.

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Ground-nesting birds are particularly vulnerable to ground-based disturbance. For example, nests may be trampled by pedestrians, off-road vehicles (Buick and Paton 1989), or cattle (32–98%; Pakanen et al. 2011, Perlut and Strong 2011, Sharps et al. 2015). In fact, increased levels of nest failure from trampling may be responsible for population declines of some ground-nesting birds (Rolek et al. 2016). Additionally, ground disturbance near nests can force incubating females to temporarily leave the nest (Sabine et al. 2006, Borneman et al. 2016). Predators key on incubating females as they flush from human disturbance, leading to greater nest depredation rates (Hillman et al. 2015, Borneman et al. 2016, Stien and Ims 2016).

One source of ground disturbance may be military training activities. For example, birds flush in response to low-flying aircraft and expend additional energy (Conomy et al. 1998*a*,*b*) and may respond to aircraft by allocating greater proportion of time to alert behaviors (Goudie and Jones 2004). These alert or defensive behaviors increase following artillery firing (Delaney et al. 2011) and ground-based training exercises (Barron et al. 2012). Moreover, military lands are managed primarily for training purposes, but conservation of natural resources is an important objective (Delaney et al. 2011). Balancing the needs of military training and biodiversity conservation may lead to conflicting management objectives. Moreover, linking long-term effects of behavioral changes from military training to reproductive effects remains a research priority (Barron et al. 2012).

The influence of military activity is of particular concern for ground-nesting birds such as Bachman's sparrows (*Peucaea aestivalis*). The Bachman's sparrow has experienced long-term population declines (Sauer et al. 2014), and the species is closely associated with the endangered fire-maintained longleaf pine (*Pinus palustris*) ecosystem (Dunning and Watts 1990, Plentovich et al. 1998, Winiarski et al. 2017*c*, Fish et al. 2018), common on military bases in the southeastern United States. Bachman's sparrows forage (Allaire and Fisher 1975) and nest (Haggerty 1995, Jones et al. 2013, Winiarski et al. 2017*a*) in the dense herbaceous layer that develops immediately following prescribed fire, and ground-based military training commonly occurs in these same fire-maintained forests. Ground-based military training may destroy sparrow nests, reduce vegetation cover near nests, or cause breeding sparrows to disperse to avoid training exercises.

Our objective was to determine the effects of 2 levels of ground-based disturbance (i.e., high- [HIT] and low-intensity training [LIT]) generated by military foot travel and off-road vehicle use, on Bachman's sparrow breeding ecology. We evaluated effects of the 2 levels of military training activity on pairing success, fledging success, territory abandonment, nest survival, abundance of breeding males, and habitat use of male Bachman's sparrows during the breeding season.

STUDY AREA

Fort Bragg Military Installation (i.e., Fort Bragg) is a 73,469-ha property managed by the United States Department of Defense. Located in the Sandhills physiographic region of North Carolina, USA, Fort Bragg lies in the longleaf pine ecosystem and is characterized by rolling hills with open canopy longleaf pine in the uplands interspersed with lowland drainages 40–165 m above sea level. Upland vegetation primarily consists of longleaf pine, loblolly pine (*Pinus taeda*), wiregrass (*Aristida stricta*), and turkey oak (*Quercus cerris*). Lowland areas are dominated by oaks (*Quercus* spp.), sweetgum (*Liquidambar styraciflua*), and gallberry (*Ilex glabra*). Dominant fauna included white-tailed deer (*Odocoileus virginianus*), coyote (*Canis latrans*), wild turkey (*Meleagris gallopavo*), gray fox (*Urocyon cinereoargenteus*), fox squirrel (*Sciurus niger*), corn snake (*Pantherophis guttatus*), black racer (*Coluber constrictor*), black rat snake (*Pantherophis obsoletus*), and American kestrel (*Falco sparverius*). Bachman's sparrow typically breed April–August, with the greatest nesting effort between May–June (Haggerty 1988, Stober and Krementz 2000). Longleaf pine uplands on Fort Bragg primarily were targeted for growing-season prescribed fire application once every 3 years (Cantrell et al. 1995). However, managers used dormant-season prescribed fire when growing-season fire was precluded for logistical reasons. Lowland forests had saturated soils that suppressed prescribed fire, were densely vegetated, and were dominated by a mixed broadleaf-pine plant community (Just et al. 2015). Fort Bragg is characterized by hot-humid summers, temperate winters, and 1.17 m of average annual rainfall.

Fort Bragg employed approximately 56,000 army personnel who conducted year-round training exercises, including tactical maneuvers, live-fire exercises, and paratrooper drops. We consulted extensively with Range Control Officers to identify discrete training areas that received varying levels of ground-based military activity, suitable for HIT and LIT classification. We conducted our study in 6 observation areas (Fig. 1): 3 in HIT areas ($\bar{x} = 770 \pm 122$ [SE] ha) and 3 in LIT areas ($\bar{x} = 776 \pm 251$ ha). The HIT areas were characterized by presence of permanent upland orienteering training courses and received frequent foot traffic (once every 1–3 days) in male sparrow territories by ground troops. The LIT areas had no permanent training feature to concentrate troop activities and male sparrow territories were characterized by infrequent foot traffic (typically received <1 training event/month). Observation of troop activity supported Range Control's classification; we observed ground troops and off-road vehicles more often in HIT compared to LIT areas, and subsequently, vegetation was trampled in HIT areas more often than LIT areas. We primarily observed small groups (<10) or individual troops in the observation areas, but occasionally we observed large (>30 troops) training activities (A. Fish, North Carolina State University, personal observation). Troop activity was primarily during daylight hours but also occurred overnight. Management activities, including prescribed burning, were similar between HIT and LIT areas.

METHODS

Data Collection

We captured Bachman's sparrows early in the breeding season (Apr 2014–2016) by target netting singing males and flushing birds into mist nests (Jones and Cox 2007). We determined sex by cloaca examination and presence of a brood patch (Pyle 1997). We attached a federal aluminum band and a unique set of 3 color bands to each captured bird. We were unable to capture some males and monitored them as unmarked individuals. Additionally, we attached a backpack style 0.55-g radio-transmitter to some females (Blackburn Custom Transmitters, Nacogdoches, TX, USA). We attached transmitters using a thigh mounted figure-8 harness system (Rappole and Tipton 1991) or a modified weak-link harness system (Kesler 2011). Radio-transmitters did not exceed 5% of adult body mass. All animal handling techniques were approved by the Institutional Animal Care and Use Committee at North Carolina State University (protocol number14-011-O).

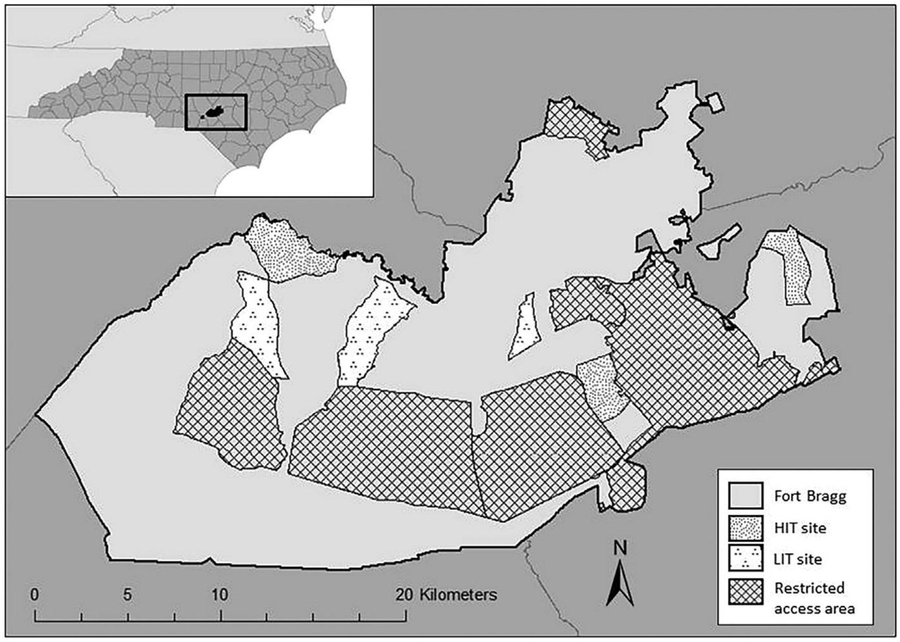

Figure 1. Fort Bragg Military Installation in south central North Carolina, USA. We conducted territory monitoring in 2014–2016 at 3 sites designated high-intensity training (HIT) and 3 designated low-intensity training (LIT).

We monitored 40 male territories between a half hour before sunrise and the first 5 hours of daylight from April to July each year. We had a single observer follow an individual male for 1 continuous hour once a week, revisited continually throughout the summer, recording sparrow activity, and behaviors associated with nesting (e.g., singing, conspecific interactions, nest building, feeding nestlings, presence of fledglings; Vickery et al. 1992*b*). We compiled observation data into 3 seasonal productivity metrics spanning the entire breeding season (pairing success, fledging success, and territory abandonment) based on the Vickery Reproductive Index monitoring protocols (Vickery et al. 1992*a*,*b*; Tucker et al. 2006). We defined a male as paired if we observed a female for >4 weeks, defined fledging success as a territory that fledged young by observing adults feeding young, and recorded territory abandonment if we failed to detect the territorial pair for >4 weeks (Vickery et al. 1992*a*, Tucker et al. 2006). If a male abandoned a territory following prescribed fire application, we censored the territory from the sample. We recorded all male locations using a global positioning system.

We located nests opportunistically and using radio-telemetry. We tracked females with radio-transmitters 2 to 4 times per week throughout the breeding season (Apr–Jul). Using the homing method (Small et al. 2015), we visually confirmed incubation status of each female to locate nests. We flagged nests 10–30 m away and monitored nests 2–4 times a week until success or failure (Martin and Guepel 1993). We did not determine clutch size because of concerns about altering or destroying vegetation to access the well-hidden and fragile ground nests of the species. We classified nests as successful only when we detected fledglings near the nest or when we observed adults feeding young.

We estimated breeding Bachman's sparrow male abundance in each of the observation areas. We randomly generated 10 point-count locations in each observation area using ArcMAP (Environmental Systems Research Institute, Redlands, CA, USA). All point count locations were in mature longleaf pine uplands and >250 m apart. We visited each point 3 times between 21 April and 4 July 2014–2016, using a single observer each year. We surveyed points between a half hour before sunrise and the first 5 hours of daylight. Each survey was 8 minutes long with 4 minutes of passive observation followed by 4 minutes of periodic playback (McNeil et al. 2014, Taillie et al. 2015). We included only males detected within 100 m of the point count center in analysis to prevent double-counting males and pseudo-replication in our sample.

We compared habitat use of breeding males between HIT and LIT areas to assess if male sparrows in HIT areas used sites with different vegetation characteristics than LIT males. We measured vegetation composition and structure at a randomly selected subset of ≤10 locations for each marked male. We measured vegetation at every meter along 2 perpendicular 10-m transects centered on the male location. We recorded all grass and shrub contacts (hits) along a 2-m tall, 2.54-cm diameter Wiens pole (Wiens 1974). We classified all perennial woody stems as a shrub, including tree regeneration. We quantified 3 vegetation metrics (grass cover, shrub cover, and shrub height) for their influence on Bachman's sparrow habitat use (Brooks and Stouffer 2010, Taillie et al. 2015, Winiarski et al. 2017*b*). We obtained grass and shrub percent cover estimates by calculating the proportion of Wiens poles with ≥1 grass or shrub hit at each male survey location. We measured shrub height by recording the tallest shrub hit to the nearest 10 cm interval on each Wiens pole, and averaged heights for each survey plot.

Statistical Analyses

We used seasonal productivity metrics gathered during territory monitoring to calculate the proportion of males that successfully paired, fledged young, or abandoned territories. We compared proportions between HIT and LIT training areas using a Chi-square test of independence (McHugh 2013).

We compared daily nest survival between HIT and LIT training areas using the nesting model (Dinsmore and Dinsmore 2007) in Program MARK (White and Burnham 1999), with the daily nest survival estimate calculated from the monitoring interval used as the experimental unit. We formatted data into 6 group level covariates (i.e., LIT 2014, LIT 2015, LIT 2016, HIT 2014, HIT 2015, and HIT 2016) for the analysis and created 4 *a priori* models to test the influence of training intensity and year as possible predictors of nest success. Vegetation structure and composition of nest sites do not influence Bachman's sparrow nest survival on Fort Bragg, so we did not include these factors in the analysis (Winiarski et al. 2017*a*). We used Akaike's Information Criterion corrected for small sample size (AIC_c) to rank model fit, and chose the model with the lowest AIC_c score as most parsimonious (Burham and Anderson 2002). We considered models competitive if they differed by <2 AIC_c units for every additional parameter of the top model, ignoring models with non-informative parameters (Arnold 2010).

We used N-mixture modeling in Program Unmarked to generate Bachman's sparrow relative abundance estimates following a Poisson distribution, and included a year effect on detection (Fiske and Chandler 2011). We ran detection models including military training intensity, ordinal date, temperature, wind, time, and ambient noise, but none of these covariates improved detection estimates and we proceeded with a year effect on detection as most parsimonious. The use of N-mixture models has been criticized because individuals are not marked and therefore detection estimates can confound abundance estimates. Bachman's sparrows are highly secretive and even when detected, re-sighting, and identifying individuals is not logistically feasible, preventing use of a mark-resight analysis framework. The detection estimate used in the N-mixture model was similar to other detection estimates for Bachman's sparrows (Cox and Jones 2009, Taillie et al. 2015, Fish et al. 2018); therefore, we proceeded with use of a N-mixture model. We created a state covariate to account for HIT and LIT areas, which allowed for comparison of relative abundance between HIT and LIT training areas.

We created generalized linear mixed effect models using the lme4 package (Bates et al. 2015) in Program R (R version 3.2.2, www.r-project.org, accessed 29 Jan 2016) to compare micro-habitat use between HIT and LIT areas. We specified a logit link function and a binomial response (where 1 = HIT locations, 0 = LIT locations). We used 10 randomly selected locations for each male, but when an individual had been re-sighted fewer than 10 times, we used fewer locations. We included individual as a random effect in the model to account for variation among territories, and included habitat metrics as fixed effects. We ran 3 models, each with a single response variable (grass cover, shrub cover, and shrub height), and compared parameter estimates between HIT and LIT areas. We set alpha at 0.05 for all analyses.

RESULTS

We captured and marked 46 males in HIT and 42 males in LIT areas from 2014–2016 (Table 1). We monitored an additional 8 unmarked males in HIT and 10 in LIT sites. We captured and attached radio-transmitters to 19 females in HIT and 18 in LIT areas. The mean female Bachman's sparrow weight was 19.94 ± 0.26 (SE) g, and radio-transmitters (0.55 g) comprised $2.76 \pm 0.04\%$ of female body mass.

We monitored and scored 52 territories in HIT and 54 territories in LIT areas (Table 2). We censored 14 males because their territories were burned during prescribed fire application and we did not locate males after the burn (Table 2). We were unable to re-locate most males between breeding seasons but monitored 11 males for 2 breeding seasons and 2 males for 3 seasons.

Approximately 25% of male Bachman's sparrows abandoned territories during the study (Table 3). training areas ($\chi^2_1 < 0.001$, $P = 1.0$; Table 3) and among years. Territory abandonment primarily occurred early in the breeding season (Apr–May; $n = 20$) but continued throughout the breeding season (Jun–Aug; $n = 6$), and even after successfully fledging young ($n = 4$). Only 1 territory abandonment, in 2015, was linked with a military training event, during which a large portion of the understory vegetation was trampled. Males paired with females ($\chi^2_1 < 0.001$, $P = 1.0$) and successfully fledged young ($\chi^2_1 < 0.001$, $P = 1.0$) similarly between HIT and LIT areas (Table 3).

We located 60 nests in HIT and 50 nests in LIT areas, with 27 and 21 located with radio-telemetry, respectively. Daily nest survival rates were similar between HIT ($\bar{x} = 0.947 \pm 0.009$) and LIT ($\bar{x} = 0.942 \pm 0.011$) areas, but

Table 1. Number of marked and unmarked Bachman's sparrow males monitored on Fort Bragg Military Installation, North Carolina, USA, 2014–2016, in high-intensity training (HIT) and low-intensity training (LIT) areas.

	HIT	LIT
2014		
Male—new capture	20	19
Male—previous capture	0	0
Male—unmarked	0	1
Female—radio-marked	7	5
Total	27	25
2015		
Male—new capture	13	9
Male—previous capture	3	7
Male—unmarked	4	4
Female—radio-marked	7	8
Total	27	28
2016		
Male—new capture	13	14
Male—previous capture	3	1
Male—unmarked	4	5
Female—radio-marked	5	5
Total	25	25

Table 2. Number of male Bachman's sparrow breeding territories monitored and censored on Fort Bragg Military Installation, North Carolina, USA, 2014–2016, in high-intensity training (HIT) and low-intensity training (LIT) areas. We censored territories from analysis when they were burned by prescribed fire and males were not re-located.

Year	HIT	LIT
Males monitored		
2014	16	19
2015	17	15
2016	19	20
Total	52	54
Males censored		
2014	4	1
2015	3	5
2016	1	0
Total	8	6

survival varied by year (Table 4). Nest failure ($n = 61$) primarily was caused by depredation ($n = 58$), but additional causes included prescribed fire ($n = 1$), female depredation ($n = 1$), and abandonment ($n = 1$). During the 2015 breeding season, 1 nest was trampled by military personnel, but ≥ 1 nestling force-fledged. We considered the nest successful because we observed a juvenile with marked adults after nest destruction. Additionally in 2016, 1 nest was located 5–10 m from a large military training event, with substantial vegetation trampling from vehicles and ground troops. The female continued to incubate the nest, which successfully hatched before being depredated in the nestling stage by an unknown predator.

Relative abundance of male sparrows was similar between HIT and LIT training areas ($\beta = 0.11$; $P = 0.24$). After back-transforming parameter estimates, we generated abundance estimates of 0.16 (95% CI = 0.15–0.18) and 0.15 (95% CI = 0.13–0.18) males/ha in HIT and LIT areas, respectively.

We collected vegetation metrics for 98 males at 921 locations, averaging 9.40 ± 0.06 locations/male. We censored locations from 22 males because their territories were burned prior to vegetation sampling or because we did not collect locations prior to territory abandonment. Male Bachman's sparrows used micro-habitat similarly in HIT and LIT areas. Grass cover ($\beta = 0.30$; $P = 0.92$), shrub cover ($\beta = 0.70$; $P = 0.85$), and shrub height ($\beta = -0.04$; $P = 0.87$) at male locations were similar between HIT and LIT areas. Males in HIT and LIT areas selected for 0.71 ± 0.01 and 0.68 ± 0.01 proportion grass cover, 0.32 ± 0.01 and 0.28 ± 0.01 proportion shrub cover, and 45.81 ± 1.20 and 49.70 ± 1.33 cm shrub height, respectively.

Table 3. The proportion of male Bachman's sparrows that abandoned territories, paired with females, or fledged young in high-intensity training (HIT) and low-intensity training (LIT) areas at Fort Bragg Military Installation, North Carolina, USA, 2014–2016.

	HIT (*n*)	LIT (*n*)	χ^2	*P*-value
Abandonment				
2014	0.25 (16)	0.32 (19)		
2015	0.18 (17)	0.13 (15)		
2016	0.42 (19)	0.35 (20)		
Total	0.29 (52)	0.28 (54)	<0.001	1.00
Pairing				
2014	0.88 (16)	0.78 (19)		
2015	0.82 (17)	0.80 (15)		
2016	0.58 (19)	0.70 (20)		
Total	0.75 (52)	0.76 (54)	<0.001	1.00
Fledge young				
2014	0.44 (16)	0.53 (19)		
2015	0.65 (17)	0.53 (15)		
2016	0.47 (19)	0.55 (20)		
Total	0.52 (52)	0.54 (54)	<0.001	1.00

Table 4. Daily nest survival models for Bachman's sparrows in areas of high- and low-intensity training at Fort Bragg Military Installation, North Carolina, USA, 2014–2016.

Model	K[a]	AIC_c[b]	ΔAIC_c	w_i[c]
Year	3	337.06	0.00	0.61
Null	1	338.84	1.78	0.25
Training	2	340.68	3.62	0.10
Year + training	6	342.63	5.57	0.04

[a] Number of parameters.
[b] Akaike's Information Criterion corrected for small sample size.
[c] Model weight.

DISCUSSION

Varying levels of ground-based military training on Fort Bragg did not influence the reproductive ecology of Bachman's sparrows. In fact, a radio-marked female successfully hatched a nest in 2016 after substantial vegetation trampling 5–10 m from the nest site, indicating tolerance to disturbance as long as the nest bowl was not affected. Similarly, other species of ground-nesting birds do not exhibit decreased nest survival in response to disturbance (Johnson et al. 2012, Bleho et al. 2014, Lowe et al. 2014), and some ground-dwelling birds can tolerate low levels of human disturbance without incurring fitness costs (Gill et al. 2001). However, we documented 1 territory abandonment in a HIT area following a ground-based disturbance event in 2015 when ground vegetation was trampled in >50% of the territory. Although it exceeds the training intensity typical on Fort Bragg, a ground disturbance threshold likely exists beyond which breeding Bachman's sparrows abandon territories for less disturbed areas.

The drop zones and artillery firing points, where most multi-day field camps and bivouac training sites were constructed on Fort Bragg, were characterized by bare ground, no tree canopy, and sparse understory vegetation that is not occupied by Bachman's sparrow. Hence, the most impactful training activities on Fort Bragg generally were situated away from breeding Bachman's sparrows. Bachman's sparrows are unambiguously associated with upland pine woodland on Fort Bragg (Fish et al. 2018), using the dense herbaceous groundcover for nesting and foraging (Allaire and Fisher 1975, Haggerty 1995, Jones et al. 2013). Ground training in upland forested areas consisted of individual or small groups of troops (<10) traversing through Bachman's sparrow territories for short durations (<1 hr) and did not influence Bachman's sparrow habitat use.

Bachman's sparrows are well adapted to frequent fire (Tucker et al. 2004), which may make them better adapted to the low-intensity training activities characteristic in the forests on Fort Bragg and other similar military installations. Growing-season prescribed fire application coincides with the peak of the Bachman's sparrow nesting season, yet few nests are destroyed by prescribed fire (Tucker et al. 2006, Winiarski et al. 2017*a*). Nearly all sparrow nests occurred in forest units burned <3 years prior, which limited nest exposure to fire given the 3-year prescribed fire return interval on Fort Bragg. During our study, only 1 of 110 (<1%) nests was destroyed by fire and similarly only 1 (<1%) nest was trampled by ground troops, albeit still successful. Bachman's sparrows exhibit high rates of naturally occurring nest failure, yet individuals readily re-nest with multiple nesting attempts throughout the breeding season (Haggerty 1988, Stober and Kremnetz 2000). Moreover, Bachman's sparrows commonly produce multiple broods within a single breeding season (Haggerty 1988, Stober and Kremnetz 2000, Tucker et al. 2006), with as many as 3 possible under ideal conditions (Stober and Krementz 2000). Bachman's sparrow adaptation to high nest failure rates suggests sparrows could compensate for minimal military-caused nest failure by readily re-nesting.

Our study builds on previous research that suggests varying levels of military training activities have limited influence on the demography of breeding birds. Nest survival was not affected by military training for shrub-nesting northern cardinals (*Cardinalis cardinalis*; Barron et al. 2012) or cavity-nesting red-cockaded woodpeckers (*Picoides borealis*; Doresky et al. 2001, Delaney et al. 2011). Giocomo et al. (2008) documented low rates of nest destruction from ground-based military training for dickcissels (*Spiza americana*) and grasshopper sparrows (*Ammodramus savannarum*). White-eyed vireos (*Vireo griseus*) exposed to ground-based disturbance maintained normal breeding activities and resource provisioning to young (Bisson et al. 2009). Additionally, military training did not contribute to nest failures of ground-nesting wild turkey (*Meleagris gallopavo*; 42 nests monitored) and northern bobwhite (*Colinus virginianus*; 30 nests monitored) on Fort Bragg (Kilburg et al. 2014, Rosche 2018). However, if nestlings receive lower quality or quantity of food, carryover effects from diminished body condition to delayed wing development can increase post-fledging juvenile mortality (Jones et al. 2017). We observed 1 case of nestlings force-fledging to avoid being trampled and the post-fledging fate of those individuals was unknown.

We compared the effects of military training between 2 levels of military training, but we were unable to compare to a control site with no military training activity. Hence, we were only able to investigate the effects of variable training intensity and not the effects of military training alone. Ideally, we would have been able to eliminate military activities from a portion of Fort Bragg, in turn providing us a true control for military activity and creating a third level of training intensity (i.e., no training). However, removing training activities from a large portion of the military base for an extended period was not practical. Moreover, the unique environmental conditions on Fort Bragg, notably the open longleaf pine-wiregrass plant community resulting from frequent prescribed fire, distinguish the study area from neighboring properties and prevented locating a no-training control with similar management history and vegetation conditions. Nevertheless, we believe the level of anthropogenic disturbance on the LIT sites is representative of what Bachman's sparrow would experience on most non-military public lands, including disturbance from land management activities such as prescribed burning and from recreational use. Moreover, Bachman's sparrow daily nest survival in HIT and LIT areas on Fort Bragg (0.945) was similar to daily nest survival rates documented elsewhere in the species' range: Alabama (0.935), Arkansas (0.946), Georgia (0.96), and South Carolina (0.899–0.952; Haggerty 1988, Stober and Krementz 2000, Tucker et al. 2006, Jones et al. 2013). Hence, military training activities, regardless of intensity, likely had limited impact on Bachman's sparrow reproductive ecology on Fort Bragg.

Future research on effects of military activity on wildlife should focus on a wider range of training intensities. Training events are highly diverse and vary by duration (single-day event or multiday bivouac camp), equipment (live fire, artillery, ground troops, or all-terrain vehicles), size (single or multiple units), time of day, and use of air support (helicopters, low-flying jets, or paratroopers), depending on the specific training objectives. The variability of training exercises among and within military bases, and the diversity of species occupying these bases, limit the applicability of our study across all military bases and species. Regardless, we expect a similar response by Bachman's sparrows to ground disturbances of similar type and intensity on other military bases in the species' range.

MANAGEMENT IMPLICATIONS

Breeding Bachman's sparrows did not experience demographic costs in response to ground-based training activity at the levels we studied. Military bases with similar levels of ground-based training to Fort Bragg are not likely to negatively affect Bachman's sparrow breeding ecology. However, if military bases have more off-road vehicles (e.g., Humvees, all-terrain vehicles, tanks) or have substantially greater ground troop concentrations (i.e., consistently having >30 troops together), additional investigation and protection for ground-nesting birds may be required. Other species of birds may react similarly to military activity similar, but nesting and breeding ecology is highly variable and additional research is needed to determine species-specific responses.

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