Fort Bragg Landbird Monitoring Program

Report for the 2017 Field Season

January 31, 2018

The Institute for Bird Populations

U.S. Department of the Army, Fort Bragg

Fort Bragg Landbird Monitoring Program

Report for the 2017 Field Season

Steven Albert, Chris Ray, and Lynn Schofield
The Institute for Bird Populations
P.O. Box 1346
Point Reyes Station, CA 94956-1346

and

Jessie Schillaci
RCW Monitoring Program Coordinator
Directorate of Public Works IMBG-PWE-E
2175 Reilly Road Stop A
Fort Bragg, NC 28310-5000

Please cite this publication as:

Albert, S., C. Ray, J. Schillaci, and L. Schofield. 2018. The Fort Bragg landbird monitoring project: report for the 2017 field season. The Institute for Bird Populations, Point Reyes Station, CA.

Cover photo: Pine Warbler by Rick from Alabama via Flickr Creative Commons

Contents

Acknowledgments

We thank the 2017 crew members, David Farris and Justin Fischer, for their hard work and dedication to the project. We are also grateful to all Fort Bragg administrators and other staff who facilitated our permits and access, and who supported this project.

This report is Contribution No. 578 of The Institute for Bird Populations.

List of Figures

List of Tables

Appendices

Executive Summary

The primary goal of Fort Bragg, North Carolina is to maintain Army mission readiness and a high level of training for the soldiers operating there. However, trainers, planners, land managers, administrators, and others, must balance many competing needs and uses that occur on the base, including the protection of natural resources and adherence to federal land use and wildlife laws such as the Endangered Species Act and the Migratory Bird Treaty Act. The Institute for Bird Populations (IBP) has been an active partner with Fort Bragg since 1995, when it assisted with the establishment and operation of several bird monitoring and banding stations under the Monitoring Avian Productivity and Survivorship (MAPS) demographic monitoring program. To supplement these data, in 2017, in cooperation with base natural resources management staff, IBP developed and carried out a series of point count surveys to detect presence and density of landbirds across the base. The goals of the program are to gain an accurate picture of the summer resident breeding species and their densities on Fort Bragg within the most prevalent habitat types, track population changes in these species over time, and provide information to base natural resource personnel that will help them manage Fort Bragg's terrestrial ecosystems. In 2017, we detected 5,225 individuals of 73 bird species, including species of management interest such as the Red-cockaded Woodpecker (*Leuconotopicus borealis*) and Swainson's Warbler (*Limnothlypis swainsonii*). Density and diversity were relatively evenly distributed across the project area, though some portions of the Fort were not surveyed due to access constraints. We used Bayesian hierarchical modeling to produced density estimates for 23 species. With additional years of data collection, as more data add to the robustness of the density estimation models, it is likely we will be able to develop increasingly precise density estimates, and bring additional species into the model.

Introduction

At more than 255 square miles, Fort Bragg is one of the largest military installations in the world. In addition to training facilities and housing, the base has a variety of natural habitats, including some of the largest remnants of the endangered longleaf pine ecosystem. Competing demands on this landscape, most importantly training and mission readiness -- but also including wildlife, watershed protection, hunting, outdoor recreation, and compliance with federal laws such as the Endangered Species and Migratory Bird Treaty Act -- mean that base managers must balance a variety of activities for multiple stakeholders and objectives.

Fort Bragg has an active land management program that has won several awards for its bird conservation. The Fort Bragg Integrated Natural Resources Management Plan and the Adaptive Ecosystem Management Program Endangered Species Management Component require that migratory birds are considered in natural resource management planning and project implementation. Central to these strategies are the base's efforts to restore and maintain habitat for the federally-endangered Red-cockaded Woodpecker. Current management includes frequent prescribed fires to maintain the open, mature stands of longleaf pine in which the species thrives. In addition to managing for Red-cockaded Woodpecker, one of the primary objectives of base natural resource managers is to understand broader changes to flora and fauna communities so that ecosystem management can proceed in an appropriate direction.

Birds, with their rapid metabolism and high ecological position on most food webs, are excellent indicators of habitat quality and environmental change (Carignan and Villard 2002). In addition, birds' relative abundance in terrestrial ecosystems and their high detectability make them easy and cost-efficient to monitor. From 1995-2009 and 2015-16, base personnel, in collaboration with the Institute for Bird Populations, operated a series of avian demographic monitoring stations under the auspices of the Monitoring Avian Productivity and Survivorship (MAPS) Program (Albert et al. 2017, Nott et al. 2010). The program is designed to examine avian "vital rates" of productivity, survivorship, and recruitment by mist netting and banding birds, and recording the species, age, and sex of birds, and examining various physical parameters. The program developed a baseline of information about landbirds on the base. In order to supplement demographic data, and include a wider suite of species in the monitoring effort, base natural resource managers and IBP jointly decided to initiate a protocol of point counts. The current objectives of the partnership between Fort Bragg and IBP are to:

- Gain an accurate picture of the summer resident breeding species and their densities on Fort Bragg within the most prevalent habitat types.
- Track population changes in these species over time.
- Provide information to base natural resource personnel to promote effective management for a natural suite of species within Fort Bragg's terrestrial ecosystems.

Study Area

Natural vegetation on Fort Bragg is dominated by plant communities associated with the imperiled longleaf pine-wiregrass ecosystem (Table 1, Figures 1 and 2). Of the historical 90-million acres of old-growth longleaf pine ecosystem of the Southeastern U.S., only about 3% remains today. Fort Bragg contains approximately 81,000 contiguous acres, one of the largest remaining blocks of this habitat, and conducts extensive restoration and active management every year. Habitat management goals are largely to support efforts to restore and manage populations of the federally-endangered Red-cockaded Woodpecker, which prefers old-growth pine stands largely free of understory. Other habitats on the Fort include bottomland forest, mixed shrubland, and scattered stands of hardwoods (Table 1).

Table 1. Habitat types on Fort Bragg (data from Fort Bragg GIS Department).

Habitat Type	Acres
Southern Yellow Pine	98,160
Bottomland Forest/Hardwood Swamp	14,031
Mixed Shrubland	6,686
High Intensity Developed	6,535
Managed Herbaceous Cover	5,659
Mixed Upland Hardwoods	5,457
Mixed Hardwoods/Conifer	5,343
Unmanaged Herbaceous Upland	5,065
Unconsolidated Sediment	2,636
Low Intensity Developed	1,229
Deciduous Shrubland	1,208
Cultivated	804
Evergreen Shrubland	706
Oak/Gum/Cypress	692
Water Bodies	636
Unmanaged Herbaceous Wetland	92
Needleleaf Deciduous	22
Total	**154,961**

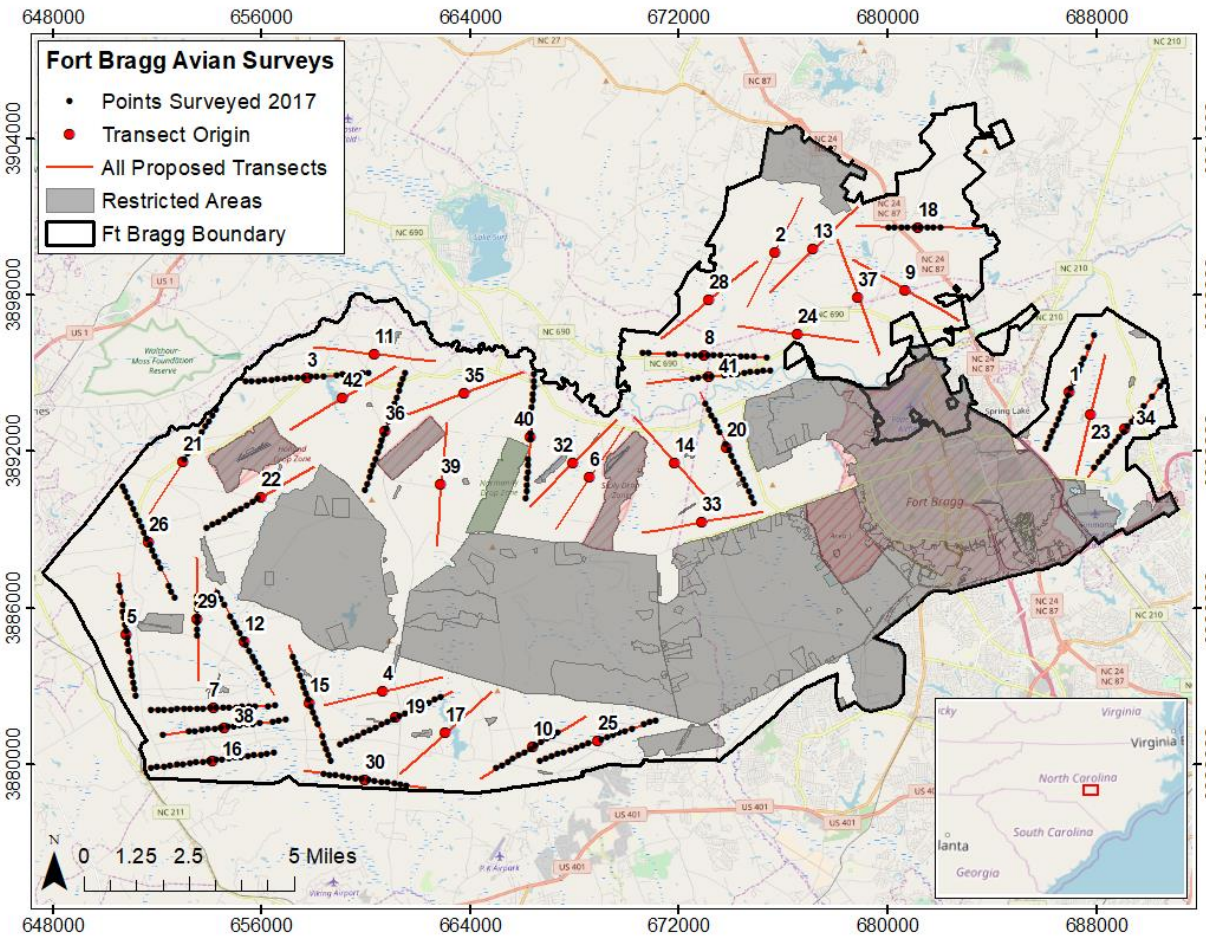

Figure 1. Study area and all transects (surveyed and not surveyed) in relation to off-limits areas at Fort Bragg, 2017. We generated more transects than we could sample to have backup sites in the event of access issues.

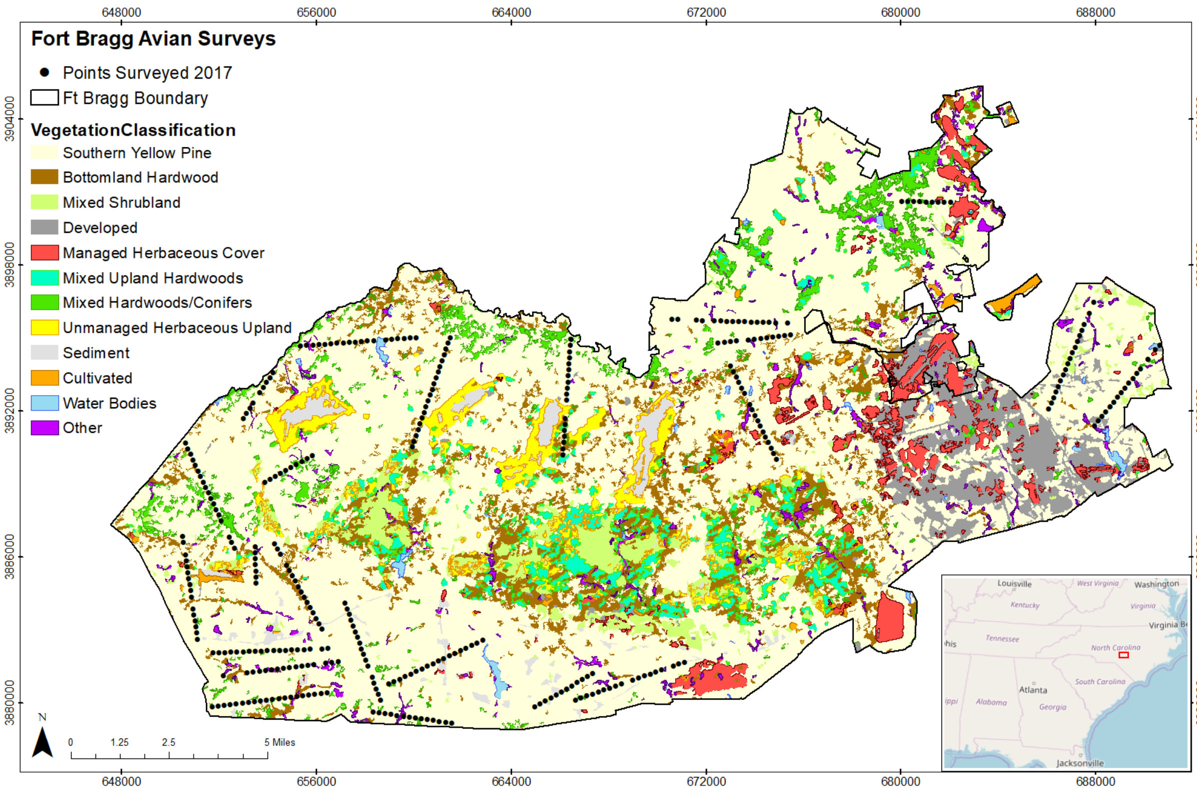

Figure 2. Habitats in the study area (data from Fort Bragg GIS Department), with surveyed points.

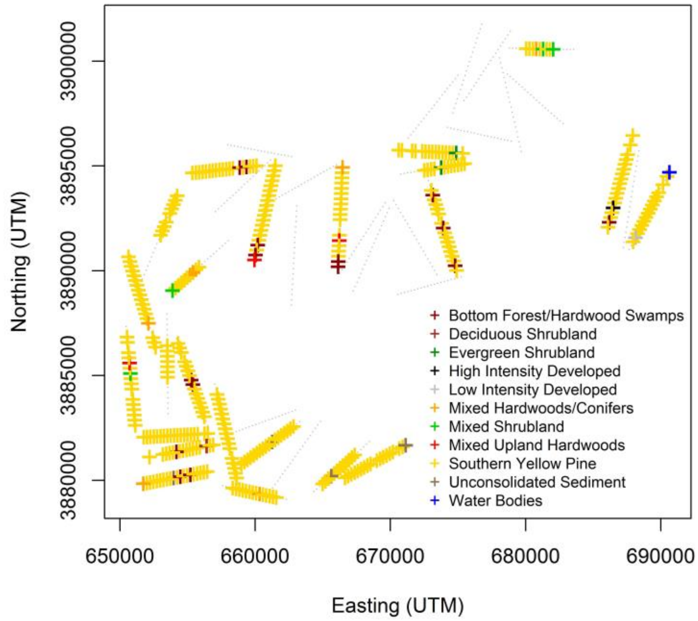

Figure 3. Detail of actual points surveyed by habitat.

Methods

Sample Design

Transects were established in GIS by selecting randomly generated points within the accessible areas of Fort Bragg, i.e. excluding areas of dense development, impact or other off limits areas, the cantonment area, the military landing zone, military drop zones, areas behind locked gates, or any areas determined by base staff to be off limits due to training, sensitivity, or other reasons (Figures 1, 2, and 3). From each random point, we generated a linear transect of 20 points, spaced every 250 m, extending a total of 4,750 meters along a randomly generated bearing (0-360 degrees). Transects that crossed the boundary of surveyable areas or intersected with another existing transect were dropped. Transects were generated iteratively until a total of 40 were sited. This was intentionally more than the number of transects we planned on surveying, but we created extra transects so that we would have survey areas available in the event that some planned transects were permanently or temporarily off limits due to access, training, or other activities. Transects were divided into two halves (A and B) and point numbered A1-A10 and B1-B10, starting at the point closest to the center.

Crew Training and Certification

We deployed two biologists with extensive birding experience and familiarity with birds of the region by sight, song, and call. From May 1 to 5 the biologists were trained in field and data management protocols. For the first 5 days of field studies, the crew worked together so they could gain a familiarity with the base and to verify that they both understood the protocols. From the second week on, they worked independently.

Data Collection

Point count data were collected between May 3 and June 15, 2017. Crew members worked together to survey a single 20-point transect each morning, starting together at the midpoint, and proceeding in opposite directions to the ends, before meeting up again at the termination of their work. They were provided with maps, GPS units, and coordinates with all transect points. In addition, crew members were provided with an electronic copy of the field map, which they downloaded to their smartphones, and used the *Avenza Maps* app, which displayed their real-time location in relation to each transect point on the electronic field map. All of these tools enabled the crews to have high confidence that they had navigated to the selected points to within a few meters or less. Point counts began within 10 minutes of civil sunrise and were completed after surveying all points possible. All points were completed before 11:00 a.m.

At each point observers recorded the starting time, scored the degree of noise interference (e.g., from wind or traffic), recorded the weather conditions, prior to beginning the point count. Counts lasted 7 minutes but were partitioned into three time intervals (0 to 3 min, 3 to 5 min, and 5 to 7 min) to make the data more useful for occupancy modeling, which relies on detection or non-detection of individual birds within discrete intervals to estimate detection probability. Observers noted each time interval in which they detected each individual bird.

Distance estimation is an important part of modeling density. Detection probability of individual birds declines with distance from the observer, at a rate that is generally best modeled individually for each species. Accordingly, observers estimated (or measured with an electronic rangefinder) the horizontal distance to each bird upon initial detection. Observers also recorded whether the distance estimates were based on an aural or visual detection, and whether the bird ever sang during the point count.

After completing their fieldwork each day, observers reviewed each other's data forms for missing or incorrectly recorded data, discussed any interesting or surprising bird detections, and completed a Transect Visit Log summarizing the day's efforts.

Data Management

At the end of each day, data were entered into a Microsoft Access database which was then reviewed for completeness, missing or out-of-range values, and logical consistency; errors were corrected immediately. At the end of the field season, field forms were stored with digital records at the IBP offices in Point Reyes Station, CA. GPS data were downloaded and processed, and the resulting coordinate data were uploaded to the project database.

Data Analysis

Detection probability includes effects of a species' availability for detection (how likely will it sing?) and perceptibility (how likely will we hear it?). Recording the time intervals in which the bird was detected and the distance to the bird enabled analyses that accounted for birds present but undetected during each survey (Royle et al. 2004, Alldredge et al. 2007) – a correction factor that could greatly impact density estimates – using a hierarchical Bayesian model suggested by Amundson et al. (2014). Population density was estimated for species detected frequently enough to support an estimate of detection probability. Observer effects on detection were included, if necessary, to improve model fit. A similar application of hierarchical Bayesian models to point-transect surveys with unequal count intervals was detailed in Ray et al. (2017*a* and 2017*b*), and is described here in brief.

Models that distinguish the *detected population* from the *whole population* are often termed hierarchical (Royle 2004) and involve the creation of a series of sub-models to clarify each level of uncertainty in the relationship. A simple example would involve a count of y individuals from a population of size N and an individual detection probability of p. The hierarchy in this example involves one level at which y is a function of parameters N and p, and another level at which p is a function of potential covariates like observer identity. Bayesian models allow us to estimate the "posterior" probability density of each parameter value, provided that we supply a "prior" probability density summarizing any prior information about the distribution of values the parameter might take. Bayesian methods require estimation of the joint probability density of all model parameters, a computationally intensive process facilitated by simulation methods such as Markov chain Monte Carlo (MCMC). MCMC can be used to sample from the joint posterior distribution of model parameters by following a semi-random walk through parameter space and biasing most steps toward values that increase the probability of obtaining the observed data given the proposed model. If we require that the joint probability of obtaining the observed data generally increases as we step through parameter estimates, then a long series (MCMC chain) of these samples will eventually converge toward the best estimates for each parameter, and plotting a histogram of samples from this vicinity will reveal the shape of each parameter's posterior distribution.

We used the JAGS programmable platform (Plummer 2003) to perform MCMC simulation and to provide summaries of the resulting samples, such as a credible interval (CRI) for each parameter estimate. In this report, a 95% CRI refers to a Bayesian credible interval which contains the value of the focal parameter with a subjective probability of 0.95, assuming an appropriate prior distribution for the parameter. In every case, we used a "flat" prior to minimize any influence on the posterior estimate of each parameter. All analyses and implemented in the R statistical computing environment (R Core Team 2017), using jagsUI (Kellner 2015) to call JAGS from R.

Our hierarchical model accounted for two components of individual detection: 1) availability, the probability that a bird will perform a detectable action, like singing; and 2) perceptibility, the probability that observers will perceive that action. Data from multiple count intervals were used to generate individual detection histories modeled within a closed-population framework to characterize availability (Alldredge et al. 2007). We followed Farnsworth et al. (2002) in modeling availability from time-removal data, in which each detection of a unique individual was assigned to one of three count intervals (minutes 0-3, 3-5 or 5-7), and subsequent detections of the same individual were ignored. We modeled availability as a function of q, the per-minute probability of a bird's failure to sing or otherwise be available for detection. The probability that a bird was present and not available during all three count intervals (totaling seven minutes) was q^7, and availability was $1-q^7$. If covariates of availability were needed to improve model performance, availability could be modeled as a function of point-specific covariates, x_k, as $\text{logit}(q_k) = \alpha_0 + \sum_x \alpha_x x_k$, where subscripts k indicate point. To characterize effects of distance on perceptibility, we first dropped about 10% of the farthest (and presumably least accurate) detections of each species to obtain the maximum effective detection distance (per Kéry and Royle 2016). We then sorted the remaining detection distances into variable-width bins, equalizing the number of detections in each bin (Amundson et al. 2014). We followed Buckland et al. (2001) in modeling the probability of detecting a bird in a given distance bin using the half-normal distribution. The steepness of the half-normal is controlled by shape parameter σ, the decay rate of detections with distance, potentially modeled as a function of point-specific covariates as $\log(\sigma_k) = \log(\sigma_0) + \sum_x \alpha_x x_k$.

We combined these models of q and σ (components of p) with a model of N in an "N-mixture" or binomial mixture model (Royle et al. 2004). N-mixture models typically pair a Poisson model of N (abundance) with a binomial model of y (count). N-mixture models provide a hierarchical extension of generalized linear models (GLMs), linking multiple GLMs to allow for structure in parameters at each hierarchical level (Royle 2004). In this report, a Poisson model of λ (expected N) as a function of environmental covariates is linked with two binomial models expressing detection as functions of survey conditions. Specifically, observed counts y_k are assumed to derive from a binomial distribution with parameters determined by the number of birds available for detection n_k and their probabilities of detection (a function of σ_k), while n_k values derive from a binomial distribution with parameters determined by the true abundance of birds N_k and the probability that each bird present is available for detection (a function of q_k). Finally, N_k values derive from a Poisson distribution with parameter λ (a function of covariates), as

y_k ~ binomial($f(\sigma_k)$,n_k),
n_k ~ binomial($f(q_k)$,N_k) and
N_k ~ Poisson($\lambda = f(x_k)$).

Models of $f(\sigma_k)$, $f(q_k)$ and $\lambda = f(x_k)$ considered in this report are summarized in Table 2.

Table 2. Models used to estimate components of detection probability (*q* = availability and *σ* = perceptibility) and abundance (*λ* = mean of *N*) of landbird populations at Fort Bragg in 2017.

Model	Linear Predictors
A	$\text{logit}(q_k) = \alpha_0$
	$\log(\sigma_k) = \log(\sigma_0)$
	$\log(\lambda_k) = \beta_0 + \beta_1 habitat_k + transect_k^*$
B	$\text{logit}(q_k) = \alpha_0$
	$\log(\sigma_k) = \log(\sigma_0) + a_1 observer$
	$\log(\lambda_k) = \beta_0 + \beta_1 habitat_k + transect_k^*$

Both models in Table 2 allowed for log-linear effects of habitat (vegetation type) and transect on expected N (λ_k). Allowing for a random effect of transect helped account for spatial autocorrelation in counts among point-count stations. The fixed effect of habitat was coded as an effect of Southern Yellow Pine presence (1) or absence (0) at the point-count station, rather than accounting for each vegetation type, due to the predominance of Southern Yellow Pine on the base. Model A included no covariates of detection while model (B) included an observer effect on detection distance.

Mean population density (N per hectare) was calculated by averaging λ_k over all k point-count stations surveyed and then dividing by the effective area surveyed at each station. Effective area surveyed varied with the maximum detection distance for each species ($d_{\max}$), which was taken as the maximum detection distance after censoring the farthest 10% of detection distances for the species. In some cases, we censored additional detection distances to avoid significant covariance in distance- and time-to-detection, which would violate model assumptions. As detailed in Ray et al. (2017 *a*), model convergence of parameter estimates was assessed using the Gelman-Rubin potential scale reduction parameter, R-hat, and visual inspection of MCMC samples from three chains of length 60000, after discarding the first 10000 steps and thinning to

5000 samples. Components of model fit were characterized using Bayesian *P*-values, which suggest adequate fit when in the range 0.1-0.9 and good fit when near 0.5.

Results

Habitats Surveyed and Species Detected

We surveyed 355 points arrayed along 23 transects. A large majority (89%) of surveyed points fell in Southern yellow pine habitat (Figure 3). We detected 5,225 individual birds of 73 species, an average of 14.7 detections per point. The most frequently detected species were Pine Warbler (*Setophaga pinus*), Great-crested Flycatcher (*Myiarchus crinitus*), Mourning Dove (*Zenaida macroura*), Eastern Towhee (*Pipilo erythrophthalmus*), Blue Jay (*Cyanocitta cristata*), Blue-gray Gnatcatcher (*Polioptila caerulea*), Bachman's Sparrow (*Peucaea aestivalis*), Prairie Warbler and Common Yellowthroat (*Geothlypis trichas*) (Table 3, Figure 4). Species combined as "RARE" in Figure 4 were detected fewer than 10 times.

Table 3. Number of individual detections and number of points (out of 355 total points surveyed) with detections during point counts at Fort Bragg, 2017 (for scientific names of species, see Appendix A).

Species	Total number of detections	Number of points with detections	Species	Total number of detections	Number of points with detections
Wood Duck	2	1	Tufted Titmouse	172	148
Mallard	1	1	White-breasted Nuthatch	68	59
Turkey Vulture	1	1	Brown-headed Nuthatch	164	124
Red-shouldered Hawk	1	1	Carolina Wren	163	130
Red-tailed Hawk	4	4	Blue-gray Gnatcatcher	193	139
Wild Turkey	3	3	Eastern Bluebird	100	88
Northern Bobwhite	33	26	Wood Thrush	3	3
Killdeer	1	1	American Robin	53	42
Mourning Dove	244	181	Gray Catbird	9	8
Yellow-billed Cuckoo	67	58	Northern Mockingbird	51	45
Eastern Screech-Owl	1	1	Brown Thrasher	31	24
Barred Owl	2	2	Cedar Waxwing	25	15
Common Nighthawk	44	31	Blue-winged Warbler	20	18
Chimney Swift	10	7	Orange-crowned Warbler	1	1
Ruby-throated Hummingbi	6	6	Yellow-throated Warbler	11	8
Belted Kingfisher	1	1	Pine Warbler	579	293
Red-headed Woodpecker	118	97	Prairie Warbler	186	123
Red-bellied Woodpecker	51	44	American Redstart	3	3
Downy Woodpecker	31	30	Swainson's Warbler	10	8
Hairy Woodpecker	8	6	Ovenbird	36	27
Red-cockaded Woodpecke	98	70	Common Yellowthroat	184	152
Northern Flicker	71	66	Hooded Warbler	9	9
Pileated Woodpecker	74	64	Yellow-breasted Chat	18	17
Eastern Wood-Pewee	143	123	Summer Tanager	181	148
Acadian Flycatcher	7	7	Eastern Towhee	208	146
Great Crested Flycatcher	276	205	Bachman's Sparrow	187	125
Eastern Kingbird	13	10	Chipping Sparrow	97	66
White-eyed Vireo	32	29	Field Sparrow	2	2
Yellow-throated Vireo	9	9	Northern Cardinal	160	130
Blue-headed Vireo	5	5	Blue Grosbeak	86	65
Red-eyed Vireo	24	20	Indigo Bunting	135	103
Blue Jay	203	133	Red-winged Blackbird	10	6
American Crow	182	136	Eastern Meadowlark	3	3
Fish Crow	23	21	Common Grackle	17	10
Purple Martin	5	4	Brown-headed Cowbird	90	75
Barn Swallow	4	4	American Goldfinch	9	8
Carolina Chickadee	113	91			

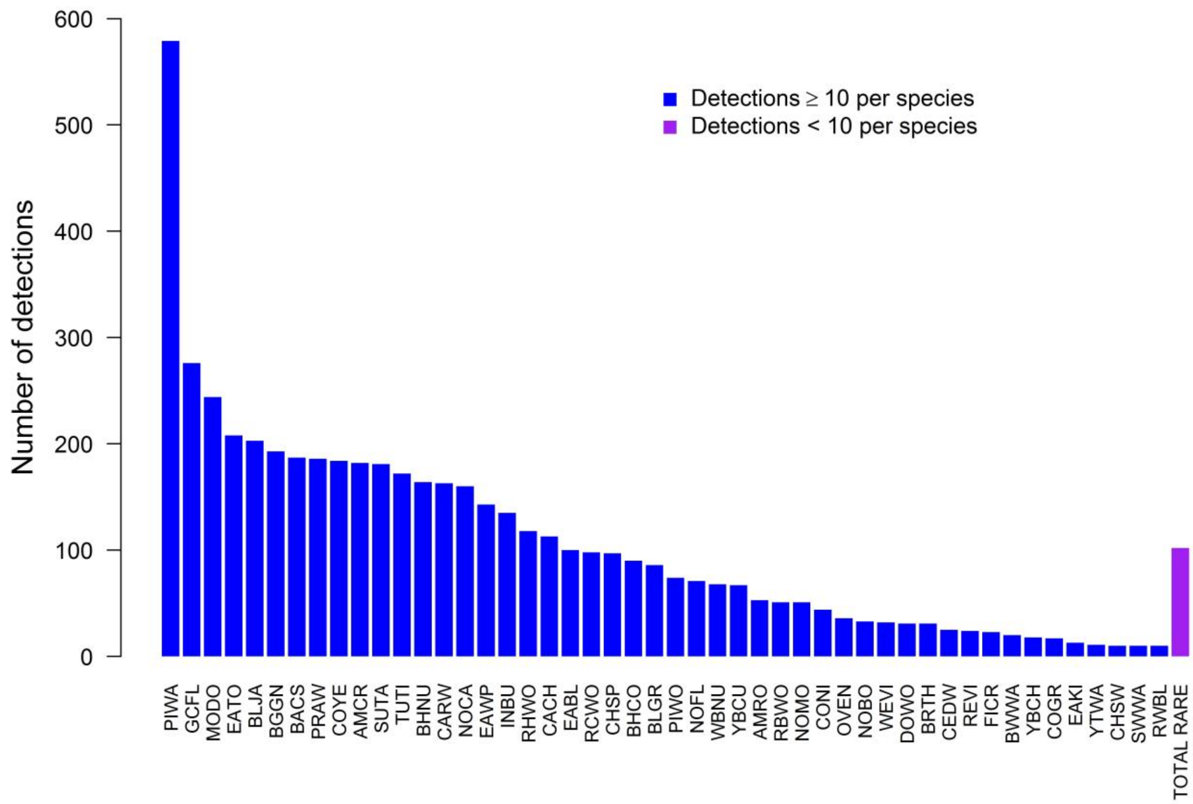

Figure 4. Number of detections, by species, during point counts at Fort Bragg point counts in 2017 (for species abbreviations, see Appendix A). "RARE" pools all species that were detected fewer than 10 times.

Apparent avian abundance was relatively evenly distributed throughout the base (Figure 5). Due to the limited abundance of habitats other than Southern yellow pine, we did not analyze density or species richness data by habitat.

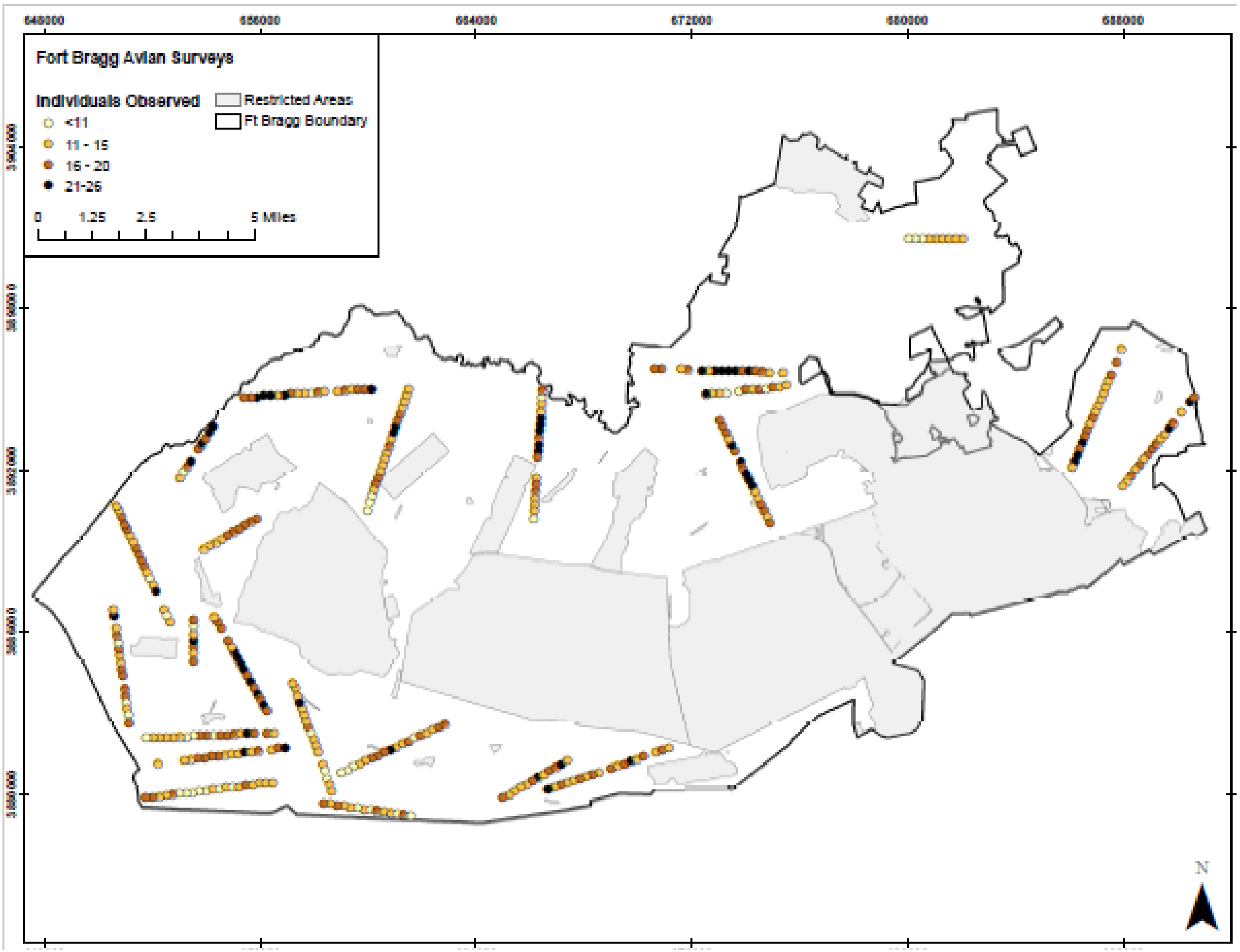

Figure 5. Point counts completed at Fort Bragg in 2017, with number of birds detected. Points with few detections (light circles) and many detections (dark circles) were relatively evenly distributed across the base.

Species Density

We attempted to estimate population density of species with >50 detections. Of 31 such species, we were able to model population density of 24 species with confidence (Table 4 and Figure 6). Although it was possible to fit models of population density using the 98 detections of Red-cockaded Woodpecker, the cooperative breeding system of this species does not conform to the assumptions of our detection sub-model. Therefore, we did not quantify population density for Red-cockaded Woodpecker in this report. Because estimates of population density are sensitive to estimates of detection probability, we report metrics of fit for sub-models of species detectability (Table 4 and Figure 6).

For the sub-model of availability, Bayesian *P*-values cluster near 0.5, suggesting good fit for all species. For the sub-model of detectability, which incorporates both availability and the distance-mediated effects of species perceptibility, Bayesian *P*-values range 0.07-0.92, suggesting adequate fit for all species except Pine Warbler (0.92) and Blue Jay (0.07). Observer effects (Model B) were included only when they were supported and desirable for improving the fit of the detectability sub-model. For Pine Warbler and Blue Jay, however, including an effect of observer on detection distance did not alter fit to the detectability sub-model. In these cases, we also estimated population density using data from one observer at a time. For Pine Warbler, an observer effect was supported and density estimates varied from 1.29 birds/ha when based on observer A data to 3.16 birds/ha for observer B. For Blue Jay, an observer effect was not supported and density estimates varied from 0.31 birds/ha for observer A to 0.18 birds/ha for observer B.

Table 4. Modeled species density (birds per hectare), model type and model fit for 23 commonly-detected species. Terms and models are explained in the text.

	Density (birds/ha)				Bayesian *P*-value[3]	
Species	**Mean estimate**	**Lower 95% CRI[1]**	**Upper 95% CRI**	**Model Type[2]**	**Availability sub-model**	**Detectability sub-model**
Mourning Dove	0.27	0.21	0.34	B	0.52	0.68
Red-headed Woodpecker	0.25	0.18	0.36	A	0.5	0.47
Northern Flicker	0.41	0.1	1.01	A	0.53	0.57
Eastern Wood Pewee	0.22	0.17	0.28	A	0.57	0.83
Great-crested Flycatcher	0.82	0.61	1.12	A	0.48	0.25
Blue Jay	0.22	0.17	0.28	A	0.41	0.07
American Crow	0.08	0.06	0.13	A	0.48	0.47
Tufted Titmouse	0.29	0.22	0.39	B	0.56	0.63
White-breasted Nuthatch	0.31	0.17	0.68	A	0.52	0.48
Brown-headed Nuthatch	0.76	0.61	0.96	A	0.59	0.88
Carolina Wren	0.29	0.21	0.39	A	0.54	0.75
Blue-gray Gnatcatcher	1.44	1.14	1.83	A	0.51	0.67
American Robin	0.14	0.08	0.28	A	0.47	0.25
Eastern Towhee	0.48	0.39	0.59	B	0.5	0.64
Bachman's Sparrow	0.3	0.24	0.38	A	0.47	0.26
Chipping Sparrow	0.56	0.35	0.97	B	0.42	0.13
Common Yellowthroat	0.41	0.33	0.51	A	0.54	0.87
Pine Warbler	2.14	1.88	2.41	B	0.53	0.92
Prairie Warbler	0.26	0.2	0.33	A	0.46	0.26
Summer Tanager	0.41	0.33	0.52	A	0.52	0.76
Northern Cardinal	0.55	0.39	0.85	A	0.54	0.75
Blue Grosbeak	0.22	0.16	0.3	A	0.49	0.36
Indigo Bunting	0.42	0.32	0.58	A	0.5	0.53

[1]The 95% Bayesian CRI contains the target parameter (mean density) with probability 0.95.
[2]Model A included no covariates; model B included an observer effect on the distance-mediated detection rate.
[3]Bayesian *P*-values near 0.5 suggest good model fit; values ranging 0.1-0.9 suggest adequate fit.

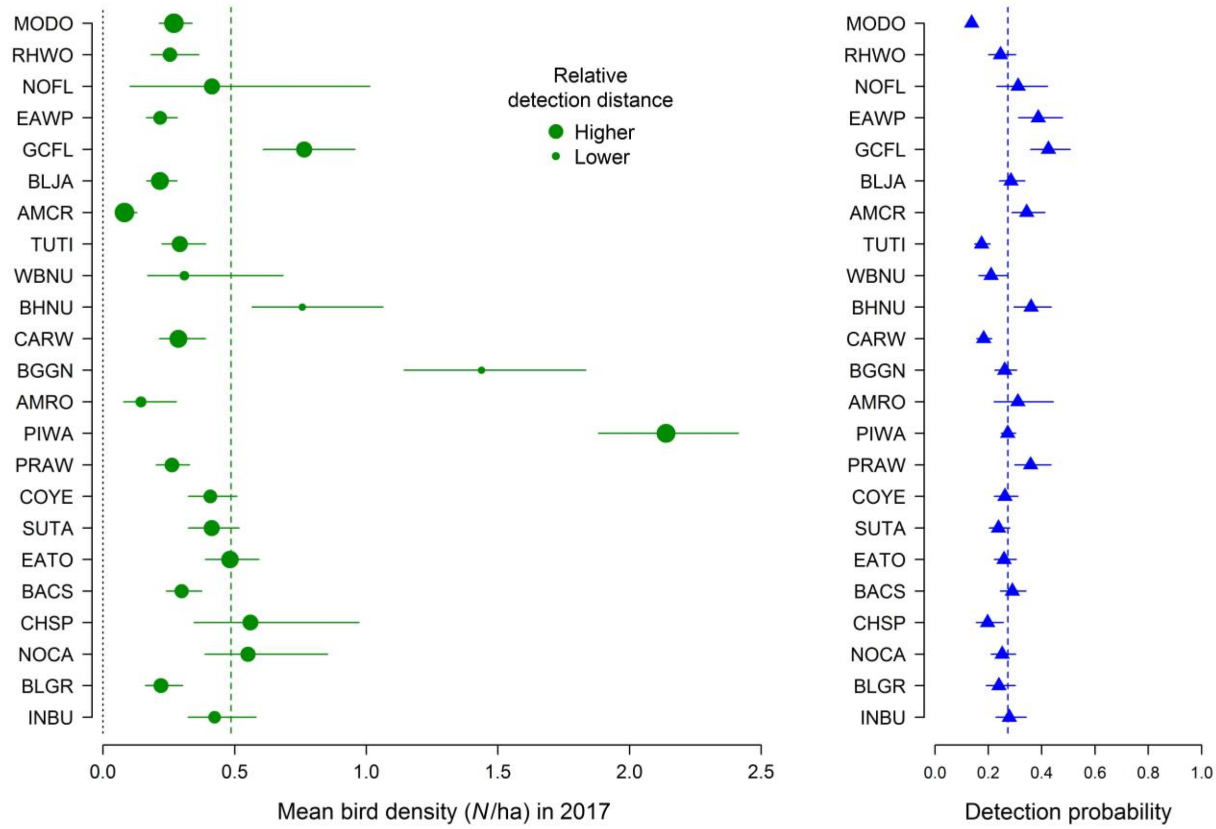

Figure 6. Estimates of population density (left-hand panel) and detection probability (right-hand panel) for 23 species commonly detected in 2017 point counts, including 95% credible intervals for each species (horizontal lines) and means across species (dashed vertical lines). Species are listed in descending order of raw count to illustrate influences of maximum detection distance (relative dot sizes) and detection probability on the relationship between raw count and estimated density. Detection probability includes effects of a bird's availability for detection (how likely will it sing?) and perceptibility (how likely will we hear it?). Species abbreviations are listed in Appendix A.

These density estimates are similar to values reported by other studies of several of these species conducted within the southeastern United States. For example, our estimate of 2.14 Pine Warblers/ha was similar to estimates from several other studies (Johnston and Odom 1956) and our density estimates were similar to other regional estimates for Blue Gray Gnatcatcher (Strom 1983, Christman 1983), Brown-headed Nuthatch (Hamel 1992) Northern Cardinal (Halkin and Linville 1999). In addition, as additional years of data are gathered, the precision of the density model will increase, and enable us to track changes over time.

Species of Management Interest

In addition to Red-cockaded Woodpecker, base natural resource managers expressed an interest in Swainson's Warbler, a species which may be declining regionally (North American Breeding Bird Survey 2018). Over the course of the field season, Swainson's Warbler was detected 10 times, including six detections by one observer and four by the other (multiple observers detecting by song and at short distances reduces the possibility of false detections). The warblers sang in 9 of 10 cases, and observation distances ranged from 25 to 100 meters (mean = 56 m). Taken together, these results strongly suggest the presence of breeding Swainson's Warblers on the base in 2017. Nine of the 10 detections occurred in Southern Yellow Pine, and one in Bottomland Hardwood Forest (Figure 7).

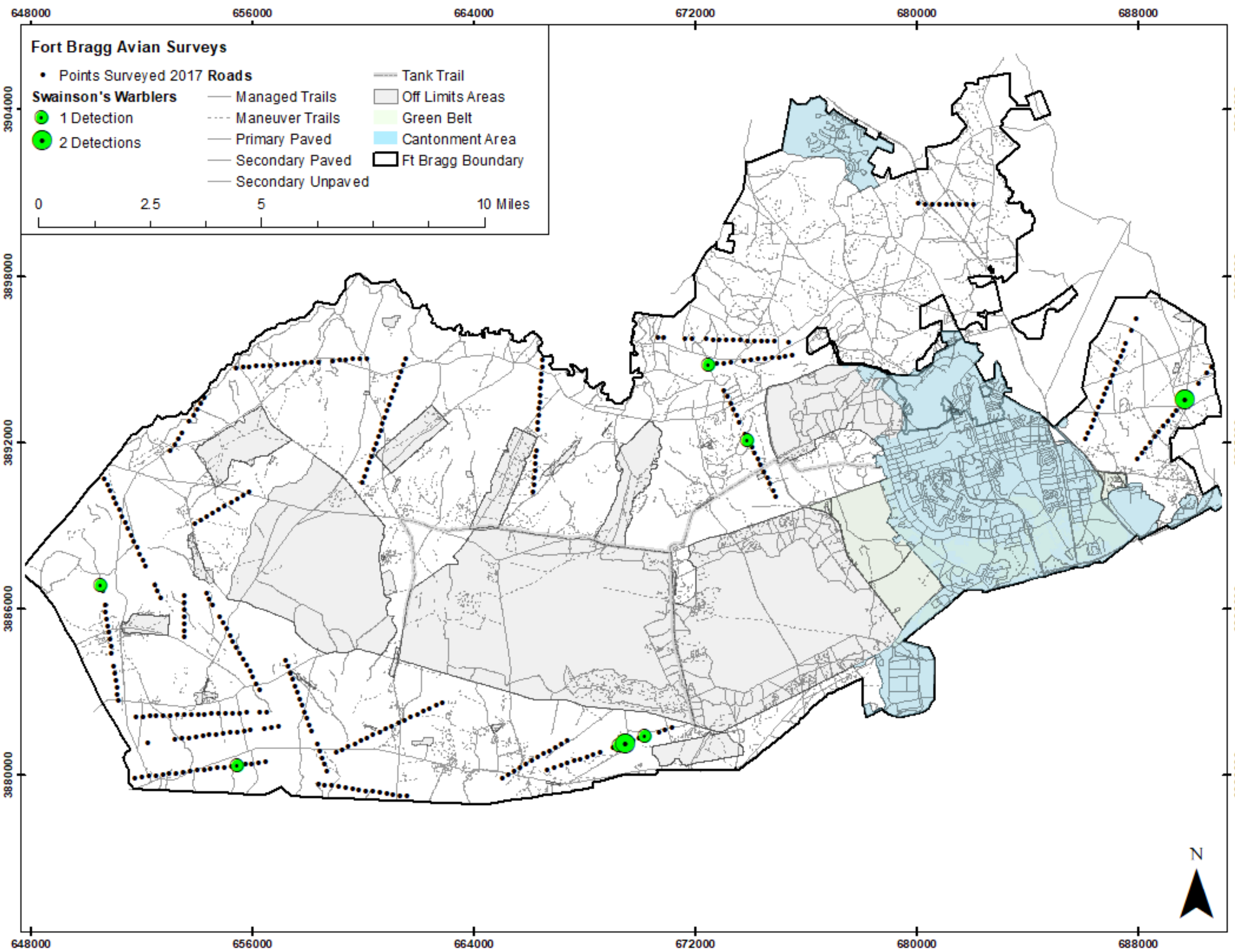

Figure 7. Swainson's Warbler detections during point counts in 2017.

Discussion

The sample sizes obtained from point-count surveys in 2017 allowed us to estimate population density for 23 species, including most species that were detected at least 50 times. Adding additional years of data will allow us to estimate annual densities for species encountered fewer than 50 times per year, because the number of total detections across years will likely rise faster than the number of parameters estimated from the data. In addition, we will likely be able to add additional species into density estimates in future years as cumulative sample sizes become more robust.

Effects of habitat on population density

The generally positive effect of the southern yellow pine (SYP) habitat type on several species that we detected was an expected result, as many of the species have a known affinity with this habitat. Other habitats are much less common and widely scattered, limiting our ability to use habitat effect as a variable. If habitat effects are a key question for some species in the future, we could increase the number of point-count stations in non-SYP habitats to address this.

Survey point locations

The subset of points selected for survey can vary among years without compromising annual estimates of population density across the base. As long as points surveyed are drawn from the original set of 800 points selected to represent the sampling frame, population density estimates will be comparable across years. The modeling framework used here is robust to any number of years of missing data from each point-count station, because population density is actually estimated for every point and year in the dataset, provided appropriate covariates exist or can be estimated for each point in each year (Kéry and Royle 2016).

Summary and Next Steps

The point count approach and our protocols and analysis provided a successful approach for estimating the density of nearly two dozen landbird species at Fort Bragg, including species of management concern. Density estimates for all species analyzed were similar to regional estimates for the same species. Increasing data size and refining distance estimation in the coming years will increase the accuracy of the model and the subsequent density estimates, and likely enable estimates of additional species. Combined with historic demographic data from the MAPS program, we are developing a more complete picture of avian population dynamics on the base. In addition the addition of stratified random sampling transects in habitats other than southern yellow pine may yield estimates for species not captured in southern yellow pine habitat. There appears to be enough habitat in some areas to accommodate this modification.

Literature Cited

Albert, S., D. Kaschube, and R. Taylor. 2017. The 2016 Annual Report of the Monitoring Avian Productivity and Survivorship (MAPS) Program on Fort Bragg, North Carolina. The Institute for Bird Populations, Point Reyes Station, CA.

Alldredge, M.W., K.H. Pollock, T.R. Simons, J.A. Collazo, and S.A. Shriner. 2007. Time-of-detection method for estimating abundance from point-count surveys. Auk 124:653.Sauer, J.R., J.E. Hines, and J. Fallon. 2008. The North American breeding bird survey, results and analysis 1966-2007. Version 5.15.2008. USGS Patuxent Wildlife Research Center, Laurel, MD.

Amundson, C.L., J.A. Royle, and C.M. Handel. 2014. A hierarchical model combining distance sampling and time removal to estimate detection probability during avian point counts. 131:476–494.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers, and L. Thomas. 2001. Introduction to distance sampling. Oxford University Press, Oxford, United Kingdom.

Carignan, V., and M.A. Villard. 2002. Selecting indicator species to monitor ecological integrity: a review. Environmental Monitoring and Assessment 78:45-61.

Christman, S.P. 1983. Mississippi Delta bottomland hardwoods (unmanaged). American Birds 37:67.

Farnsworth, G.L., K.H. Pollock, J.D. Nichols, T.R. Simons, J.E. Hines, and J.R. Sauer. 2002. A removal model for estimating detection probabilities from point-count surveys. Auk 119:414–425.

Halkin, S.L. and S.U. Linville. 1999. Northern Cardinal (*Cardinalis cardinalis*), version 2.0. In: The Birds of North America (P.G. Rodewald, editor). Cornell Lab of Ornithology, Ithaca, New York.

Hamel, P. B. 1992. Land manager's guide to the birds of the south. The Nature Conservancy, Chapel Hill, North Carolina and the U.S. Forest Service, Southern Region.

Johnston, D.W., and E.P. Odum. 1956. Breeding bird populations in relation to plant succession on the Piedmont of Georgia. Ecology 37:50-62.

Kellner, K. 2015. jagsUI: a wrapper around 'rjags' to streamline 'JAGS' analyses. R package version 1.3.7. http://CRAN.R-project.org/package=jagsUI.

North American Breeding Bird Survey. 2018. Swainson's Warbler, *Limnothlypis swainsonii*, BBS Trend, 1966-1996.

Nott, M.P., P. Pyle, and D.R. Kaschube. 2010. The 2009 report of the Monitoring Avian Productivity and Survivorship (MAPS) Program on Fort Bragg, North Carolina. The Institute for Bird Populations, Point Reyes Station, CA.

Plummer, M. 2003. JAGS: A program for analysis of Bayesian graphical models using Gibbs sampling. Pages 1-10 in Hornik, K., F. Leisch, and A. Zeileis (eds.), Proceedings of the 3rd International Workshop on Distributed Statistical Computing (DCS2003), March 20–22, Technische Universität, Vienna, Austria.

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Ray, C., J.F. Saracco, M.L. Holmgren, R.L. Wilkerson, R.B. Siegel, K.J. Jenkins, J.I. Ransom, P.J. Happe, J.R. Boetsch, and M.H. Huff. 2017 a. Recent stability of resident and migratory landbird populations in National Parks of the Pacific Northwest. Ecosphere 8:e01902.

Ray, C., J. Saracco, K. Jenkins, M. Huff, P. Happe, and J. Ransom. 2017 b. Development of a robust analytical framework for assessing landbird population trends, dynamics and relationships with environmental covariates in the North Coast and Cascades Network. National Park Service Natural Resource Report NPS/NCCN/NRR—2017/1483. National Park Service, Fort Collins, Colorado.

Royle, J.A. 2004. N-mixture models for estimating population size from spatially replicated counts. Biometrics 60:08–115.

Strom, K. 1983. Virgin hardwood swamp forest. American Birds 37:65.

Appendix A. Common and Scientific Names of Species Detected

Common Name	Abbr.	Scientific Name	Common Name	Abbr.	Scientific Name
Wood Duck	WODO	*Aix sponsa*	Tufted Titmouse	TUTI	*Baeolophus bicolor*
Mallard	MALL	*Anas platyrhynchos*	Brown-headed Nuthatch	BHNU	*Sitta pusilla*
Northern Bobwhite	NOBO	*Colinus virginianus*	White-breasted Nuthatch	WBNU	*Sitta carolinensis*
Wild Turkey	WITU	*Meleagris gallopavo*	Carolina Wren	CARW	*Thryothorus ludovicianus*
Mourning Dove	MODO	*Zenaida macroura*	Blue-gray Gnatcatcher	BGGN	*Polioptila caerulea*
Yellow-billed Cuckoo	YBCU	*Coccyzus americanus*	Eastern Bluebird	EABL	*Sialia sialis*
Common Nighthawk	CONI	*Chordeiles minor*	Wood Thrush	WOTH	*Hylocichla mustelina*
Chimney Swift	CHSW	*Chaetura pelagica*	American Robin	AMRO	*Turdus migratorius*
Ruby-throated Hummingbird	RTHU	*Archilochus colubris*	Gray Catbird	GRCA	*Dumetella carolinensis*
Killdeer	KILL	*Charadrius vociferus*	Brown Thrasher	BRTH	*Toxostoma rufum*
Turkey Vulture	TUVA	*Cathartes aura*	Northern Mockingbird	NOMO	*Mimus polyglottos*
Red-shouldered Hawk	RSHA	*Buteo lineatus*	Cedar Waxwing	CEDW	*Bombycilla cedrorum*
Red-tailed Hawk	RTHA	*Buteo jamaicensis*	American Goldfinch	AMGO	*Spinus tristis*
Eastern Screech-Owl	EASO	*Megascops asio*	Eastern Towhee	EATO	*Pipilo erythrophthalmus*
Barred Owl	BAOW	*Strix varia*	Bachman's Sparrow	BACS	*Peucaea aestivalis*
Belted Kingfisher	BEKI	*Megaceryle alcyon*	Chipping Sparrow	CHSP	*Spizella passerina*
Red-headed Woodpecker	RHWO	*Melanerpes erythrocephalus*	Field Sparrow	FISP	*Spizella pusilla*
Red-bellied Woodpecker	RBWO	*Melanerpes carolinus*	Yellow-breasted Chat	YBCH	*Icteria virens*
Downy Woodpecker	DOWO	*Picoides pubescens*	Eastern Meadowlark	EAME	*Sturnella magna*
Hairy Woodpecker	HAWO	*Leuconotopicus villosus*	Red-winged Blackbird	RWBL	*Agelaius phoeniceus*
Red-cockaded Woodpecker	RCWO	*Leuconotopicus borealis*	Brown-headed Cowbird	BHCO	*Molothrus ater*
Northern Flicker	NOFL	*Colaptes auratus*	Common Grackle	COGR	*Quiscalus quiscula*
Pileated Woodpecker	PIWO	*Hylatomus pileatus*	Ovenbird	OVEN	*Seiurus aurocapillus*
Eastern Wood-Pewee	EAWP	*Contopus virens*	Blue-winged Warbler	BWWA	*Vermivora cyanoptera*
Acadian Flycatcher	ACFL	*Empidonax virescens*	Swainson's Warbler	SWWA	*Limnothlypis swainsonii*
Great-crested Flycatcher	GCFL	*Myiarchus crinitus*	Orange-crowned Warbler	OCWA	*Vermivora celata*
Eastern Kingbird	EAKI	*Tyrannus tyrannus*	Common Yellowthroat	COYE	*Geothlypis trichas*
White-eyed Vireo	WEVI	*Vireo griseus*	Hooded Warbler	HOWA	*Setophaga citrina*
Yellow-throated Vireo	YTVI	*Vireo flavifrons*	American Redstart	AMRE	*Setophaga ruticilla*
Blue-headed Vireo	BHVI	*Vireo solitarius*	Pine Warbler	PIWA	*Setophaga pinus*
Red-eyed Vireo	REVI	*Vireo olivaceus*	Yellow-throated Warbler	YTWA	*Setophaga dominica*
Blue Jay	BLJA	*Cyanocitta cristata*	Prairie Warbler	PRAW	*Setophaga discolor*
American Crow	AMCR	*Empidonax virescens*	Summer Tanager	SUTA	*Piranga rubra*
Fish Crow	FICR	*Corvus ossifragus*	Northern Cardinal	NOCA	*Cardinalis cardinalis*
Purple Martin	PUMA	*Progne subis*	Blue Grosbeak	BLGR	*Passerina caerulea*
Barn Swallow	BASW	*Hirundo rustica*	Indigo Bunting	INBU	*Passerina cyanea*
Carolina Chickadee	CACH	*Poecile carolinensis*			