



Bird Community Monitoring at New River Gorge National River, Gauley River National Recreation Area, and Bluestone National Scenic River, 1997 – 2018

Natural Resource Report NPS/NERI/NRR—2022/2341



ON THE COVER

New River Gorge, New River Gorge National River
Photograph by: Matthew DeSaix

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Natural Resource Report NPS/NERI/NRR—2022/2341

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Abstract

Birds are prominent features of National Park Service (NPS) lands and are effective indicators for monitoring ecosystem health. Assessing the temporal change of avian species abundance depends on long-term monitoring of bird communities and trends, however long-term monitoring programs are generally uncommon. In this report, we summarize 22 years (1997-2018) of point count data across five sites on West Virginia NPS lands (three in New River Gorge National River, one in Gauley River National Recreation Area, and one in Bluestone National Scenic River) and compare these results to our analysis of Breeding Bird Survey data for the same time period across all of West Virginia. The objectives of this analysis are two-fold: 1) describe the biotic integrity of the NPS lands in West Virginia and 2) quantify trends in guilds and species abundance. During the 20-year period of this survey, 85 breeding resident species were detected. The West Virginia NPS lands are home to stable populations of Wood Thrush and Yellow-billed Cuckoo, both species of continental concern by Partners in Flight. Seven species have declined precipitously on NPS lands during this time period. Three of these species are also experiencing declines across the rest of West Virginia (Blue-gray Gnatcatcher, Carolina Chickadee, Kentucky Warbler), but the other 4 species are stable across West Virginia (Acadian Flycatcher, Black-throated Green Warbler, Northern Parula, Swainson's Warbler). Four species that are declining across West Virginia (Great Crested Flycatcher, Indigo Bunting, Red-eyed Vireo, and Worm-eating Warbler) are stable on southern West Virginia NPS lands. Additionally, the upper-canopy foraging guild of species has decreased significantly on NPS lands in southern West Virginia. An analysis of community biotic integrity revealed that the southern West Virginia NPS lands have been stable at a rating of high biotic integrity every year for the duration of this survey. Future research should delve into the underlying factors that may be driving the trends in abundance at different scales.

Acknowledgements

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Introduction

Across North America, the majority of avian species exhibit significant declines, and this has resulted in an overall 29% decline in abundance since 1970 (Rosenberg et al. 2019). Assessing the temporal change of avian species abundance depends on long-term monitoring of bird communities and trends; however, long-term monitoring programs are generally uncommon. In the New River Gorge National River (NERI), Gauley River National Recreation Area (GARI), and Bluestone National Scenic River (BLUE), the National Park Service (NPS) has conducted avian point count surveys for over 20 years. The goal of the avian monitoring program is to provide status and trends data on the bird communities of these southern West Virginia NPS lands.

The combined NPS management areas of NERI, GARI, and BLUE total 88,625 acres and are classified as Appalachian mixed mesophytic forest. Avian species of eastern forests are estimated to have experienced declines among 63% of species with an estimated 18% loss in abundance since 1970 (Rosenberg et al. 2019). One specific threat to the Eastern hemlock (*Tsuga canadensis*) forests of West Virginia is the hemlock woolly adelgid (*Adelgis tsugae*). Since the 1950s, eastern hemlocks have been declining in the United States due to infestation by hemlock woolly adelgid (HWA; Havill et al. 2014). These forests provide dense canopy growth for avian species and create high quality aquatic habitat by providing cool refuges in streams (Ross et al. 2003). HWA was not detected in the vicinity of the New River Gorge National River until 2002. There are many concerns that the loss of hemlock forests will drastically impact the species that rely on them.

Birds are a useful ecological indicator since they serve a prominent role in numerous ecosystems (O'Connell et al. 2000) and their response to disturbances (e.g. habitat loss) are well-studied (Faaborg et al. 1995, Rosenberg et al. 1999). Additionally, birds are cost-effective ecological indicators as many species are readily detectable with a single survey method (Ralph et al. 1995). Furthermore, birds are an important factor contributing to visitation of NPS lands and wildlife watchers as a whole contribute roughly \$80 billion to the U.S. economy (USDOI 2016).

In this report, we summarize 22 years (1997-2018) of point count data across five sites (three in NERI, one in GARI, and one in BLUE; Figure 1) on NPS lands in West Virginia. Analyzing long-term bird data will provide more specific information regarding the status of bird communities on these NPS lands in relation to bird communities across West Virginia. The objectives of this analysis are two-fold:

- 1) Describe the biotic integrity of the National Park Service lands in southern West Virginia
- 2) Quantify trends in guilds and species abundance

In order to compare avian trends on NPS managed land with a broader area, we also analyze West Virginia Breeding Bird Survey (BBS) data for the same time period, following best practices by the United States Geological Survey (Link and Sauer 2002, Link and Sauer 2011). These results provide the first comprehensive analysis of these point count data and will provide a valuable contribution to effective natural resource management decision-making regarding bird communities in this region.

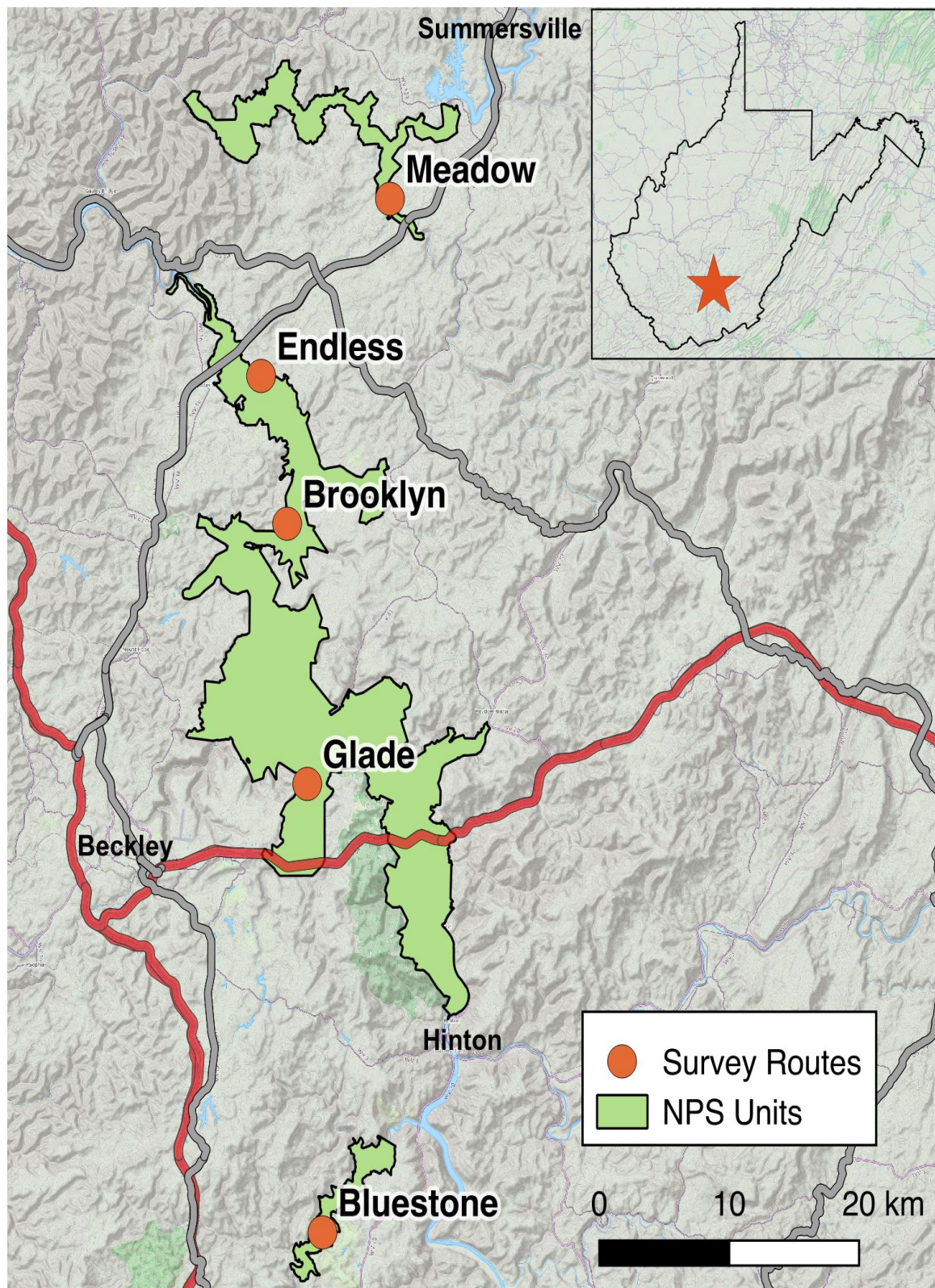


Figure 1. Survey locations (from north to south) in Gauley River National Recreation Area, New River Gorge National River, and Bluestone National Scenic River.

Methods

Survey Routes

The first point count routes (Brooklyn and Glade Creek) were established in 1997 in NERI. The Brooklyn route runs along the former Chesapeake and Ohio Railroad path between Brooklyn Mine Tipple and Fire Creek Pool. The Glade Creek route begins at the Glade Creek Trailhead, following the creek upstream. The following year, two more survey routes were established: Meadow River in GARI and Bluestone River Lodge in BLUE. The Meadow River route follows the abandoned railroad along the Meadow River, beginning at the mouth of Hedrick's Creek and ending at Carnifex Tunnel. The Bluestone River Lodge route was established along the Bluestone Turnpike Trail. The Endless Wall route was established in NERI in 2009 and it follows the Endless Wall Trail on the northern rim of the New River Gorge. Four of the routes are comprised of 20 points, and Endless Wall consists of 14 points. Between 1997 and 2009, sampling efforts among the different survey routes were variable and there was no sampling at any survey route in 2007 (Table 1). The elevation of the points across all sites ranged from 310 to 585 meters (m), with Bluestone River Lodge at 447 to 472 m, Brooklyn at 310 to 349 m, Endless Wall at 484 to 585 m, Glade Creek at 370 to 489 m, and Meadow River at 421 to 498 m. The total length of the routes ranged from 2.7 to 4.9 kilometers (km), with Bluestone River Lodge at 4.7 km, Brooklyn at 4.8 km, Endless Wall at 2.7 km, Glade Creek at 4.1 km, and Meadow River at 4.5 km.

Table 1. Number of point count survey points surveyed by route per year in three National Park Service units in southern West Virginia.

Year	Brooklyn	Glade	Bluestone	Meadow	Endless
1997	20	20	–	–	–
1998	20	–	20	20	–
1999	20	20	20	20	–
2000	20	20	20	20	–
2001	20	20	20	20	–
2002	20	20	20	20	–
2003	20	–	20	20	–
2004	20	–	20	20	–
2005	20	–	20	20	–
2006	20	–	20	20	–
2007	–	–	–	–	–
2008	–	–	20	–	–
2009	20	20	20	20	14
2010	20	20	20	20	14
2011	20	20	20	20	14
2012	20	20	20	20	14
2013	20	20	20	20	14

Table 1 (continued). Number of point count survey points surveyed by route per year in three National Park Service units in southern West Virginia.

Year	Brooklyn	Glade	Bluestone	Meadow	Endless
2014	20	20	20	20	14
2015	20	20	20	20	14
2016	20	20	20	8	14
2017	20	20	20	20	14
2018	20	20	20	20	14

Field Methods

The point count routes were established following a protocol developed by the West Virginia Department of Natural Resources Nongame Wildlife and Natural Heritage Program in conjunction with the West Virginia Partners in Flight. Routes were limited to no more than 20 points to ensure that surveyors had sufficient time to survey all points within the optimal time parameters. Surveys began approximately at sunrise and were completed by 10:00 A.M. Most of the routes were surveyed between June 1 and June 30, though some surveys were completed as early as May 30 and as late as July 3. This timing was established to limit the surveys to summer breeding species and avoid counting passage migrants. Each survey route was conducted by one experienced observer who could identify bird species by sight and sound, with an emphasis on knowing the songs and calls.

The protocol set the survey time period at 5 minutes and was split between two time intervals: 0-3 minutes and 3-5 minutes. When only considering the 0-3 minute interval, the point count methods in this study are directly comparable to the BBS (Ralph et al. 1995). The distance between points on a survey route varied, but the minimum distance in closed forest was 250 m. In more open terrain, the distance was increased from 250 m to reduce the occurrence of individual birds being counted on multiple points. Distances to birds were also recorded for two categories: 1) within 50 m from the point, 2) greater than 50 m from the point. Surveys were not conducted in adverse weather conditions (i.e. rain, dense fog, high winds, etc.).

Data Analysis

All analyses were conducted in R 3.6.1 (R Core Team 2019). The main objectives were to characterize the following:

- Trends in Species Abundance
- Community Biotic Integrity

Trends in Species Abundance

The total number of detections for all species encountered across routes were summarized for 1997-2018. Detections were only considered from the distance categories of within 50 m and greater than 50 m from the point count site, but not flyovers. Detections were included for identification made by both sight and sound (songs and calls). Additionally, the species list was filtered to only include likely breeding residents (i.e., late-spring migrants were removed). All species names have been recorded with the common name in the text and four-letter alpha code in the figures.

We used a log-linear hierarchical model for analyzing changes in species abundance (Link and Sauer 2002, Link and Sauer 2011). This model is the standard approach for the analysis of BBS data by the United States Geological Survey and we replicated the model in order to standardize our results with BBS analysis methods (Link and Sauer 2002, Link and Sauer 2011). In short, counts are modeled as independent Poisson random variables with means that are log-linear functions of the explanatory variables.

$$\log(\lambda_{i,j,t}) = S_i + \beta_i(t - t^*) + \omega_j + \gamma_{i,t} + \varepsilon_{i,j,t} + \eta I[j, t]$$

The explanatory variables are stratum-specific intercepts (S) and slopes (β ; where t^* is the baseline year), observer-route combination (ω), year (γ), novice observer (η ; with the indicator function of whether it is an observer's first year conducting BBS counts), and overdispersion effects (ε). For the analysis of the NPS point count data, all routes were considered part of the same stratum. The hierarchical model requires the specification of prior distributions and we followed the suggestions by Link and Sauer (2011). Parameters S , η , and β were given diffuse normal distributions (mean 0, variance 10^6). Observer-route (ω), year (γ), and overdispersion (ε) effects were treated as mean zero normal random variables. Variances were limited to diffuse inverse gamma prior distributions (scale and shape set to 0.001). The annual indices of abundance are exponentiated sums of stratum, year, and trend effects scaled by the proportion of routes in the stratum of which a species was observed:

$$n_{i,t} = z_i \exp(S_i + \beta_i(t - t^*) + \gamma_{i,t} + 0.5\sigma_\omega^2 + 0.5\sigma_\varepsilon^2)$$

We followed the Link and Sauer (2002) definition of trends as an interval-specific geometric mean of yearly changes in the population size. Thus, we calculated the trend from 1997 to 2018 as:

$$B_i = \left\{ \frac{n_{i,t_b}}{n_{i,t_a}} \right\}^{\frac{1}{t_b - t_a}}$$

where $t_b = 2018$ and $t_a = 1997$. The yearly percent change was calculated by $100(B-1) \%$.

The models were fit using Markov chain Monte Carlo as implemented in the program JAGS (Plummer 2003) through the R package bbsBayes (Smith and Edwards 2020). Model convergence was verified by the Rhat statistic – that is, parameter estimates were considered converged once the Rhat statistic was less than 1.1. Trends were considered significant if the 95% confidence intervals of the trend estimate were completely above 0 (positive significant trend) or below 0 (negative significant trend). In addition, we used to posterior trend estimates of individual species to estimate the trends of different guilds (Table 2) that were relevant to the Bird Community Index estimates (see next section).

Table 2. The 16 response guilds as outlined by O’Connell et al. (2000) are defined by three different biotic integrity elements (functional, compositional, and structural) and are broken up into defining species as specialists or generalists. An “X” indicates that condition exists for that element and an en-dash (–) indicates that it is not. The BCI was specifically developed for the mid-Atlantic highlands region and a higher BCI score is reflected by a larger proportion of specialist species in the community.

Biotic Integrity Element	Response Guild	Specialist	Generalist
Functional	Omnivore	–	X
Functional	Bark prober	X	–
Functional	Ground gleaner	X	–
Functional	Upper-canopy forager	X	–
Functional	Lower-canopy forager	X	–
Compositional	Exotic/non-native	–	X
Compositional	Resident	–	X
Compositional	Temperate migrant	–	X
Compositional	Single-brooded	X	–
Compositional	Nest predator/Brood parasite	–	X
Structural	Canopy nester	X	–
Structural	Shrub nester	–	X
Structural	Forest-ground nester	X	–
Structural	Open-ground nester	X	–
Structural	Forest generalist	–	X
Structural	Interior forest obligate	X	–

In order to compare the trends in abundance from the NPS point counts with the broader region, we also analyzed the BBS point count data for West Virginia with all of the same species and across the same time interval (1997 – 2018). We downloaded all raw BBS data from 1997-2018 for the relevant species and implemented the same log-linear hierarchical model as explained previously.

Community Biotic Integrity

A primary purpose of the bird monitoring protocol is to describe the biotic integrity of the NPS resources. To do this, we implemented the bird community index (BCI), an index of biotic integrity that is based on the breeding bird community composition of the central Appalachians (O’Connell et al. 2000). The BCI was originally developed as a component of the U.S. Environmental Protection Agency, Environmental Monitoring and Assessment Program’s Mid-Atlantic Highlands Assessment (O’Connell et al. 2000). BCI values are based on 16 response guilds and the relationship of the guild to different elements of biotic integrity (Table 2). Bird species are assigned to different response guilds and BCI describes the overall bird community’s biotic integrity based on the proportion of each response guild present (O’Connell et al. 2000). The calculation of BCI is outlined in detail in Marshall et al. (2012). BCI values are further categorized by ecological condition: highest integrity = 60.1-77.0, high integrity = 52.1-60.0, medium integrity = 40.1-52.0, low integrity = 20.5-40.0 (O’Connell et al. 2000). While previous studies have used raw detections to measure BCI (Marshall

et al. 2013), we estimated BCI based on the posterior abundance estimates from the log-linear hierarchical model in order to better account for variation in abundance estimates. Thus, for each posterior iteration, we estimated the proportions of the different guilds and calculated the mean and 95% confidence intervals for BCI.

Results

A total of 90 species and 11,311 individual birds were detected on the survey routes from 1997 – 2018 (Appendix A). Of these 90 species, 85 species are considered breeding residents of West Virginia. Red-eyed Vireo was the most commonly detected species with a total of 2,032 detections, or 18.0% of total detections. Seven species (Red-eyed Vireo, Scarlet Tanager, Wood Thrush, Acadian Flycatcher, American Crow, Louisiana Waterthrush, and Tufted Titmouse) accounted for nearly 50% of all detections.

Trends in Species Abundance

Hierarchical modeling was performed for 38 species that had at least 50 observations from all the NPS survey routes and were considered breeding residents of West Virginia. Of these 38 species, 7 species (Kentucky Warbler, Blue-gray Gnatcatcher, Acadian Flycatcher, Black-throated Green Warbler, Northern Parula, Carolina Chickadee, and Swainson's Warbler) experienced significant declines on the NPS lands from 1997 – 2018 and the other 26 species had stable trend estimates (Figure 2). All 7 species with significant population changes have declined precipitously in the 22 years of the survey and are at less than 25% of their estimated abundance in 1997 (Figure 3). Kentucky Warblers had the steepest declines with a mean yearly change at -19.33% (Table 3) and have since become absent from any of the NPS point counts (Figure 3). Blue-gray Gnatcatchers have declined yearly by -14.77% and are currently at 3.78% of their estimated abundance in 1997 (Table 3, Figure 3).

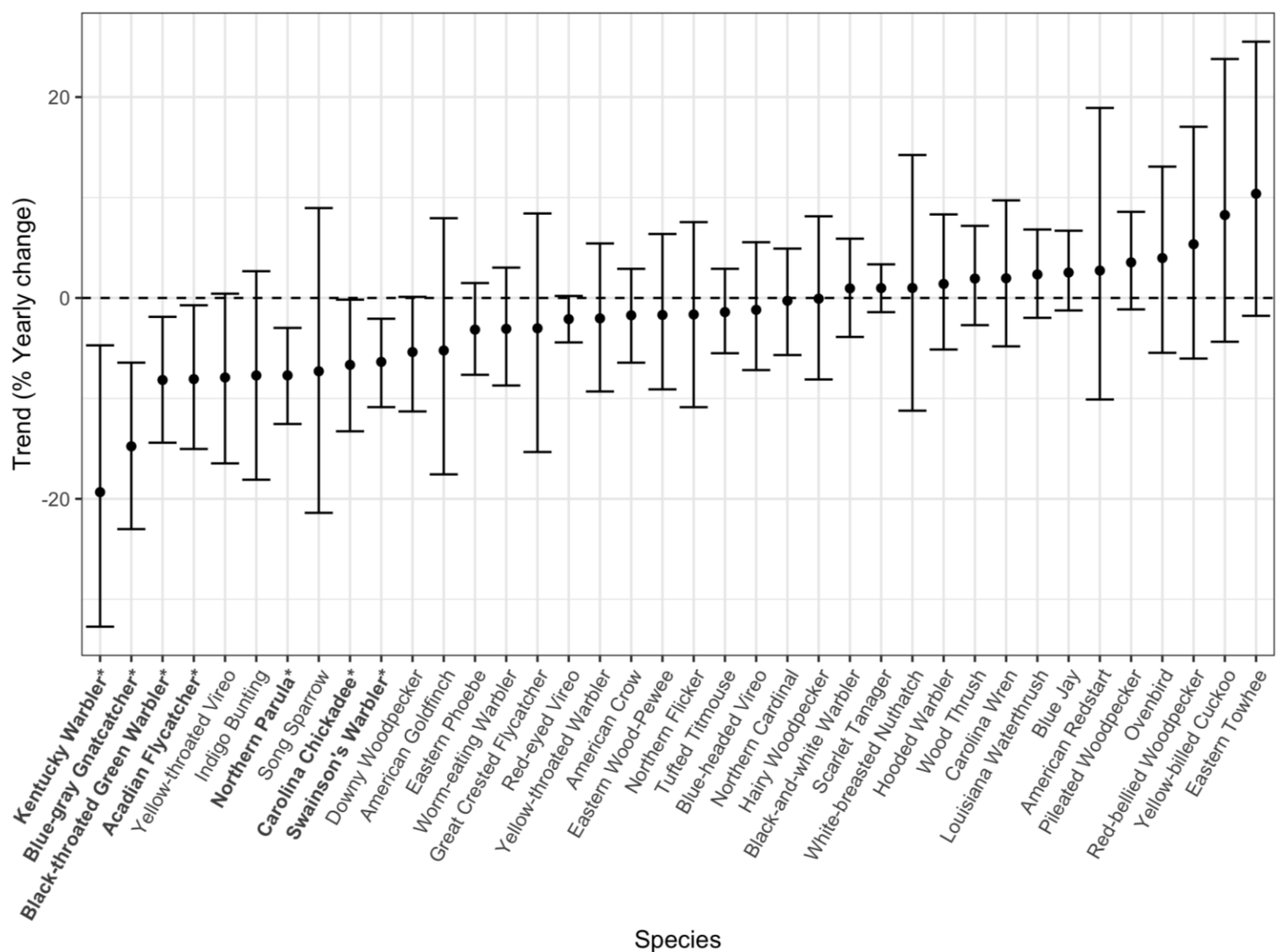


Figure 2. Yearly percent trends for species on the NPS routes, 1997 – 2018. Points indicate the mean trend posterior distribution, while the confidence intervals cover the range of 2.5% to 97.5% of the posterior distribution. Trends are considered significant if the 95% confidence interval does not overlap 0. Species with significant trends have bold font and are labeled with *.

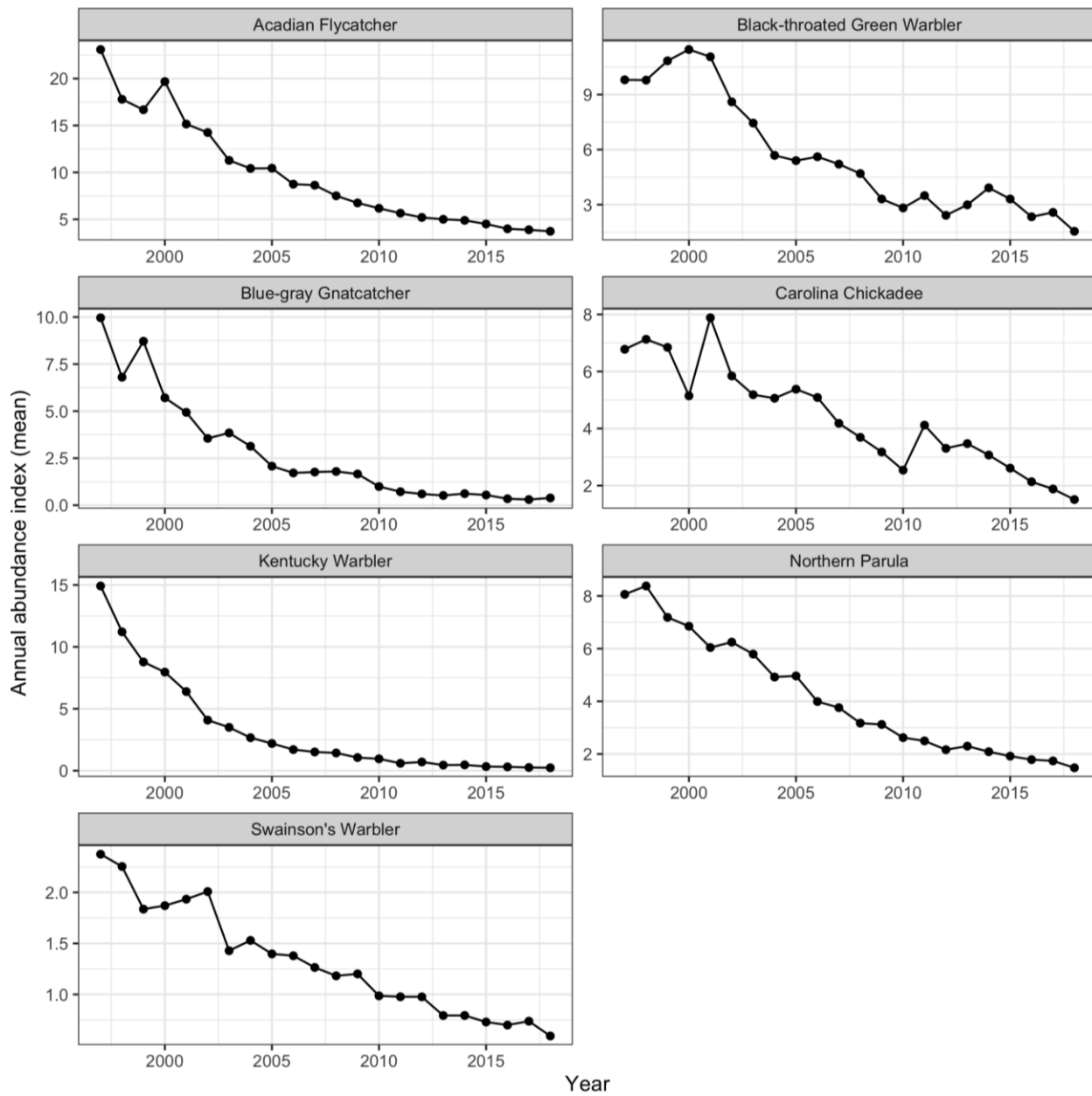


Figure 3. Mean annual abundance indices plotted over the time period 1997 to 2018 for the seven significantly declining species on the NPS routes. Note that the y-axes are on different scales.

Table 3. A log-linear hierarchical model was used to assess 38 species for changes in abundance on NPS lands and across West Virginia (raw BBS data). The mean provides the mean posterior distribution trend estimate and the 95% CI provides the lower (2.5%) and upper (97.5%) bounds of the posterior distribution.

Species	NPS mean	NPS 95% CI		BBS mean	BBS 95% CI	
		Lower	Upper		Lower	Upper
Acadian Flycatcher	-8.08	-15.03	-0.73	-0.58	-1.70	0.55
American Crow	-1.73	-6.44	2.90	-0.26	-1.03	0.52
American Goldfinch	-5.23	-17.56	7.94	0.93	-0.38	2.26
American Redstart	2.73	-10.11	18.92	2.93	0.96	4.93
Black-and-white Warbler	0.95	-3.88	5.90	-1.68	-3.69	0.30
Blue-gray Gnatcatcher	-14.77	-23.01	-6.44	-4.98	-6.81	-3.18
Blue-headed Vireo	-1.18	-7.18	5.55	1.63	-1.65	4.99
Blue Jay	2.53	-1.25	6.69	1.22	-0.10	2.58
Black-throated Green Warbler	-8.17	-14.41	-1.88	0.21	-2.58	3.04
Carolina Chickadee	-6.66	-13.27	-0.17	-3.08	-4.78	-1.27
Carolina Wren	1.96	-4.82	9.72	3.62	2.30	4.96
Downy Woodpecker	-5.39	-11.3	0.11	-1.62	-3.31	0.14
Eastern Phoebe	-3.15	-7.65	1.48	0.00	-1.08	1.11
Eastern Towhee	10.37	-1.78	25.51	0.73	-0.09	1.56
Eastern Wood-Pewee	-1.69	-9.10	6.37	-0.10	-1.35	1.22
Great Crested Flycatcher	-3.02	-15.34	8.41	-3.50	-5.67	-1.42
Hairy Woodpecker	-0.07	-8.11	8.13	1.42	-1.61	4.62
Hooded Warbler	1.40	-5.13	8.32	-1.27	-3.24	0.66
Indigo Bunting	-7.72	-18.1	2.66	-2.27	-2.92	-1.60
Kentucky Warbler	-19.33	-32.73	-4.72	-5.24	-7.74	-2.71
Louisiana Waterthrush	2.34	-1.98	6.81	1.37	-0.89	3.80
Northern Cardinal	-0.28	-5.69	4.91	0.82	0.05	1.63
Northern Flicker	-1.65	-10.90	7.55	-0.32	-1.20	0.64
Northern Parula	-7.71	-12.55	-2.98	-0.29	-2.07	1.53
Ovenbird	3.97	-5.46	13.07	-0.18	-1.30	0.95
Pileated Woodpecker	3.54	-1.14	8.57	1.53	-0.15	3.26
Red-bellied Woodpecker	5.35	-6.03	17.04	5.16	3.59	6.78
Red-eyed Vireo	-2.11	-4.43	0.20	-1.14	-1.84	-0.48
Scarlet Tanager	0.98	-1.42	3.35	0.06	-0.98	1.17
Song Sparrow	-7.30	-21.39	8.95	0.52	-0.21	1.24
Swainson's Warbler	-6.37	-10.87	-2.07	4.36	-2.68	11.55
Tufted Titmouse	-1.41	-5.50	2.90	0.59	-0.43	1.56
White-breasted Nuthatch	1.00	-11.23	14.23	1.23	-0.56	2.94
Worm-eating Warbler	-3.08	-8.71	3.02	-3.74	-6.56	-0.66
Wood Thrush	1.93	-2.71	7.17	0.47	-0.51	1.47
Yellow-billed Cuckoo	8.26	-4.36	23.79	3.23	0.55	6.10
Yellow-throated Vireo	-7.92	-16.47	0.42	1.29	-0.28	3.00
Yellow-throated Warbler	-2.03	-9.31	5.43	1.37	-0.12	2.98

Acadian Flycatchers and Black-throated Green Warblers are both hemlock-associated species and have declined at similar yearly rates (-8.08% and -8.17% respectively; Table 3, Figure 3). Northern Parula have declined at a rate of -7.71%/year and have roughly 18% the population size now that they did in 1997. Carolina Chickadees have steadily declined at -6.66%/year and are now at 21.9% of their original population size. Swainson's Warblers have consistently been scarce on the NPS survey routes, but they are now at 24.6% of their original population size after declining on average -6.37%/year (Figure 3, Table 3).

In relation to the rest of West Virginia, 3 of the 7 species declining on NPS lands (Blue-gray Gnatcatcher, Carolina Chickadee, Kentucky Warbler) were also found to be declining across BBS routes in West Virginia (Table 3). The other 4 declining species (Acadian Flycatcher, Black-throated Green Warbler, Northern Parula, Swainson's Warbler) on NPS lands were stable across BBS routes in West Virginia (Table 3). Great Crested Flycatcher, Indigo Bunting, Red-eyed Vireo, and Worm-eating Warbler were all found to be declining significantly across BBS routes but stable on NPS lands (Table 3).

Trends in abundance from 1997 - 2018 were also assessed for the 15 of the 16 response guilds that are used to measure BCI (there were no present exotic species on NPS lands). Fourteen of the 15 guilds had stable trends, however the upper-canopy foraging guild has significantly decreased at a mean rate of -5.96%/year (Figure 4). The upper-canopy foraging guild assessment consisted of 7 species with sufficient data for analysis (Blue-gray Gnatcatcher, Black-throated Green Warbler, Northern Parula, Red-eyed Vireo, Scarlet Tanager, Yellow-throated Vireo, Yellow-throated Warbler; Appendix B).

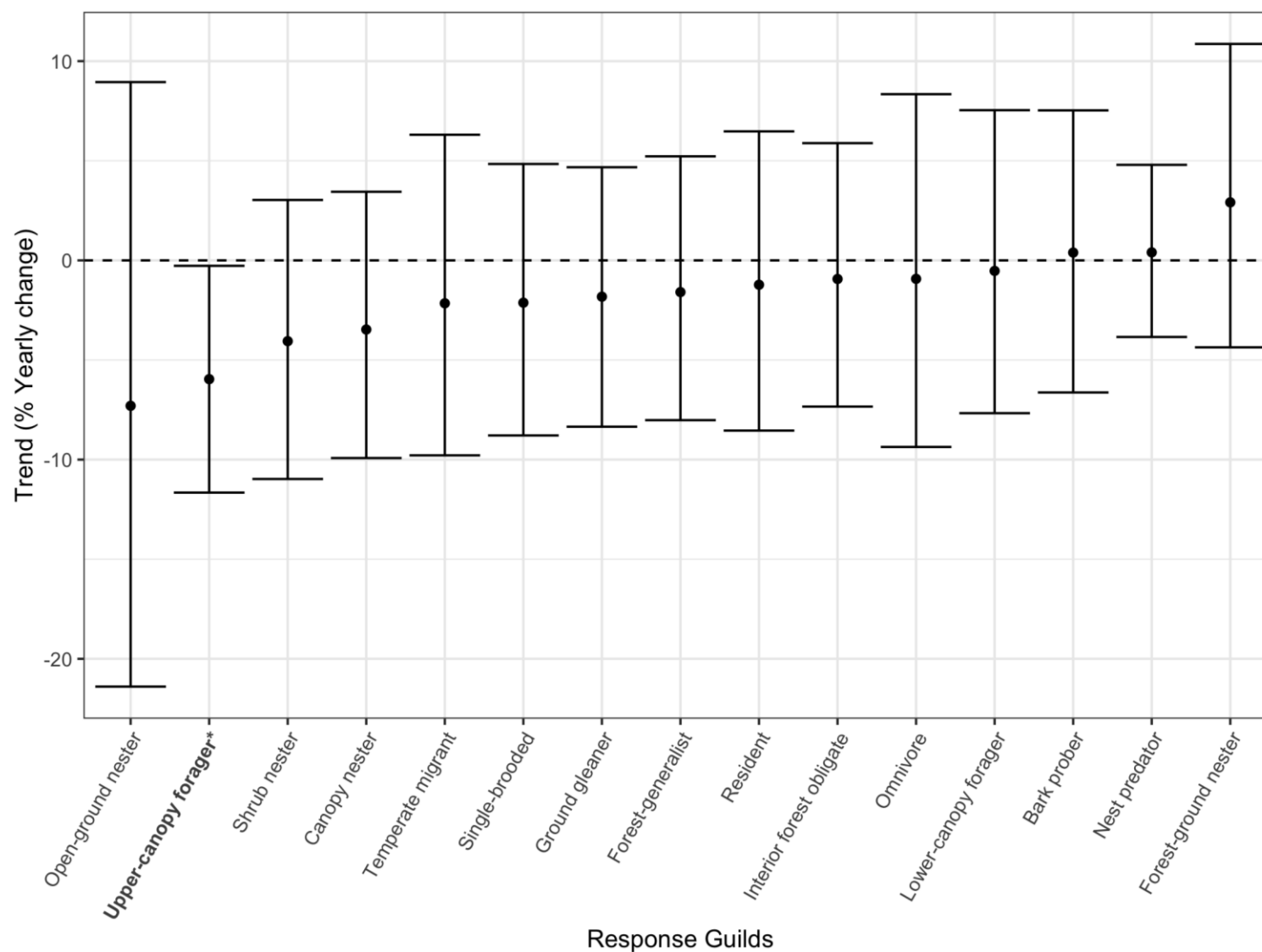


Figure 4. Trends in abundance for the 16 response guilds. Fifteen of the guilds had stable trends from 1997-2018 while the upper-canopy foraging guild declined significantly with a mean rate of -5.96%/year. Trends are considered significant if the 95% confidence interval does not contain 0 and guilds with significant trends have bold font and are labeled with *.

Community Biotic Integrity

The 38 species used for estimating trends in abundance were also used in the assessment of BCI for all of the NPS lands surveyed. Due to the large variation in posterior abundance estimates for each species, the BCI measures within a year fluctuated considerably across all four biotic integrity categories (Low to Highest; Figure 5). However, there was little variation among years and the mean yearly BCI were all in the High integrity category, except the BCI estimate for 2004 was in the upper bounds of Medium integrity (Figure 5).

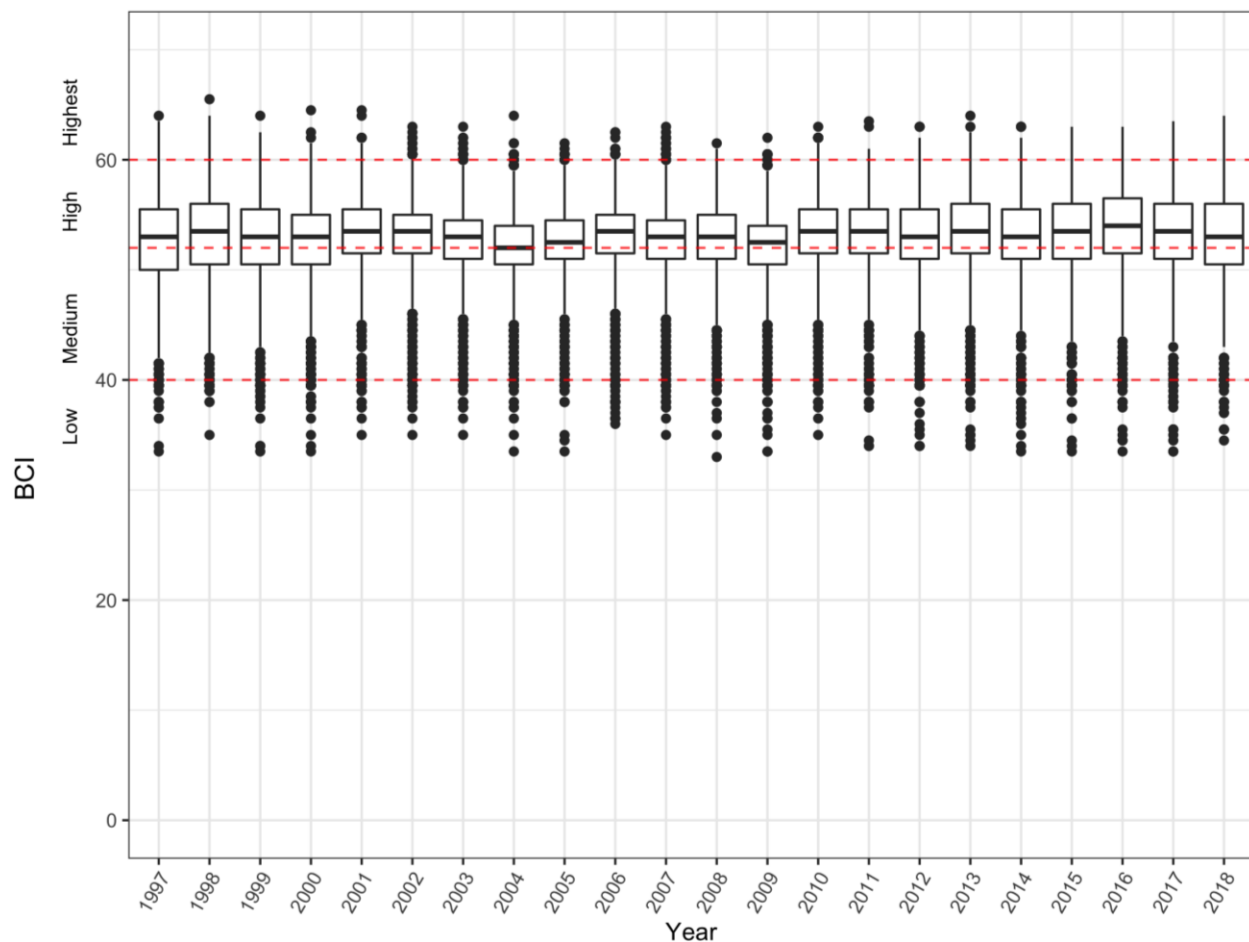


Figure 5. Bird community indices (BCI) by year show consistent mean BCI estimates (a summary from posterior distribution of individual species abundance estimates) across years but high variation within years. All yearly mean BCI estimates are within the High integrity category. The center line of the boxplots represent the median and the upper and lower bounds of the box are the 75% and 25% percentiles, respectively. The vertical lines, whiskers, represent 1.5 times the interquartile range of the boxplot and all points outside the whiskers are considered outliers.

Discussion

As bird populations world-wide are generally in decline, long-term monitoring is essential for determining where shifts in abundance are occurring and with what magnitude. In this report, we summarized 22 years of point count data from New River Gorge National River, Gauley River National Recreation Area and Bluestone National Scenic River.

Avian species trends

Avian species trends on southern West Virginia NPS lands were compared with statewide West Virginia BBS routes due to the same methodological approaches and use of data from the same time periods. The West Virginia Breeding Bird Atlas (WVBBA) and Eastern Rivers and Mountains Network (ERMN) have also conducted avian point count surveys in the region for trend analyses but we have not compared our specific trends due to differences in methods and time periods covered (Marshall *et al.* 2016).

Black-throated Green Warblers and Acadian Flycatchers are both eastern hemlock associated species that have significantly declined on the NPS routes, but have not been declining across West Virginia (Table 3). In the rest of the Appalachians, hemlock mortality from HWA have resulted in widespread declines, as well as the disappearance, of Black-throated Green Warblers (Tingley 2002). In the rest of the breeding range, Acadian Flycatchers predominantly nest in mature deciduous forests, especially in the presence of small streams and swamps (Allen *et al.* 2017). The Endless Wall route was the only location with another hemlock associated species, the Blue-headed Vireo, as one of the most detected species (Appendix A). While Blue-headed Vireos are considered to be very adaptable to resource availability (Petit *et al.* 1990), there are concerns this species may experience significant declines from hemlock loss in the future (Morton and James 2014). The analysis of BBS and NPS routes found that Blue-headed Vireo were stable across both of these spatial scales and management areas.

Swainson's Warblers have experienced significant declines of -6.37%/year over the past 20 years on the NPS routes, but they have remained stable throughout the rest of West Virginia (Table 3). The Meadow River site had the most detections of Swainson's Warblers. Swainson's Warblers are a secretive warbler (family Parulidae) that predominantly breeds in the bottomlands of the Mississippi Alluvial Valley and Coastal Plain, but is also present in the mixed mesophytic forests of the southern Appalachian Mountains (Anich *et al.* 2020). Throughout West Virginia, residential development has been the predominant factor in reducing suitable breeding habitat (Hall 1983). Additional habitat comparison of Meadow River to the other sites may provide key insight on what promotes Swainson's Warbler occupancy in certain NPS land units.

Across all surveys, Red-eyed Vireos were the most commonly detected species (Appendix A). One factor in the large number of detections of Red-eyed Vireos is that they are a prolific songster on their breeding grounds (Cimprich *et al.* 2018). Red-eyed Vireos occupy deciduous and mixed deciduous-coniferous forest throughout their range, and in the southeastern United States they are most abundant in the riparian areas of these forests (Hamel 1992). Despite being stable on the NPS routes, Red-eyed Vireos are significantly declining across West Virginia BBS routes (Table 3).

Wood Thrush are a species of Continental Concern in the Partners in Flight (PIF) Watchlist and have declined range-wide by 72% since 1970 (Rosenberg *et al.* 2016). They are currently stable on NPS lands in West Virginia (Table 3) and one of the most commonly detected species (Appendix A). Population viability models with Wood Thrush have shown that the protection of large tracts of land are an important factor in population persistence (Bonnot *et al.* 2013), highlighting the importance of the protection of NPS lands. Kentucky Warblers are another species of Continental Concern in the PIF Watchlist (Rosenberg *et al.* 2016) and are declining on NPS lands in West Virginia as well as across the state (Table 3). Yellow-billed Cuckoos are considered a common bird in steep decline by the PIF Watchlist (Rosenberg *et al.* 2016). However, they are currently stable on southern West Virginia NPS lands and increasing across the rest of West Virginia (Table 3).

The decline of the upper-foraging guild on southern West Virginia NPS lands highlights an important area for future research. Individually, 3 of these species (Blue-gray Gnatcatcher, Black-throated Green Warbler, Northern Parula) were significantly declining on southern West Virginia NPS lands and 2 of these species were declining across West Virginia (Blue-gray Gnatcatcher, Red-eyed Vireo; Table 3). More work is needed to determine the specific factors underlying these trends in order to help keep these species from being added to the PIF Watchlist.

Community Biotic Integrity

BCI estimates were consistent from 1997 to 2018 with all yearly estimates being in the high integrity category (mean 52.6, range 51.8 – 53.2; Figure 5). In a broader study conducted from 2007 to 2012 by the NPS Eastern Rivers and Mountains Network, which ranges from West Virginia to Pennsylvania, Marshall *et al.* (2013) found that the three NPS units they surveyed in southern West Virginia (NERI, GARI, and BLUE) had higher BCI values than the NPS units in Pennsylvania. The ERMN BCI measures for the West Virginia NPS units were all in the highest integrity category: 62 (NERI), 60 (GARI), and 64 (BLUE; Marshall *et al.* 2013). However, the results from Marshall *et al.* (2013) and this study may not be directly comparable because this study had 5-minute point counts and used posterior estimates of abundance to measure BCI while Marshall *et al.* (2013) had 10-minute point counts and used raw detections to measure BCI. Longer point counts could potentially allow for a higher proportion of specialist species that are potentially less readily detected. Despite these differences, Marshall *et al.* (2013) also found a consistency of BCI scores across the period of 2007 – 2012. Importantly, our results found consistent BCI measures from 1997 to 2018 despite showing a significant decline in the specialist group of upper-canopy foragers.

Summary

From 1997-2018, 90 species were detected on the southern West Virginia NPS lands, of which 85 are likely breeding residents. Wood Thrush are a continental species of concern by Partners in Flight but are currently stable across the southern West Virginia NPS survey routes and one of the most commonly detected species. The Yellow-billed Cuckoo is another species of continental concern that is stable on southern West Virginia NPS lands. However, the avian communities across NERI, GARI, and BLUE have 7 species experiencing significant declines. Three of these species are also experiencing declines across the rest of West Virginia (Blue-gray Gnatcatcher, Carolina Chickadee, Kentucky Warbler), but the other 4 species are stable across West Virginia (Acadian Flycatcher, Black-throated Green Warbler, Northern Parula, Swainson's Warbler). Four species that are declining across West Virginia (Great Crested Flycatcher, Indigo Bunting, Red-eyed Vireo, and Worm-eating Warbler) are stable in NERI, GARI, and BLUE. Additionally, the upper-canopy foraging guild of species has decreased significantly in NERI, GARI, and BLUE. An analysis of community biotic integrity revealed that these NPS units have been stable at a rating of high biotic integrity every year for the duration of this study. Future research should delve into the underlying factors that may be driving the trends in abundance at different scales.

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Appendix A

Table A-1. Total number of detections of species across routes from 1997-2018.

Common Name	Scientific Name	Bluestone	Brooklyn	Endless	Glade	Meadow
Acadian Flycatcher	<i>Empidonax virens</i>	70	108	7	258	16
American Crow	<i>Corvus brachyrhynchos</i>	70	164	43	24	49
American Goldfinch	<i>Spinus tristis</i>	8	76	45	4	4
American Redstart	<i>Setophaga ruticilla</i>	12	54	0	13	4
American Robin	<i>Turdus migratorius</i>	3	5	18	1	0
American Woodcock	<i>Scolopax minor</i>	1	1	0	0	0
Barred Owl	<i>Strix varia</i>	0	1	2	1	0
Bald Eagle	<i>Haliaeetus leucocephalus</i>	0	3	0	0	0
Baltimore Oriole	<i>Icterus galbula</i>	1	16	0	3	0
Black-and-white Warbler	<i>Mniotilta varia</i>	46	46	44	26	21
Black-capped Chickadee	<i>Poecile atricapillus</i>	2	0	0	0	4
Belted Kingfisher	<i>Megasceryle alcyon</i>	12	8	0	15	1
Blue-gray Gnatcatcher	<i>Poliophtila caerulea</i>	21	43	1	11	0
Brown-headed Cowbird	<i>Molothrus ater</i>	1	0	0	0	0
Blue-headed Vireo	<i>Vireo solitarius</i>	56	12	59	31	13
Blackburnian Warbler	<i>Setophaga fusca</i>	0	0	1	0	0
Blue Jay	<i>Cyanocitta cristata</i>	108	77	34	20	98
Blackpoll Warbler	<i>Setophaga striata</i>	1	0	0	0	0
Brown Creeper	<i>Certhia americana</i>	0	0	0	0	1
Black-throated Blue Warbler	<i>Setophaga caerulea</i>	2	2	0	1	0
Black-throated Green Warbler	<i>Setophaga virens</i>	26	22	37	18	67
Broad-winged Hawk	<i>Buteo platypterus</i>	1	1	0	1	0
Blue-winged Warbler	<i>Vermivora cyanoptera</i>	1	0	0	0	2

Table A-1 (continued). Total number of detections of species across routes from 1997-2018.

Common Name	Scientific Name	Bluestone	Brooklyn	Endless	Glade	Meadow
Carolina Chickadee	<i>Poecile carolinensis</i>	55	87	20	25	9
Canada Goose	<i>Branta canadensis</i>	0	14	0	0	2
Carolina Wren	<i>Thryothorus ludovicianus</i>	89	152	16	16	60
Canada Warbler	<i>Cardellina canadensis</i>	0	0	0	0	6
Cedar Waxwing	<i>Bombycilla cedrorum</i>	6	3	4	2	1
Cerulean Warbler	<i>Setophaga cerulea</i>	13	13	0	4	0
Chipping Sparrow	<i>Spizella passerina</i>	1	0	0	1	2
Chimney Swift	<i>Chaetura pelagica</i>	1	4	0	1	0
Common Grackle	<i>Quiscalus quiscula</i>	0	20	0	6	0
Common Merganser	<i>Mergus merganser</i>	1	0	0	0	0
Common Raven	<i>Corvus corax</i>	6	7	8	0	0
Dark-eyed Junco	<i>Junco hyemalis</i>	0	0	0	0	2
Downy Woodpecker	<i>Dryobates pubescens</i>	50	73	11	32	4
Eastern Phoebe	<i>Sayornis phoebe</i>	37	26	19	28	34
Eastern Screech-Owl	<i>Megascops asio</i>	0	1	0	0	0
Eastern Towhee	<i>Pipilo erythrophthalmus</i>	8	6	31	0	9
Eastern Wood-Pewee	<i>Contopus virens</i>	68	14	23	4	0
Great Blue Heron	<i>Ardea herodias</i>	0	0	0	2	0
Great Crested Flycatcher	<i>Myiarchus crinitus</i>	11	10	16	1	1
Golden-crowned Kinglet	<i>Regulus satrapa</i>	2	0	0	0	0
Gray Catbird	<i>Dumetella carolinensis</i>	0	1	0	1	0
Golden-winged Warbler	<i>Vermivora chrysoptera</i>	1	0	0	0	0
Hairy Woodpecker	<i>Dryobates villosus</i>	15	15	9	10	2
Hooded Warbler	<i>Setophaga citrina</i>	9	89	87	8	129
House Wren	<i>Troglodytes aedon</i>	0	1	3	0	0

Table A-1 (continued). Total number of detections of species across routes from 1997-2018.

Common Name	Scientific Name	Bluestone	Brooklyn	Endless	Glade	Meadow
Indigo Bunting	<i>Passerina cyanea</i>	21	117	3	0	8
Kentucky Warbler	<i>Geothlypis formosa</i>	3	43	0	2	1
Louisiana Waterthrush	<i>Parkesia motacilla</i>	159	107	8	110	25
Mallard	<i>Anas platyrhynchos</i>	1	0	0	0	0
Mourning Dove	<i>Zenaida macroura</i>	0	5	19	1	1
Northern Cardinal	<i>Cardinalis cardinalis</i>	36	100	23	13	31
Northern Flicker	<i>Colaptes auratus</i>	18	21	3	3	1
Northern Parula	<i>Setophaga americana</i>	66	83	1	18	12
Northern Waterthrush	<i>Parkesia noveboracensis</i>	0	0	1	0	0
Northern Rough-winged Swallow	<i>Stelgidopteryx serripennis</i>	0	5	0	1	1
Orchard Oriole	<i>Icterus spurius</i>	0	6	0	1	0
Osprey	<i>Pandion haliaetus</i>	1	0	0	0	0
Ovenbird	<i>Seiurus aurocapilla</i>	58	7	77	68	5
Peregrine Falcon	<i>Falco peregrinus</i>	0	1	0	0	0
Pine Warbler	<i>Setophaga pinus</i>	0	0	25	0	0
Pileated Woodpecker	<i>Dryocopus pileatus</i>	45	70	29	20	14
Rose-breasted Grosbeak	<i>Pheucticus ludovicianus</i>	6	0	2	1	0
Red-bellied Woodpecker	<i>Melanerpes carolinus</i>	9	53	23	5	0
Red-eyed Vireo	<i>Vireo olivaceus</i>	317	364	121	244	168
Red-shouldered Hawk	<i>Buteo lineatus</i>	0	0	0	0	1
Red-tailed Hawk	<i>Buteo jamaicensis</i>	8	6	0	1	2
Ruby-throated Hummingbird	<i>Archilochus colubris</i>	2	0	0	0	0
Ruffed Grouse	<i>Bonasa umbellus</i>	5	0	0	1	0
Scarlet Tanager	<i>Piranga olivacea</i>	213	178	74	156	116

Table A-1 (continued). Total number of detections of species across routes from 1997-2018.

Common Name	Scientific Name	Bluestone	Brooklyn	Endless	Glade	Meadow
Song Sparrow	<i>Melospiza melodia</i>	10	46	0	0	0
Spotted Sandpiper	<i>Actitis macularius</i>	1	0	0	0	0
Swainson's Warbler	<i>Limnothlypis swainsonii</i>	0	2	15	0	104
Tree Swallow	<i>Tachycineta bicolor</i>	1	5	0	1	0
Tufted Titmouse	<i>Baeolophus bicolor</i>	100	163	60	29	35
Turkey Vulture	<i>Cathartes aura</i>	4	5	1	0	4
Warbling Vireo	<i>Vireo gilvus</i>	0	0	0	1	0
White-breasted Nuthatch	<i>Sitta carolinensis</i>	8	10	13	8	0
White-eyed Vireo	<i>Vireo griseus</i>	0	0	1	0	0
Worm-eating Warbler	<i>Helmitheros vermivorum</i>	75	76	19	9	18
Wild Turkey	<i>Meleagris gallopavo</i>	8	3	1	1	0
Winter Wren	<i>Troglodytes hiemalis</i>	1	2	0	0	12
Wood Duck	<i>Aix sponsa</i>	0	1	0	0	0
Wood Thrush	<i>Hylocichla mustelina</i>	117	83	64	210	42
Yellow-billed Cuckoo	<i>Coccyzus americanus</i>	8	28	10	1	1
Yellow Warbler	<i>Setophaga petechia</i>	0	5	0	0	0
Yellow-throated Vireo	<i>Vireo flavifrons</i>	14	51	19	13	0
Yellow-throated Warbler	<i>Setophaga dominica</i>	56	199	16	35	0

Appendix B

Table B-1. Guild classification of the 38 species used in analyses of abundance and bird community index (BCI). These species all had at least 50 total detections and were listed as appropriate BCI reference species by O’Connell et al. (2000). An “X” indicates that condition exists for that species and an en-dash (–) indicates that it is not.

Common Name	Omnivore	Bark prober	Ground gleaner	Upper-canopy forager	Lower-canopy forager	Resident	Temperate migrant	Single-brooded	Nest predator	Canopy nester	Shrub nester	Open-ground nester	Forest-ground nester	Forest-generalist	Interior forest obligate
Acadian Flycatcher	–	–	–	–	–	–	–	–	–	X	X	–	–	–	X
American Crow	X	–	–	–	–	X	–	X	X	X	–	–	–	–	–
American Goldfinch	X	–	–	–	–	X	–	X	–	–	X	–	–	–	–
American Redstart	–	–	–	–	X	–	–	X	–	X	–	–	–	–	X
Black-and-white Warbler	–	X	–	–	–	–	–	X	–	–	–	–	X	–	X
Blue-gray Gnatcatcher	–	–	–	X	–	–	X	X	–	X	–	–	–	X	–
Blue-headed Vireo	–	–	–	–	X	–	X	X	–	X	–	–	–	–	X
Blue Jay	X	–	–	–	–	X	–	–	X	X	–	–	–	X	–
Black-throated Green Warbler	–	–	–	X	–		–	X	–	X	–	–	–	–	X
Carolina Chickadee	–	–	–	–	X	X	–	X	–	–	–	–	–	–	–
Carolina Wren	–	–	–	–	X	X	–	–	–	–	–	–	–	X	–
Downy Woodpecker	–	X	–	–	–	X	–	–	–	–	–	–	–	X	–
Eastern Phoebe	–	–	–	–	–	–	X	–	–	–	–	–	–	X	–
Eastern Towhee	X	–	–	–	–	–	X	–	–	–	–	–	X	X	–
Eastern Wood-Pewee	–	–	–	–	–	–	–	X	–	X	–	–	–	X	–
Great Crested Flycatcher	–	–	–	–	–	–	–	X	–	–	–	–	–	X	–
Hairy Woodpecker	–	X	–	–	–	X	–	X	–	–	–	–	–	–	X
Hooded Warbler	–	–	–	–	X	–	–	X	–	–	X	–	–	–	X
Indigo Bunting	X	–	–	–	–	–	–	–	–	–	X	–	–	–	–
Kentucky Warbler	–	–	X	–	–	–	–	X	–	–	–	–	X	–	X
Louisiana Waterthrush	–	–	–	–	–	–	–	X	–	–	–	–	X	–	X
Northern Cardinal	X	–	–	–	–	X	–	–	–	–	X	–	–	X	–
Northern Flicker	–	–	X	–	–	X	–	X	–	–	–	–	–	X	–
Northern Parula	–	–	–	X	–	–	–	X	–	X	–	–	–	X	–
Ovenbird	–	–	X	–	–	–	–	X	–	–	–	–	X	–	X
Pileated Woodpecker	–	X	–	–	–	X	–	X	–	–	–	–	–	–	X
Red-bellied Woodpecker	–	X	–	–	–	X	–	X	–	–	–	–	–	X	–
Red-eyed Vireo	–	–	–	X	–	–	–	X	–	–	X	–	–	X	–
Scarlet Tanager	–	–	–	X	–	–	–	X	–	X	–	–	–	–	X
Song Sparrow	X	–	–	–	–	X	–	–	–	–	–	X	–	–	–
Swainson's Warbler	–	–	X	–	–	–	–	X	–	–	X	–	–	–	X
Tufted Titmouse	–	–	–	–	X	X	–	X	–	–	–	–	–	X	–

Table B-1 (continued). Guild classification of the 38 species used in analyses of abundance and bird community index (BCI). These species all had at least 50 total detections and were listed as appropriate BCI reference species by O’Connell et al. (2000). An “X” indicates that condition exists for that species and an en-dash (–) indicates that it is not.

Common Name	Omnivore	Bark prober	Ground gleaner	Upper-canopy forager	Lower-canopy forager	Resident	Temperate migrant	Single-brooded	Nest predator	Canopy nester	Shrub nester	Open-ground nester	Forest-ground nester	Forest-generalist	Interior forest obligate
White-breasted Nuthatch	–	X	–	–	–	X	–	X	–	–	–	–	–	–	X
Worm-eating Warbler	–	–	X	–	–	–	–	X	–	–	–	–	X	–	X
Wood Thrush	X	–	–	–	–	–	–	–	–	X	–	–	–	X	–
Yellow-billed Cuckoo	–	–	–	–	X	–	–	X	–	–	X	–	–	X	–
Yellow-throated Vireo	–	–	–	X	–	–	–	X	–	X	–	–	–	X	–
Yellow-throated Warbler	–	X	–	X	–	–	X	X	–	X	–	–	–	–	X

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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