



Streamside Bird Monitoring in the Eastern Rivers and Mountains Network

Delaware Water Gap National Recreation Area
2007–2019

Natural Resource Report NPS/ERMN/NRR—2021/2326



ON THE COVER

Veery (*Catharus fuscescens*) with caterpillar in bill. One of the most abundant bird species at Delaware Water Gap National Recreation Area point count stations. Photo © Bill Thompson.

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Executive Summary

This report summarizes the first 12 years (2007 to 2019) of monitoring the streamside bird community at Delaware Water Gap National Recreation Area (Delaware Water Gap NRA). During that time period 13 observers conducted 3,970 point count surveys detecting 33,263 individual birds at 216 point count stations within the park.

Delaware Water Gap NRA contains a rich and diverse streamside bird community with a total of 112 species detected; 87 of which were target species and presumed to be breeding in the park during summer months. The majority were forest-associated species including forest interior species whose life-histories depend on large tracts of mature, unfragmented, deciduous forest and forest generalist species. However, several abundant species were associated with early-successional forests, shrubby fields, and suburban landscapes reflecting the mixed vegetation/habitat structure at the park including at the point count stations.

Twenty-three species overall and three of the five most abundant species were of conservation importance in the Appalachian Mountains bird conservation region highlighting the significance of Delaware Water Gap NRA and the surrounding landscape to avian conservation.

Trends in unadjusted abundance over the period of monitoring were assessed for the 87 species in the target population (Table E-1). Trends in adjusted abundance that take into account detection probability were estimated for 53 species for which there were sufficient data.

Table E-1. Summary of trends in unadjusted abundance for 87 bird species at Delaware Water Gap National Recreation Area point count stations from 2007–2019.

Abundance Trend		Number of Species (% total)	Species
Symbol	Definition		
↑↑	Significant Increase	10 (11%)	Gray Catbird, Veery, American Goldfinch, Ruby-throated Hummingbird, Northern Parula, Winter Wren, American Robin, Prairie Warbler, Hooded Warbler, Common Grackle
↑	Increase	13 (15%)	—
↔	Stable	54 (62%)	—
↓	Decrease	10 (11%)	—
↓↓	Significant Decrease	0	—

It is striking, and one of the more significant findings of the monitoring program to date, that out of 87 species in the target population, 77 species (89%) were stable or increasing and only 10 species (11%) declined during the period of monitoring (none significantly).

Several of the species showing stable or increasing populations trends at Delaware Water Gap NRA point count stations were species of regional conservation importance due to decades of population declines throughout the Appalachians (e.g., Wood Thrush) or were priority species for regional conservation (e.g., Scarlet Tanager, Wood Thrush, Eastern Wood-Pewee, and Hooded Warbler). An encouraging sign in the face of recent overwhelming evidence of dramatic declines in bird populations.

One possible explanation for these findings may be that many of these species were responding positively to the decline of the Eastern hemlock (*Tsuga canadensis*; due to the hemlock woolly adelgid, *Adelges tsugae*) and concurrent transition from hemlock dominated stream drainages to stands of mixed deciduous forest with proportionally less hemlock.

This report provides the first information regarding long-term population trends of breeding birds in Delaware Water Gap NRA which is the primary objective of the monitoring protocol. Continued monitoring will provide new insights and future analyses will explore specific factors linked to population trends. As anthropogenic land use and climate change continue to reshape the Appalachian landscape, park managers will need this information to best allocate effort that aligns with regional conservation planning and other park priorities.

Acknowledgments

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List of Acronyms

ALPO:	Allegheny Portage Railroad National Historic Site
BLUE:	Bluestone National Scenic River
DEWA:	Delaware Water Gap National Recreational Area
ERMN:	Eastern Rivers and Mountains Network
FONE:	Fort Necessity National Battlefield
FRHI:	Friendship Hill National Historic Site
GARI:	Gauley River National Recreational Area
IMD:	Inventory and Monitoring Division
JOFL:	Johnstown Flood National Memorial
NB:	National Battlefield
NERI:	New River Gorge National Park and Preserve
NHS:	National Historic Site
NMem:	National Memorial
NP & PRES:	National Park and Preserve
NPS:	National Park Service
NRA:	National Recreation Area
NSR:	National Scenic River
SRR:	Scenic and Recreational River

Introduction

Each summer, more than 130 bird species breed within the national parks of the Eastern Rivers and Mountains Network. These birds are essential components of park ecosystems and have tremendous appeal to visitors and stewards of national parks. They rely on habitats associated with the extensive network of forested Appalachian streams to eat, build nests, and raise their young. Some remain in the parks year-round and others, including tanagers, thrushes, vireos, flycatchers, and warblers are migrants that fly thousands of miles twice a year between breeding and wintering areas—connecting the parks, landscapes, and people of eastern North America to those of Central and South America.

The National Park Service Inventory and Monitoring Division implements an integrated long-term ecological monitoring program to track changes in a suite of selected park resources and processes termed "vital signs" (Fancy et al. 2009, Marshall and Piekielek 2007). As part of this program the Eastern Rivers and Mountains Network monitors breeding bird populations in seven national parks under a peer-reviewed protocol referred to as the streamside bird monitoring protocol (Marshall et al. 2016). The background and justification for monitoring breeding birds, rationale for focusing monitoring on the bird community along streams, monitoring objectives, and other programmatic considerations are described in detail in the protocol.

The information gained from this monitoring program helps inform park management decision making to ensure park resources remain unimpaired for the enjoyment of future generations and to preserve the habitats and ecosystems on which these birds depend.

This report summarizes results from the beginning of the program in 2007 through 2019 at Delaware Water Gap NRA, with emphasis on species-specific trends during this time period. Detecting changes in species abundance over time is the primary objective of the protocol (Marshall et al. 2016).

Methods

The following sections describe procedures as of 2014 and incorporate several changes to the protocol that have occurred since monitoring began in 2007 (documented in Marshall et al. 2016) including the following. First, a redesign of the site selection methodology occurred in 2014 and as a result new sites and point count stations were established at Delaware Water Gap NRA in 2014 (Tables 1 and 2). Although new sites were established, the target sampling area was the same and many sites were in close proximity to the original sites. Second, all sites were sampled every year from 2007–2012 whereas every-other-year sampling began with the 2014/2015 sampling period. Third, the point count duration increased from 5 to 10 minutes in 2011.

Marshall et al. (2013) summarized results for the 2007–2012 period including methods, terminology, and maps of sampling locations.

Table 1. Number of sites sampled by park and year between 2007 and 2019 as part of the Eastern Rivers and Mountains Network Streamside Bird Monitoring Protocol.

Park	2007	2008	2009	2010	2011	2012	2013	2014/15	2016/17	2018/19
ALPO	1	2	3	3	3	3	4	2	2	4
BLUE	0	0	2	2	2	3	3	4	4	4
DEWA	21	24	24	24	24	24	0	32	32	32
FONE	0	3	3	3	3	3	3	2	2	4
FRHI	0	2	2	2	2	2	2	2	2	2
GARI	3	3	3	3	3	6	0	0	0	0
NERI	22	25	25	25	24	24	0	35	35	35
Total	47	59	62	62	61	64	12	77	77	81

Table 2. Number of point count stations sampled by park and year between 2007 and 2019 as part of the Eastern Rivers and Mountains Network Streamside Bird Monitoring Protocol. A total of 317 unique stations were sampled across all parks and years.

Park	2007	2008	2009	2010	2011	2012	2013	2014/15	2016/17	2018/19
ALPO	5	8	11	11	11	11	12	6	6	12
BLUE	0	0	10	10	10	13	8	12	12	12
DEWA	105	120	120	120	120	120	0	96	96	96
FONE	0	10	10	10	10	10	9	6	6	12
FRHI	0	9	9	9	9	9	6	6	6	6
GARI	15	15	15	15	15	28	0	0	0	0
NERI	110	125	125	125	120	120	0	105	105	105
Total	235	287	300	300	295	311	35	231	231	243

Field Methods and Sampling Locations

Point count surveys are the most widely used quantitative method of monitoring bird populations (e.g., Ralph et al. 1995) and are used in this protocol as well (Marshall et al. 2016). The survey technique involves using a standardized methodology to record (“count”) all birds seen or heard during a fixed amount of time at count locations (“points”). The resultant counts are used as an index of population abundance and are amenable to a number of analytical techniques to adjust for potential detection biases (i.e., failing to detect and count birds that are actually present at the site).

Thirty-two sites were sampled in Delaware Water Gap NRA (Table 1, Figure 1). Each site consisted of three spatially replicated point count stations with point centers spaced 200 m apart; adjacent and parallel to the stream (Table 2, Figure 2). Each site was defined as a discrete 100 m segment of stream where benthic macroinvertebrates, water quality, stream habitat (Tzilkowski et al. 2016, Tzilkowski 2021) and stream fish (Faulk and Weber 2016) were also sampled. All 32 sampling sites at Delaware Water Gap NRA were selected using a random, probability-based design with the intent of making inferences regarding the streamside bird community in the wadeable stream target area (Marshall et al. 2016).

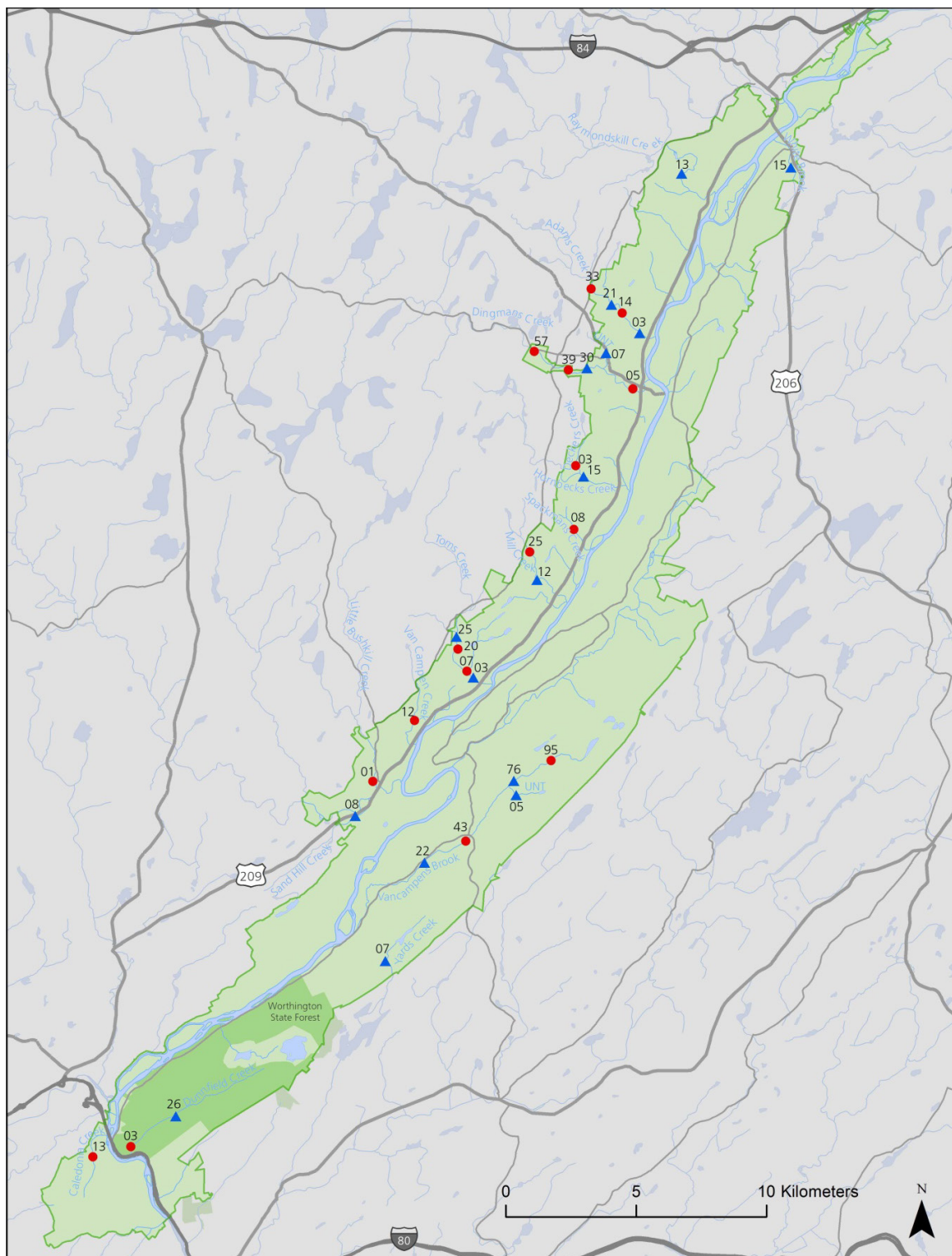


Figure 1. Location of 32 sampling sites selected for monitoring streamside birds at Delaware Water Gap National Recreation Area as part of the Eastern Rivers and Mountains Network streamside bird monitoring protocol. Red circles indicate 16 sites sampled in Panel 1; Blue triangles indicate 16 sites sampled in Panel 2. Numbers refer to the site names in Marshall et al. (2016).

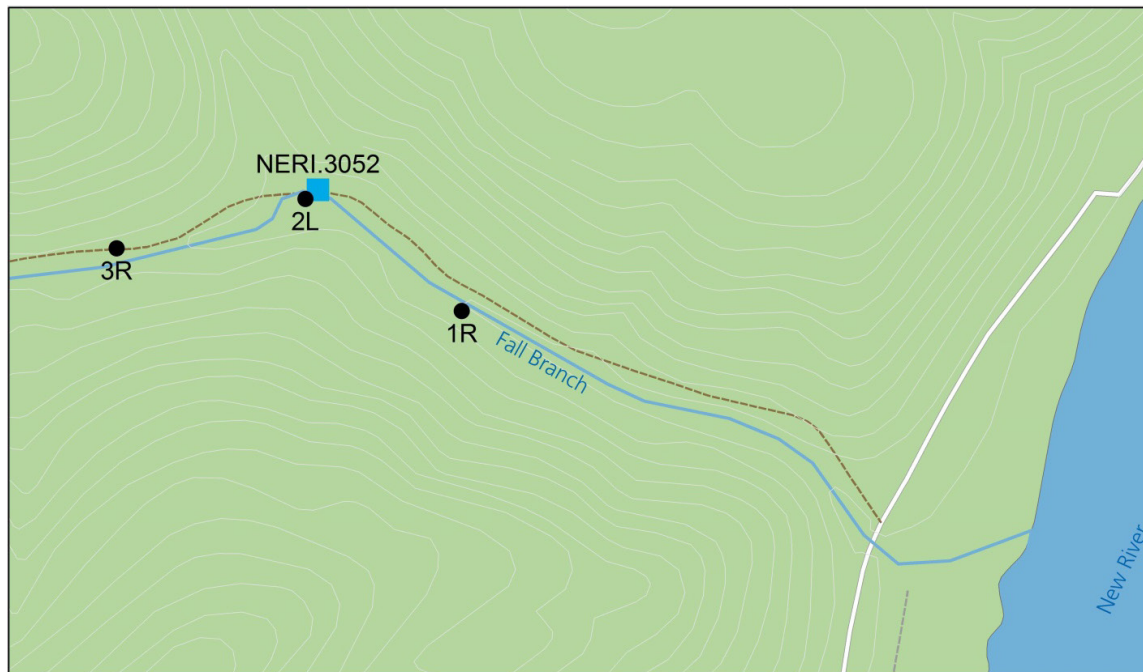


Figure 2. Example of a streamside bird sampling site with three point count stations (black circles) spaced 200 m apart. Point count station 2L is located immediately adjacent to the randomly selected 100 m stream reach where sampling for benthic macroinvertebrates and fish occurs (blue square). The site depicted is Fall Branch 07 (NERI.3052) at New River Gorge National Park and Preserve.

Sampling occurs annually but sites were divided into two sampling panels so that each site is sampled every other year; consequently, it takes two years to sample all 32 sites.

Data collection consisted of trained and experienced field personnel (here forward; observers) navigating to permanent point count stations (Figure 3) which served as the center of a circular sampling area and remaining at the point for 10 minutes counting all birds detected. The following information for each individual bird detected was recorded: 1) species identity; 2) type of detection (e.g., song, call, drumming, visual); 3) distance from observer (<50 m, 50–75 m, or >75 m); 4) if the bird was a juvenile; 5) if the bird was flying over the canopy at the time of detection; and 6) the minute of first detection.



Figure 3. Example of multi-colored cable ties and engraved aluminum tree tag used to permanently mark point count stations that are part of the Eastern Rivers and Mountains Network streamside bird monitoring protocol.

Observers visited each point count station four times during each sampling season on days with minimal precipitation and little wind and conducted a single 10 minute count each visit (temporal replicates; Table 3). Each point count occurred between sunrise and 4.5 hours after sunrise to limit sampling to the period of the day when birds were most active and vocal (>97% of all detections were auditory meaning that the observer detected a song, call or other audible cue rather than seeing the bird, which is typical of point counts conducted in forested environments).

Table 3. Number of point counts by park and year between 2007 and 2019 as part of the Eastern Rivers and Mountains Network Streamside Bird Monitoring Protocol.

Park	2007	2008	2009	2010	2011	2012	2013	2014/15	2016/17	2018/19	Total
ALPO	20	32	44	44	44	44	48	24	24	48	372
BLUE	0	0	40	40	40	52	32	48	48	48	348
DEWA	420	478	480	480	480	480	0	384	384	384	3970
FONE	0	40	40	40	40	40	36	24	24	48	332
FRHI	0	36	36	36	36	36	24	24	24	24	276
GARI	60	60	60	60	60	112	0	0	0	0	412
NERI	440	498	500	500	480	480	0	420	420	420	4158
Total	940	1144	1200	1200	1180	1244	140	924	924	972	9868

Target Population

Sampling was limited to the breeding season (mid-May through early-July) for eastern North America resident and neotropical (Central America, South America, and the Caribbean) migratory bird species that potentially breed in the streamside sampling area. Species in the Order Passeriformes (perching birds including songbirds) were particularly well sampled; additionally, species in the orders Piciformes (woodpeckers), Columbiformes (doves and pigeons), Cuculiformes (cuckoos), and Apodiformes (swifts and hummingbirds) constitute the target population. In the central Appalachians, this group of birds includes about 112 potential species (e.g., O’Connell et al. 2000). In general, these species establish breeding pairs in defined territories for the duration of the sampling period so that the point count methodology can be used to estimate the abundance of breeding birds in the sampled area.

While detections of nocturnal raptors like owls (Strigiformes), diurnal raptors (Accipitriformes), waterfowl (Anseriformes), waders (Peleconiformes), turkey and grouse (Galliformes), and other non-target species do occur, they constitute less than 1% of all detections which effectively precludes these groups from any meaningful status and trends analyses.

Data Analysis

In addition to summaries of the species detected and their conservation status, two indices of abundance were estimated to evaluate if trends in abundance have occurred over time. The first index, referred to as the “unadjusted” estimate, was calculated by dividing the total number of birds detected by the number of point count stations sampled (i.e., birds per point). The maximum number of detections per species across the four visits was used in this calculation. A hypothetical example is shown in Table 4.

Table 4. Hypothetical example showing the number of birds of a single species detected during each of four visits to six point count stations including the maximum number detected during any single visit.

Point Count Station	Visit 1	Visit 2	Visit 3	Visit 4	Maximum
1	1	1	1	1	1
2	0	1	0	1	1
3	1	0	2	1	2
4	0	0	0	0	0
5	1	0	0	0	1
6	0	0	0	0	0
Mean birds per point					0.83

Because some birds present during the point count period were likely not detected by the observer (Simons et al. 2007, Johnson 2008, Schmidt et al. 2013, Marshall et al. 2016), a second “adjusted” estimate was calculated that incorporated detection probabilities into the abundance estimates. For the adjusted estimates, the point count data were analyzed with N-mixture models (Royle 2004, Kery et al. 2005) in the ‘unmarked’ R package using the *pcount* function (Fiske and Chandler 2011) to explicitly estimate both a detection probability and an estimate of abundance adjusted by the detection probability. The data from all sampling years and the four visits within years were fit to four models. These models can be viewed as hypotheses regarding variability over time (e.g., years) in detection probability and bird abundance. Year of sampling was included as a covariate in models where either detection and/or abundance varied through time. No other covariates were used in these analyses. The four models were: a null model where both detection and abundance were constant (i.e., both abundance and detection were the same in all years of sampling and did not vary across years); a model where detection probability varied over time (i.e., sampling years) but abundance was constant; a model where detection probability was constant but abundance varied over time; and a model where both detection and abundance varied over time. All models used the Poisson mixture and $K=9$ and the analyses were run for each species independently. Abundance estimates for each sampling year were derived from the weighted average of all four models because a best model ($AICc < 2$) was rarely indicated.

The null model was also used to estimate the mean species abundance across all years of monitoring.

For both the unadjusted and adjusted estimates, trends were evaluated by fitting linear models to the annual abundance estimates regressed against sampling year. The linear model slope provides both the direction (e.g., positive slopes indicate increases in abundance over time) and magnitude of change for each species. Species were considered to have statistically significant increases or decreases when the slope was significantly different from zero ($\alpha = 0.05$) and were considered “stable” when the SE of the slope estimate overlapped zero.

All analyses were performed in the statistical software program R (version 4.0.3; R Core Team 2020).

The datasets and statistical code are available from the NPS IRMA DataStore (<https://irma.nps.gov/>).

Results

Thirteen observers conducted a total of 3,970 point counts at 216 unique point count stations at Delaware Water Gap NRA during the 12 year period between program inception in 2007 and 2019 (Tables 3 and 5). All point count stations were sampled the expected four times per year during the appropriate sampling year with the exception of the second visit to two point count stations (DEWA.1017.251 and DEWA.1021.32) in 2008 due to human error (99% sampling completeness) and all data were approved or certified prior to analyses as defined by the quality assurance procedures described in the protocol and quality assurance plan (Marshall et al. 2016, Marshall and Callahan 2018).

Table 5. Thirteen observers conducted a total of 3,970 point counts at Delaware Water Gap National Recreation Area between 2007 and 2019 as part of the Eastern Rivers and Mountains Network streamside bird monitoring protocol.

Observer	2007	2008	2009	2010	2011	2012	2014/15	2016/17	2018/19	Total
AJS	0	18	0	0	0	0	0	0	0	18
BXW	0	0	0	0	0	0	0	0	90	90
CXR	0	0	0	0	0	0	96	0	0	96
GAL	0	0	0	0	60	0	0	0	0	60
JAY	250	350	10	230	0	0	0	0	0	840
KMS	0	0	0	0	0	0	0	96	0	96
LAS	150	0	0	0	0	0	0	0	0	150
MJT	0	0	0	0	0	0	0	96	102	198
MXD	0	0	0	0	0	0	96	0	0	96
NMF	0	10	230	0	110	240	96	96	96	878
NTE	0	0	0	220	200	0	0	0	0	420
SAS	0	50	230	0	70	240	96	96	96	878
TLM	20	50	10	30	40	0	0	0	0	150
Total	420	478	480	480	480	480	384	384	384	3970

The 13 observers detected 33,263 individual birds representing 112 species during all years of sampling (Appendix 1). These totals do not include records where the observer could not identify the bird to species. Even though observers were encouraged to use an “unidentified bird” category to limit false positive observations, these constituted less than 1.4% of all records across all years and parks due to observer experience and training.

Observers detected 6.5 species per point count, on average, across all 3,970 point counts conducted. The maximum number of species detected during a single point count was 20 and only 34 counts had ≥ 15 species. On average observers detected 10.9 individual birds per point ranging from 1 to 34 during all years of monitoring.

Nonnative bird species were rarely detected (only five European Starling, two House Sparrow, and one Mute Swan detections; scientific names of all species used in the text are in Appendix 1).

No state or federally threatened or endangered species were detected during monitoring.

In order to examine consistent patterns over time, the total observations summarized above were standardized in two ways. First, the duration of all 2011–2019 point counts were standardized to 5 minutes in length to be consistent with the 2007–2010 data by excluding all records that occurred after the fifth minute. Second, several data flags were used to remove non-target observations. These include 208 records flagged as “flyovers” indicating that detected bird(s) were flying overhead (i.e., above the forest canopy and not “using” the sampled area) at the time of detection (including 63 American Crow, 37 Cedar Waxwing, 30 Turkey Vulture, 29 American Goldfinch, and 26 Tree Swallow detections). And 450 records flagged as “juveniles” (birds hatched and fledged during the sampling season including 143 Louisiana Waterthrush).

Results presented hereafter are based on this standardized dataset but otherwise include records from all distance bands and detection types.

Species Richness, Abundance, and Conservation Status

On average observers detected 70 species per year ranging from 63 (2011 and 2015) to 76 (2010) (Figure 4). The number of birds detected per point has increased from 2007–2019 (Figure 5).

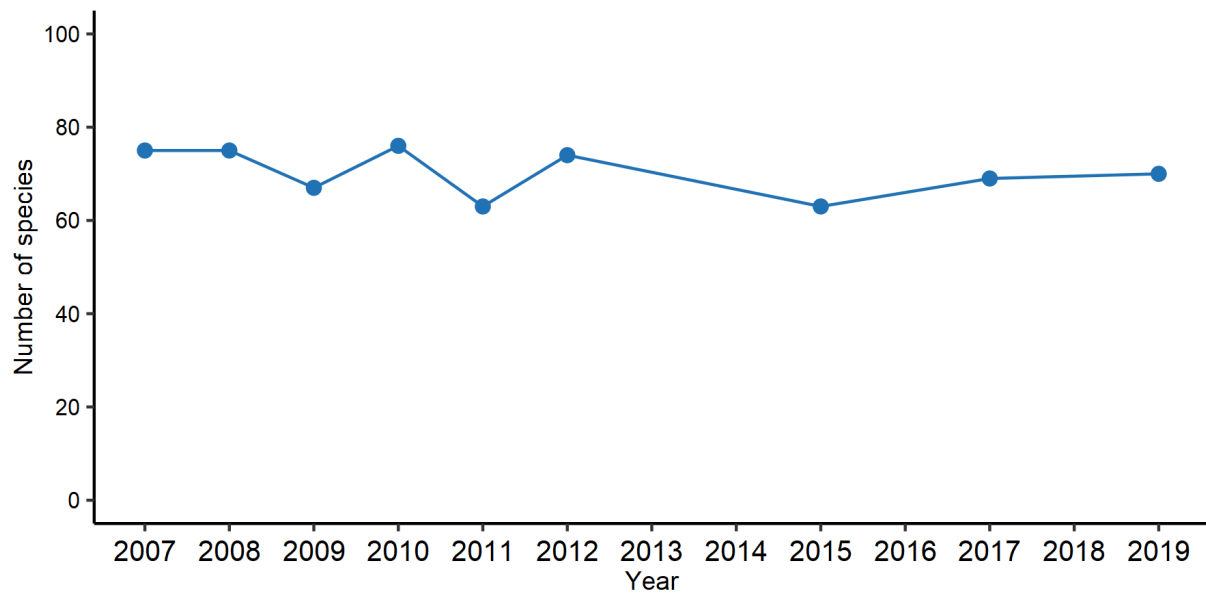


Figure 4. Total number of streamside bird species detected at Delaware Water Gap National Recreation Area point count stations from 2007–2019.

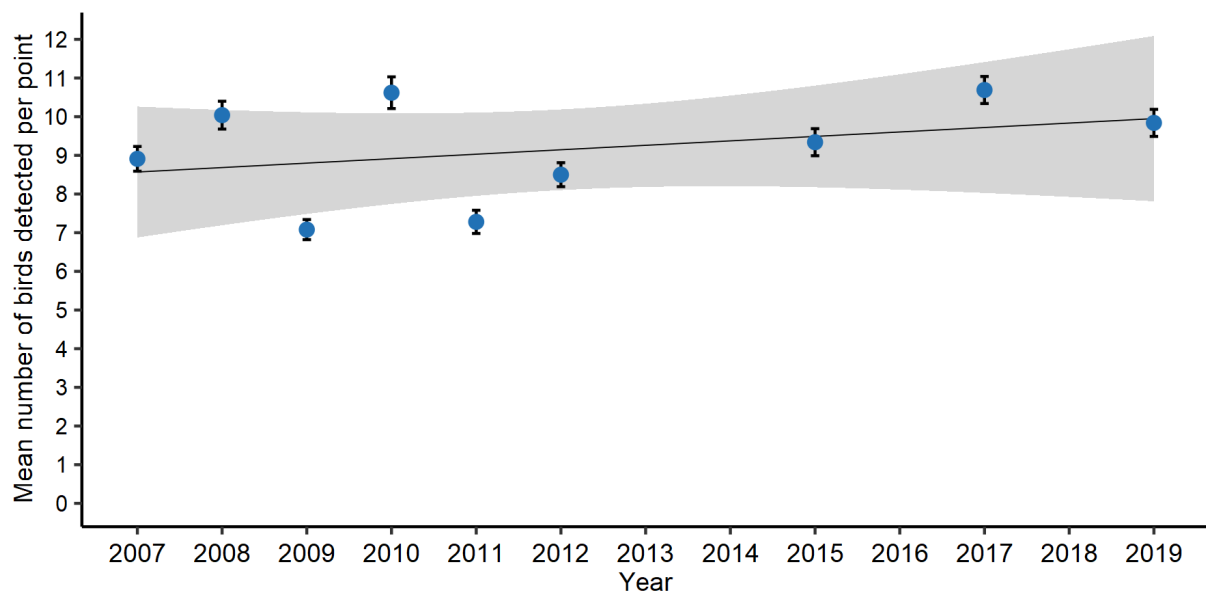


Figure 5. Number of birds detected per point count station at Delaware Water Gap National Recreation Area from 2007–2019. Mean per year (blue circles ± 1 SD) and linear trend (black horizontal line with $\pm$ SE gray shading) depicted.

Appendix 2 summarizes the average abundance from 2007–2019 for all 87 species in the target population (adjusted estimates are available for the 53 species detected most frequently; for species detected less frequently the data were too sparse for the model to converge on an estimate).

The Ovenbird was the most abundant bird species detected at Delaware Water Gap NRA point count stations followed by the Red-eyed Vireo (Appendix 2 and Figure 6) which is likely one of the most abundant forest birds in the Appalachians. These two species were more than twice as abundant as any other and 28% of all detections were of just these two species (Appendix 1).

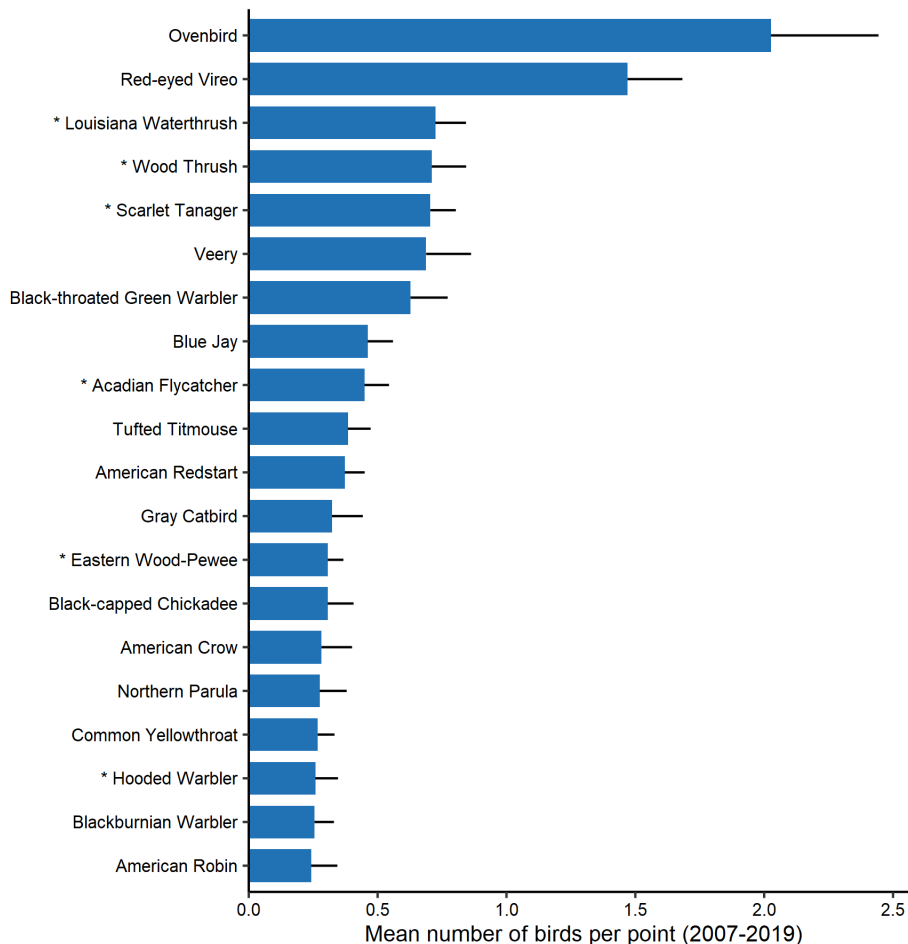


Figure 6. Twenty most abundant streamside bird species at Delaware Water Gap National Recreation Area point count stations from 2007–2019. Bars represent the unadjusted mean birds per point (+1SD) across all years of monitoring. *Species of regional conservation importance (Panjabi et al. 2020).

The majority of the 20 most abundant species were forest-associated species including several forest interior species (e.g., Ovenbird, Louisiana Waterthrush, Wood Thrush and Acadian Flycatcher) and forest generalist species (e.g., Red-eyed Vireo, Blue Jay, and Tufted Titmouse). However, several abundant species were associated with early-successional forests, shrubby fields, and suburban landscapes (e.g., Gray Catbird, American Robin, and Common Yellowthroat) reflecting the mixed vegetation/habitat structure at the park including the areas surrounding the point count stations.

Twenty-three species overall (Appendix 2) and three of the top five most abundant species (Figure 6) were of conservation importance in the Appalachian Mountains bird conservation region (BCR 28;

<https://nabci-us.org/resources/bird-conservation-regions-map/>) based on the peer-reviewed ranking criteria of the conservation consortium Partners in Flight (Panjabi et al. 2020).

Conservation “importance” includes one designation for species facing multiple threats and currently in decline (“conservation concern”) and a non-mutually exclusive designation (“conservation stewardship”) which emphasizes the regional responsibility to maintain these populations because the majority of the global population breeds in the Appalachian Mountains region. Figures 7 and 8 show the most abundant species at Delaware Water Gap NRA point count stations in these two categories, respectively.

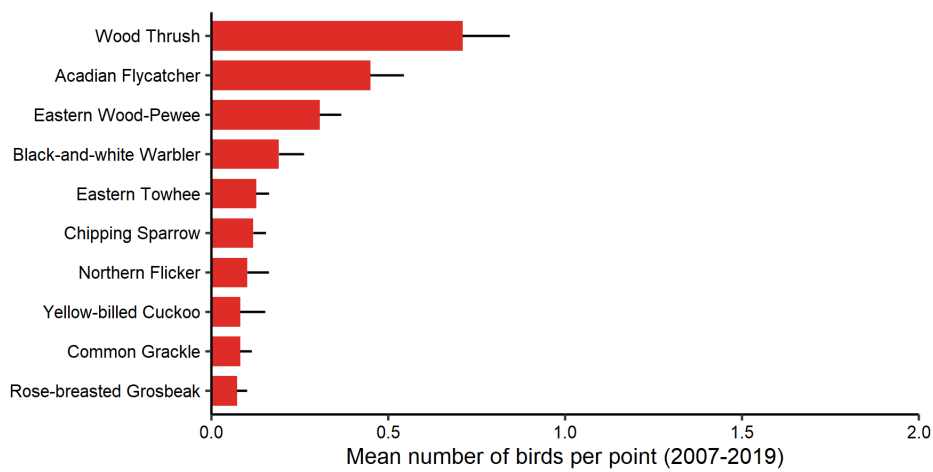


Figure 7. Ten most abundant streamside bird species of regional conservation concern (Panjabi et al. 2020) at Delaware Water Gap National Recreation Area point count stations from 2007–2019. Bars represent the mean unadjusted birds per point (+1SD) across all years of monitoring.

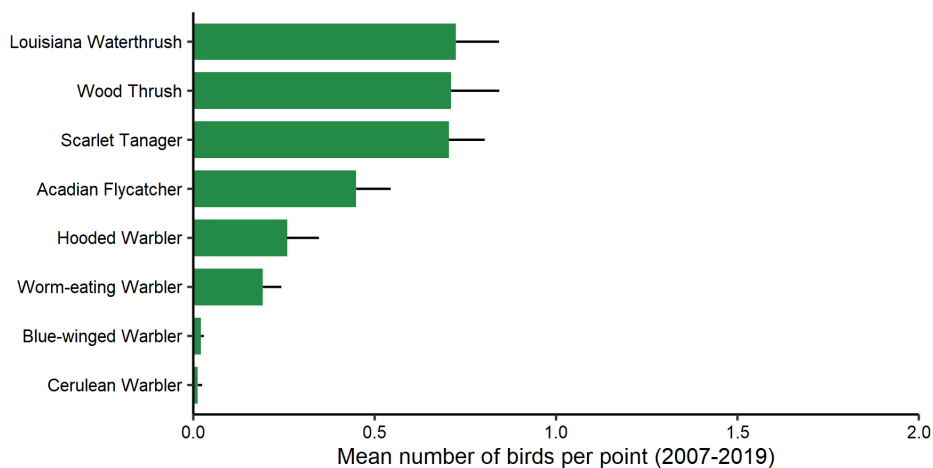


Figure 8. Abundance of streamside bird species of regional conservation stewardship (Panjabi et al. 2020) at Delaware Water Gap National Recreation Area point count stations from 2007–2019. Bars represent the mean unadjusted birds per point (+1SD) across all years of monitoring.

Trends in Abundance

Trends in unadjusted abundance were estimated for all 87 species in the target population. Trends in adjusted abundance were estimated for 53 species for which there were sufficient data for models to converge on annual estimates (Appendix 2). Examples of species-specific trends are shown below.

The Veery, one of the most abundant species at Delaware Water Gap NRA point count stations, showed the greatest increase during the period of monitoring (Figure 9). The slope of the linear trend line (0.035 birds per point per year; Figure 9 and Appendix 2) suggests that Veery have increased by about 0.51 birds per point since monitoring began—an 82% increase. Adjusted estimates also showed a statistically significant increase of similar magnitude (Figure 9, Appendix 2).

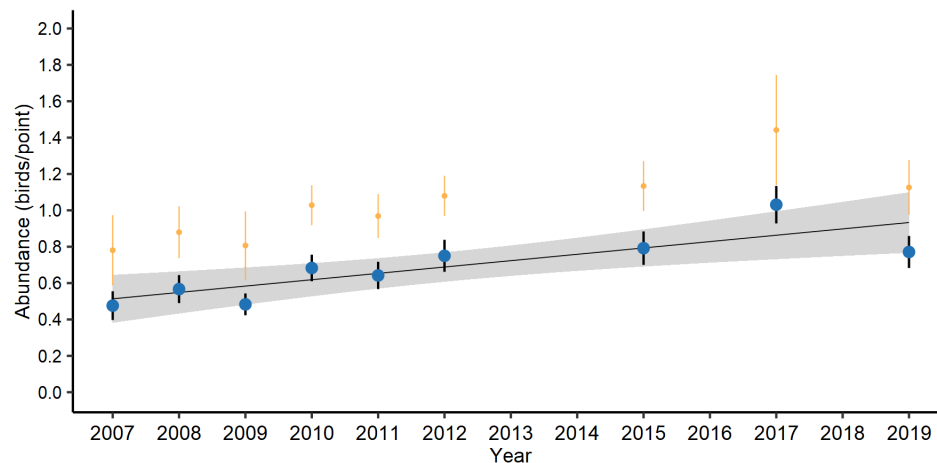


Figure 9. Veery abundance at Delaware Water Gap National Recreation Area point count stations from 2007–2019. Unadjusted (blue circles $\pm 1SD$) and adjusted (yellow circles $\pm SE$) abundance estimates shown. Linear trend (black horizontal line with $\pm SE$ gray shading) of unadjusted estimates shows a significant increase in abundance over time. Adjusted estimates also show evidence of a significant increase over time (linear trend line not shown).

Several other species showed increases in abundance including the Hooded Warbler (Figure 10) and Wood Thrush (Figure 11) both of which are of regional conservation importance. The Wood Thrush has been declining throughout its range for decades but appears stable at Delaware Water Gap NRA point count stations during the period of monitoring.

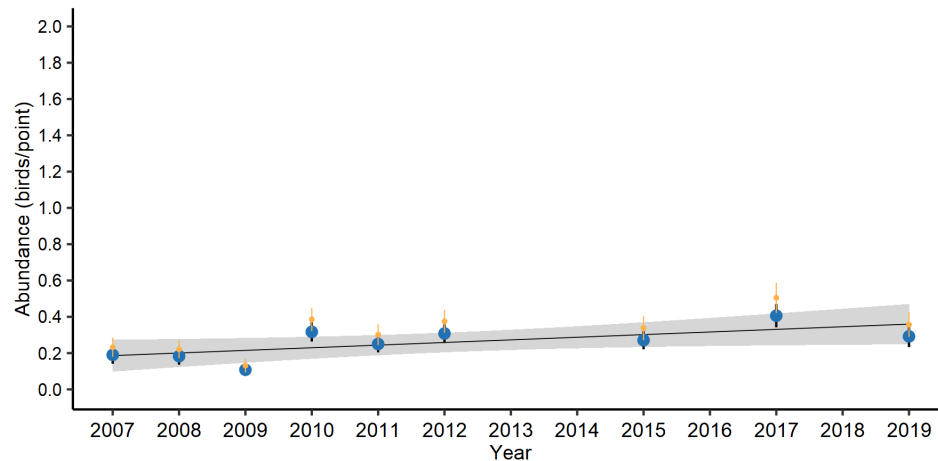


Figure 10. Hooded Warbler abundance at Delaware Water Gap National Recreation Area point count stations from 2007–2019. Unadjusted (blue circles ± 1 SD) and adjusted (yellow circles $\pm$ SE) abundance estimates shown. Linear trend (black horizontal line with $\pm$ SE gray shading) of unadjusted estimates shows a significant increase in abundance over time. Adjusted estimates also show evidence of a significant increase over time (linear trend line not shown).

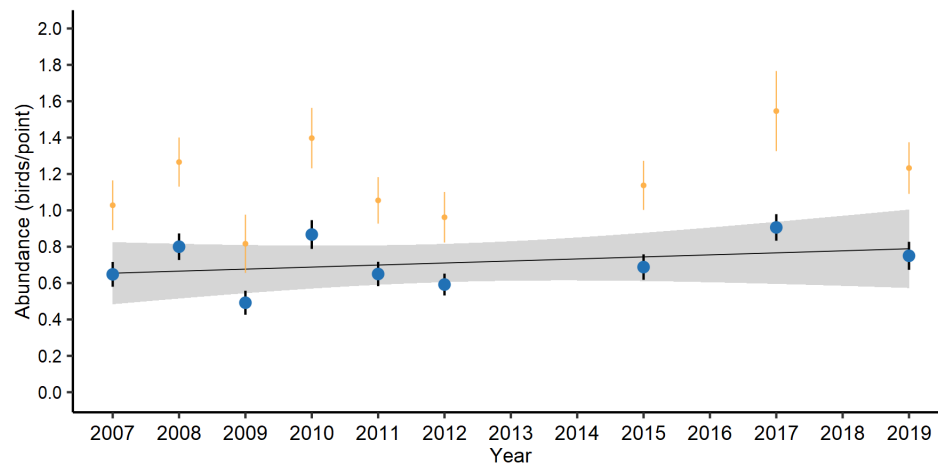


Figure 11. Wood Thrush abundance at Delaware Water Gap National Recreation Area point count stations from 2007–2019. Unadjusted (blue circles ± 1 SD) and adjusted (yellow circles $\pm$ SE) abundance estimates shown. Linear trend (black horizontal line with $\pm$ SE gray shading) of unadjusted estimates suggests a stable population abundance over time. Adjusted estimates were also stable over time (linear trend line not shown).

The Acadian Flycatcher, the ninth most abundant species at Delaware Water Gap NRA point count stations as well as a species of regional conservation importance, showed some variability in abundance over time but abundance was essentially stable during the period of monitoring based on both unadjusted and adjusted estimates (Figure 12).

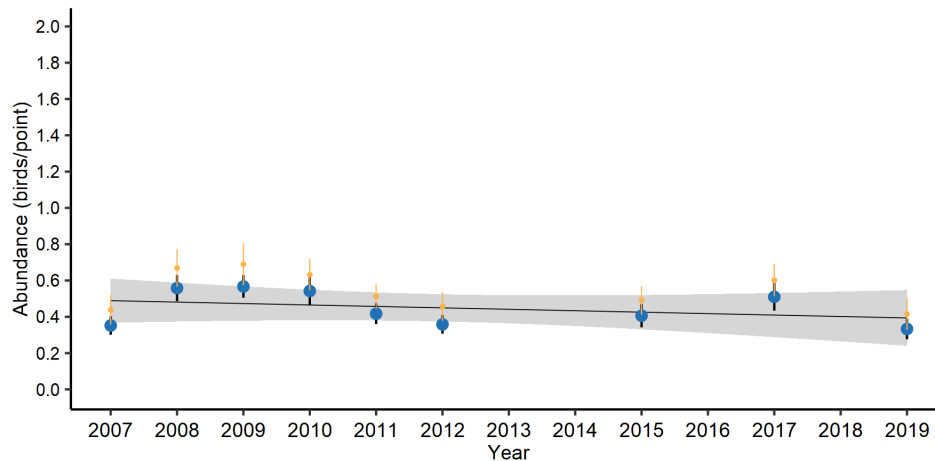


Figure 12. Acadian Flycatcher abundance at Delaware Water Gap National Recreation Area point count stations from 2007–2019. Unadjusted (blue circles $\pm 1SD$) and adjusted (yellow circles $\pm SE$) abundance estimates shown. Linear trend (black horizontal line with $\pm SE$ gray shading) of unadjusted estimates suggests a non-significant decline in abundance over time. Adjusted estimates showed the same pattern (linear trend line not shown).

The American Crow, a familiar year-round resident in the park, showed signs of a decrease in abundance during the period of monitoring at Delaware Water Gap NRA point count stations (Figure 13).

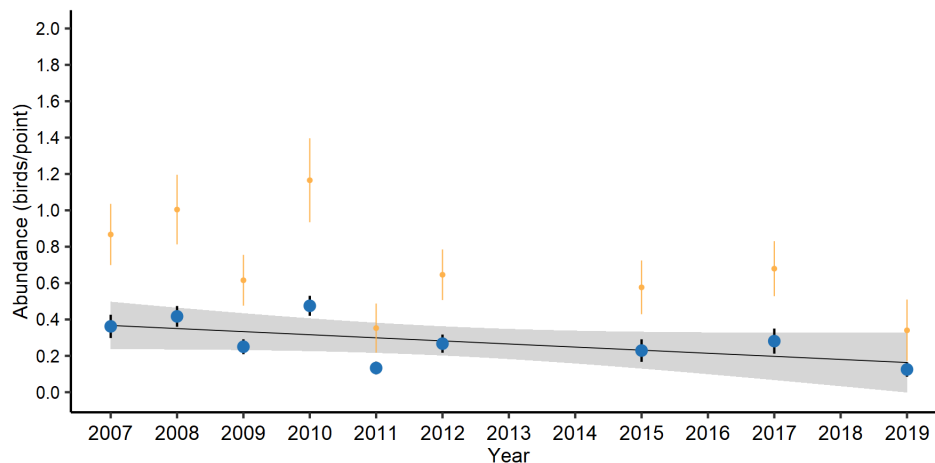


Figure 13. American Crow abundance at Delaware Water Gap National Recreation Area point count stations from 2007–2019. Unadjusted (blue circles $\pm 1SD$) and adjusted (yellow circles $\pm SE$) abundance estimates shown. Linear trend (black horizontal line with $\pm SE$ gray shading) of unadjusted estimates suggests a non-significant decline in abundance over time. Adjusted estimates showed the same pattern (linear trend line not shown).

Recalling that the slope of the linear model provides both the direction and magnitude of change in abundance over time, results for numerous species can be presented in a concise format using just this statistic. Trend estimates for the 20 most abundant species were summarized this way in Figure 14 and for all 87 target species in Appendix 3. Eighteen of the 20 most abundant species appear to be either stable or increasing in abundance during the period of monitoring based on unadjusted abundance estimates. Two species appear to be declining.

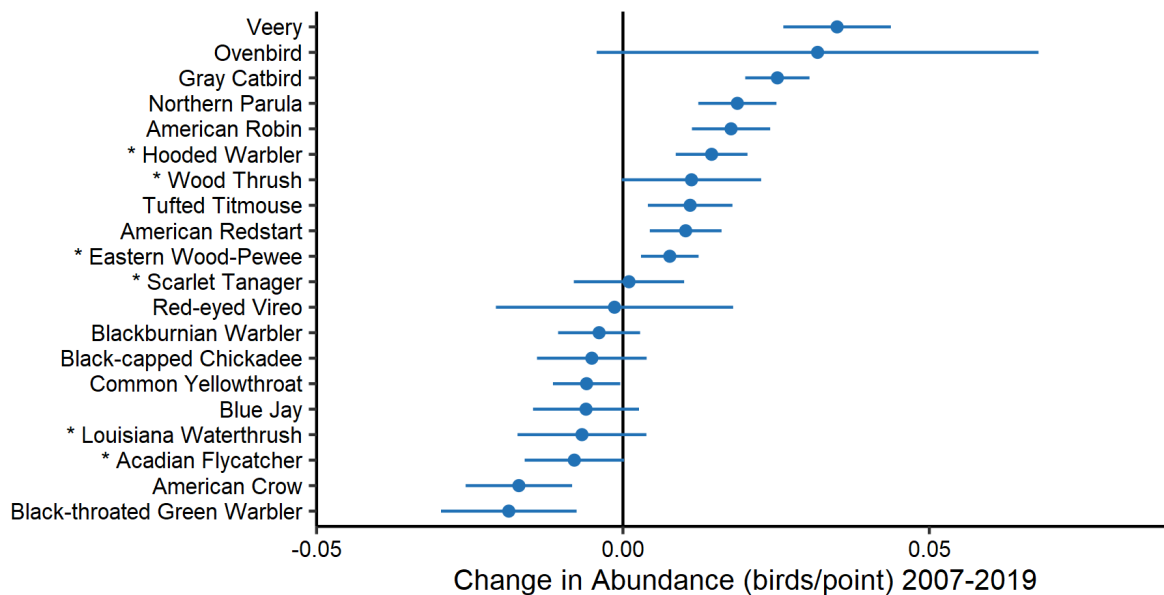


Figure 14. Trend estimates (slope $\pm$ SE of linear model regressing unadjusted abundance estimates against sampling year) for the twenty most abundant streamside bird species at Delaware Water Gap National Recreation Area point count stations from 2007–2019. Slope values >0 indicate a linear increase in abundance over time and values <0 indicate a linear decrease in abundance over time. Values where the SE of the estimate includes 0 indicate no change in abundance over time. *Species of regional conservation importance (Panjabi et al. 2020).

Discussion

This report summarizes the first 12 years of monitoring the streamside bird community at Delaware Water Gap NRA extending the analyses in Marshall et al. (2013). During the 2007–2019 time period, 13 observers conducted 3,970 point count surveys and detected 33,263 individual birds at 216 point count stations within the park.

Delaware Water Gap NRA contains a rich and diverse streamside bird community with a total of 89 species detected; 87 of which are target species and presumed to be breeding in the park during summer months. The majority were forest-associated species including forest interior species whose life-histories depend on large tracts of mature, unfragmented, deciduous forest and forest generalist species. However, several abundant species were associated with early-successional forests, shrubby fields, and suburban landscapes reflecting the mixed vegetation/habitat structure at the park including the area surrounding the point count stations.

Twenty-three species, and three of the five most abundant species, were of conservation importance in the Appalachian Mountains bird conservation region highlighting the significance of Delaware Water Gap NRA and the surrounding landscape to avian conservation.

It is not uncommon for land managers to be confronted with multiple species of conservation importance, yet which require very different habitats (e.g., early successional forest and shrubby fields versus older, unfragmented forest stands) and the situation is no different for managers of Delaware Water Gap NRA. The mosaic of habitats and natural and cultural resource values at the park should allow creation of management zones and management actions that potentially benefit multiple species. Information in this report and future analyses should support these decisions.

Trends in unadjusted abundance over the period of monitoring were assessed for all 87 species in the defined target population (Appendix 2 and 3). Trends in adjusted abundance that take into account detection probability were estimated for 53 species for which there were sufficient data. Both estimates were included in this report to provide multiple lines of evidence when assessing population trends.

It is striking, and one of the more significant findings of the monitoring program to date, that out of 87 species in the target population, 77 species (89%) appear to be stable or increasing and only 10 species (3%) appear to be declining during the period of monitoring (Table 6). The slope of either the unadjusted or adjusted abundance estimates (and typically both; Appendix 2) showed statistically significant positive trends for 10 species and negative trends for no species (Table 6). Several of the species showing either stable or increasing population trends at Delaware Water Gap NRA point count stations are species of regional conservation importance due to decades of population declines throughout the Appalachians (e.g., Wood Thrush) or are the priority species for regional conservation (e.g., Scarlet Tanager, Wood Thrush, Eastern Wood-Pewee, and Hooded Warbler). An encouraging sign in the face of recent overwhelming evidence of dramatic declines in bird populations (Rosenberg et al. 2019).

Table 6. Summary of trends in unadjusted abundance for 87 bird species at Delaware Water Gap National Recreation Area point count stations from 2007–2019. Significant increases or decreases determined by a significant ($p < 0.05$) linear model slope of either the unadjusted or adjusted abundance estimates (Appendix 2).

Abundance Trend		Number of Species (% total)	Species
Symbol	Definition		
↑↑	Significant Increase	10 (11%)	Gray Catbird, Veery, American Goldfinch, Ruby-throated Hummingbird, Northern Parula, Winter Wren, American Robin, Prairie Warbler, Hooded Warbler, Common Grackle
↑	Increase	13 (15%)	–
↔	Stable	54 (62%)	–
↓	Decrease	10 (11%)	–
↓↓	Significant Decrease	0	–

One explanation for these unexpected findings may be that many of these species are responding positively to the decline of the Eastern hemlock (*Tsuga canadensis*; due to the hemlock woolly adelgid, *Adelges tsugae*) and concurrent transition from hemlock dominated stream drainages to stands of mixed deciduous forest with proportionally less hemlock. For example, species such as Ovenbird, Veery, Wood Thrush, Northern Parula, and Hooded Warbler are associated with deciduous forest habitat and would benefit from the transition from hemlock to hardwood; and are among the species increasing the most (Figure 13). Similarly, Winter Wren, which could benefit from habitat created by dying and fallen hemlock trees, are also increasing (Appendix 2). Whereas the hemlock associated species (Black-throated Green Warbler, Acadian Flycatcher, Hermit Thrush, and Blackburnian Warbler; Figure 13 and Appendix 2) were essentially stable or declining (albeit non-significantly) during this time period. These findings are consistent with other recent research at the park on the changes in the bird community associated with the decline of Eastern hemlock (e.g., Toenies et al. 2018).

It is also notable that the American Crow, a familiar but uncommon species at all ERMN parks, appeared to decline at Delaware Water Gap NRA based on unadjusted estimates (Figure 13, Appendix 2). American Crows were rarely detected at any ERMN park during the 2014–2019 period and there was only a single detection at Delaware Water Gap NRA in 2018 and 2019, potentially due to mortality associated with West Nile virus (e.g., Caffrey et al. 2005, LaDeau et al. 2011, Bolgiano 2019)

One limitation of the monitoring program so far was the establishment of new point count stations beginning in 2014 (Tables 1 and 2; Marshall et al. 2016). It is possible that some of the apparent patterns and trends were confounded with this change and reflect changes in the locations sampled rather than “real” changes in abundance. Examination of the examples in Figures 9–13 do not support this argument (i.e., abundance estimates and trends before and after the change were not

obviously inconsistent) but this explanation should be considered. A reassessment of these trends should be more definitive after 1–2 more sampling years now that the point count stations have stabilized and reliance on the assumption that both sampling periods accurately represent the same target population will become less important.

This report provides the first information regarding long-term population trends of breeding birds in Delaware Water Gap NRA which is the primary objective of the monitoring protocol. Continued monitoring will provide new insights and future analyses will explore specific factors linked to population trends. As anthropogenic land use and climate change continue to reshape the Appalachian landscape, park managers will need this information to best allocate effort that aligns with regional conservation planning and other park priorities.

Literature Cited

- Bolgiano, N. 2019. Evidence for West Nile virus-related avian declines in Pennsylvania. *Pennsylvania Birds* 33(1):1–11.
- Caffrey, C., C. R. Shauna, and T. J. Weston. 2005. West Nile virus devastates an American crow population. *The Condor* 107(1):128–132.
- Chesser, R. T., K. J. Burns, C. Cicero, J. L. Dunn, A. W. Kratter, I. J. Lovette, P. C. Rasmussen, J. V. Remsen, Jr., D. F. Stotz, and K. Winker. 2019. Check-list of North American Birds (online). American Ornithological Society. Available at: <http://checklist.aou.org/taxa> (accessed 27 July 2021).
- Fancy, S. G., J. E. Gross, and S. L. Carter. 2009. Monitoring the condition of natural resources in US National Parks. *Environmental Monitoring and Assessment* 151:161–174.
- Faulk, E. A., and A. S. Weber. 2017. Eastern Rivers and Mountains Network stream fish monitoring: Summary of 2013–2014 pilot sampling. Natural Resource Data Series NPS/ERMN/NRDS—2017/1084. National Park Service, Fort Collins, Colorado.
- Fiske, I., and R. Chandler. 2011. unmarked: An R package for fitting hierarchical models of wildlife occurrence and abundance. *Journal of Statistical Software* 43(10):1–23.
- Johnson, D. H. 2008. In defense of indices: The case of bird surveys. *Journal of Wildlife Management* 72(4):857–868.
- Kery, M., Royle, J. A., and Schmid, H. 2005. Modeling avian abundance from replicated counts using binomial mixture models. *Ecological Applications* 15:1450–1461.
- LaDeau, S. L., C. A., Calder, P. J. Doran, and P. P. Marra. 2011. West Nile virus impacts in American crow populations are associated with human land use and climate. *Ecological Research* 26(5):909–916.
- Marshall, M., and K. Callahan. 2018. Streamside bird monitoring protocol for the Eastern Rivers and Mountains Network: Quality assurance plan version 1.0. Natural Resource Report NPS/ERMN/NRR—2018/1772. National Park Service, Fort Collins, Colorado.
- Marshall, M., B. Mattsson, K. Callahan, and T. Master. 2013. Streamside bird monitoring: Eastern Rivers and Mountains Network 2007–2012 summary report. Natural Resource Data Series NPS/ERMN/NRDS—2013/449. National Park Service, Fort Collins, Colorado.
- Marshall, M., C. Tzilkowski, and K. Callahan. 2016. Streamside bird monitoring protocol for the Eastern Rivers and Mountains Network: Protocol narrative version 3.0. Natural Resource Report NPS/ERMN/NRR—2016/1224. National Park Service, Fort Collins, Colorado.

- Marshall, M. R., and N. B. Piekielek. 2007. Eastern Rivers and Mountains Network Ecological Monitoring Plan. Natural Resource Report NPS/ERMN/NRR—2007/017. National Park Service. Fort Collins, CO.
- O'Connell, T. J., L. E. Jackson, and R. P. Brooks. 2000. Bird guilds as indicators of ecological condition in the central Appalachians. *Ecological Applications* 10:1706–1721.
- Panjabi, A. O., W. E. Easton, P. J. Blancher, A. E. Shaw, B. A. Andres, C. J. Beardmore, A. F. Camfield, D. W. Demarest, R. Dettmers, R. H. Keller, K. V. Rosenberg, T. Will, and M. A. Gahbauer. 2020. Avian Conservation Assessment Database Handbook, Version 2020. Partners in Flight Technical Series No. 8.1. Available at: <http://pif.birdconservancy.org/acad.handbook.pdf> (accessed 27 July 2021).
- R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available at: <https://www.r-project.org/> (accessed 27 July 2021).
- Ralph, C. J., S. Droege, and J. R. Sauer. 1995. Managing and monitoring birds using point counts: standards and applications. Pages 161–168 *in* C. J. Ralph, J. R. Sauer, and S. Droege, editors. *Monitoring Bird Populations by Point Counts*. USDA Forest Service General Technical Report PSW GTR 149, Pacific Southwest Research Station, Berkeley, California.
- Robinson, S. K., F. R. Thompson III, T. M. Donovan, D. R. Whitehead, and J. Faaborg. 1995. Regional forest fragmentation and the nesting success of migratory birds. *Science* 267:1987–1990.
- Rosenberg, K. V., A. M. Dokter, P. J. Blancher, J. R. Sauer, A. C. Smith, P. A. Smith, J. C. Stanton, A. Panjabi, L. Helft, M. Parr, and P. P. Marra. 2019. Decline of the North American avifauna. *Science* 366:120–124.
- Rosenstock, S. S., D. R. Anderson, K. M. Giesen, T. Leukering, and M. F. Carter. 2002. Landbird counting techniques: Current practices and an alternative. *Auk* 119:46–53.
- Royle, J. A. 2004. N-mixture models for estimating population size from spatially replicated counts. *Biometrics* 60(1):108–115.
- Sauer, J. R., W. A. Link, and J. E. Hines. 2020. The North American Breeding Bird Survey, Analysis Results 1966–2019: U.S. Geological Survey data release. Available at: <https://doi.org/10.5066/P96A7675> (accessed 27 July 2021).
- Schmidt, J. H., C. L. McIntyre, and M. C. MacCluskie. 2013. Accounting for incomplete detection: What are we estimating and how might it affect long-term passerine monitoring programs? *Biological Conservation* 160:130–139.
- Simons, T. R., M. W. Alldredge, K. H. Pollock, and J. M. Wettroth. 2007. Experimental analysis of the auditory detection process on avian point counts. *Auk* 124:986–999.

- Toenies, M. J., D. A. W. Miller, M. R. Marshall, and G. E. Stauffer. 2018. Shifts in vegetation and avian community structure following the decline of a foundational forest species, the eastern hemlock. *Condor* 120:489–506.
- Tzilkowski, C. J., A. S. Weber, K. K. Callahan, and M. R. Marshall. 2016. Protocol implementation plan for benthic macroinvertebrate monitoring in the Eastern Rivers and Mountains Network. Natural Resource Report NPS/ERMN/NRR—2016/1265. National Park Service, Fort Collins, Colorado.
- Tzilkowski, C. 2021. Benthic macroinvertebrate monitoring in Eastern Rivers and Mountains Network wadeable streams: 2014–2019 summary report. Natural Resource Report NPS/ERMN/NRR—2021/2283. National Park Service, Fort Collins, Colorado. Available at: <https://doi.org/10.36967/nrr-2286761> (accessed 27 July 2021).

Appendix 1. List of 130 bird species detected and total number of detections by park during implementation of the Eastern Rivers and Mountains Network Streamside Bird Monitoring Protocol 2007–2019.

Table A1-1. Taxonomy follows Chesser et al. (2019). Four letter species codes from the Institute for Bird Populations (<https://www.birdpop.org/pages/birdSpeciesCodes.php>).

Order	Family	Common Name	Code	Scientific Name	ALPO	FONE	FRHI	DEWA	BLUE	NERI	GARI
Anseriformes	Anatidae	Canada Goose	CANG	<i>Branta canadensis</i>	0	0	0	27	0	34	0
Anseriformes	Anatidae	Mute Swan	MUSW	<i>Cygnus olor</i>	0	0	0	1	0	0	0
Anseriformes	Anatidae	Wood Duck	WODU	<i>Aix sponsa</i>	0	0	0	3	0	1	0
Anseriformes	Anatidae	American Black Duck*+	ABDU	<i>Anas rubripes</i>	0	0	0	1	0	0	0
Anseriformes	Anatidae	Mallard	MALL	<i>Anas platyrhynchos</i>	0	0	0	28	0	0	0
Anseriformes	Anatidae	Hooded Merganser	HOME	<i>Lophodytes cucullatus</i>	0	0	0	1	0	0	0
Anseriformes	Anatidae	Common Merganser	COME	<i>Mergus merganser</i>	0	0	0	5	0	0	0
Galliformes	Phasianidae	Ruffed Grouse	RUGR	<i>Bonasa umbellus</i>	0	0	0	0	7	3	0
Galliformes	Phasianidae	Wild Turkey	WITU	<i>Meleagris gallopavo</i>	0	10	4	30	2	8	0
Pelecaniformes	Ardeidae	Great Blue Heron	GBHE	<i>Ardea herodias</i>	0	0	0	32	1	0	0
Pelecaniformes	Ardeidae	Green Heron*+	GRHE	<i>Butorides virescens</i>	0	0	0	1	0	0	0
Cathartiformes	Cathartidae	Turkey Vulture	TUVU	<i>Cathartes aura</i>	0	0	2	41	1	9	1
Accipitriformes	Accipitridae	Bald Eagle	BAEA	<i>Haliaeetus leucocephalus</i>	0	0	0	8	0	0	1
Accipitriformes	Accipitridae	Sharp-shinned Hawk	SSHA	<i>Accipiter striatus</i>	0	0	0	1	0	1	1

* Species of conservation importance: Regional Importance, as determined by Partners in Flight (Panjabi 2020).

+ Species of conservation importance: Regional Concern, as determined by Partners in Flight (Panjabi 2020).

^ Species of conservation importance: Regional Stewardship, as determined by Partners in Flight (Panjabi 2020).

Table A1-1. Taxonomy follows Chesser et al. (2019). Four letter species codes from the Institute for Bird Populations (<https://www.birdpop.org/pages/birdSpeciesCodes.php>).

Order	Family	Common Name	Code	Scientific Name	ALPO	FONE	FRHI	DEWA	BLUE	NERI	GARI
Accipitriformes	Accipitridae	Cooper's Hawk	COHA	<i>Accipiter cooperii</i>	0	5	0	3	0	5	1
Accipitriformes	Accipitridae	Red-shouldered Hawk	RSHA	<i>Buteo lineatus</i>	1	3	14	14	0	17	5
Accipitriformes	Accipitridae	Broad-winged Hawk	BWHA	<i>Buteo platypterus</i>	3	4	3	26	0	2	0
Accipitriformes	Accipitridae	Red-tailed Hawk	RTHA	<i>Buteo jamaicensis</i>	4	5	0	21	2	2	0
Charadriiformes	Charadriidae	Killdeer	KILL	<i>Charadrius vociferus</i>	2	2	0	1	0	0	0
Charadriiformes	Scolopacidae	Spotted Sandpiper	SPSA	<i>Actitis macularius</i>	0	0	0	2	0	0	0
Columbiformes	Columbidae	Mourning Dove	MODO	<i>Zenaida macroura</i>	9	6	0	215	5	73	6
Cuculiformes	Cuculidae	Yellow-billed Cuckoo*+	YBCU	<i>Coccyzus americanus</i>	4	9	5	115	10	57	7
Cuculiformes	Cuculidae	Black-billed Cuckoo*+	BBCU	<i>Coccyzus erythrophthalmus</i>	0	1	1	17	0	0	0
Strigiformes	Strigidae	Eastern Screech-Owl*+	EASO	<i>Megascops asio</i>	0	0	0	0	1	1	0
Strigiformes	Strigidae	Great Horned Owl	GHOW	<i>Bubo virginianus</i>	0	1	0	5	0	0	0
Strigiformes	Strigidae	Barred Owl	BADO	<i>Strix varia</i>	0	1	1	4	0	14	3
Strigiformes	Strigidae	Northern Saw-whet Owl	NSWO	<i>Aegolius acadicus</i>	0	0	0	0	0	2	0
Apodiformes	Apodidae	Chimney Swift*+	CHSW	<i>Chaetura pelagica</i>	26	11	1	16	2	7	0
Apodiformes	Trochilidae	Ruby-throated Hummingbird	RTHU	<i>Archilochus colubris</i>	9	11	8	58	5	47	7
Coraciiformes	Alcedinidae	Belted Kingfisher*+	BEKI	<i>Megasceryle alcyon</i>	2	1	0	70	5	8	1
Piciformes	Picidae	Red-headed Woodpecker	RHOW	<i>Melanerpes erythrocephalus</i>	0	0	0	0	0	1	0
Piciformes	Picidae	Red-bellied Woodpecker	RBWO	<i>Melanerpes carolinus</i>	83	70	71	186	5	72	8

* Species of conservation importance: Regional Importance, as determined by Partners in Flight (Panjabi 2020).

+ Species of conservation importance: Regional Concern, as determined by Partners in Flight (Panjabi 2020).

^ Species of conservation importance: Regional Stewardship, as determined by Partners in Flight (Panjabi 2020).

Table A1-1. Taxonomy follows Chesser et al. (2019). Four letter species codes from the Institute for Bird Populations (<https://www.birdpop.org/pages/birdSpeciesCodes.php>).

Order	Family	Common Name	Code	Scientific Name	ALPO	FONE	FRHI	DEWA	BLUE	NERI	GARI
Piciformes	Picidae	Yellow-bellied Sapsucker	YBSA	<i>Sphyrapicus varius</i>	0	0	0	1	0	2	0
Piciformes	Picidae	Downy Woodpecker	DOWO	<i>Dryobates pubescens</i>	46	15	46	220	14	121	23
Piciformes	Picidae	Hairy Woodpecker	HAWO	<i>Dryobates villosus</i>	9	13	14	113	14	65	10
Piciformes	Picidae	Northern Flicker*+	NOFL	<i>Colaptes auratus</i>	16	32	19	185	8	76	16
Piciformes	Picidae	Pileated Woodpecker	PIWO	<i>Dryocopus pileatus</i>	32	59	44	192	30	272	49
Passeriformes	Tyrannidae	Eastern Wood-Pewee*+	EAWP	<i>Contopus virens</i>	62	96	133	580	18	154	18
Passeriformes	Tyrannidae	Acadian Flycatcher*+^	ACFL	<i>Empidonax virescens</i>	88	149	317	1046	297	3267	174
Passeriformes	Tyrannidae	Willow Flycatcher	WIFL	<i>Empidonax traillii</i>	0	1	0	3	0	0	0
Passeriformes	Tyrannidae	Least Flycatcher*+	LEFL	<i>Empidonax minimus</i>	0	1	0	1	0	0	0
Passeriformes	Tyrannidae	Eastern Phoebe	EAPH	<i>Sayornis phoebe</i>	21	11	2	481	34	419	54
Passeriformes	Tyrannidae	Great Crested Flycatcher	GCFL	<i>Myiarchus crinitus</i>	8	8	3	179	1	38	11
Passeriformes	Tyrannidae	Eastern Kingbird	EAKI	<i>Tyrannus tyrannus</i>	0	0	0	13	0	0	0
Passeriformes	Vireonidae	White-eyed Vireo	WEVI	<i>Vireo griseus</i>	0	2	0	0	0	0	0
Passeriformes	Vireonidae	Yellow-throated Vireo	YTVI	<i>Vireo flavifrons</i>	1	5	16	213	12	39	10
Passeriformes	Vireonidae	Blue-headed Vireo	BHVI	<i>Vireo solitarius</i>	23	44	1	316	51	510	63
Passeriformes	Vireonidae	Warbling Vireo	WAVI	<i>Vireo gilvus</i>	0	1	0	16	0	0	0
Passeriformes	Vireonidae	Red-eyed Vireo	REVI	<i>Vireo olivaceus</i>	464	436	352	3786	358	3281	191
Passeriformes	Corvidae	Blue Jay	BLJA	<i>Cyanocitta cristata</i>	66	85	61	829	44	469	60
Passeriformes	Corvidae	American Crow	AMCR	<i>Corvus brachyrhynchos</i>	87	144	136	546	27	409	96

* Species of conservation importance: Regional Importance, as determined by Partners in Flight (Panjabi 2020).

+ Species of conservation importance: Regional Concern, as determined by Partners in Flight (Panjabi 2020).

^ Species of conservation importance: Regional Stewardship, as determined by Partners in Flight (Panjabi 2020).

Table A1-1. Taxonomy follows Chesser et al. (2019). Four letter species codes from the Institute for Bird Populations (<https://www.birdpop.org/pages/birdSpeciesCodes.php>).

Order	Family	Common Name	Code	Scientific Name	ALPO	FONE	FRHI	DEWA	BLUE	NERI	GARI
Passeriformes	Corvidae	Fish Crow	FICR	<i>Corvus ossifragus</i>	0	0	0	1	0	0	0
Passeriformes	Corvidae	Common Raven	CORA	<i>Corvus corax</i>	2	6	4	53	2	24	3
Passeriformes	Hirundinidae	Tree Swallow	TRES	<i>Tachycineta bicolor</i>	0	0	0	36	0	6	0
Passeriformes	Hirundinidae	Northern Rough-winged Swallow	NRWS	<i>Stelgidopteryx serripennis</i>	0	0	0	8	0	0	2
Passeriformes	Hirundinidae	Barn Swallow*+	BARS	<i>Hirundo rustica</i>	0	0	0	10	0	0	0
Passeriformes	Paridae	Carolina Chickadee	CACH	<i>Poecile carolinensis</i>	0	3	42	0	77	399	56
Passeriformes	Paridae	Black-capped Chickadee	BCCH	<i>Poecile atricapillus</i>	37	88	0	477	3	3	1
Passeriformes	Paridae	Tufted Titmouse	TUTI	<i>Baeolophus bicolor</i>	111	116	123	628	62	729	81
Passeriformes	Sittidae	Red-breasted Nuthatch	RBNU	<i>Sitta canadensis</i>	0	0	0	5	0	0	0
Passeriformes	Sittidae	White-breasted Nuthatch	WBNU	<i>Sitta carolinensis</i>	54	65	31	176	11	111	11
Passeriformes	Certhiidae	Brown Creeper	BRCR	<i>Certhia americana</i>	0	51	4	174	6	7	1
Passeriformes	Troglodytidae	Carolina Wren	CARW	<i>Thryothorus ludovicianus</i>	31	14	62	76	32	235	50
Passeriformes	Troglodytidae	House Wren	HOWR	<i>Troglodytes aedon</i>	15	17	0	47	0	0	0
Passeriformes	Regulidae	Golden-crowned Kinglet	GCKI	<i>Regulus satrapa</i>	2	2	0	3	0	2	0
Passeriformes	Turdidae	Eastern Bluebird	EABL	<i>Sialia sialis</i>	1	0	8	12	0	2	0
Passeriformes	Turdidae	Veery	VEER	<i>Catharus fuscescens</i>	0	0	0	1525	0	5	0
Passeriformes	Turdidae	Swainson's Thrush	SWTH	<i>Catharus ustulatus</i>	0	0	0	0	0	1	0
Passeriformes	Turdidae	Hermit Thrush	HETH	<i>Catharus guttatus</i>	0	0	0	112	0	4	0

* Species of conservation importance: Regional Importance, as determined by Partners in Flight (Panjabi 2020).

+ Species of conservation importance: Regional Concern, as determined by Partners in Flight (Panjabi 2020).

^ Species of conservation importance: Regional Stewardship, as determined by Partners in Flight (Panjabi 2020).

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Passeriformes	Turdidae	Wood Thrush*+^	WOTH	<i>Hylocichla mustelina</i>	132	137	94	1509	210	2127	104
Passeriformes	Turdidae	American Robin	AMRO	<i>Turdus migratorius</i>	118	82	24	485	7	134	23
Passeriformes	Mimidae	Gray Catbird	GRCA	<i>Dumetella carolinensis</i>	55	61	0	823	2	54	3
Passeriformes	Mimidae	Northern Mockingbird	NOMO	<i>Mimus polyglottos</i>	0	0	0	0	0	1	1
Passeriformes	Mimidae	Brown Thrasher	BRTH	<i>Toxostoma rufum</i>	0	4	0	3	1	0	0
Passeriformes	Sturnidae	European Starling+	EUST	<i>Sturnus vulgaris</i>	4	3	0	5	0	5	0
Passeriformes	Bombycillidae	Cedar Waxwing	CEDW	<i>Bombycilla cedrorum</i>	19	35	2	354	3	35	15
Passeriformes	Parulidae	Blue-winged Warbler*^	BWWA	<i>Vermivora cyanoptera</i>	0	0	0	32	0	0	0
Passeriformes	Parulidae	Golden-winged Warbler*+	GWWA	<i>Vermivora chrysoptera</i>	0	9	0	0	0	0	0
Passeriformes	Parulidae	Northern Parula	NOPA	<i>Setophaga americana</i>	7	14	4	552	64	229	104
Passeriformes	Parulidae	Yellow Warbler	Yewa	<i>Setophaga petechia</i>	0	4	1	211	0	3	0
Passeriformes	Parulidae	Chestnut-sided Warbler	CSWA	<i>Setophaga pensylvanica</i>	1	88	0	26	0	5	0
Passeriformes	Parulidae	Magnolia Warbler	MAWA	<i>Setophaga magnolia</i>	0	22	0	3	0	2	0
Passeriformes	Parulidae	Black-throated Blue Warbler	BTBW	<i>Setophaga caerulescens</i>	1	3	0	15	1	166	9
Passeriformes	Parulidae	Yellow-rumped Warbler	YRWA	<i>Setophaga coronata</i>	0	1	0	1	0	0	2
Passeriformes	Parulidae	Black-throated Green Warbler	BTNW	<i>Setophaga virens</i>	49	58	2	1415	33	566	97
Passeriformes	Parulidae	Blackburnian Warbler	BLBW	<i>Setophaga fusca</i>	1	32	0	471	0	38	0
Passeriformes	Parulidae	Yellow-throated Warbler*^	YTWA	<i>Setophaga dominica</i>	0	0	18	0	33	149	28
Passeriformes	Parulidae	Pine Warbler	PIWA	<i>Setophaga pinus</i>	0	0	0	162	0	1	1

* Species of conservation importance: Regional Importance, as determined by Partners in Flight (Panjabi 2020).

+ Species of conservation importance: Regional Concern, as determined by Partners in Flight (Panjabi 2020).

^ Species of conservation importance: Regional Stewardship, as determined by Partners in Flight (Panjabi 2020).

Table A1-1. Taxonomy follows Chesser et al. (2019). Four letter species codes from the Institute for Bird Populations (<https://www.birdpop.org/pages/birdSpeciesCodes.php>).

Order	Family	Common Name	Code	Scientific Name	ALPO	FONE	FRHI	DEWA	BLUE	NERI	GARI
Passeriformes	Parulidae	Prairie Warbler*+	PRAW	<i>Setophaga discolor</i>	0	7	0	103	0	0	0
Passeriformes	Parulidae	Blackpoll Warbler	BLPW	<i>Setophaga striata</i>	0	1	0	0	0	6	1
Passeriformes	Parulidae	Cerulean Warbler*+^	CERW	<i>Setophaga cerulea</i>	1	14	1	17	4	19	6
Passeriformes	Parulidae	Black-and-white Warbler*+	BAWW	<i>Mniotilta varia</i>	0	4	0	327	51	807	68
Passeriformes	Parulidae	American Redstart	AMRE	<i>Setophaga ruticilla</i>	64	52	10	825	59	650	51
Passeriformes	Parulidae	Worm-eating Warbler*^	WEWA	<i>Helmitheros vermivorum</i>	0	0	0	360	78	234	4
Passeriformes	Parulidae	Swainson's Warbler*+	SWWA	<i>Limnothlypis swainsonii</i>	0	0	0	0	0	52	104
Passeriformes	Parulidae	Ovenbird	OVEN	<i>Seiurus aurocapilla</i>	155	149	103	5540	167	1609	158
Passeriformes	Parulidae	Louisiana Waterthrush*^	LOWA	<i>Parkesia motacilla</i>	74	30	143	1537	157	1431	157
Passeriformes	Parulidae	Kentucky Warbler*+	KEWA	<i>Geothlypis formosa</i>	0	0	1	4	2	5	0
Passeriformes	Parulidae	Common Yellowthroat	COYE	<i>Geothlypis trichas</i>	94	232	12	558	0	6	2
Passeriformes	Parulidae	Hooded Warbler*^	HOWA	<i>Setophaga citrina</i>	14	122	19	576	27	830	296
Passeriformes	Parulidae	Canada Warbler*+	CAWA	<i>Cardellina canadensis</i>	0	0	0	4	0	0	0
Passeriformes	Icteridae	Yellow-breasted Chat*+	YBCH	<i>Icteria virens</i>	0	1	0	0	0	0	0
Passeriformes	Passerellidae	Eastern Towhee*+	EATO	<i>Pipilo erythrophthalmus</i>	100	216	130	240	14	242	28
Passeriformes	Passerellidae	Chipping Sparrow*+	CHSP	<i>Spizella passerina</i>	6	16	3	240	0	6	6
Passeriformes	Passerellidae	Field Sparrow*+	FISP	<i>Spizella pusilla</i>	14	91	5	39	2	13	0
Passeriformes	Passerellidae	Vesper Sparrow	VESP	<i>Poocetes gramineus</i>	0	1	0	0	0	0	0
Passeriformes	Passerellidae	Savannah Sparrow	SAVS	<i>Passerculus sandwichensis</i>	0	7	0	0	0	0	0

* Species of conservation importance: Regional Importance, as determined by Partners in Flight (Panjabi 2020).

+ Species of conservation importance: Regional Concern, as determined by Partners in Flight (Panjabi 2020).

^ Species of conservation importance: Regional Stewardship, as determined by Partners in Flight (Panjabi 2020).

Table A1-1. Taxonomy follows Chesser et al. (2019). Four letter species codes from the Institute for Bird Populations (<https://www.birdpop.org/pages/birdSpeciesCodes.php>).

Order	Family	Common Name	Code	Scientific Name	ALPO	FONE	FRHI	DEWA	BLUE	NERI	GARI
Passeriformes	Passerellidae	Song Sparrow	SOSP	<i>Melospiza melodia</i>	64	117	41	347	1	34	9
Passeriformes	Passerellidae	Swamp Sparrow	SWSP	<i>Melospiza georgiana</i>	0	1	0	0	0	0	0
Passeriformes	Passerellidae	White-throated Sparrow	WTSP	<i>Zonotrichia albicollis</i>	0	0	0	6	0	0	0
Passeriformes	Passerellidae	Dark-eyed Junco	DEJU	<i>Junco hyemalis</i>	3	0	0	17	0	1	0
Passeriformes	Cardinalidae	Northern Cardinal	NOCA	<i>Cardinalis cardinalis</i>	74	84	120	197	33	304	56
Passeriformes	Cardinalidae	Rose-breasted Grosbeak*+	RBGR	<i>Pheucticus ludovicianus</i>	36	33	3	107	1	103	1
Passeriformes	Cardinalidae	Indigo Bunting	INBU	<i>Passerina cyanea</i>	64	186	58	242	14	204	30
Passeriformes	Icteridae	Red-winged Blackbird	RWBL	<i>Agelaius phoeniceus</i>	0	48	3	131	0	2	0
Passeriformes	Icteridae	Common Grackle*+	COGR	<i>Quiscalus quiscula</i>	24	4	2	204	0	11	1
Passeriformes	Icteridae	Brown-headed Cowbird	BHCO	<i>Molothrus ater</i>	16	23	19	405	1	23	9
Passeriformes	Icteridae	Orchard Oriole	OROR	<i>Icterus spurius</i>	0	0	0	2	0	0	0
Passeriformes	Icteridae	Baltimore Oriole	BAOR	<i>Icterus galbula</i>	5	11	3	263	2	39	0
Passeriformes	Fringillidae	Pine Siskin	PISI	<i>Spinus pinus</i>	0	0	0	1	0	0	0
Passeriformes	Fringillidae	American Goldfinch	AMGO	<i>Spinus tristis</i>	20	24	5	111	3	60	15
Passeriformes	Passeridae	House Sparrow	HOSP	<i>Passer domesticus</i>	21	0	0	2	0	0	0
Passeriformes	Cardinalidae	Scarlet Tanager*^	SCTA	<i>Piranga olivacea</i>	195	164	143	1429	173	1792	125
Passeriformes	Poliophtidae	Blue-gray Gnatcatcher	BGGN	<i>Poliophtila caerulea</i>	6	13	16	223	17	77	11
Passeriformes	Troglodytidae	Winter Wren	WIWR	<i>Troglodytes hiemalis</i>	2	1	0	133	0	25	13
Passeriformes	Fringillidae	Purple Finch	PUFI	<i>Haemorhous purpureus</i>	0	0	0	2	0	0	0

* Species of conservation importance: Regional Importance, as determined by Partners in Flight (Panjabi 2020).

+ Species of conservation importance: Regional Concern, as determined by Partners in Flight (Panjabi 2020).

^ Species of conservation importance: Regional Stewardship, as determined by Partners in Flight (Panjabi 2020).

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Order	Family	Common Name	Code	Scientific Name	ALPO	FONE	FRHI	DEWA	BLUE	NERI	GARI
Passeriformes	Fringillidae	House Finch	HOFI	<i>Haemorhous mexicanus</i>	1	0	0	8	0	0	0
Passeriformes	Parulidae	Tennessee Warbler	TEWA	<i>Leiothlypis peregrina</i>	0	2	5	0	0	0	0
Passeriformes	Parulidae	Orange-crowned Warbler	OCWA	<i>Leiothlypis celata</i>	0	0	0	0	0	0	1
Passeriformes	Parulidae	Nashville Warbler	NAWA	<i>Leiothlypis ruficapilla</i>	0	0	0	1	0	0	0
Total Species					64	85	59	112	60	89	66
Total Detections					2759	3811	2518	33263	2307	23114	2560

* Species of conservation importance: Regional Importance, as determined by Partners in Flight (Panjabi 2020).

+ Species of conservation importance: Regional Concern, as determined by Partners in Flight (Panjabi 2020).

^ Species of conservation importance: Regional Stewardship, as determined by Partners in Flight (Panjabi 2020).

Appendix 2. Abundance and trend estimate for 87 target bird species detected at Delaware Water Gap National Recreation Area point count stations 2007–2019.

Table A2-1. Trend estimate based on slope of linear model regressing abundance estimate against sampling year. Species sorted from highest to lowest unadjusted abundance estimates. Scientific names in Appendix 1. [SD, standard deviation; SE, standard error; p, p-value].

Common Name	Unadjusted Abundance (mean)	Unadjusted Abundance (1SD)	Unadjusted Linear Trend	Unadjusted Linear Trend (SE)	Unadjusted Linear Trend (p)	Adjusted Abundance (mean)	Adjusted Abundance (1SD)	Adjusted Linear Trend	Adjusted Linear Trend (SE)	Adjusted Linear Trend (p)
Ovenbird	2.026	0.418	0.032	0.036	0.408	2.675	0.076	0.005	0.052	0.930
Red-eyed Vireo	1.470	0.213	-0.001	0.019	0.945	2.044	0.076	-0.007	0.029	0.812
Louisiana Waterthrush*	0.724	0.119	-0.007	0.011	0.545	1.916	0.196	0.000	0.000	0.179
Wood Thrush*	0.710	0.133	0.011	0.011	0.358	1.116	0.062	0.024	0.018	0.241
Scarlet Tanager*	0.705	0.099	0.001	0.009	0.916	1.374	0.102	0.001	0.006	0.932
Veery	0.688	0.174	0.035	0.009	0.005	0.970	0.048	0.041	0.010	0.005
Black-throated Green Warbler	0.628	0.144	-0.019	0.011	0.136	0.841	0.041	-0.026	0.016	0.157
Blue Jay	0.461	0.098	-0.006	0.009	0.508	1.554	0.225	-0.010	0.022	0.670
Acadian Flycatcher*	0.449	0.095	-0.008	0.008	0.360	0.546	0.028	-0.010	0.009	0.308
Tufted Titmouse	0.385	0.088	0.011	0.007	0.156	1.135	0.161	0.019	0.013	0.173
American Redstart	0.373	0.077	0.010	0.006	0.124	0.458	0.026	0.000	0.001	0.664
Gray Catbird	0.323	0.119	0.025	0.005	0.002	0.374	0.023	0.019	0.008	0.051
Eastern Wood-Pewee*	0.307	0.061	0.008	0.005	0.148	0.445	0.033	0.002	0.001	0.153
Black-capped Chickadee	0.306	0.101	-0.005	0.009	0.588	1.173	0.225	-0.020	0.033	0.563
American Crow	0.282	0.119	-0.017	0.009	0.092	0.642	0.076	-0.039	0.020	0.098
Northern Parula	0.276	0.104	0.019	0.006	0.022	0.410	0.033	0.017	0.006	0.018

* Species of regional conservation importance (Panjabi et al. 2020).

Table A2-1 (continued). Trend estimate based on slope of linear model regressing abundance estimate against sampling year. Species sorted from highest to lowest unadjusted abundance estimates. Scientific names in Appendix 1. [SD, standard deviation; SE, standard error; p, p-value].

Common Name	Unadjusted Abundance (mean)	Unadjusted Abundance (1SD)	Unadjusted Linear Trend	Unadjusted Linear Trend (SE)	Unadjusted Linear Trend (p)	Adjusted Abundance (mean)	Adjusted Abundance (1SD)	Adjusted Linear Trend	Adjusted Linear Trend (SE)	Adjusted Linear Trend (p)
Common Yellowthroat	0.268	0.065	-0.006	0.005	0.316	0.335	0.023	-0.003	0.003	0.331
Hooded Warbler*	0.258	0.088	0.014	0.006	0.043	0.308	0.021	0.018	0.007	0.039
Blackburnian Warbler	0.255	0.075	-0.004	0.007	0.579	0.449	0.043	0.003	0.014	0.837
American Robin	0.242	0.101	0.018	0.006	0.028	0.543	0.072	0.039	0.014	0.028
Brown-headed Cowbird	0.239	0.101	-0.002	0.009	0.828	0.596	0.088	-0.002	0.013	0.869
Eastern Phoebe	0.237	0.080	0.011	0.006	0.108	0.448	0.051	0.009	0.005	0.097
Blue-headed Vireo	0.196	0.080	0.000	0.007	0.957	0.377	0.045	-0.019	0.025	0.473
Worm-eating Warbler*	0.192	0.051	0.007	0.004	0.100	0.289	0.028	0.000	0.000	0.059
Black-and-white Warbler*	0.191	0.071	-0.002	0.006	0.815	0.333	0.037	-0.001	0.002	0.810
Cedar Waxwing	0.174	0.046	0.006	0.004	0.134	0.361	0.049	0.002	0.001	0.145
Blue-gray Gnatcatcher	0.138	0.056	0.002	0.005	0.730	0.288	0.043	0.003	0.008	0.724
Song Sparrow	0.134	0.046	-0.003	0.004	0.518	0.144	0.013	-0.001	0.001	0.518
Northern Cardinal	0.132	0.049	-0.004	0.004	0.355	0.436	0.102	-0.008	0.008	0.380
Baltimore Oriole	0.131	0.048	0.005	0.004	0.203	0.219	0.028	0.005	0.004	0.230
Mourning Dove	0.127	0.043	0.002	0.004	0.675	0.261	0.041	-0.001	0.000	0.173
Downy Woodpecker	0.127	0.078	0.006	0.007	0.390	0.839	0.355	0.016	0.016	0.373
Eastern Towhee*	0.127	0.036	0.005	0.003	0.121	0.184	0.021	-0.001	0.001	0.534
Yellow-throated Vireo	0.123	0.041	0.003	0.004	0.434	0.214	0.029	0.000	0.002	0.989
Chipping Sparrow*	0.118	0.036	0.001	0.003	0.768	0.157	0.017	0.000	0.000	0.763
Pileated Woodpecker	0.118	0.030	-0.002	0.003	0.591	0.403	0.102	0.000	0.000	0.590

* Species of regional conservation importance (Panjabi et al. 2020).

Table A2-1 (continued). Trend estimate based on slope of linear model regressing abundance estimate against sampling year. Species sorted from highest to lowest unadjusted abundance estimates. Scientific names in Appendix 1. [SD, standard deviation; SE, standard error; p, p-value].

Common Name	Unadjusted Abundance (mean)	Unadjusted Abundance (1SD)	Unadjusted Linear Trend	Unadjusted Linear Trend (SE)	Unadjusted Linear Trend (p)	Adjusted Abundance (mean)	Adjusted Abundance (1SD)	Adjusted Linear Trend	Adjusted Linear Trend (SE)	Adjusted Linear Trend (p)
Great Crested Flycatcher	0.116	0.065	-0.008	0.005	0.187	0.494	0.148	-0.019	0.013	0.200
White-breasted Nuthatch	0.116	0.090	0.004	0.008	0.675	0.353	0.080	0.009	0.022	0.701
Indigo Bunting	0.114	0.022	0.000	0.002	0.962	0.144	0.015	0.000	0.000	0.928
Brown Creeper	0.111	0.060	-0.006	0.005	0.287	0.270	0.050	-0.012	0.009	0.253
Red-bellied Woodpecker	0.107	0.054	-0.002	0.005	0.708	0.274	0.056	-0.003	0.006	0.669
Northern Flicker*	0.102	0.061	0.006	0.005	0.319	0.383	0.111	0.020	0.020	0.342
Yellow Warbler	0.101	0.034	0.004	0.003	0.254	0.123	0.013	0.000	0.000	0.214
Pine Warbler	0.095	0.049	-0.001	0.004	0.776	0.171	0.026	-0.002	0.008	0.763
Common Grackle*	0.081	0.033	-0.005	0.002	0.060	0.119	0.016	0.004	0.001	0.008
Yellow-billed Cuckoo*	0.081	0.071	-0.004	0.006	0.497	—	—	—	—	—
Hairy Woodpecker	0.081	0.040	-0.002	0.004	0.687	0.495	0.235	-0.005	0.012	0.687
Winter Wren	0.078	0.063	0.011	0.004	0.027	—	—	—	—	—
Hermit Thrush	0.075	0.061	-0.007	0.005	0.203	0.140	0.025	-0.015	0.010	0.171
Rose-breasted Grosbeak*	0.072	0.029	-0.001	0.003	0.729	0.223	0.065	-0.001	0.003	0.663
Red-winged Blackbird	0.063	0.035	-0.004	0.003	0.192	0.076	0.010	0.000	0.000	0.359
American Goldfinch	0.055	0.027	0.005	0.002	0.014	0.198	0.076	0.002	0.001	0.068
Prairie Warbler*	0.047	0.021	0.004	0.001	0.032	0.054	0.008	0.000	0.000	0.381
Carolina Wren	0.046	0.045	0.005	0.004	0.196	—	—	—	—	—
Common Raven	0.032	0.032	0.003	0.003	0.225	—	—	—	—	—
Ruby-throated Hummingbird	0.027	0.020	0.004	0.001	0.016	—	—	—	—	—

* Species of regional conservation importance (Panjabi et al. 2020).

Table A2-1 (continued). Trend estimate based on slope of linear model regressing abundance estimate against sampling year. Species sorted from highest to lowest unadjusted abundance estimates. Scientific names in Appendix 1. [SD, standard deviation; SE, standard error; p, p-value].

Common Name	Unadjusted Abundance (mean)	Unadjusted Abundance (1SD)	Unadjusted Linear Trend	Unadjusted Linear Trend (SE)	Unadjusted Linear Trend (p)	Adjusted Abundance (mean)	Adjusted Abundance (1SD)	Adjusted Linear Trend	Adjusted Linear Trend (SE)	Adjusted Linear Trend (p)
House Wren	0.022	0.011	0.000	0.001	0.803	0.027	0.006	0.000	0.000	0.801
Blue-winged Warbler*	0.021	0.008	-0.001	0.001	0.230	0.038	0.012	0.000	0.000	0.465
Field Sparrow*	0.020	0.020	0.002	0.002	0.240	—	—	—	—	—
Chestnut-sided Warbler	0.016	0.017	0.000	0.002	0.989	—	—	—	—	—
Cerulean Warbler*	0.013	0.012	-0.001	0.001	0.511	—	—	—	—	—
Black-billed Cuckoo*	0.012	0.015	-0.001	0.001	0.703	—	—	—	—	—
Black-throated Blue Warbler	0.011	0.010	-0.001	0.001	0.309	—	—	—	—	—
Dark-eyed Junco	0.011	0.022	-0.003	0.002	0.113	—	—	—	—	—
Eastern Bluebird	0.008	0.010	0.001	0.001	0.404	—	—	—	—	—
Warbling Vireo	0.006	0.011	-0.001	0.001	0.238	—	—	—	—	—
White-throated Sparrow	0.005	0.016	-0.002	0.001	0.223	—	—	—	—	—
Eastern Kingbird	0.005	0.008	0.000	0.001	0.826	—	—	—	—	—
Canada Warbler*	0.003	0.005	0.000	0.000	0.948	—	—	—	—	—
Golden-crowned Kinglet	0.003	0.006	0.000	0.001	0.530	—	—	—	—	—
House Finch	0.003	0.006	0.000	0.001	0.756	—	—	—	—	—
Tree Swallow	0.003	0.008	0.000	0.001	1.000	—	—	—	—	—
Willow Flycatcher	0.002	0.007	0.001	0.000	0.068	—	—	—	—	—
House Sparrow	0.002	0.006	-0.001	0.001	0.223	—	—	—	—	—
Purple Finch	0.002	0.006	0.000	0.001	1.000	—	—	—	—	—
Red-breasted Nuthatch	0.002	0.006	0.000	0.001	0.642	—	—	—	—	—

* Species of regional conservation importance (Panjabi et al. 2020).

Table A2-1 (continued). Trend estimate based on slope of linear model regressing abundance estimate against sampling year. Species sorted from highest to lowest unadjusted abundance estimates. Scientific names in Appendix 1. [SD, standard deviation; SE, standard error; p, p-value].

Common Name	Unadjusted Abundance (mean)	Unadjusted Abundance (1SD)	Unadjusted Linear Trend	Unadjusted Linear Trend (SE)	Unadjusted Linear Trend (p)	Adjusted Abundance (mean)	Adjusted Abundance (1SD)	Adjusted Linear Trend	Adjusted Linear Trend (SE)	Adjusted Linear Trend (p)
Kentucky Warbler*	0.002	0.004	0.000	0.000	0.726	—	—	—	—	—
Magnolia Warbler	0.002	0.004	0.000	0.000	0.597	—	—	—	—	—
Fish Crow	0.001	0.003	0.000	0.000	0.223	—	—	—	—	—
Northern Rough-winged Swallow	0.001	0.003	0.001	0.000	0.068	—	—	—	—	—
Orchard Oriole	0.001	0.003	0.000	0.000	0.481	—	—	—	—	—
Chimney Swift*	0.001	0.003	0.000	0.000	1.000	—	—	—	—	—
European Starling	0.001	0.003	0.000	0.000	0.340	—	—	—	—	—
Least Flycatcher*	0.001	0.003	0.000	0.000	0.340	—	—	—	—	—
Nashville Warbler	0.001	0.003	0.000	0.000	0.340	—	—	—	—	—
Yellow-bellied Sapsucker	0.001	0.003	0.000	0.000	1.000	—	—	—	—	—
Yellow-rumped Warbler	0.001	0.003	0.000	0.000	0.340	—	—	—	—	—

* Species of regional conservation importance (Panjabi et al. 2020).

Appendix 3. Trend estimate for 87 target bird species detected at Delaware Water Gap National Recreation Area point count stations 2007–2019.

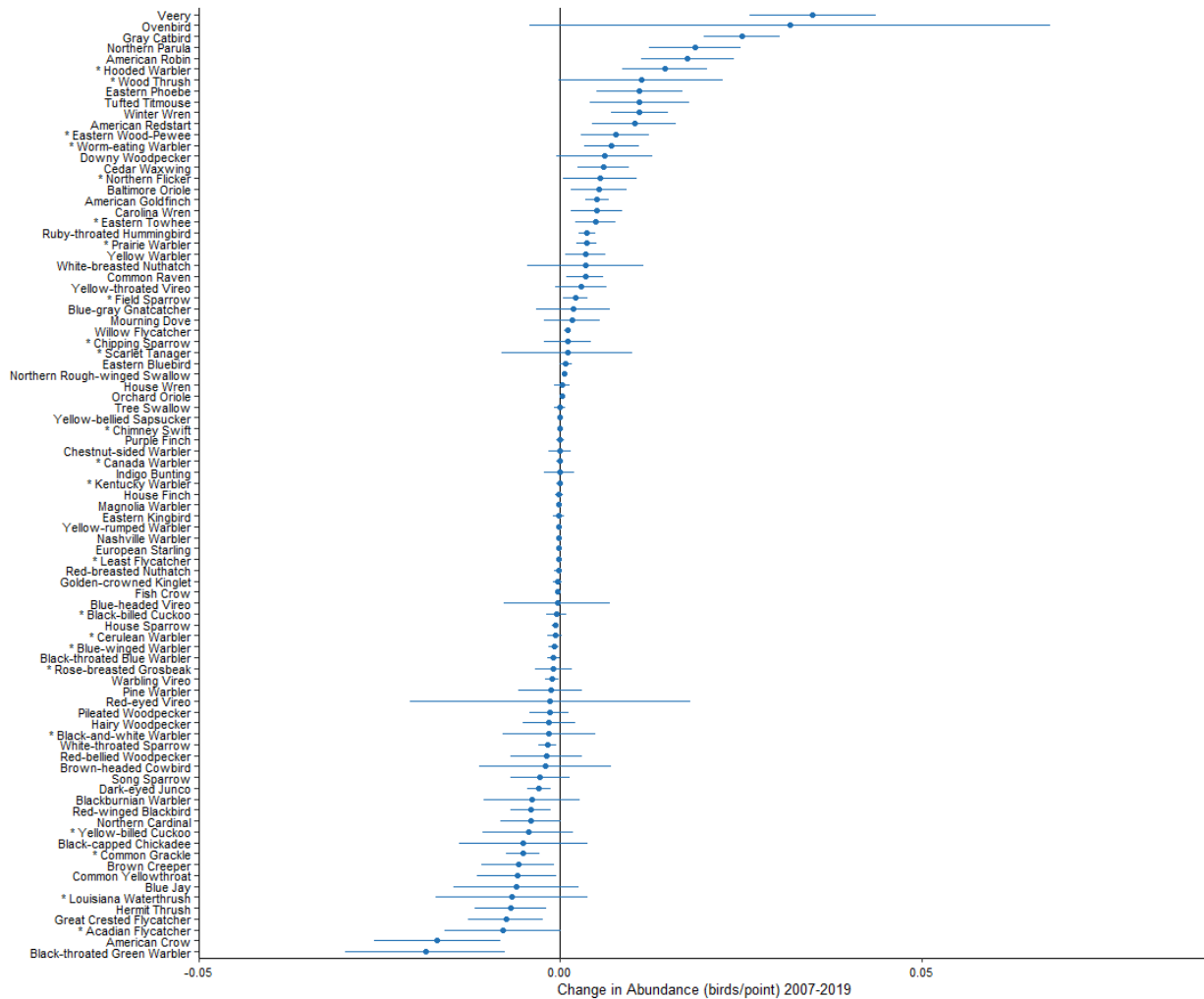


Figure A3-1. Slope $\pm$ standard error of linear model regressing unadjusted abundance estimates against sampling year. *Species of regional conservation importance (Panjabi et al. 2020). Scientific names in Appendix 1.

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