2026 Catskill Trail-less Peaks Montane Bird Study Annual Report

Kara Belinsky[1], Danielle Takacs[1], Samuel Mateo Jr.[1], Jason Hill[2], Pine Roehrs[3],

1. Department of Biological Sciences, State University of New York at New Paltz
2. Vermont Center for Ecostudies
3. NYS Department of Environmental Conservation

Photo credit- Samuel Mateo Jr. 2025

Executive Summary

The Catskill Mountains of New York State are a popular hiking destination within driving distance of the large population center of greater New York City. Recreational hiking activity soared and has stayed high since the COVID 19 shutdowns. During the same period, cell-phone hiking apps eased off-trail navigation, enabling more hikers to leave formally maintained trails, leading to proliferation of informal, visitor-created trails. Increased hiking on both informal and formal trails may disturb already struggling montane-breeding birds. Above 3,000ft, the Catskill High Peaks host sky-islands of balsam fir-spruce forests that support montane-breeding birds such as Bicknell's thrush (*Catharus bicknelli*), blackpoll warbler (*Setophaga striata*), and yellow-bellied flycatcher (*Empidonax flaviventris*), many of which nest in dense vegetation on or near the ground. Populations of montane birds are declining across the Northeastern US, with the steepest declines occurring in the Catskills. We evaluated how hiking affects Catskills montane birds by conducting breeding season point counts in each of three years (2023-2025) at 102 locations across 14 High Peaks, spanning a gradient of recreational use: low-use informal trail sites, high-use informal trail sites, and high-use sites along formal trails. In total, we detected 6,167 birds of 50 species. We then analyzed species' responses to hiking disturbance using single-season occupancy and N-mixture abundance models. Across species, occupancy tended to be modestly lower at high-use sites, while abundance responses were stronger and more consistently negative. Two montane birds that nest lower in saplings, the blackpoll (*Setophaga striata*) and magnolia warblers (*Setophaga magnolia*), showed significantly depressed occupancy and abundance at both high-use informal trail and formal trail sites. Other species had a mix of negative occupancy and abundance responses to high-use trails or were less affected, and one canopy-nesting species, the blackburnian warbler (*Setophaga fusca*), had higher occupancy and abundance at high-use trails. These results indicate that hiking disturbs several species of montane birds in the Catskills and that new management of hiking and trails may be warranted. Continued monitoring through 2027 will improve our inferences for rarer species such as Bicknell's thrush (*Catharus bicknelli*) and yellow-bellied flycatcher (*Empidonax flaviventris*), helping the New York State Department of Environmental Conservation balance human recreation with the protection of vulnerable montane breeding birds in the Catskill High Peaks.

Introduction

The Catskill Mountains of New York State, U.S., are a hiking destination located approximately 90 miles north of the large population center of greater New York City. Most of the Catskill Mountains over 3,500' are part of the Catskill Park Forest Preserve and are protected in perpetuity by Article 14 of the New York State Constitution. The Catskills High Peaks (the 35 peaks over 3500 ft. in elevation) include 16 High Peaks set aside in the 1960s as trail-less peaks, intended to provide opportunities for off-trail experiences that could only be accessed by visitors who could navigate the backcountry by map and compass. However, technological advancements in mobile phone hiking applications such as AllTrails, Gaia, and Strava increasingly allow hikers to more easily navigate the backcountry, off formally designed and maintained trails (Wilcer et al. 2019, Santos et al. 2022). In addition, outdoor recreation, including hiking, has skyrocketed globally since the COVID-19 pandemic restrictions (Beery et al. 2021, Venter et al. 2021, Ferguson et al. 2022, Smith et al. 2023), increasing the number of hikers on and off formal rails.

In 1999, the New York State Department of Environmental Conservation (DEC) made a formal agreement with the Catskill 3500 Hiking Club that they could maintain canisters holding sign-in notebooks on Catskill High Peaks without formal trails, providing valuable visitor-use data. As hikers increasingly used apps to navigate their own routes on these peaks, informal trails formed across many trail-less areas. New informal trails logged on the apps are then displayed to other hikers, further increasing informal trail use and proliferation, causing DEC to refer to the trail-less peaks as "formerly trail-less peaks" (Roehrs and Rice 2020, Boland 2023). Hiker sign-ins at Catskill 3500 Club canisters on formerly trail-less peaks nearly doubled during the pandemic restrictions in 2020 and have remained high since (Figure 1). New York State land managers at DEC are tasked with providing recreational access to public lands while also protecting the wildlife on these mountains.

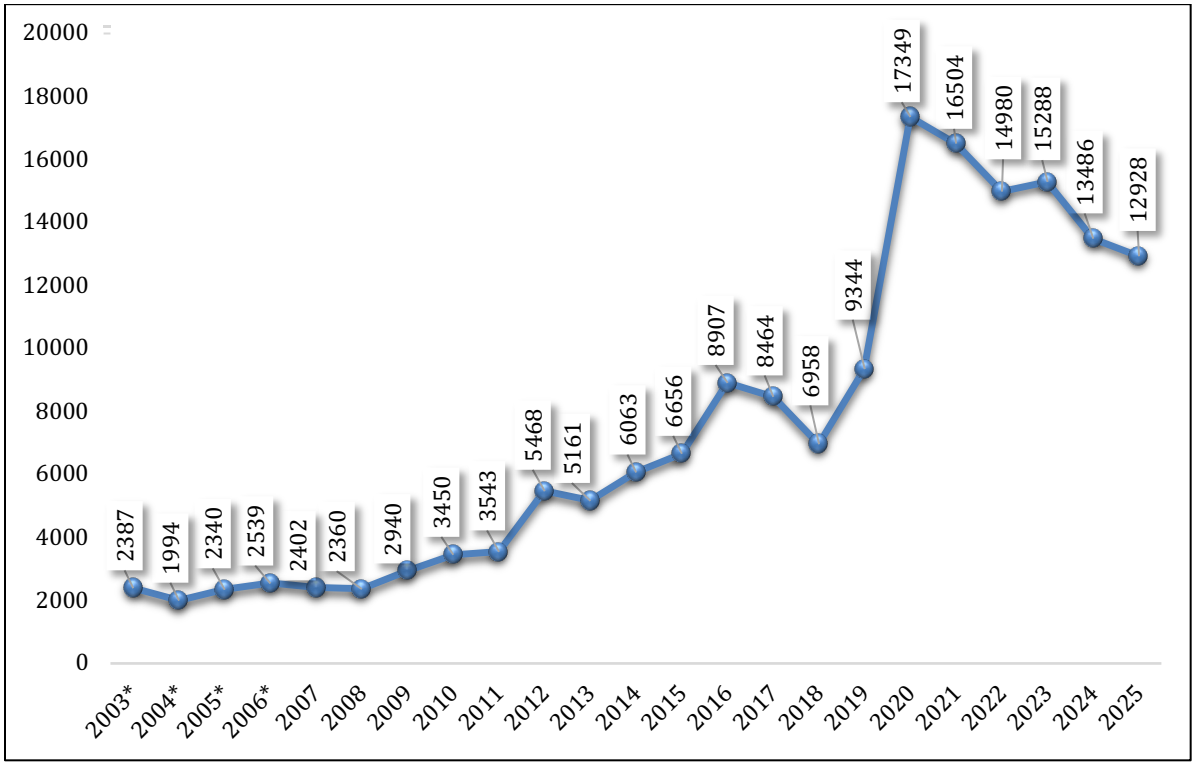

Figure 1. *Canister tallies of hikers at the summits of the formerly trail-less Catskill High Peaks in DEC Regions 3 and 4 from 2016-2025.*

The Catskill High Peaks are home to unique wildlife found in the balsam fir-spruce dominated montane forests. Montane forests in the Catskills are found at higher elevations than mid-elevation northern hardwood forests but below the sub-alpine forests of higher elevations, which, in New York State, exist only in the Adirondack Mountains. In the Catskills, montane forests cover the highest peaks, generally growing on the cool upper slopes and summits above 3,000 ft, where they thrive despite the thin soils, high winds, and frigid winter mountaintop conditions (NYNHP 2023). The montane forests in the Catskills are dominated by balsam fir (*Abies balsamea*) and red spruce (*Picea americana*) with a ground cover of extensive moss, ferns, and wildflowers such as such as northern wood sorrel (*Oxalis montana*), bunchberry (*Cornus canadensis*) and blue-bead lily (*Clintonia borealis*). These sky-islands of montane forest are listed as Imperiled or Vulnerable habitats in New York State, and as Vulnerable globally (NYNHP 2023), in part due to their shrinking area as climate change causes the plants and animals to retreat upwards due to rising temperatures (Iverson 2008, Beckage 2008, Mata-Guel 2023).

The Catskills montane forests host a community of montane-breeding birds that nest in the dense vegetation. Many bird populations are declining across North America (Johnston et al. 2025, Rosenberg et al. 2019), including montane birds (Jones et al. 2024, King et al. 2008, Scridel et al. 2018), many of which are long-distance neotropical migrants that spend their winters in Central or South America. These migratory species are some of the fastest-declining birds because they face many threats such as predation by domestic cats (Loss et al 2015), collisions with glass (Klem 2025), and habitat loss on their wintering grounds, at their migration stopover locations, as well as on their breeding grounds (Faaborg et al. 2010, Guo et al. 2023, Kramer et al. 2018).

Birds breeding in montane forests include a variety of species, some of which breed only in montane forests, while others breed across a larger range of forest habitats. One of North America's most-imperiled montane birds is also one of its rarest songbird species, the neotropical migrant Bicknell's thrush (*Catharus bicknelli*; Rimmer et al. 2001). The International Union for the Conservation of Nature (IUCN) Red List of Threatened Species lists the Bicknell's thrush as a Vulnerable To Extinction world-wide due to a small range and rapid population loss (IUCN 2026). Elsewhere in the Northeastern U.S., the Bicknell's thrush's montane breeding habitat is being fragmented by energy and communication tower development, as well as proliferating informal hiking trails (Hill 2019, Rimmer 2004). Another vulnerable montane specialist and neotropical migrant, the blackpoll warbler (*Setophaga striata*), is listed as Near Threatened globally, due to sustained population declines (IUCN 2026). Bicknell's thrush and blackpoll warbler are listed as bird Species of Interest and part of the rationale for DEC's 1999 designation of several Catskill peaks as Catskill High Peaks Bird Conservation Areas (New York State Catskills Master Plan 2014), and they may be sensitive to disturbance from hiking because they nest on the ground or low in regenerating fir and spruce saplings.

Other bird species are listed as IUCN Least Concern globally, but are also montane specialists and neotropical migrants in decline. These include yellow-bellied flycatchers (*Empidonax flaviventris*), which nest in moss cups on the ground, and Swainson's thrushes (*Catharus ustulatus)*, which nest low in conifer saplings. Bicknell's thrush and yellow-bellied flycatcher have declined significantly from 1993-2003 in New Hampshire's White Mountains (King et al. 2008). Three other species of regionally migrating montane birds that all nest on the ground in the Catskills are hermit thrushes (*Catharus guttatus*), winter wrens (*Troglodytes hiemalis*), and white-throated sparrows *(Zonotrichia albicollis)*. In addition, two generalist forest species are of interest in the Catskills because they may indicate reduced montane habitat quality: the cavity-nesting black-capped chickadee *(Poecile atricopilla*) and red squirrel (*Tamiasciurus hudsonicus*), a common nest predator (Hallworth et al. 2024).

Since 2010, the Vermont Center For Ecostudies has been monitoring bird species in montane forests across the Northeastern U.S. through their community science program, Mountain Birdwatch (MBW). MBW provides insights into the population dynamics of montane species that are rarely detected during traditional roadside monitoring schemes like the North American Breeding Bird Survey. The MBW results for the Catskills provide evidence that all the montane birds listed above have declined from 2010 to 2025, while only the generalist black-capped chickadee and red squirrel are increasing (Hill and Williams 2025; Figure 2). However, MBW monitoring only occurs on formal trails, and monitoring montane areas with informal trails is critical to inform DEC management of the Catskills High Peaks with visitor-created informal trail networks.

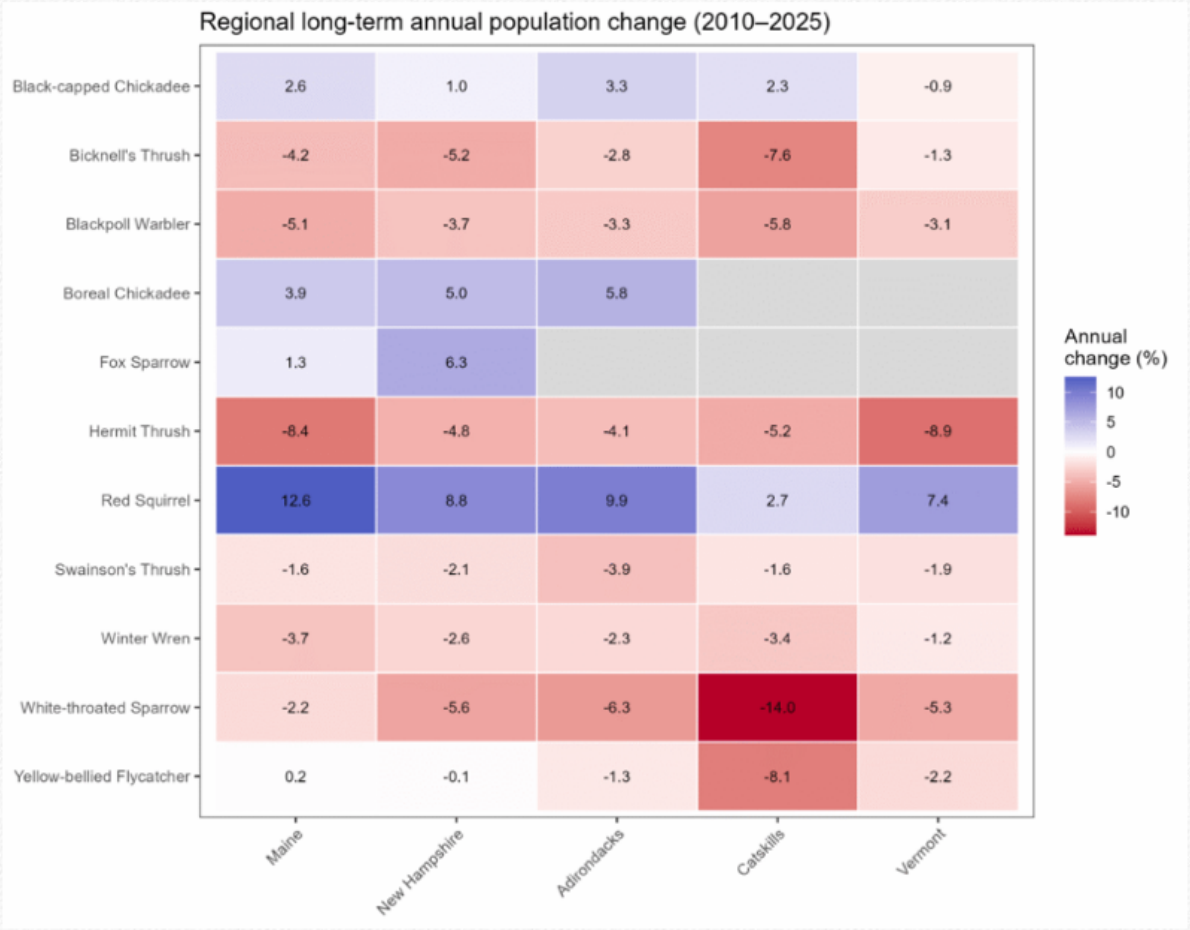

Figure 2. *Population change in montane bird species in the Catskills on formal trails monitored by Mountain Birdwatch from 2010-2025 (Hill 2025).*

Montane bird population declines in the Catskills and elsewhere are not likely driven by recreational hiking. However, disturbance caused by hiking may exacerbate existing bird population declines, and unlike other population factors, hiking can be regulated locally. Montane forests are particularly vulnerable to damage from hiking due to their thin soils, steep slopes, and sensitive ground vegetation including moss and ferns (Martin and Butler 2017). In addition, informal trails may be more disruptive to wildlife than formally designed trails because they commonly result from hikers taking the shortest route between two points, often up steep grades, resulting in increased soil and vegetative loss and prolonged disturbance as hikers spend more time to traverse them (Wimpey & Marion, 2011). Studies in other North American forests have reported that recreational hiking affects birds and other wildlife (Larson et al. 2019, Steven et al. 2011). For example, the abundance of forest-specialist birds was lower

near formal hiking trails than far from hiking trails in Colorado (Miller et al. 1998), and in Central Ontario, Canada, the area of trail-free forest habitat was positively associated with the abundance of ground-nesting and ground-foraging birds, including hermit thrush, winter wren, and white-throated sparrow (Thompson 2015). In contrast, Deluca and King (2014) found that abundances of Bicknell's thrush, yellow-bellied flycatcher, blackpoll warbler, and Swainson's thrush did not differ on formal trails as compared to off-trail locations in New Hampshire. Regardless of trails, human presence alone may disturb birds (Campbell 2011). In Wyoming sub-alpine forests, experimental human intrusions into forests far from trails reduced abundances of several species, including hermit thrush (Gutzwiller and Anderson 1999). In a related study, birds active near the ground were most sensitive to human disturbance (Gutzwiller et al. 1998).

In response to concerns about the increase in off-trail hiking and its potential effects on wildlife, DEC land managers began monitoring informal trail networks in the Catskills. Roehrs and Rice (2019) initially surveyed and assessed 39.24 miles of informal trails on all 16 formerly trail-less Catskill High Peaks for development, damage and difficulty of navigation based on National Park Service protocols (Marion 2011). Henschell and Spencer (2022) returned to these Peaks and documented a loss of moss and herbaceous plant layers and increased tree root exposure across steep slopes and on summits (often surrounding the sign-in canister) in montane forests found on Southwest Hunter, Rusk, and Balsam Cap, Friday, Lone, and Rocky Mountains. Anecdotally, they noted that Bicknell's thrush had been detected at three peaks on earlier sampling trips, but none were heard during their post-pandemic survey. Roehrs (2022) measured the post-pandemic surge in hiking on the formerly trail-less peaks by compiling hiker canister sign-in data along with data from the hiking app Strava, which provides an online heatmap of users' recreational activity. Based on analysis of these data, Roehrs reported that informal trail use on Southwest Hunter and Rusk Mountains was dramatically elevated, but restricted to consistent corridors, while similarly elevated informal trail use on Rocky, Lone, Balsam Cap and Friday Mountains produced proliferating networks of diffuse informal trails fragmenting the montane forest there. Roehrs (2022) called for further ecological monitoring to assess the effect of increased hiking and informal trails on wildlife, with montane birds highlighted as a prominent concern.

In this study, we systematically examined the effects of hiking on montane birds along high-use formal trails as compared with informal trails experiencing high and low visitor use on the Catskill High Peaks. We hypothesized that ground- and low-nesting and montane-specialist bird species would be less prevalent near formal trails and informal hiking trails with high visitor use, while generalist, cavity-nesting, and canopy tree-nesting species would be less affected.

Methods and Results

To assess the effects of hiking on montane birds in the Catskill High Peaks, we conducted point counts that we combined with point count data from MBW volunteers to describe bird populations at 102 locations across 14 Catskill High Peaks during the montane bird breeding seasons (late May though early July) each year from 2023-2025. At each location, an observer followed Mountain Birdwatch point count protocols, conducting four consecutive 5-minute point counts. Observers recorded counts and estimated locations of all bird species and red squirrels detected by sight or by sound. All point counts were conducted between 45 minutes before local sunrise and 10:00 am. Sampling points ranged in elevation from 3,300 to 4,200 ft along the peaks and ridgelines of Catskill Mountains in DEC Regions 3 and 4. Sampling points were located on formerly trail-less High Peaks surveyed by Roehrs and Rice (2019 and 2022), and on High Peaks with formal trails (Table 1). Each sampling point was chosen using aerial photos, topographic maps, and GIS to ensure that each was at least 250 m from other sampling points or formal trails and was in an area dominated by montane balsam fir-spruce forest. Sampling locations spanned a gradient of recreational hiking use divided into three categories: **1. Low**: low-frequency to no-frequency hiking use along potential or actual informal trails, **2. High**: high-frequency hiking use along

informal trails, and **3. Trailed**: high-frequency hiking use along formal trails maintained by DEC. Visitor-use classes (Low and High) were assigned using Strava heatmap data and field knowledge of trail conditions and use patterns. Low sites were located on Little Slide, the South Shoulder of Slide, past the summit on Rusk, on Southwest Hunter, on the West shoulder of Hunter, and the North Shoulder of Sugarloaf, all locations where few visitors venture. High sites were located along more popular informal trails on Rusk, Southwest Hunter, Friday, Balsam Cap, and Dink. Trailed sites were locations monitored by Mountain Bird Watch volunteers on the formal trails to the main summits of Slide, Hunter, Plateau, Black Dome, Table and Big Indian Mountains that experience high levels of visitor use.

Table 1. *Point count sampling locations broken down by peak, trail type, and visitor use.*

Location	Trail type	Visitor use	# of sampling points	
West Hunter	Informal	Low	5	
Little Slide	Informal	Low	8	
Rusk	Informal	Low	1	
Slide South Shoulder	Informal	Low	3	
Southwest Hunter	Informal	Low	4	
Sugarloaf North Shoulder	Informal	Low	4	
Low Visitation/Informal Trail TOTAL				25
Rusk	Informal	High	6	
Southwest Hunter	Informal	High	5	
Balsam Cap	Informal	High	4	
Dink	Informal	High	4	
Friday	Informal	High	5	
High Visitation/Informal Trail TOTAL				24
Hunter	Formal	High	17	
Slide	Formal	High	6	
Plateau	Formal	High	12	
North Dome	Formal	High	6	
Table	Formal	High	6	
Big Indian	Formal	High	6	
High Visitation/Formal Trail TOTAL				53
GRAND TOTAL				**102**

In total, observers recorded 6,167 detections representing 50 bird species, and 112 red squirrel detections, across the three-year study. Because each sampling event included four consecutive 5-minute count periods, these detections should not be interpreted as unique individuals; rather, they summarize overall detection frequency across repeated counts. The most-frequently detected species were yellow-rumped warbler (n = 899 detections), Swainson's thrush (n = 791), and winter wren (n = 627). Nineteen species had sufficient detections for occupancy modeling, and 12 of those also had sufficient count variation for N-mixture abundance modeling (Table 2). Rarely detected species included white-throated sparrow, black-throated blue warbler (*Setophaga caerulescens*), American goldfinch (*Spinus tristis*), red crossbill (*Loxia curvirostra*), hairy woodpecker (*Leuconotopicus villosus*), and black-and-white warbler (*Mniotilta varia*). Most sites (77.45%) were sampled every year (mean = 2.63, SD = 0.57), and the dataset consisted of 277 unique site-by-year samples.

Table 2. Bird species with sufficient data to be included in analyses and their natural history attributes. *English name, alpha code, Latin name, nest type/location, nest substrate. Color indicates nest height range. Symbology denotes species' migratory status as either long-distance neotropical (***), regional or elevational (**), or non-migratory (*). Natural history information obtained from Birds of the World species accounts (https://birdsoftheworld.org/bow/home).*

Yellow-bellied Flycatcher*** YBFL *Empidonax flaviventris* Open cup/ground Moss	Magnolia Warbler*** MAWA *Setophaga magnolia* Open cup/low trunk Spruce or fir sapling	Blue Jay* BLJA *Cyanocitta cristata* Open cup/tree branch Variable large tree	**Legend:** Nest Height Range 0-2 ft 2-5 ft 5-15 ft 15-25 ft
Hermit Thrush ** HETH *Catharus guttatus* Open cup/ground Lycopodium/bunchberry	Blackpoll Warbler*** BLPW *Setophaga striata* Open cup/low trunk Spruce or fir sapling	American Robin* AMRO *Turdus migratorius* Open cup/tree branch Variable deciduous tree	Blackburnian Warbler*** BLBW *Setophaga fusca* Open cup/canopy tree branch Hemlock or spruce tree
Winter Wren ** WIWR *Troglodytes troglodytes* Rootlet dome/ground Under bank, root, or log	Bicknell's Thrush*** BITH *Catharus bicknelli* Open cup/low trunk Fir or birch sapling	Red-breasted Nuthatch* RBNU *Sitta canadensis* Cavity/tree hole Fir or Pine tree or snag	Black-throated Green Warbler*** BTNW *Setophaga virens* Open cup/canopy tree branch Hemlock or pine tree
Ovenbird*** OVEN *Seiurus aurocapilla* Grass, stem dome/ground Under leaf litter/grass	Swainson's Thrush*** SWTH *Catharus ustulatus* Open cup/low branch Conifer sapling, or shrub	Purple Finch** PUFI *Haemorhous purpureus* Open cup/tree branch Fir, pine, or spruce tree	Golden-crowned Kinglet** GCKI *Regulus satrapa* Open cup/far canopy branch Fir or spruce tree crown
Dark-eyed Junco** DEJU *Junco hyemalis* Grass dome/ground Under bank, root, or log	Black-capped Chickadee* BCCH *Poecile atricopilla* Cavity/tree hole Birch or maple tree	Yellow-rumped Warbler** YRWA *Setophaga coronata* Open cup/far tree branch Hemlock or spruce tree	Red Squirrel* RESQ *Tamiasciurus hudsonicus* Cavity/tree hole Conifer tree

Our primary goal was to describe patterns in montane bird occupancy and abundance as they relate to our visitor-use trail categories (Low, High, and Trailed), which are likely proxies of human use intensity, including both direct disturbance from hikers and habitat alteration associated with trail development. We used a combination of occupancy and N-mixture models to analyze the data. From those data, we derived detection histories of either presence-absence for occupancy models, or raw counts for N-mixture models. Potential site covariates included visitor-use trail class (Low, High, Trailed), year and elevation, and potential detection covariates included the point count start time (expressed as minutes after midnight) and sampling station background noise (an observer-estimated value on a scale of 1 [quiet] to 10 [too loud to hear any birds]).

Occupancy Models

We fit single-season occupancy models for individual species using unmarked in R (Fiske and Chandler 2011; R Core Team 2026). Detection probability was allowed to vary among candidate covariates (with and without start time and background noise), and occupancy was modeled as a function of trail class, year, and elevation. We focused on species with >15 site-year detections because preliminary testing revealed that species with fewer site-year detections had inadequate data for these occupancy models. Model selection proceeded in two stages: we first identified the most-supported detection structure among models, and then selected the parsimonious occupancy models within $\Delta AIC \leq 2$ of the top-supported model.

Across 19 species, differences in occupancy among site classes were generally modest on the probability scale, but directional patterns were consistent across many species. Many species showed broadly overlapping confidence intervals across site classes. Occupancy at High and Trailed sites increased with baseline occupancy at Low sites, but the slope of this relationship was consistently <1, and indicated a systematic reduction in occupancy relative to low-use sites (Figure 3). Some montane species showed significantly reduced occupancy at both High and Trailed sites as compared to Low sites: blackpoll warblers, magnolia warblers, Swainson's thrushes, and dark-eyed juncos. Forest-generalist blue jays were the only species with significantly higher occupancy at both High and Trailed sites compared to Low sites. One notable pattern is that species whose highest occupancy occurred at Trailed sites tended to have lower overall occupancy, whereas widespread species tended to peak at Low or High off-trail sites. This suggests that association with trails may reflect tolerance for hiking activity and trails rather than preference, particularly for less widespread species.

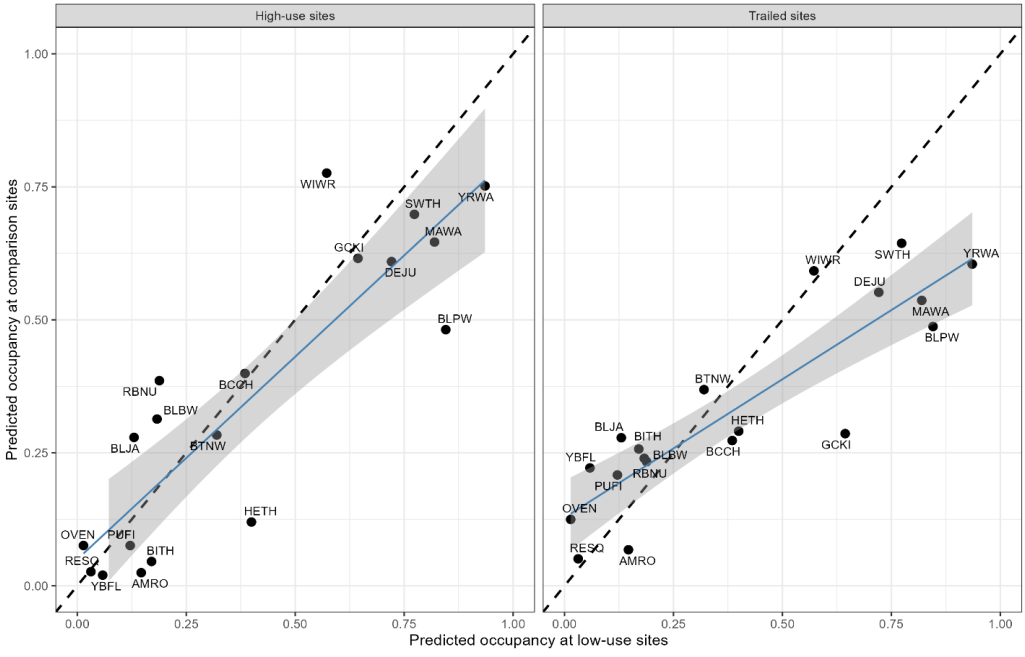

Figure 3. Predicted occupancy at Low sites (x-axis) for 19 species, compared to their predicted occupancy at High (left panel) and Trailed (right panel) sites. *The blue line is a mean linear regression line (with shaded confidence interval in gray) fit to the occupancy model predicted estimates. The dashed lines represent parity (i.e., slopes of 1.0). Slopes <1 in both panels indicate that while occupancy at High and Trailed sites increases with baseline occupancy at Low sites, it does so consistently at reduced levels, suggesting a broad but modest reduction in site use along the disturbance gradient.*

N-mixture Models

Occupancy models are a powerful, robust framework, but occupancy models alone may miss biologically meaningful changes if species remain present but change in abundance along gradients of human use. However, N-mixture models require relatively more complex data than occupancy models and require counts beyond 0s and 1s. First, we screened species to determine which species had sufficient data for N-mixture models. Rather than using site-year detections alone, as we did for the occupancy models, we screened species based on their count structure, focusing on whether there was sufficient information to estimate abundance. Key metrics included the number of site-years with detections, the proportion of counts >1, and the maximum observed count. Using these criteria, 12 species were retained for N-mixture modeling. This screening was intentionally conservative to prioritize model stability over species coverage. For each candidate species, we fit Poisson N-mixture models with abundance modeled as a function of trail class, year and elevation. Detection was either modeled as constant (intercept only) or included background noise. The upper bound on latent abundance was set to K = 20 (higher values gave identical results). Like our occupancy models, we evaluated model behavior using convergence diagnostics, size of standard errors relative to coefficient estimates, and parametric bootstrap goodness-of-fit.

In contrast to occupancy results, abundance responses to trail class were stronger, more consistent, and more frequently negative. In many species, occupancy remained high across site classes while abundance declined, indicating density reductions rather than complete avoidance. For the most frequently detected species: abundance was highest at Low sites, declined at High sites, and declined further at Trailed sites. For example, Yellow-rumped Warbler showed a ~23% lower abundance at High sites relative to Low, and a ~43% lower abundance at Trailed sites relative to Low. Across the 12 species negative abundance effects associated with Trailed sites were common, while effects associated with High sites were intermediate; predictably, results were less certain for species with relatively few detections during point counts. Blackpoll, magnolia, and yellow-rumped warblers had significantly lower abundance at High and Trailed sites compared to Low sites. Bicknell's thrush were significantly less abundant at High sites compared to Low sites, with nonsignificant differences in abundance between Trailed and Low sites. Two species had significantly or nearly significantly higher abundance at High or Trailed sites than at Low sites: blackburnian warbler and winter wren.

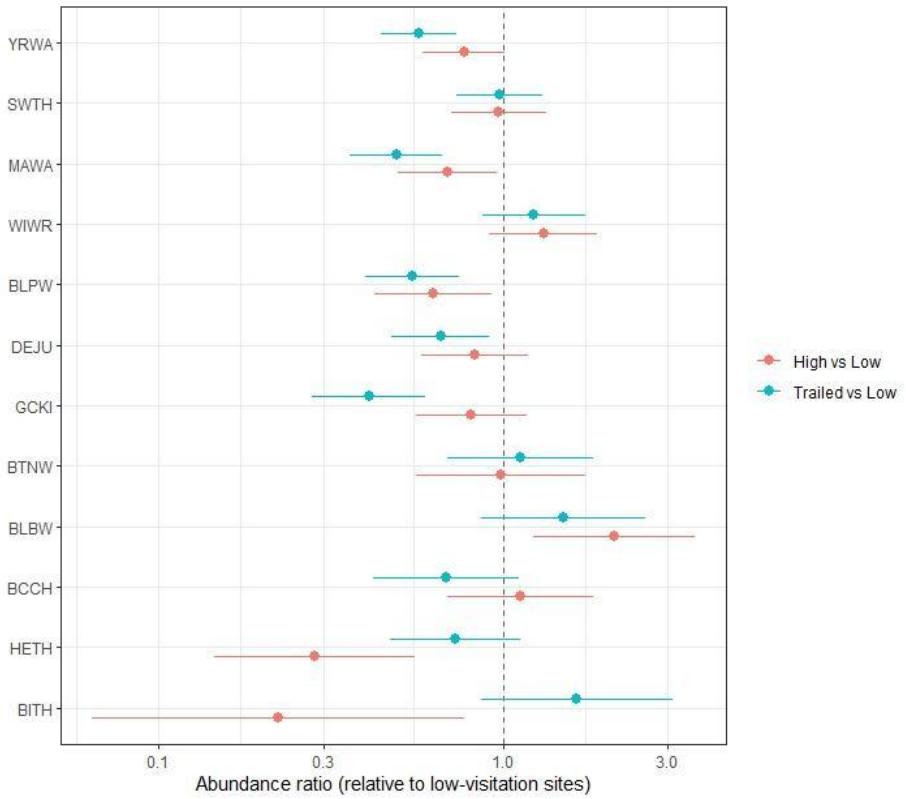

Figure 4. *Results of the N-mixture models mean point estimates (dots) and 95% confidence intervals (whiskers) showing the abundance ratio (abundance at High [red] or Trailed [blue] sites compared to Low sites). The x-axis is shown on the log scale, and the dashed vertical line represents parity. Species are arranged top-to-bottom in decreasing data richness, which is reflected in the increasing size of the confidence intervals towards the bottom.*

Synthesis

The occupancy models suggest that hiking trails and human disturbance are associated with a modest redistribution of bird species rather than outright exclusion, while the N-mixture models indicate more consistent declines in local bird abundance, particularly at Trailed sites. Effect sizes are species-specific but directionally consistent overall (Figure 5). Most species cluster near the origin of the synthesis figure, indicating relatively small changes in both occupancy and abundance among site classes. However, several species—particularly montane forest specialists—fall in the lower-left quadrants, showing reduced occupancy and abundance at Trailed sites (Figure 5). Very few species show the opposite pattern. Two montane specialist species, blackpoll and magnolia warblers have significantly negative responses to both High and Trailed sites in both occupancy and abundance. Bicknell's thrushes have a mixed response: they have decreased occupancy and abundance at High vs. Low sites, but higher occupancy and marginally higher abundance at Trailed sites than Low sites. Swainson's thrushes have decreased occupancy at High and Trailed sites as compared to Low sites, but no change in abundance due to trail class. Dark-eyed juncos and yellow-rumped warblers both have reduced occupancy at High and Trailed sites, with decreased abundance at Trailed sites, but no significant difference between abundance at High and Low sites. Similarly, hermit thrushes also have reduced occupancy at High and Trailed sites, with decreased abundance at High sites, but no significant difference between abundance at Trailed and Low sites. In contrast, Blackburnian warblers show increased occupancy and abundance at High sites vs Low. Winter wrens show higher occupancy at High than Low sites, marginally higher occupancy at Trailed than Low sites, and marginally higher abundance at High and Trailed sites than Low sites. The

only generalist species included in both models, black-capped chickadees, show no significant effect of trail type on abundance, although they may show reduced occupancy at Trailed sites as compared to Low sites. Taken together, these results suggest that recreational use in the Catskills affects population density more than presence, with effects that are detectable but generally moderate. Nonetheless, the consistency of negative abundance responses across multiple species suggests that even moderate recreational use influences population density in this montane forest system.

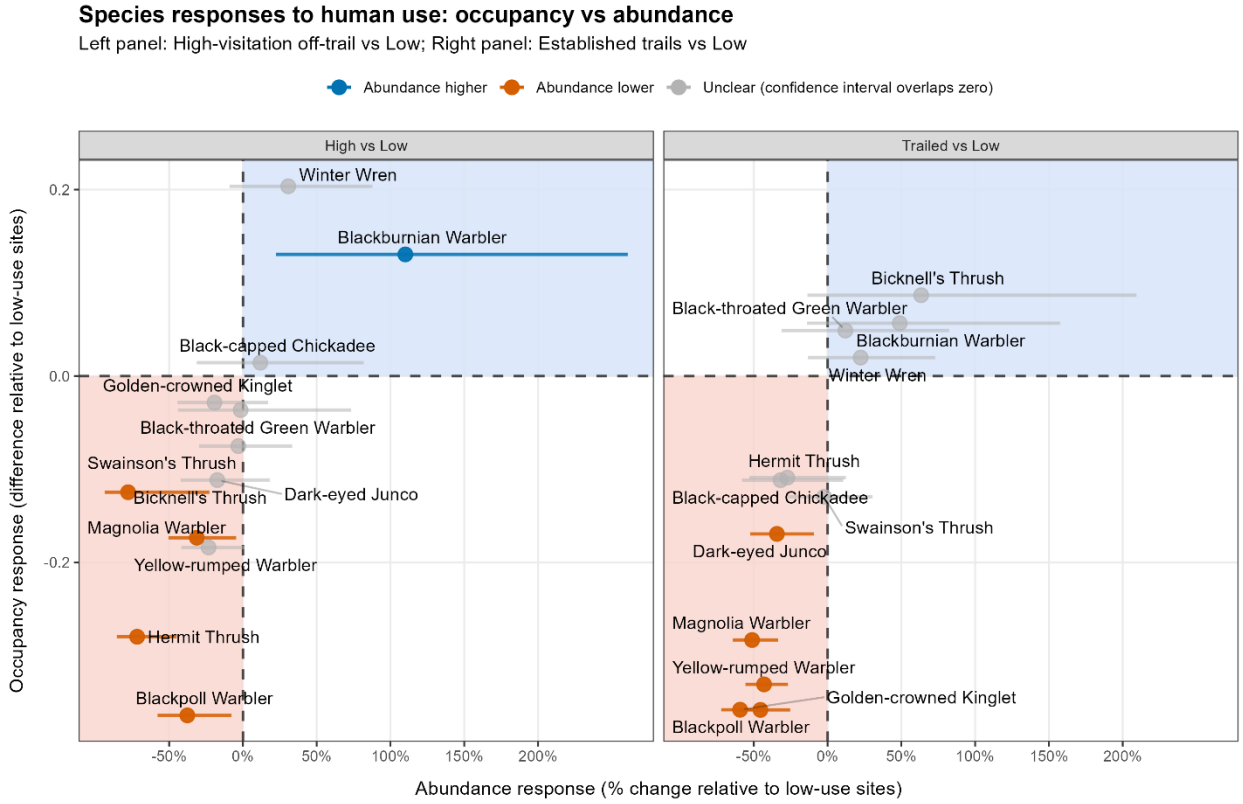

Figure 5. Comparison of occupancy and N-mixture model results for the 12 species that were included in both analyses. *The x-axis shows the percent change in estimated abundance (from the N-mixture models) relative to low-use, off-trail sites. Species to the right of the vertical dashed line (representing no difference in abundance) indicate species that were more abundant at high-use (left panel) or trailed sites (right panel), compared to low-use sites. The y-axis shows the difference in occupancy probability relative to low-use sites; species above the horizontal dashed line (representing no difference in occupancy) indicate species with greater occupancy at high-use (left panel) or trailed (right panel) sites. Therefore, species in the upper-right (blue) quadrants represent species with higher occupancy and abundance at more heavily used sites (i.e., High-use and Trailed), whereas points in the lower-left (red) quadrants represent species with lower occupancy and abundance in those settings.*

Discussion

In the Catskills, most montane forest specialist bird species' occupancy and abundance were greater in areas with less developed trails and fewer human hikers. These results align with our expectations and support the conclusions of other studies regarding the relationship between recreation and wildlife (reviewed in Larson et al. 2016 and Steven et al. 2011). The effect sizes of the decreases we estimated are modest for occupancy and stronger but still moderate for abundance. However, even modest reductions are of concern for vulnerable species already in steep decline due to other less tractable causes

such as habitat loss. Several montane specialists that nest low in saplings showed the strongest declines in our study, with some ground-nesting species also reduced, while canopy and cavity-nesting generalist species were either unaffected or were more common along more developed trails or trails with higher human use. These results support our hypothesis that species nesting on or near the ground are more vulnerable to hiking disturbance because they occupy the same physical space as hikers, whereas canopy-dwelling and cavity-nesting species may be less directly exposed. Generalist bird species may also be more behaviorally flexible and may be more habituated to humans. A few species of conservation concern were not detected with enough frequency to either be included in our full analysis, or to have conclusive results, a shortcoming that two more seasons of data may address.

In general, our results echo those reported by other researchers, including a recent meta-analysis of the effects of human recreation on wildlife (Larson et al. 2019). Larson et al. (2019) found that higher recreation levels significantly decreased bird species richness and abundance across studies. In addition, they found that birds with small body sizes (such as songbirds) and those that nest on the ground were most affected. Shrub-nesting birds were not significantly affected in Larson et al. (2019), but this is most likely due to the small sample size of papers focusing on shrub-nesting birds, and because the shrub nesting species included were not montane species. Bötsch et al. (2018) compared montane bird abundance and species richness at locations near and far from trails in forests with high human-visitation as compared with low-human visitation in Switzerland. They found that bird abundance and species richness was depressed near trails with high-visitation and not near trails with low human-visitation, indicating that human presence disturbing birds is more deleterious than habitat alteration due to trails at these sites (Bötsch et al. 2018).

In contrast, Grooms and Urbanek (2018) examined the differential effects of human visitors and a variety of trail variables, including vegetation layers, trail width, and depth on birds in four forested state parks in Arkansas, USA. They found that human use and trail attributes both explained reductions in bird abundance and richness, but that habitat and trail attributes were more strongly negative than human use. Oliver et al. (2026) completed a large study comparing the effects of habitat alteration as compared to human presence using mobile phone tracking data for humans in 2019 and during pandemic restrictions in 2020 compared with GPS tracking of 37 mammal and bird species across the USA. They reported that wildlife reacted to habitat alteration and human presence in species-specific and sometimes in interacting ways. That study was limited to animals carrying GPS transmitters, so the birds were large-bodied raptors, waders, waterfowl, and corvids, but one relevant result was that human-adapted species tended to respond positively to habitat alteration and human presence while non-adapted species responded negatively. The design of our study allowed us to consider some differential effects of trails as compared to human visitation, and how these factors may be species-specific based on habitat preferences and behavior.

The montane-breeding bird specialists that were most strongly affected in our study were blackpoll and magnolia warblers, which are both declining neotropical migrants that nest low in shrubs or saplings. We sampled these species with high frequency, and their occupancies and abundances were significantly reduced at both high-visitation formal and informal trails as compared to low-visitation informal trails, indicating that they are disturbed by both trail development and human hiking activity. In contrast, Deluca and King (2014) found no effect of trails on blackpoll warbler abundance or nest-survival in New Hampshire, U.S.; However, their study was conducted in a less human-populated region with larger areas of balsam fir-spruce forests on the higher-elevation White Mountains, during a time period before the current post-pandemic surge in outdoor recreation. Across the Northeast and Midwestern U.S., Ralston et al (2015) reported that montane bird populations were declining, most notably blackpoll and magnolia warblers, Bicknell's thrush, and yellow-bellied flycatcher, highlighting the precarity of these montane species. Another neotropical migrant species, yellow-rumped warbler, also decreased in occupancy and abundance across both high-use trail sites in our study, although they are

widespread generalist forest birds that nest higher in trees. Nonetheless, they forage for insects by gleaning from foliage throughout all forest layers, spending some time in the understory where they may be disturbed by hikers. Blackburnian warblers are a widespread neotropical migrant species, but they nest and forage high in the canopy, which may explain why they are the only species in our study exhibiting significantly higher occupancy and abundance on high-use trails and marginally higher occupancy and abundance on formal high-use trails than on low-use informal trails.

Our results indicate that declining sapling-nesting thrushes have species-specific responses to hiking and trails. Montane specialist Swainson's thrushes have significantly reduced occupancy along both formal and informal high-use trail sites, but trail and visitation type had a marginal or no effect on their abundances, perhaps because they nest in a wide variety of conifer samplings. Bicknell's thrush occupancy and abundance are significantly reduced at high-use informal trails, but they may have marginally higher occupancy and abundance at high-use formal trails. This result hints that Bicknell's thrush is responding negatively to human presence, but perhaps positively to the habitat alteration of developed trails. These data are preliminary because Bicknell's thrushes are uncommon and one of the least-detected analyzed species in our study. However, it is possible that Bicknell's thrushes favor formal trails. Bicknell's thrushes are known to prefer nesting in regenerating balsam fir and spruce saplings, likely because they provide dense cover. In nature, such areas of regeneration would occur after a large tree fall or small forest fire created small openings in the dense montane forest. Long term fire suppression may have reduced natural gaps in the Catskills. Formal trails that become wide enough to let in light can have a similar effect of accelerating dense growth along trail edges, and Bicknell's thrushes are known to nest in similarly human-altered habitats along ski runs in Vermont, U.S. (Hill and Campbell 2019, Rimmer et al. 2004) and clear-cuts in New Brunswick, CA (Nixon et al. 2001). Unfortunately, while skiing activity occurs when Bicknell's thrushes are wintering in the Caribbean, and clear-cutting occurs infrequently, hiking activity along formal trails is high during the June breeding season for Bicknell's thrushes in the Catskills. Any preference for nesting along hiking trails may be an example of an ecological trap- where instincts cause wildlife to make choices that are deleterious (reviewed in Robertson and Hutto 2006), such as when a nesting habitat preference reduces nesting success by leading Bicknell's thrushes to nest in locations prone to hiking disturbance or destruction. Aside from affecting occupancy and abundance, human disturbance may affect wildlife individually by changing behavior and physiology (reviewed by Bateman and Fleming 2017), including increasing stress levels leading to reproductive losses. For example, Barton and Holmes (2007) found that open cup songbird nests in shrubs and on the ground had higher rates of abandonment when near off-road vehicle trails in California scrub-shrub habitats, Bötsch et al. (2020) measured lower levels of protective maternally-transmitted antibodies in blood samples of great tit (*Parus major*) nestlings in nest boxes that were experimentally disturbed by human hikers in France, and Urhan et al. (2025) report that great tits breeding in nest boxes with higher levels of human disturbance produced smaller clutches and smaller chicks but did not have reduced fledging success in the Netherlands.

Several ground-nesting montane species showed mixed responses or no response to hiking activity and trails or were rarely detected in our study. Winter wrens showed higher or marginally higher occupancy or abundance at high-use informal or formal trails despite being a ground-nesting species. This species may simply not be disturbed by hiking or trails, and they may prefer habitats located near trails, possibly because they often nest under roots and rocks on steep slopes along ravines or close to rushing streams where their invertebrate prey are plentiful, which are also desirable topographies for hiking trails. Dark-eyed juncos and hermit thrushes are regionally migrating species that are ground-nesting, but widespread across forest types and they exhibited reduced occupancy at both high-use trail types and a mix of reduced and unaffected abundances along more developed trails and trails with higher hiker use. Yellow-bellied flycatchers are neotropical migrants and montane specialists that nest in moss cups on the ground. They were detected only just frequently enough to be included in our occupancy model, and they don't appear to be affected by trails, but this may be because their detection rates were too low for any

trends to be conclusive. Yellow-bellied flycatchers are rare, secretive, and they have simple and quiet calls that may be more challenging to detect and identify. White-throated sparrow is a ground-nesting species experiencing steep declines in the Catskills (Hill and Williams 2025), which are located along the Southern limit of this species' breeding range, although they winter across New York State. We did not detect them with enough frequency to include them in our analyses.

Our results for ground- and shrub-nesting birds are generally congruent with those of researchers, including Kangas et al. (2010) who found that ground- and shrub- nesting birds were the most sensitive to hiking disturbance, while tree- and cavity-nesting species were least affected across birds in Finnish montane forests. We also detected red squirrels at moderate frequencies in our study, and Warkentin et al. (2025) reported that they may be linked to decreased montane bird abundances in the montane forests of Newfoundland, CA, potentially due to increased nest predation (Feldman et al. 2023), as the squirrels advance into higher-elevation habitats along with progressing climate change. Vegetation shifts have the potential to indirectly increase interspecific competition faced by montane bird species as lower elevation bird species move upslope (Chen 2011). Neate-Clegg et al. (2024) report that bird species may adjust their response to climate change phenologically by migrating and breeding earlier before shifting their ranges to more suitable habitat, but this evolutionary strategy may not be possible in montane areas because winter conditions last through spring, creating already compressed breeding seasons with little scope for adjusting breeding phenology to cope with climate change.

Several attributes of trail structure and human hiking activity may mediate effects on wildlife. Rodriguez-Prieto et al. (2014) simulated how three different proposed trail networks would affect a community of nine songbird species inside a protected forest in Indiana, U.S. They concluded that the proposals with increased trail length and density would significantly increase human disturbance of the birds, although the intensity of the effects were species-specific based on each species' sensitivity to disturbance and habitat preferences. Designing fewer but more sustainable high-use trails for recreationalists to enjoy while leaving larger areas of wildlife habitat undisturbed is a key strategy for alleviating harm to wildlife. Meadema et al. (2020) assessed the sustainability of trail designs sampled along the Appalachian Trail, U.S., and found that trails with alternating up and down grades routed across moderately steep mountain slopes, instead of straight upslope, best prevented soil loss and trail widening. Narrow trails concentrate hiking use and may reduce damage to vegetation and thus reduce disturbance and damage to bird habitat. Hiking with dogs, which is common in the Catskills, contributes to wildlife disturbance (Banks and Bryant 2005, Lenth et al. 2008), since birds perceive dogs as predators; disturbance by dogs can be alleviated by requiring dogs to be leashed, especially during the breeding season (Barnett et al. 2023, Thomas et al. 2024).

Larson et al. (2016) report that few of the 274 research articles on the effects of human recreation on wildlife that they reviewed proposed management recommendations, but the most common recommendations were: 1) leaving areas of protected lands without trails and/or restricting human access to them, 2) educating visitors on their potential effects on wildlife, 3) capping total numbers of visitors allowed in protected areas, 4) limiting recreational access during breeding seasons, and 5) and enforcing leash laws for pets and enacting rules restricting hiking to formal trails. Changing management of popular natural resources, especially when the changes may include restrictions on recreationalist's behavior, is challenging. However, most recreationalists treasure the natural places they enjoy, and evidence indicates that the post-pandemic increase in outdoor recreation is altering people's values, with people reporting an increased importance of spending time in nature (Tansil et al. 2022), often leading to an increased desire to protect wild places (Pichlerova et al. 2023, Yap et al. 2021).

Conclusion

Recreational hiking is disturbing already-imperiled montane bird species in the Catskills High Peaks, and land managers at DEC are responsible for attempting to mitigate these effects. In 2022, the DEC announced a Visitor Use Management (VUM) planning process to identify solutions to the proliferation of informal trail networks on the formerly trail-less Catskill High Peaks, including their effects on wildlife. In 2025, DEC released a draft of the new VUM for the Catskills formerly trail-less peaks that included the first year of data from this study, which were preliminary data from a single season. In that first year, we found that the combined numbers of all birds and of montane bird species were significantly lower at high-use formal trails, intermediate at high-use informal trails, and highest at low-use informal trails, and while this evidence was sufficient to substantiate concern and initiate further study, it could not provide species-specific results needed to inform detailed management decisions. Our current dataset is now large enough for robust analysis for most species, and the remaining two years of data should strengthen our ability to assess the effects of hiking on less common species including Bicknell's thrush and yellow-bellied flycatcher. In our preliminary study, we also measured trail and habitat attributes across trail types and found that montane bird abundances overall were correlated with vegetation density. In 2026, we are completing a revised assessment of habitat and trail types that we will use to further tease apart species-specific effects of trail and habitat alterations as compared to hiking disturbance by human presence.

Goals for the final VUM and management actions to follow include: 1) identify informal trails that may harm rare or threatened species, 2) identify preferred routes to consolidate foot traffic to a single corridor to reduce affects on wildlife, and 3) establish formal trails designed to reduce and prevent future harm to wildlife while providing sustainable and fulfilling hiking experiences for human visitors. Land managers could further reduce hiker's use of unsustainable informal trails by seeking removal of these trails from hiking apps and maps, and the inclusion of information about how to reduce disturbance to wildlife while hiking, including favoring formal trails and leashing pets during the montane bird breeding season. In addition, installing educational signage at trailheads could help visitors to better appreciate the Catskill's montane forests, the wildlife that depend on them, and how hiking behavior can help safeguard these vulnerable species so future generations of wildlife can thrive for future generations of hikers to enjoy.

References Cited:

Beckage, B., Osborne, B., Gavin, D.G., Pucko, C., Siccama, T. and Perkins, T. (2008). A rapid upward shift of a forest ecotone during 40 years of warming in the Green Mountains of Vermont, Proc. Natl. Acad. Sci. U.S.A. 105 (11) 4197-4202, https://doi.org/10.1073/pnas.0708921105

Beery, Thomas and Olsson, Matilda and Vitestam, Moa (2021). Covid-19 and outdoor recreation management: Increased participation, connection to nature, and a look to climate adaptation. Journal of Outdoor Recreation and Tourism. 36. 100457. 10.1016/j.jort.2021.100457.

Boland, Garrett (2023). Monitoring and Mapping Informal Trail Networks Using Smartphone Applications: A Literature Review and Case Study in the Catskills. SUNY College of Environmental Science and Forestry: Syracuse.

Campbell, Michael O'Neal (2011). "Passerine Reactions to Human Behaviour and Vegetation Structure in Peterborough, Canada." Urban Forestry and Urban Greening [Jena], vol. 10, no. 1, 2011, pp. 47–51, https://doi.org/10.1016/j.ufug.2010.10.001

Catskill Park State Land Master Plan (2014). State of New York. pp.23. https://extapps.dec.ny.gov/docs/lands_forests_pdf/cpslmp.pdf

Deluca, W.V. and King, D.I. (2014), Influence of hiking trails on montane birds. Jour. Wild. Mgmt., 78: 494-502. https://doi.org/10.1002/jwmg.675

Faaborg, J., Holmes, R. T., Anders, A. D., Bildstein, K. L., Dugger, K. M., et al. (2010). Conserving migratory land birds in the New World: Do we know enough? Ecological Applications, 20(2), 398–418. http://www.jstor.org/stable/27797816

Ferguson, M. D., McIntosh, K., English, D. B. K., Ferguson, L. A., Barcelona, R., Giles, G., … Leberman, M. (2022). The Outdoor Renaissance: Assessing the Impact of the COVID-19 Pandemic upon Outdoor Recreation Visitation, Behaviors, and Decision-Making in New England's National Forests. Society and Natural Resources, 35(10), 1063–1082. https://doi.org/10.1080/08941920.2022.2055247

Fiske, I., and Chandler, R. (2011). Unmarked: An R Package for Fitting Hierarchical Models of Wildlife Occurrence and Abundance. Journal of Statistical Software, 43(10), 1–23. https://doi.org/10.18637/jss.v043.i10

Guo, F., Buler J.J., Smolinsky J.A., and Wilcove D.S. (2023). Autumn stopover hotspots and multiscale habitat associations of migratory landbirds in the eastern United States, Proc. Natl. Acad. Sci. U.S.A. 120 (3) e2203511120, https://doi.org/10.1073/pnas.2203511120

Gutzwiller, K.J., Marcum, H.A., Harvey, H.B., Roth, J.D., and Anderson, S.H. (1998). Bird Tolerance to Human Intrusion in Wyoming Montane Forests. The Condor, 100(3), 519–527. https://doi.org/10.2307/1369718

Gutzwiller, K. J., and Anderson, S. H. (1999). Spatial Extent of Human-Intrusion Effects on Subalpine Bird Distributions. The Condor, 101(2), 378–389. https://doi.org/10.2307/1370001

Henschell, Max. (2022) "Effects of Informal Trail Use on Natural Communities in Catskill Park". New York Natural Heritage Program.

Hill J.M., and Williams D.M. (2025). The State of the Mountain Birds Report: Northeast 2025. Vermont Center for Ecostudies, White River Junction, VT. https://mountainbirds.vtecostudies.org/

Hill J.M., and Campbell J. (2019). Continued Exploration of the Relationship between Downhill Ski Area Edges and Bicknell's Thrush in the Northeastern U.S. Using Mountain Birdwatch Data (2016-2019). Vermont Center for Ecostudies. 27 pp.

IUCN. 2025. The IUCN Red List of Threatened Species. Version 2025-2. https://www.iucnredlist.org. Accessed on [Jun 18, 20206].

Iverson, L. R., Prasad, A. M., Matthews, S. N., and Peters, M. (2008). Estimating potential habitat for 134 eastern US tree species under six climate scenarios. Forest Ecology and Management. 254. 390-406. 10.1016/j.foreco.2007.07.023.

Johnston, A., Rodewald, A. D., Strimas-Mackey, M., Auer, T., Hochachka, W. M., et al. (2025). North American bird declines are greatest where species are most abundant. Science (New York, N.Y.), 388(6746), 532–537. https://doi.org/10.1126/science.adn4381

Jones, H. H., C. Ray, M. Johnson, and R. Siegel (2024). Breeding birds of high-elevation mixed-conifer forests have declined in national parks of the southwestern U.S. while lower-elevation species have increased, with responses to drought varying by habitat, Ornithological Applications, Volume 126, Issue 2, May 2024, duae007, https://doi.org/10.1093/ornithapp/duae007

King, D.I., Lambert, J.D., Buonaccorsi, J.P. et al. (2008). Avian population trends in the vulnerable montane forests of the Northern Appalachians, USA. Biodivers Conserv 17, 2691–2700. https://doi.org/10.1007/s10531-007-9244-9

Klem, D Jr. (2025) Bird-window collisions: a critical review, The Wilson Journal of Ornithology, 137:4, 501-531. https://doi.org/10.1080/15594491.2025.2542043

Kramer G.R., Andersen D.E., Buehler D.A., et al (2018). Population trends in Vermivora warblers are linked to strong migratory connectivity, Proc. Natl. Acad. Sci. U.S.A. 115 (14) E3192-E3200, https://doi.org/10.1073/pnas.1718985115

Larson C.L., Reed S.E., Merenlender A.M., Crooks K.R. (2019). A meta-analysis of recreation effects on vertebrate species richness and abundance. Conservation Science and Practice. 2019;1:e93. https://doi.org/10.1111/csp2.93LARSONETAL

Loss S.R., Will T., Marra P.P. (2015). Direct Mortality of Birds from Anthropogenic Causes. Annual Review Ecology, Evolution, and Systematics. 46:99-120. https://doi.org/10.1146/annurev-ecolsys-112414-054133

Marion, Jeff. 2011. “Research and Management of Informal (Visitor-Created) Trails in Protected Areas”. Patuxent Wildlife Research Center. https://www.usgs.gov/centers/eesc/science/research-and-management-informal-visitor-created-trails-protected-areas#publications

Martin, R., and Butler, D. R. (2017). A Framework for Understanding Off-trail Trampling Impacts in Mountain Environments. The George Wright Forum, 34(3), 354–367

Mata-Guel, E. O., Soh, M. C. K., Butler, C. W., Morris, R. J., Razgour, O. and Peh, K. S. H. (2023). Impacts of anthropogenic climate change on tropical montane forests: an appraisal of the evidence. Biol Rev, 98: 1200-1224. https://doi.org/10.1111/brv.12950

Miller, S. G., Knight, R. L., and Miller, C. K. (1998). Influence of Recreational Trails on Breeding Bird Communities. Ecological Applications, 8(1), 162–169. https://doi.org/10.2307/2641318

NYNHP. 2023. Mountain Spruce-Fir Forest. New York Natural Heritage Program. https://guides.nynhp.org/mountain-spruce-fir-forest/

R Core Team (2026). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Rimmer, C. C., and McFarland, K. P. (2001). Known Breeding and Wintering Sites of a Bicknell's Thrush. The Wilson Bulletin, 113(2), 234–236. http://www.jstor.org/stable/4164339

Rimmer, C. C., McFarland, K. P., Lambert, J. D., and Renfrew, R. B. (2004). Evaluating the use of Vermont ski areas by Bicknell's Thrush: applications for Whiteface Mountain, New York. Woodstock, VT: Vermont Institute of Natural Science.

Roehrs, P. and Rice, A. (2019). Visitor Use Study of the Trail-less Peaks over 3,500' in the Catskills. https://www.dec.ny.gov/docs/lands_forests_pdf/traillessreport2019.pdf

Roehrs, P. (2022). Addendum to the 2019 Visitor Use Study of the Catskill Trail-less Peaks over 3,500'. https://www.dec.ny.gov/docs/lands_forests_pdf/traillessaddendum2022.pdf

Rosenberg K.V., Dokter A.M., Blancher P.J., Sauer J.R., et al. (2019). Decline of the North American Avifauna. Science366,120-12. DOI:10.1126/science.aaw1313

Santos, T., Mendez, R., Farias-Tobridoni, E., Juliao, R. P., and Pereira da Silva, C. (2022). Volunteered Geographical Information and Recreational Uses within Metropolitan and Rural Contexts. ISPRS International Journal of Geo-Information. 11. 144. 10.3390/ijgi11020144.

Scridel, D., Brambilla, M., Martin, K., Lehikoinen, A., Iemma, A., Matteo, A., Jähnig, S., Caprio, E., Bogliani, G., Pedrini, P., Rolando, A., Arlettaz, R. and Chamberlain, D. (2018), A review and meta-analysis of the effects of climate change on Holarctic mountain and upland bird populations. Ibis, 160: 489-515. https://doi.org/10.1111/ibi.12585

Smith, I., Velasquez, E., Norman, P., and Pickering, C. (2023). Effect of the COVID-19 pandemic on the popularity of protected areas for mountain biking and hiking in Australia: Insights from volunteered geographic information. Journal of Outdoor Recreation and Tourism, 41, 100588. doi: 10.1016/j.jort.2022.100588. Epub 2022 Nov 14. PMID: 37521257; PMCID: PMC9659557.

Steven, R., Pickering, C. M., and Castley, G. J. (2011). A Review of the Impacts of Nature Based Recreation on Birds. Journal of Environmental Management. 92. 2287-94. 10.1016/j.jenvman.2011.05.005.

Thompson, B. (2015). Recreational Trails Reduce the Density of Ground-Dwelling Birds in Protected Areas. Environmental Management, 55, 1181–1190. doi: 10.1007/s00267-015-0458-4. Epub 2015 Mar 27. PMID: 25813628.

Venter, Z. S., Barton, D. N., Gundersen, V., Figari, H., and Nowell, M. S. (2021). Back to nature: Norwegians sustain increased recreational use of urban green space months after the COVID-19 outbreak. Landscape and urban planning, 214, 104175. https://doi.org/10.1016/j.landurbplan.2021.104175

Wilcer, S. R., Larson, L. R., Hallo, J. C., and Baldwin, E. (2019). Exploring the Diverse Motivations of Day Hikers: Implications for Hike Marketing and Management. The Journal of Park and Recreation Administration. https://doi.org/10.18666/JPRA-2019-9176

Wimpey, J., and Marion, J. (2011). A Spatial Exploration of Informal Trail Networks Within Great Falls Park, VA. Journal of Environmental Management, 92, 1012–1022. https://doi.org/10.1016/j.jenvman.2010.11.015