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Conservation of Boreal Birds in the Adirondack Park: Report to the New York State Department of Environmental Conservation

Federal Aid Grant W-173-G

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Introduction

The Adirondack Park in northern New York State represents the southern range extent for several species of boreal forest birds within eastern North America. These populations are subject to the stresses imposed by conditions at the range margin, and geographically isolated from conspecific populations found farther north. These birds are vulnerable to climate change due to their affinity for northern boreal habitat types and are expected to be sensitive to warming temperatures (Moore 2002, Niemi et al. 1998, Pastor et al. 1998). Boreal habitats in the Adirondacks are naturally fragmented and less continuous than the Canadian boreal, with patches of boreal wetland habitat surrounded by temperate forest habitat types (Jenkins 2010). Additionally, habitats within the Adirondack landscape are further fragmented by small amounts of agriculture and developed land uses.

Several key findings have arisen from more than 15 years of monitoring boreal birds and investigating drivers of population change and the potential implications of climate change for these species and their habitats in New York State (Glennon 2014, Glennon 2017, Glennon 2018, Glennon et al. 2019a,b). Among them, we have learned that: (1) boreal bird populations in New York are dynamic, (2) some of these dynamics are driven by climate and anthropogenic landscape change, and (3) numerous species appear to be in decline. Our research has found that boreal birds are much more likely to disappear from smaller, isolated wetlands that are close to roads and other infrastructure. These are sensitive species and may face competition from more cosmopolitan birds (e.g., blue Jay, red-winged blackbird) that successfully exploit altered habitats. Some species also appear to be moving northward or upslope in response to climate change and all are sensitive to changing temperature and precipitation patterns. Ultimately, the declining status of boreal birds in our landscape is likely the result of a combination of these factors. We have also learned from this work that annual monitoring is financially difficult to sustain. In 2018, the New York State Department of Environmental Conservation (NYSDEC) and the Wildlife Conservation Society (WCS) partnered to develop a monitoring plan for boreal birds which included a power analysis for trend detection, and evaluation of methods used to date and potential alternatives (Glennon 2018). This effort revealed that the most efficient course of action would be to continue the existing relatively low-cost monitoring at approximately 60 sites annually, which provides occupancy estimates with good precision for a number of target species. For some species, however, very low occupancy rates in the Adirondack landscape present challenges to trend estimation that are difficult to overcome. For all species, use of expert observers is highly recommended and for those exhibiting negative trends and chronically low occurrence, targeted research may help elucidate the causes of decline. To address these needs, the following objectives were proposed to NYSDEC in association with Federal Aid in Wildlife Restoration Grant W-173-G.

Objectives:

1. Monitor lowland boreal bird species at select locations in the Adirondacks.
2. Analyze data obtained from monitoring in order to determine boreal bird trends and identify priority locations for boreal birds and their land protection status.
3. Conduct targeted research to determine potential causes of observed declines in boreal bird populations.

The 2022 field season marked the 16th year of our dataset of boreal bird occupancy in the Adirondack Park. Building on the prior analysis of 10-year trends (Glennon 2017), the current project revisits our analysis to update trend information and determine if observed patterns of decline are continuing. We use our foundation of monitoring data and predictive occupancy modeling for priority locations, combined with a review of related literature and findings from recent research into temperature and precipitation effects on boreal birds (Glennon et al. 2019a, Glennon et al. 2019b) to provide recommendations and best management practices for the management of boreal SGCN and their habitats.

All but two of the focal species our of long-term monitoring are Species of Greatest Conservation Need (SGCN) within USFWS Region 5 and several are SGCN for three or more states within the region (olive-sided flycatcher, rusty blackbird, spruce grouse, bay-breasted warbler, Cape May warbler) allowing our findings and recommendations to be of use in other northeastern states. These efforts also allow us to address two additional New York State Wildlife Action Plan objectives of (1) identifying focus areas for high priority SGCN and important habitats and (2) sharing information regarding important SGCN, their habitats, and best practices for conservation with county and town governments to inform their land use decision making conservation efforts (NYSDEC 2015).

This report addresses the following tasks associated with Objectives 1 and 2 outlined above:

Objective 1: Analyze data obtained from monitoring in order to determine boreal bird trends and identify priority locations for boreal birds and their land protection status.

- Task 1 – Compile all data from 2007 – 2021 and conduct 16-year trend analysis, following past occupancy modeling analysis methods.
- Task 2 – Conduct predictive occupancy modeling to identify locations throughout the park that are most likely to be occupied consistently by boreal birds; overlay predicted occupancy with land ownership and resilience to identify best examples of large, well-connected resilient habitats.
- Task 3 – Using results of Task 2, identify appropriate audiences/landowners and potential management options.

Objective 2 - Develop recommendations/Best Management Practices (BMPs) and outreach materials for priority locations based on ownership.

- Task 4 – Review literature on peatland and boreal forest management practices, informed by results of predictive modeling and relevant land ownerships, management units and land use classes.
- Task 5 – Investigate adequacy of existing wetland protections for boreal habitats in the Adirondack Park, best practices for boreal wetland and protection, opportunities for habitat management, and ways in which these can be turned into practical recommendations and tailored to individual audiences.
- Task 6 – Develop fact sheets for boreal habitats and best management practices in New York.

Methods and Results

Objective 1: Analyze boreal bird trends and identify priority locations

Task 1 – Trend analysis

Approach

We compiled all boreal bird occupancy data from 2007 – 2022. Boreal birds have been sampled since approximately 2005 in locations throughout a broad portion of the Adirondack Park. This work was supported by a New York State Wildlife Grant in 2007 – 2009 and a variety of funding sources have contributed to maintaining monitoring efforts since that time. Though data are sparse in some years, relatively consistent monitoring has occurred since 2007 and focused on a set of 58 sites that have served as the basis for population trend analysis and research. These data have been utilized in a number of publications including Glennon (2014), Ralston et al. (2015), McNulty et al. (2016), Glennon et al. (2019a and b), and McNulty et al. (2021). Methods are described in several papers but briefly, consist of standard point count methods using unlimited distance, 10-minute counts at a series of 5 locations within a given sampling location. Replication is spatial rather than temporal; each site is visited once per season and the wetland itself is considered to be the sample site, with 5 spatial replicates located within it. Data are collected by trained observers, several of whom have been a part of the data collection efforts for this project since its inception.

Two minor changes were made to our dataset for the purpose of the current analysis. First, in addition to the 58 long-term sites that have previously been analyzed, we incorporated data from 7 additional sites resulting in a total of 65 locations (Figure 1). These additional data result from monitoring efforts at Shingle Shanty Preserve and Research Station, a 15,000-acre research preserve west of Long Lake, NY which contains approximately 2,000 acres of highly intact boreal wetland habitat. The remoteness and pristine condition of boreal wetlands at Shingle Shanty, combined with their location at lower latitudes than many of our existing sample sites, make them a valuable addition to the current analysis. There are sufficient data from these sites in combination with ours that they can be incorporated into the long-term analysis and enhance our ability to calculate detection and occupancy for all species. Data collection at this site has also used the same point count methodology, with points similarly arranged along transects. In cases where Shingle Shanty transects were longer than 5 points, we subset locations into series of 5 points to match our existing data structure. Second, for the purpose of this analysis, we incorporated information and analysis for Canada warbler (*Cardellina canadensis*), for which adequate observations exist in our dataset to calculate trends. Though this species was not included in our original target set for the project, it has a relatively similar North American boreal distribution and possibly should have been included in our focal

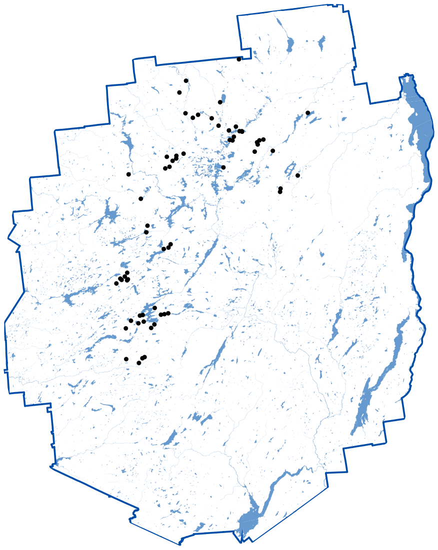

Figure 1. Boreal bird sampling locations 2007 – 2022.

set. Focal species for this project additionally include American three-toed woodpecker (*Picoides dorsalis*), black-backed woodpecker (*Picoides arcticus*), olive-sided flycatcher (*Contopus cooperi*), yellow-bellied flycatcher (*Empidonax flaviventris*), Canada jay (*Perisoreus canadensis*), boreal chickadee (*Poecile hudsonicus*), Tennessee warbler (*Leiothlypis peregrina*), Cape May warbler (*Setophaga tigrina*), bay-breasted warbler (*Setophaga castanea*), palm warbler (*Setophaga palmarum*), Lincoln's sparrow (*Melospiza lincolnii*), and rusty blackbird (*Euphagus carolinus*).

We compiled and formatted occurrence data for all species in all locations, in addition to detection covariates for information on time, date, location, temperature, wind and sky conditions, and observer for each survey at each site. Data were input into R statistical software (R Core Team 2021), and we ran trend analyses using the package 'unmarked,' which fits hierarchical models of animal abundance and occurrence to data collected on unmarked animals using survey methods such as point counts, distance sampling, and double observer sampling (Fiske and Chandler 2011). We used the function colext to run an initial set of models to determine the best predictors of detection probability for each species. Colext fits the dynamic colonization-extinction model of MacKenzie et al. (2006) and is suitable for multiyear survey efforts. We set occupancy (ψ), colonization (γ), and extinction (ε) as constant and modeled the influence of date, time, temperature, wind, sky condition, and observer for each species. Upon determining the best detection covariates for each of our target species, we used the ranef function to calculate empirical Bayes estimates of the number of sites occupied, or probability of occupancy, for each species by year. We calculated the rate of change in occupancy, or lambda (λ) for each year from 2008-2022 and calculated the geometric mean of the λ to determine an overall estimate of the population trend. In general, a population with a λ of 1 can be inferred as stable, while values less than or greater than 1 indicate a declining or increasing trend respectively (Kery et al. 2010).

Findings

To date, monitoring efforts have resulted in more than 39,000 records of birds in boreal wetland habitats in the Adirondack Park. This includes occurrences for more than 140 species in 139 locations since 2003. Our monitoring efforts since 2007 have focused primarily on 58 sites in which we have made detections of 125 species including all boreal targets. Occurrences of 4 species, however, are too sparse to calculate trends or determine predictors of occupancy. Over the course of this work, we have only had sporadic detections of three-toed woodpecker, bay-breasted warbler, Cape May warbler, and Tennessee warbler. The reasons for their low occurrence are unknown, but the 3 warblers are budworm specialists and may occur more reliably in the park on occasions of spruce budworm outbreaks. Three-toed woodpecker is more common in western landscapes and has been recorded in our data in only a limited number of sites. As such, we report results for our other target species only - black-backed woodpecker (BBWO), boreal chickadee (BOCH), Canada warbler (CAWA), Canada jay (CAJA), Lincoln's sparrow (LISP), olive-sided flycatcher (OSFL), palm warbler (PAWA), rusty blackbird (RUBL), and yellow-bellied flycatcher (YBFL).

Trend analysis indicated declining occupancy for the majority of species. Black-backed woodpecker, boreal chickadee, Lincoln's sparrow, olive-sided flycatcher, rusty blackbird, and yellow-bellied flycatcher all exhibited patterns of decline in low elevation boreal wetlands between 2007 and 2022 (Table 1). These declines were steepest for boreal chickadee and rusty blackbird. Among the remaining species, Canada jay appears to be stable, while Canada warbler and palm warbler show very modest increasing occupancy patterns (Figure 2).

Table 1. Probability of occupancy (Ψ) at start (2007) and end (2022) of report period and mean annual rate of change in occupancy (λ; geometric mean) for 9 species of boreal birds in 65 Adirondack peatlands.

Species	AOU code	Ψ (2007)	Ψ (2022)	Mean λ
Black-backed woodpecker	BBWO	0.82	0.52	0.97
Boreal chickadee	BOCH	0.54	0.09	0.89
Canada jay	CAJA	0.72	0.68	1.00
Canada warbler	CAWA	0.47	0.52	1.01
Lincoln's sparrow	LISP	0.64	0.54	0.99
Olive-sided flycatcher	OSFL	0.53	0.33	0.97
Palm warbler	PAWA	0.42	0.58	1.02
Rusty blackbird	RUBL	0.40	0.09	0.91
Yellow-bellied flycatcher	YBFL	0.85	0.65	0.98

In addition to landscape context, boreal birds are strongly impacted by climate conditions and sites with higher mean annual temperatures during the breeding and winter season, and sites with less and less variable precipitation in both summer and winter are more likely to become and remain occupied (Glennon et al. 2019a). As in past analyses, we again obtained temperature and precipitation data from the Parameter-elevation Relationships on Independent Slopes model (PRISM, Daly et al. 2008). We obtained mean temperature and precipitation values for study site locations for all months and years between December 2006 and August 2022 and calculated mean winter (December – March) and breeding (May – August) season temperature, variability in winter and breeding season temperature, mean winter and breeding season precipitation, and variability in winter and breeding season precipitation. Additionally, we calculated mean resilience values within 500m of each boreal transect using the Resilient and Connected Landscapes dataset of Anderson et al. (2016). Resilience refers to the capacity of a site to adapt to climate change while still maintaining diversity. Resilient sites are considered natural strongholds – places where the direct effects of climate change are moderated by complex topography and connected natural landcover, and where the current landscape contains high quality biodiversity features. The theoretical and analytical foundations of resilience science are described in Anderson and Ferree (2010) and Anderson et al. (2014).

To determine if previously identified drivers remained important in predicting current patterns, we repeated the analytical approach of Glennon et al. (2019a) to explore the influence of both landscape and climate characteristics on predicted occupancy. For each target species, we ran a set of models examining the influence of wetland area, connectivity, latitude, elevation, human footprint, resilience, mean and variability in winter and breeding season temperature, and mean and variability in winter and breeding season precipitation (Table 2). We did not place any covariates on occupancy, believing it to be reflective of past dynamics (Sjögren-Gulve and Hanski 2000), and we limited models to a single site covariate to simplify interpretation of results. We held one dynamic rate constant and varied the other within the model set and ran models separately for colonization and extinction and separately for each species in this now 16-year dataset. We drew inferences from the betas and estimates of γ and ε for all models and used factor weights to explore the relative importance of each covariate across all species (Burnam and Anderson 2002, Schlesinger et al. 2008).

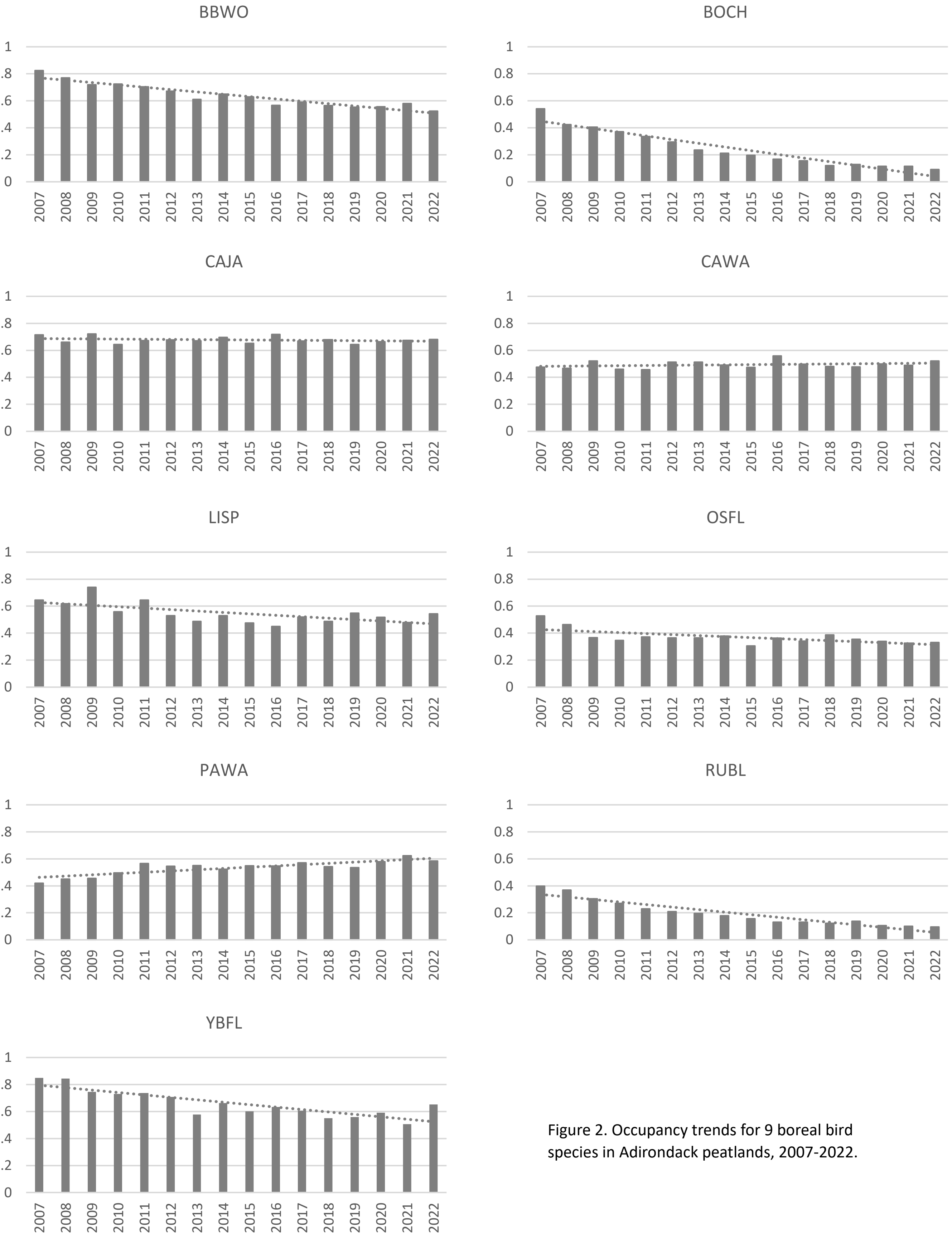

Figure 2. Occupancy trends for 9 boreal bird species in Adirondack peatlands, 2007-2022.

Task 2 – Predictive occupancy modeling and identification of best examples of large, well-connected resilient habitats

Approach

Following past methods and building on prior identification of important drivers of dynamic colonization and extinction rates among these species, we compiled and formatted site covariate data for all sites to use in occupancy modeling. Prior efforts had identified the importance of landscape context (wetland area, connectivity, latitude, elevation, and human footprint) as well as climate conditions (mean and variation in breeding and winter season temperature and precipitation) as important drivers of colonization and extinction patterns among boreal birds in Adirondack peatlands (Glennon 2014, Glennon et al. 2019a,b). Because boreal habitats in the Adirondacks are naturally fragmented and exist as patches of boreal habitat within a matrix of northern hardwood and conifer forest, metapopulation dynamics are expected and have been confirmed among these species (Glennon 2014). Multiseason occupancy models predict occupancy (ψ), colonization (γ), and extinction (ε) and allow for the modeling of site covariates that influence these dynamic rates. Occupancy probability can be interpreted as the proportion of sites occupied, or the probability that any individual site is occupied based on its site characteristics. Relatedly, colonization probability indicates the probability that a site unoccupied in year t becomes occupied in year t+1, while extinction probability indicates the probability that an occupied site in year t becomes unoccupied in year t+1. Our past research has revealed that, as predicted by metapopulation biology (Hanski 1998), larger and more well-connected sites are more likely to become and remain occupied by boreal birds in the Adirondacks and further, that sites that are less impacted by anthropogenic landscape alterations (human footprint, i.e., roads, buildings, etc.) are more likely to become and remain occupied as are sites at high latitude and low elevation (Glennon 2014, Glennon et al. 2019a).

Following past analyses, we utilized wetland cover type data provided by the Adirondack Park Agency (APA) to characterize wetland size and connectivity. These maps were produced by APA staff and exist for all watersheds in the Adirondacks. All park wetlands are classified by system, which describes the complex of wetlands and deepwater habitats that share the influence of similar hydrologic, geomorphologic, chemical, or biological factors (e.g., palustrine, lower perennial riverine) and class, which describes the general appearance of the habitat in terms of either the dominant life form of the vegetation or the physiography and composition of the substrate (e.g., forested/evergreen, broad-leaved deciduous scrub/shrub; Cowardin et al. 1979). In keeping with past consultation with local wetland ecologists to determine which of these class types best correspond with boreal wetland habitats, we utilized palustrine systems within 7 class types: FO1 – forested, broad-leaved deciduous, FO2 – forested, needle-leaved deciduous, FO4 – forested, evergreen, FO5 – forested, dead, SS1 – broad-leaved, deciduous scrub/shrub, SS3 – broad-leaved evergreen scrub/shrub, and SS4 – needle-leaved evergreen scrub/shrub (Langdon et al. 2015). Polygons within these classes were merged in ArcMap to create a layer representing boreal wetlands and used to identify wetland size. In order to represent wetland connectivity, we buffered each of the study wetlands by 5 km and summarized the total available boreal habitat within the same cover type wetland polygons inside of the 5 km radius. Elevation was identified with a digital elevation model and a regional human footprint dataset (Woolmer et al. 2008) was used to characterize the relative human influence at each of the study wetlands as per Glennon (2014).

Table 2. Models used to predict probability of occupancy (ψ), colonization (γ), and extinction (ε) for 9 bird species in boreal wetlands of the Adirondack Park, NY, 2007 – 2022. Detection covariates are not shown but used the best predictors for each species from previous model set.

Colonization Models	Extinction Models
ψ (.), γ(.), ε(.)	ψ (.), γ(.), ε(.)
ψ (.), γ(Wetland Area), ε(.)	ψ (.), γ(.), ε(Wetland Area)
ψ (.), γ(Connectivity), ε(.)	ψ (.), γ(.), ε(Connectivity)
ψ (.), γ(Latitude), ε(.)	ψ (.), γ(.), ε(Latitude)
ψ (.), γ(Elevation), ε(.)	ψ (.), γ(.), ε(Elevation)
ψ (.), γ(Human Footprint), ε(.)	ψ (.), γ(.), ε(Human Footprint)
ψ (.), γ(Resilience), ε(.)	ψ (.), γ(.), ε(Resilience)
ψ (.), γ(Mean Breeding Temp), ε(.)	ψ (.), γ(.), ε(Mean Breeding Temp)
ψ (.), γ(Mean Winter Temp), ε(.)	ψ (.), γ(.), ε(Mean Winter Temp)
ψ (.), γ(Breeding Temp Variability), ε(.)	ψ (.), γ(.), ε(Breeding Temp Variability)
ψ (.), γ(Winter Temp Variability), ε(.)	ψ (.), γ(.), ε(Winter Temp Variability)
ψ (.), γ(Mean Breeding Precip), ε(.)	ψ (.), γ(.), ε(Mean Breeding Precip)
ψ (.), γ(Mean Winter Precip), ε(.)	ψ (.), γ(.), ε(Mean Winter Precip)
ψ (.), γ(Breeding Precip Variability), ε(.)	ψ (.), γ(.), ε(Breeding Precip Variability)
ψ (.), γ(Winter Precip Variability), ε(.)	ψ (.), γ(.), ε(Winter Precip Variability)

From model results, we compiled information on key drivers of colonization and extinction across species and confirmed that past predictors remained important for predicting occupancy of our target species. We then developed a method for predicting occupancy across the Adirondack Park to identify wetlands in which boreal bird persistence was expected to be highest and to identify underlying land ownership patterns. To do so, we chose predictors that could reasonably be compiled across all boreal wetlands in the park from among those with highest demonstrated importance across species from the results of individual species models. These included wetland area, latitude, elevation, and mean breeding and winter temperature and precipitation based on long-term climate normals. The full set of potential boreal wetlands in the park based on APA mapping comprised a total of 67,891 polygons. We applied a 10ha threshold size as a reasonable lower size limit that would be likely to be occupied by target species based on existing occurrence data across our range of study locations. This threshold resulted in 6,378 wetlands for which attribute information was compiled. Area, latitude, and elevation information were determined as described previously for study wetlands. Mean temperature and precipitation data were compiled from long term climate normals again obtained from PRISM data (Daly et al. 2008). Because modeling of future climate is challenging on small scales and especially in mountainous terrain (Dobrowski 2011), we expected that climate normals were a reasonable means of describing patterns in temperature and precipitation across the park in the absence of fine-scale climate predictions. Normals are average monthly conditions over the most recent 3 full decades; current normals correspond to the period 1991 – 2020. Though variability in temperature and precipitation also demonstrated important influences on boreal bird occupancy and is expected to continue to do so, we had no available data source to describe expected climate variability across the park.

To predict boreal bird occupancy across the park using compiled site covariate information, we combined bird data across all species and modeled them simultaneously at a community level. We then used the predict function in R to apply the community level data to predict occupancy across the park based on each of the predictor variables, using a separate model for each predictor and placing it as a covariate on extinction. Predicted extinction probability for all 6,378 boreal wetlands was extracted from each model and then, in each case, subtracted from 1 in order to provide an estimate of persistence rather than extinction. In other words, the opposite of the probability of a site becoming unoccupied is that the site will remain occupied. We then calculated an average persistence value for all wetlands based on predicted persistence as influenced by each of the predictor variables. The average persistence scores were joined to the attribute table for boreal wetland polygons in ArcMap and used to examine patterns of distribution and land ownership associated with high value wetlands. We selected the 30 largest wetlands predicted to have highest persistence (> 81%) and assigned them a resilience value based on Anderson et al. (2016) mapping to demonstrate the best examples of high value, resilient boreal habitats across the park.

Findings

Across species, we generally found that previous predictors of boreal bird colonization and extinction in Adirondack peatlands were similar to patterns observed previously (Glennon et al. 2019a). With the exception of olive-sided flycatcher and rusty blackbird, for most species 1-3 models captured most of the cumulative model weight for both colonization and extinction (Table 3). As we have previously observed, patterns with regard to extinction probability are more consistent across species than are those explaining colonization patterns.

Across all species, the most influential variables by factor weight explaining colonization probability were variability in breeding and winter season precipitation, followed by elevation and these were generally negatively associated with colonization. With regard to extinction, the most influential drivers by factor weight were mean breeding season temperature and variability in winter temperatures. These were positively associated with extinction, indicating that birds were more likely to abandon sites that were lower in temperature and had lower variation in winter temperatures. Though factor weights are instructive, they can also be challenging for drawing conclusions across all species because a high factor weight may be driven by high influence of a covariate on only one or a few species. For example, nearly all of the cumulative weight on breeding season temperature as a predictor of extinction probability was driven by its influence on yellow-bellied flycatcher. It is also instructive to look at the direction of influence of each predictor and the consistency of response among species, taking into account the number of species for whom each factor was among top models, regardless of individual model weights (Figure 3).

Table 3. Summary of model weights (AIC weight for model containing each covariate) and selection results from analysis of underlying dynamics for 9 bird species monitored in boreal wetlands in the Adirondack Park, NY, 2007 – 2022. Weight indicates sum of AIC weight across species of all models containing the covariate (cumulative factor weight). Bold denotes that the covariate was included in top models (ΔAIC ≤ 2.0) for the species; shading indicates a positive influence of covariate on dynamic rates of colonization and/or extinction.

Covariate	BBWO	BOCH	CAJA	CAWA	LISP	OSFL	PAWA	RUBL	YBFL	Wt.
Colonization Factors										
Wetland Area	0.04	0.00	0.08	0.01	0.01	0.02	0.00	**0.06**	0.02	0.25
Connectivity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.06**	0.00	0.06
Latitude	0.11	0.00	0.01	0.14	0.02	0.02	0.00	0.06	0.21	0.57
Elevation	0.02	0.00	**0.73**	0.03	0.01	**0.18**	0.01	**0.06**	0.06	1.11
Human Footprint	0.00	**0.64**	0.00	0.01	0.02	0.03	0.00	0.06	0.00	0.76
Resilience	0.03	0.00	0.01	0.01	0.03	0.03	0.00	0.00	0.01	0.12
Winter Temp	0.04	0.01	0.00	0.02	**0.21**	**0.07**	0.00	0.06	0.00	0.41
W Temp Var.	**0.25**	0.01	0.00	0.01	0.03	0.03	0.00	0.06	0.00	0.39
Breeding Temp	0.03	0.01	0.00	0.01	0.03	**0.08**	0.00	0.06	0.01	0.23
B Temp Var.	**0.16**	0.09	0.13	0.01	**0.46**	**0.19**	**0.98**	**0.09**	0.12	2.23
Winter Ppt	0.09	0.03	0.01	0.20	0.01	0.05	0.00	**0.06**	**0.17**	0.63
W Ppt Var.	0.07	0.11	0.00	**0.53**	0.11	0.03	0.00	**0.06**	**0.34**	1.25
Breeding Ppt	0.06	0.06	0.00	0.01	0.01	**0.12**	0.00	0.06	**0.04**	0.39
Breeding Ppt Var.	0.03	0.01	0.00	0.01	0.02	**0.10**	0.00	0.06	0.00	0.23
Extinction Factors										
Wetland Area	0.06	0.01	**0.42**	0.00	0.08	0.04	0.02	0.01	0.00	0.64
Connectivity	0.00	0.00	**0.20**	0.00	0.00	0.00	0.00	0.00	0.00	0.20
Latitude	0.07	0.02	0.02	0.16	**0.17**	0.01	**0.33**	0.01	0.00	0.78
Elevation	0.04	0.00	0.02	0.01	0.00	**0.32**	0.00	0.01	0.00	0.40
Human Footprint	0.02	0.02	0.03	0.00	0.02	0.01	0.00	0.02	0.00	0.13
Resilience	0.02	0.00	0.01	0.00	0.03	0.01	0.01	0.01	0.00	0.09
Winter Temp	0.04	0.04	0.01	**0.45**	0.06	**0.14**	0.01	0.09	0.11	0.94
W Temp Var.	**0.24**	0.09	0.01	0.00	0.04	0.01	0.01	**0.63**	0.00	1.02
Breeding Temp	0.05	0.02	0.09	0.06	0.08	0.02	0.01	0.12	**0.89**	1.33
B Temp Var.	**0.10**	0.04	0.11	0.00	**0.27**	0.02	**0.28**	0.01	0.00	0.83
Winter Ppt	0.06	**0.24**	0.03	0.05	**0.11**	0.03	**0.28**	0.12	0.00	0.82
W Ppt Var.	**0.10**	**0.31**	0.02	**0.26**	0.02	0.01	0.02	0.01	0.00	0.75
Breeding Ppt	0.05	0.03	0.01	0.00	0.04	0.07	0.01	0.02	0.00	0.22
Breeding Ppt Var.	**0.10**	**0.14**	0.01	0.00	0.05	**0.28**	0.01	0.02	0.00	0.61

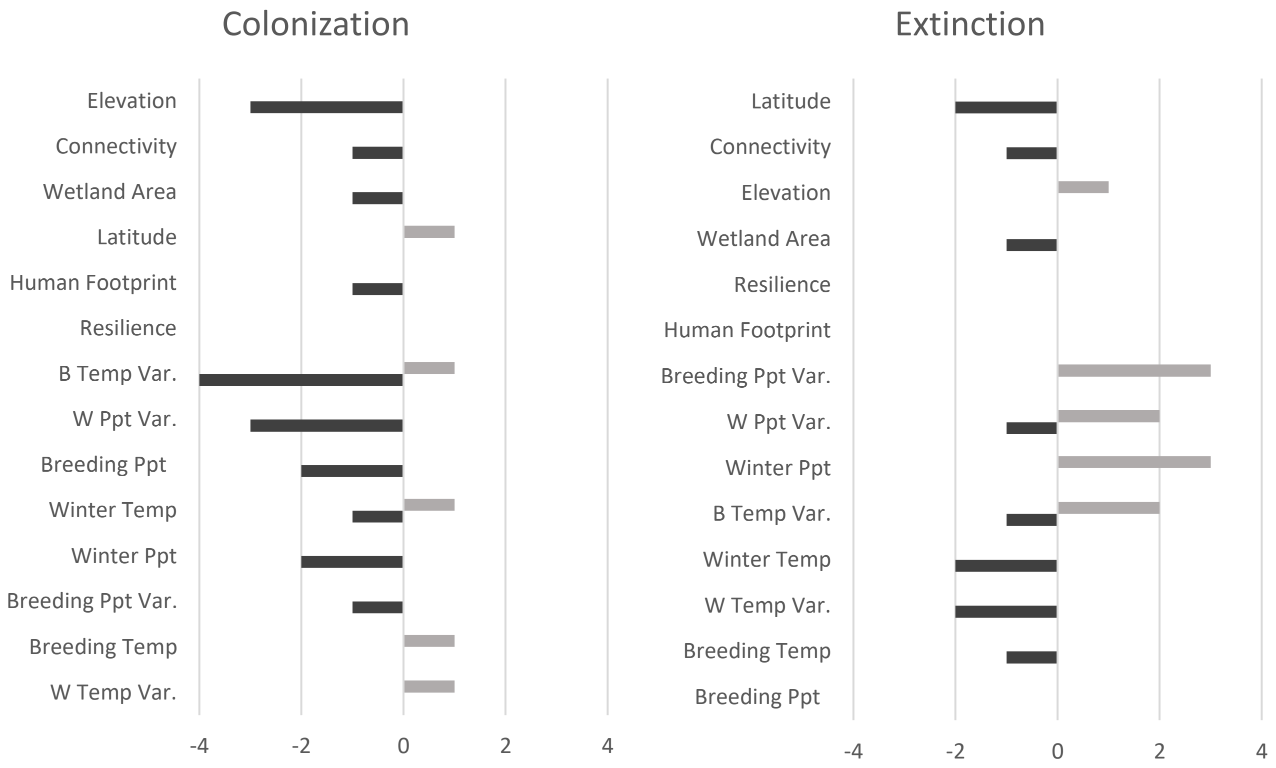

Figure 3. Influence of landscape and climate drivers on colonization and extinction dynamics among 9 boreal bird species in Adirondack wetlands, 2007-2022. This graphic represents much of the same information as the model selection results in Table 3, but represented are the *number* of species for which each covariate was among top models (AIC ≤ 2.0) rather than factor weights. Covariates are arranged from highest to lowest importance vertically for landscape (top) and climate (bottom) characteristics separately. Dark bars represent species for whom each variable was a negative influence on either colonization or extinction, and light bars represent the positive influence of each covariate. Variability in breeding season temperature, for example, was highly influential on colonization rates (among top models for 5 species), and reduced likelihood of colonization for 4 out of 5 of species.

Though it is clear that boreal bird species exhibit individualistic responses to both landscape and climate characteristics, some broad patterns can be discerned from these results. One, climate factors are included more often among top models of bird occupancy than are landscape factors. Overall, climatic factors were more likely to influence long-term colonization and extinction dynamics among our study locations than were landscape variables. Colonization was more likely at low elevation and high latitude, and at sites with low human footprint, as we would expect. It was also more likely at smaller, more isolated sites. This is potentially because larger, more connected sites are already occupied and will remain so from year to year and so the unoccupied sites in which new colonization is most likely are those that are smaller. From a climate standpoint, colonization is associated with sites with stable breeding season temperatures and stable winter precipitation patterns, and sites that are warmer and drier. These patterns are consistent with previous findings (Glennon et al. 2019a). Rather than extinction, it is perhaps more useful to consider its opposite, or persistence. Persistence was more likely at sites at high latitude and those that were larger and had higher connectivity. And from a climate standpoint, persistence over the study period was higher at sites that were drier in winter and with more stable precipitation patterns in all seasons, and sites that had higher mean temperatures during both breeding and winter seasons. Persistence was also higher in sites with less variability in breeding season temperature but more variability in winter temperatures.

We used the results from individual species models to confirm previously observed patterns and found that the incorporation of 7 additional sites and 6 additional years of data did not change our conclusions about the important drivers of boreal bird occupancy dynamics in the Adirondack Park. Large, well connected, low impact sites at high latitude and low elevation are most commonly associated with persistence and, among them, birds appear more likely to persist in areas that are generally more warm and dry, with stable winter precipitation patterns. It is clear that winter conditions are as important as those during the breeding season, though only 3 of our target species are resident birds. In particular, characteristics of winter precipitation appear to be important and perhaps influential on food resources for birds in the subsequent breeding season. Community level models in which all species were modeled simultaneously revealed that temperature and latitude were most closely associated with persistence (Table 4).

Table 4. Community level model selection results investigating drivers of extinction in 65 Adirondack peatlands, 2007-2022; all species modeled simultaneously.

Model	AIC	ΔAIC	AICwt	B	SE	P
ψ (.), γ(.), ε(Mean Breeding Temp), p(obs)	16089.3	0	0.90	-0.80	0.14	0.0000
ψ (.), γ(.), ε(Latitude), p(obs)	16094.5	5.19	0.07	-1.30	0.24	0.0000
ψ (.), γ(.), ε(Mean Winter Temp), p(obs)	16096.8	7.44	0.02	-0.81	0.17	0.0000
ψ (.), γ(.), ε(Mean Winter Ppt), p(obs)	16097.7	8.41	0.01	1.14	0.25	0.0000
ψ (.), γ(.), ε(Winter Ppt. Variability), p(obs)	16105.1	15.81	0.00	4.05	0.10	0.0002
ψ (.), γ(.), ε(Mean Breeding Ppt), p(obs)	16109.8	20.53	0.00	1.14	0.40	0.0042
ψ (.), γ(.), ε(Wetland Area), p(obs)	16111.1	21.83	0.00	0.00	0.00	0.0000
ψ (.), γ(.), ε(Winter Temp Variability), p(obs)	16114.4	25.11	0.00	-0.78	0.38	0.0402
ψ (.), γ(.), ε(Breeding Temp Variability), p(obs)	16115.1	25.77	0.00	0.93	0.48	0.0527
ψ (.), γ(.), ε(Elevation), p(obs)	16115.9	26.61	0.00	0.00	0.00	0.8031
ψ (.), γ(.), ε(Breeding Ppt. Variability), p(obs)	16118.2	28.84	0.00	0.38	0.47	0.4250
ψ (.), γ(.), ε(Human Footprint), p(obs)	16118.4	29.07	0.00	0.01	0.01	0.5190
ψ (.), γ(.), ε(Resilience), p(obs)	16118.8	29.51	0.00	0.00	0.00	0.9290
ψ (.), γ(.), ε(Connectivity), p(obs)	16266.2	176.89	0.00	0.00	0.00	0.0000

Community level model results were used to inform the prediction of occupancy across all boreal wetlands based on wetland area, latitude, elevation, and mean breeding and winter temperature and precipitation. Average persistence scores based on these characteristics among all wetlands revealed spatial patterns of important areas for boreal birds across the park (Figure 4).

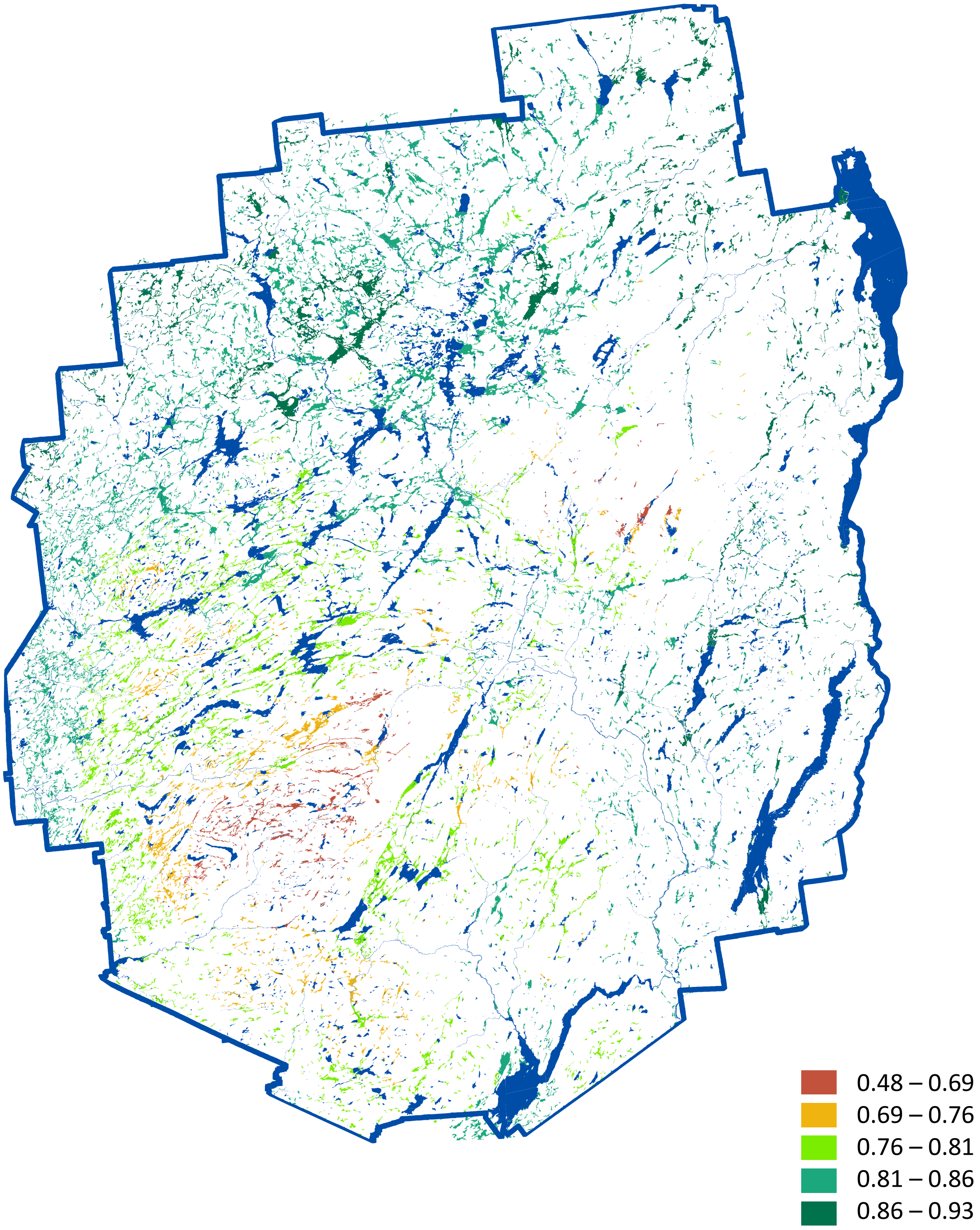

Figure 4. Predicted persistence of target birds in Adirondack boreal wetlands > 10 ha based on size, latitude, elevation, and average winter and breeding season temperature and precipitation.

The importance of the northwest quadrant of the park is revealed in the spatial pattern of predicted persistence. This zone overlaps with what is commonly referred to as the "boreal core" and is the region with the highest density of large boreal wetland complexes. It is also a relatively flat region of the park and is characterized by higher mean temperatures and lower precipitation relative to areas at higher elevation. The largest high value wetlands were found on both state and private lands, with high resilience examples in the boreal core (Figure 5).

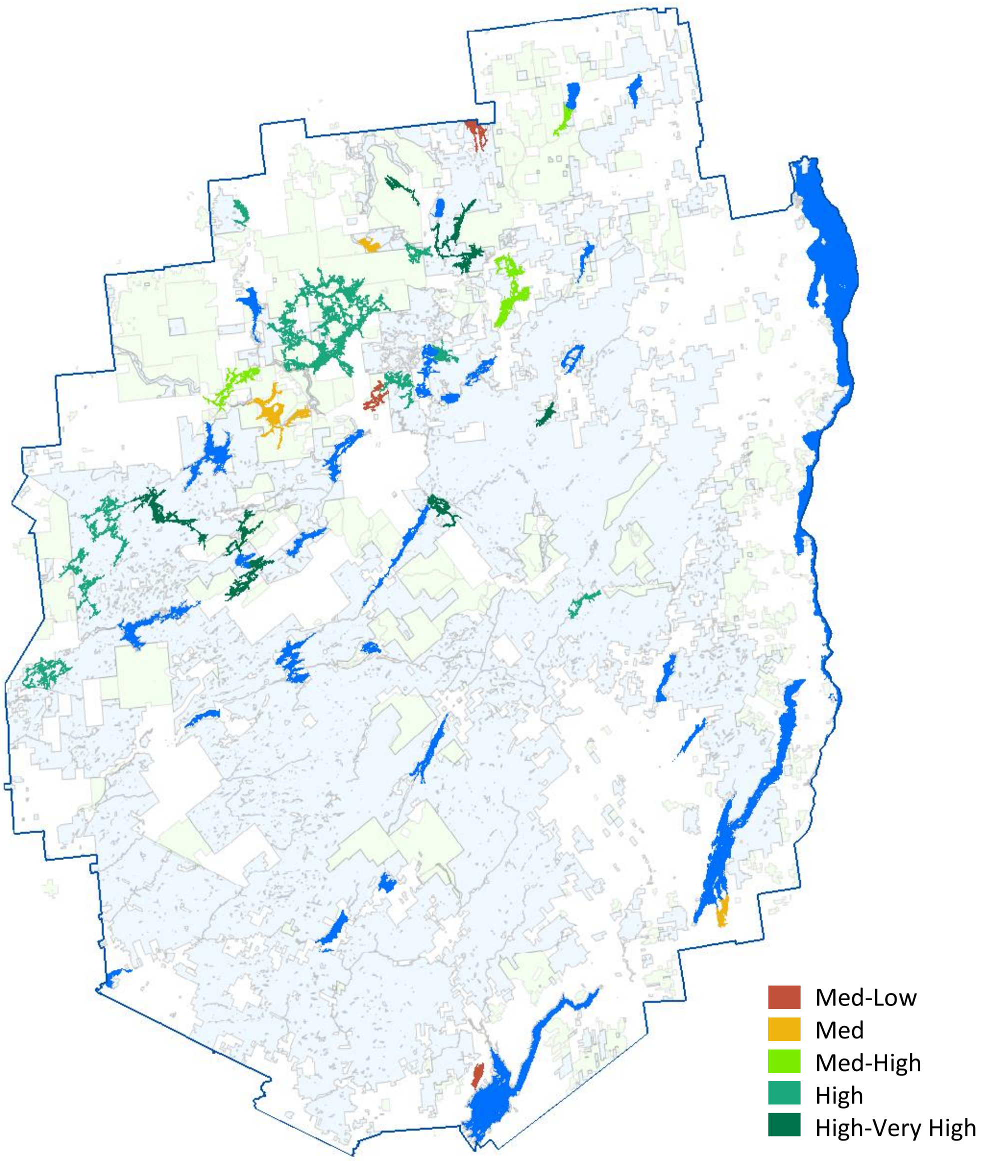

Figure 5. Largest high value boreal wetlands and their predicted resilience in the face of climate change. State land (blue), easements (green), and largest lakes shown.

Task 3 – *Identify appropriate audiences/landowners and potential management options*

Approach

To examine land ownership, we made use of the Adirondack Park land classification information representing the APA Land Use and Development Plan map and the NY State Land Master Plan map and available in shapefile format from the APA website. We also downloaded the New York Protected Areas Database (NYPAD) to gain information on conservation easements. NYPAD is a spatial database of lands protected or designated as natural areas, conservation lands, open space, or recreational areas and produced and made available for download from the New York Natural Heritage Program. We summarized the amount of boreal habitat within all categories of private ownership, as well as that on state and easements lands. We further summarized the amount of boreal habitat on state, private, and easement lands that fell within 5 categories of predicted boreal bird persistence ranging from lowest to highest in the following categories: (1) 0.48 – 0.69, (2) 0.69 – 0.76, (3) 0.76 – 0.81, (4) 0.81 – 0.86, and (5) 0.86 – 0.93 and visually examined a sample of polygons falling into the highest predicted persistence categories to explore general patterns of ownership and distribution.

Findings

Though wetlands are mapped in different ways by different organizations, we identified a total of 791,224 acres of boreal wetlands based on Adirondack Park agency covertype wetlands maps and our best judgement on which of these correspond to boreal types. A previous analysis by Glennon and Curran (2013) identified 620,019 acres of habitat in the Adirondacks within the Northern Peatland and Northern Swamp macrogroups mapped by Ferree and Anderson (2014). The Ferree and Anderson (2014) terrestrial habitat map was created with different methodology than the APA wetlands mapping and was based on predicting ecosystem types based on underlying landforms, geology, hydrology, and soils and then confirming them with forest inventory and element occurrence data from field verifications, in contrast to the APA wetlands mapping which was done with delineation from 1:40,000 color infrared NAPP imagery. We believe the APA mapping is more accurate in this context given that it was done by Adirondack wetland experts from stereoscopic aerial imagery, but the TNC dataset also has high utility because of its broad spatial coverage across eastern North America and comparability to regions outside of the park. Nevertheless, based on APA wetlands maps, the Adirondack Park contains 387,001 acres (49% of the total) of boreal wetlands on state lands and 404,223 acres (51%) on private land types. Among the private lands, 38% of boreal wetlands, or 154,232 acres are on lands under conservation easement. Across the range of values, boreal wetlands on private lands have slightly higher predicted persistence values for boreal birds than those on state lands (Table 4), which may be a reflection of the primary distribution of most of the large wetland complexes in the boreal core located at high latitude in an area of the park dominated by private land and conservation easements rather than state land. Boreal wetlands on private lands are distributed primarily on the largest land use classes of Rural Use (108,065 acres, 27%) and Resource Management (254,275 acres, 63%), with smaller amounts in Hamlet (4,846 acres, 1%), Moderate (8,892 acres, 2%), and Low Intensity Use (27,955 acres, 7%) zones. Nevertheless, their distribution across all private land types indicates the importance of a variety of audiences with regard to communicating about their importance and stewardship. Mean patch sizes of boreal wetlands are comparable across types at ~114 acres on state and ~100 acres on private lands but the variation in size is approximately twice as high on private lands.

Table 4. Distribution of boreal wetlands within private and state land use designations in the Adirondack Park, acreages and proportions within categories of projected persistence probability for boreal birds. Easement is a subset of private lands; these categories are not exclusive.

Predicted Persistence	State	Private	Easement
0.48 – 0.69	24,314 (6%)	4,216 (1%)	2,446 (2%)
0.69 – 0.76	46,239 (12%)	13,931 (3%)	7,098 (5%)
0.76 – 0.81	127,116 (33%)	59,451 (15%)	21,667 (14%)
0.81 – 0.86	154,438 (40%)	195,702 (48%)	86,254 (56%)
0.86 – 0.93	34,894 (9%)	130,922 (32%)	36,767 (24%)
Total acreage	387,001	404,223	154,232

There are 162 conservation easements in the NYPAD dataset that contain at least some boreal habitat according to our analysis. Among them, the state is a critical stakeholder, holding 110 of these easements. A total of 48 are held by NGOs, among them the Adirondack Land Trust (23) and the Nature Conservancy (19) hold the majority, and the remaining few are held by the Lake Placid Land Trust, Northeast Wilderness Trust, and Saratoga PLAN. The remaining 4 easements not held by the state or NGOs are listed as federally managed as part of the wetlands reserve program and not open to public access. They are small and on the edges of the park. The majority of NGO easements are also closed to the public and approximately 40% of them have GAP 2 status, indicating that they are managed for biodiversity. The remainder are GAP 3, which indicates that these are managed for multiple uses and can be subject to extractive use. Among state held easements, 107 out of 110 are GAP 3 status, indicating that nearly all state easements are potentially subject to extractive use including logging.

Examination of the ownership underlying the large, high value boreal wetlands identified in Figure 5 reveals that 14 of these are predominantly located on state lands, and among them are split between Wilderness and Wild Forest Areas. Important Wilderness areas for these boreal wetlands include the High Peaks, Five Ponds, Pepperbox, Hoffman Notch, and Whitney Wilderness areas. Important Wild Forest areas include Lake George, Independence River, Sargent Ponds, Aldrich Pond, Watson's East Triangle, Saranac Lakes, Debar Mountain, Whitehill, and Chazy Highlands. High value boreal habitat also occurs on 3 critical primitive areas: Dead Creek, Madawaska/Quebec Brook, and the Raquette/Jordan Boreal. The remainder of these wetlands are distributed across a mix of types including varying combinations of state, private, and easement parcels. Easements are critical to some of the most valuable boreal habitat in the park and many of them are state-owned. Important easements for boreal habitat include Nehasane, Panther Pond, Oswegatchie, Croghan, Robinwood East, Sevey, Conifer Emporium, Massawepie, Tupper Lake, Raquette River and Raquette River North, Kildare, Kushaqua, Santa Clara, Sable Highlands. The Boreal Heritage easement held by the Nature Conservancy protects very high value areas, and there are additional critical private lands holdings around the Massawepie Mire and Spring Pond Bog wetland complexes.

We conclude from these analyses that boreal habitats are located on a variety of ownerships in the park and therefore subject to a range of allowable uses and potential threats. Critical audiences for outreach around the importance and careful stewardship of boreal habitats include management and regulatory agencies, and especially NYSDEC, land or timber management entities, and private landowners.

Objective 2 - Develop Best Management Practices (BMPs) and outreach materials for priority locations based on ownership

Tasks 4, 5, and 6 – Review relevant literature, informed by results of predictive modeling and land ownership patterns; Investigate adequacy of existing wetland protections for boreal habitats in the Adirondack Park, best practices, management opportunities, and ways to tailor messages to individual audiences; Develop fact sheets for boreal habitats and best management practices in New York

Approach

We reviewed literature across a wide range of sources to understand recommended practices related to peatlands and other wetlands, as well as relevance to boreal birds and to the boreal in the context of the Adirondack Park and its location. Much of the peatland best practice literature is aimed at peatlands on a global scale and, in some cases, concerned with threats that are not relevant to our region. Still, however, the critical value of peatlands for their carbon storage function cannot be overlooked and this is the focus of much of the current global attention on peatlands. We also reviewed best practices as they relate to landscape planning practices and the recommendations for protecting critical habitat in the context of broad-scale projects such as subdivision development or recreation management plans. Because boreal wetlands are important refugia for species in a warming climate, we also reviewed a growing body of literature related to climate change refugia. Sources consulted are included in the literature section at the end of this report.

We reviewed relevant sections of the Adirondack Park Agency Rules and Regulations, the Adirondack Park Agency Act, the Freshwater Wetlands Act, the Citizen's Guide to Adirondack Park Agency Land Use Regulations, and the Freshwater Wetlands Flyer, all of which are available from the Adirondack Park Agency website. As scientists with research expertise focused primarily on boreal birds and their needs, our analysis and comment with regard to policy is limited to potential weaknesses in the existing regulations as they may affect these birds and their habitats and does not acknowledge other ways in which APA regulations may or may not be adequate for other purposes.

Findings

We found from our review of literature that the range of potential best practices for peatlands is vast and that most sources are targeted toward peatlands as a global biogeochemical resource (e.g., carbon sink); fewer are specifically relevant to our region where peatlands contribute disproportionately to regional biodiversity. Because peatlands in the Adirondacks are disjunct patches of habitat and separate from the boreal biogeographic zone to the north, some practices and approaches simply do not make sense for our region. At the same time, because our boreal peatlands are analogs for future climate change in the boreal zone and are refugia for northern species and processes at the southern range extent, they are of very high importance in the park and deserving of careful stewardship. We have done our best to collect a wide range of best practice recommendations and recognize that some of them are more suited to our region than others.

Although APA Rules and Regulations as they pertain to the legislative mandate of the agency are of high quality and generally very protective of wetland values and functions, we find a number of issues that are potentially problematic or inadequate with regard to protection of boreal birds and their habitats:

- The exceptions for agricultural activities involving wetlands are broad and may unduly affect wetlands in some locations.
- The shoreline restrictions may be inadequate for protecting important lakeshore boreal habitats due to both proximity of potential development and to the challenge of interpreting and regulating adherence to cutting restrictions in these zones.
- The setback distances associated with lot lines (200 ft) and roads (50ft) away from wetlands in the context of subdivision permitting may not be adequate for protection of boreal wetlands; past research and recommendations to the Adirondack Park Agency have suggested that roads and infrastructure can affect bird communities up to 200m (656ft) from these features (Glennon and Kretser 2013).
- The existing wetlands protection mechanisms do not account for inundation of peatlands by alterations to hydrology from road or dam construction. Flooding peatlands is a worse case scenario for both greenhouse gas emissions and mercury methylation (Turetsky and Louis 2006)

Our review of boreal habitats and their distribution, relevant literature, regulations, and potential best management practices was broad in scope, given the distribution of this habitat type and the number of species who use it. Nonetheless, our review has led us to the following general conclusions:

- The Adirondack Park has significant boreal habitat and it is distributed roughly equally between public and private lands. Its protection is by no means ensured on the Forest Preserve or on private parcels. Numerous activities ranging from recreation to habitat loss to climate change all impact boreal habitats and their wildlife.
- Though good protection exists for most of the largest and most critical boreal wetland complexes in the Adirondacks, most wetlands by nature are small. Most of the boreal bird population, therefore, is distributed in smaller more isolated wetlands, adding urgency to the need to recognize the value of these habitats and safeguard them on both public and private lands.
- The NYSDEC is a very important stakeholder with regard to boreal habitat management in the Adirondack Park, given the distribution of significant boreal on the NYS Forest Preserve and on many conservation easement lands. Best practices for recreation and timber harvest in areas involving boreal wetlands are particularly crucial.
- Several bird species are associated with boreal wetlands in the Adirondack Park and are considered Species of Greatest Conservation Need in the State. These birds are nowhere else within New York; as such, they are responsibility species for the region. A number of monitored species are declining in New York State, some of them rapidly.
- Recent research demonstrates that tree encroachment in peatlands not only affects boreal habitat, but that conifer dominated peatland forests are being encroached by broad-leaved deciduous trees, altering habitat structure and biogeochemical processes (Langdon et al. 2020). Encroachment by broad-leaved deciduous trees may be accelerated by disturbance and management actions.
- No clear silvicultural solution is evident for increasing boreal bird populations in New York State. These are not early successional species and, although some of them may benefit from habitat management, others are associated with older forest characteristics and are those for whom logging may create risks. Afforestation does represent an increasing challenge for open peatlands, but its solutions are unclear given that tree removal in peatlands has the potential to significantly alter the hydrology of these systems.

- Boreal wetlands in the Adirondacks are important climate change refugia in a warming world and our disjunct boreal habitats are sentinels of changes to come in the boreal north; they are worthy of research and monitoring to understand ongoing changes and determine how best to mitigate and adapt to them.
- Peatlands here and elsewhere store very large amounts of terrestrial carbon but alterations to these sensitive habitats have the potential to convert them from carbon sinks to carbon sources. This ecosystem service is unacknowledged in existing wetlands regulations and deserving of heightened attention.

We suggest that the most critical audiences with regard to peatland stewardship in the Adirondacks are (1) regulatory agencies including APA and DEC, (2) land and/or timber management entities, and (3) private landowners. We offer the following best practices in this table and in more condensed messages in the Fact Sheets that follow.

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