

## **Dynamics of Boreal Birds at the Edge of their Range in the Adirondack Park, NY**

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## Dynamics of Boreal Birds at the Edge of Their Range in the Adirondack Park, NY

Michale J. Glennon\*

**Abstract** - The Adirondack Park in northern New York is located at the southern range extent for several bird species that inhabit lowland boreal forest habitats, which in the Adirondacks are naturally fragmented and intermixed with eastern temperate forest types. I examined occupancy dynamics of 8 bird species in lowland boreal forest wetlands, evaluating wetland size and connectivity, on colonization and extinction dynamics for the period 2007–2011. Occurrence data from point-count surveys conformed to predictions of metapopulation theory with respect to extinction, with most species more likely to experience local extinction from smaller, more isolated wetlands. Responses to latitude and elevation were variable. Proximity of human infrastructure was the most consistent driver of short-term dynamics across species, with two-thirds more likely to colonize low-impact sites and become locally extinct from more-impacted sites. Evidence for metapopulation structure suggests that improved connectivity among wetlands and reduction of human impact near wetlands should be conservation goals for these species in the park.

### 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 periphery of their range. These birds are thought to be vulnerable to climate change because they prefer northern boreal habitat types expected to be sensitive to warming temperatures (Moore 2002, Niemi et al. 1998, Pastor et al. 1998). Habitats in the Adirondacks are naturally fragmented and less continuous than the Canadian boreal to the North, 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.

Little is known about the population status of these boreal specialists in this region of the US. The North American Breeding Bird Survey (BBS; Sauer et al. 2012) provides information on long-term trends in abundance of avian species, but trend data are often sparse for these species. The roadside nature of BBS routes, combined with the rarity of species and habitats such as these, often means that marginal populations of birds near the edges of their ranges are not well sampled (Sauer et al. 1995). Mountain Birdwatch

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(Scarlett 2012) is a land-bird monitoring program for montane species in the northeastern US, but the targets of the program and the species for which published trend information is available do not overlap with the low-elevation boreal species described here. New York State Breeding Bird Atlas data (Andrle and Carroll 1988, McGowan and Corwin 2008) provide the best information on the distribution of low-elevation boreal species in New York, but are limited as a source of information on trends. Comparisons between atlas surveys conducted 20 years apart reveal declines in occupancy across the state for some boreal bird species, and increases for others (McGowan and Corwin 2008). Because of these limitations, scientists at the Wildlife Conservation Society, Adirondack Program (hereafter WCS), have been monitoring a suite of 12 species in lowland boreal habitats of the Adirondacks, including an intensive period of data collection between 2007 and 2011. In this paper, I use occupancy data from this survey to explore short-term trends in and potential drivers of boreal bird dynamics at their southern range extent in this part of the northeast US.

Given the fragmentation of habitats for boreal forest birds in the northeast, one might expect that these species follow the predictions of metapopulation theory, which generally apply to any species inhabiting a patchy habitat or any spatially structured population (Akçakaya et al. 2006, Hanski 1998). Sjögren-Gulve and Hanski (2000) suggest that metapopulation models are best applied to systems of relatively small habitat patches that are highly fragmented and cover maximally some 20% of the landscape. Lowland boreal habitats in the Adirondacks cover approximately 11% of the landscape and are scattered throughout the 19,700-km<sup>2</sup> park (Jenkins 2010). According to metapopulation theory, long-term population dynamics should be driven by size and connectivity of habitat patches. Therefore, boreal birds should be more likely to colonize large, well-connected habitat patches and to experience local extinction in smaller, more isolated patches (Hames et al. 2001, Hanski 1998, Pulliam 1988).

In addition to habitat patch size and connectivity, habitat degradation from climate change and anthropogenic development may also affect population dynamics of boreal birds in this region. Because these species are on the edge of their range experiencing long-term population trends in the Adirondacks. As such, they may be moving up in either latitude or elevation or both (Parmesan 2006). Several authors have noted actual or predicted changes in the ranges of boreal bird species as a result of climate change (Brommer 2004, La Sorte and Thompson 2007, Parmesan 2006, Thomas and Lennon 1999, Zuckerman et al. 2009). Zuckerman et al. (2009) found that southern range boundaries of New York birds shifted northward 11.4 km in the time between the 1985 and 2005 atlases of breeding birds in New York State (Andrle and Carroll 1988, McGowan and Corwin 2008). Though occurring over a longer time interval than the dataset described here, such observed shifts in patterns of bird occupancy suggest that range boundaries may be changing rapidly for some species. Thomas and Lennon (1999) found that the northern range margins of British birds shifted northwards by 18.9 km in a 20-year period, and similarly,

Dtq o ogt\*4226+kfgpvkŁgf"rqngyctf"ujkhvu"qh"3;"mo"kp"vjg"tcpig"octikpu"qh"Hkpkuj"  
 birds in only a 12-year period of time. A meta-analysis of range-boundary changes  
 for more than 1700 species in the Northern Hemisphere estimated that northern and  
 upper-elevational boundaries had shifted, on average, 6.1 km per decade northward  
 or 6.1 m per decade upward (Parmesan and Yohe 2003). The rapidity of these shifts  
 uwi iguvu"vjcv"vjg"kpłwgpeg"qh"gnxcvkqp"qt"ncvkvwfg"qp"eqnqpk|cvkqp"cpf"gzvkpevkqp"





## Methods

### Bird data collection

*Focal species.* The bird data analyzed for this paper are the result of a long-term monitoring program run by the Adirondack Program of the WCS for the purpose of understanding the distribution, abundance, and population trends of a suite of boreal birds in the park. All of the focal species are at or close to the southern extent of their eastern North American range in the Adirondack Park and all are known to occur in the Canadian boreal. A set of species was selected from those deemed

Table 1, continued.

Name	Area (km <sup>2</sup> )	Latitude (N)	Longitude (W)	Ownership
Hitchens Bog	1.04	44°6'34"	74°39'17"	NYS: Primitive Area
Horseshoe Bog	1.55	44°7'57"	74°38'46"	NYS: Primitive Area
Lqpgu"Rqpf"Dqi"	2042"	66°49':\$"	96°54'3':\$"	P [U<"Yknf"Hqtguy
Lqpgu"Rqpf"Qwngv"	203:"	66°49'6\$"	96°34'63\$"	P [U<"Yknf"Hqtguy
Lqpgu"Rqpf"Qcfc"	2042"	66°49'9\$"	96°33'7';\$"	P [U<"Yknf"Hqtguy
Kildare Bear Creek	5.23	44°19'30"	74°33'38"	Private
Kildare Bog	0.42	44°19'55"	74°32'33"	Private
Ncuv" I cur"Hgp"	3076"	65°73'36\$"	96°58'79\$"	P [U<"Yknf"Hqtguy
Nkvnng"Ejgtt{"Rcej"Rqpf"	2029"	66°3':2\$"	95°78'44\$"	P [U<"Yknf"Hqtguy
Nquv"Rqpfu"	2026"	65°63);\$"	96°62'3';\$"	P [U<"Yknf"Hqtguy
Lower St. Regis	0.19	44°26'2"	74°14'16"	Private: easement
Madawaska	1.50	44°30'27"	74°24'38"	NYS: Primitive Area
Octkqp"Tkxgt"Hgp"Egptcn"	4065"	65°72'4\$"	96°56'59\$"	P [U<"Yknf"Hqtguy
Octkqp"Tkxgt"Hgp"Gcu"	4065"	65°72'34\$"	96°55):\$"	Rtkxcvg
Octkqp"Tkxgt"Hgp"Yguv"	4065"	65°6';78\$"	96°57'48\$"	P [U<"Yknf"Hqtguy
Massawepie Mire	6.06	44°13'31"	74°40'40"	Private: easement
Ogcejwo"Ncmg"Uycor"	30:8"	66°54'63\$"	96°39'6':\$"	P [U<"Yknf"Hqtguy
Ogpq"Dqi"	2072"	66°52'77\$"	96°44':2\$"	P [U<"Yknf"Hqtguy
Oqqug"Rqpf"Qcfc"	2059"	66°44'47\$"	96°:65\$"	P [U<"Yknf"Hqtguy
Quiqqf"Tkxgt"	50:6"	66°44':3\$"	96°35'64\$"	P [U<"Yknf"Hqtguy
Paul Smiths Bog Complex	0.38	44°25'20"	74°14'37"	Private: easement
Quebec Brook	2.05	44°29'40"	74°20'34"	NYS: Primitive Area
Red River	0.12	43°41'2"	74°44'52"	Private: easement
Tgiku/UrkvLtg"	2085"	66°47'42\$"	96°37'4':\$"	Rtkxcvg<"gcu o gpv
Rock Pond	1.31	44°21'56"	74°33'14"	Private: easement
Round Lake Bog	1.08	44°3'24"	74°34'18"	Private
Tqwwg"77"Dnqqokpifcng"	5056"	66°46'6';\$"	96°49'68\$"	P [U<"Yknf"Hqtguy
Sabattis Circle Road	0.32	44°4'13"	74°32'30"	Private: easement
Sevey Bog	2.14	44°15'29"	74°41'49"	Private
Silver Lake Bog	0.57	44°28'50"	73°53'18"	Private: easement
Unwuj"Rqpf"	2073"	66°44':32\$"	96°33':59\$"	P [U<"Yknf"Hqtguy
Uqwwj"Kpngv"Hgp"Pqtvj"	2098"	65°69'7':\$"	96°59'55\$"	P [U<"Yknf"fgtpguu
Uqwwj"Kpngv"Hgp"Uqwwj"	2098"	65°69'39\$"	96°59'6':\$"	P [U<"Yknf"fgtpguu
Spring Pond Bog	4.19	44°22'12"	74°30'10"	Private: easement
Spring Pond Bog South	4.19	44°21'37"	74°30'57"	Private: easement
Uwopgt"Uvknncvgt"	2028"	65°63'3';\$"	96°5';64\$"	P [U<"Yknf"Hqtguy
Ton-Da-Lay	2.08	44°22'41"	74°28'30"	Private: easement
Twin Brook Bog	0.81	44°34'58"	74°29'33"	Private: easement
Ygwgtp"Dtqypju"Vtcev"Kpngv"Hgp"	3084"	65°6':34\$"	96°63'39\$"	P [U<"Yknf"Hqtguy

to best represent the lowland boreal habitats of the Adirondacks and to be best sampled with a point-count methodology. Those species are *Picoides dorsalis* Baird (American Three-toed Woodpecker), *Picoides arcticus* Swainson (Black-backed Woodpecker), *Contopus cooperi* (Uyckpuqp)\*Qnkxg/ukfgf" Hn{ecvejgt+." *Empidonax tchikgptku*" Dcktf" cpf" Iktctf"\* [gnny/dgmkgf" Hn{ecvejgt+." *Perisoreus canadensis* L. (Gray Jay), *Poecile hudsonicus*" Hqtuvgt"\* Dqtgcn" Ejkemcfgg+." *Oreothlypis peregrina* Wilson (Tennessee Warbler), *Setophaga tigrina* Gmelin (Cape May Warbler), *Setophaga castanea* Wilson (Bay-breasted Warbler), *Setophaga palmarum* Gmelin (Palm Warbler), *Melospiza lincolni* Audubon (Lincoln's Sparrow), and *Euphagus carolinus* Müller (Rusty Blackbird).

*Site selection* Cp" kpkvkn" nkuv" qh" rvygpkcn" Lgnf" ukvgu" ycu" eq o rknf" d{ "eqpuwnvki" a variety of data sources including Adirondack Park Agency wetlands inventory data, New York State Breeding Bird Atlas data (Andrle and Carroll 1988, McGowan and Corwin 2008), postings to the Northern New York Breeding Bird Listserv, and nqecn" gzrgtv" qrkpkqp0" Vjg" Lpcn" nkuv" qh" uvvf{ "ukvgu" ycu" vjgp" fgvgto kpgf" d{ "ugngevki" from within the potential list to include a number of the major well-known boreal wetlands of the Adirondack Park and a random sample of smaller, less-known locations. Because the lowland boreal habitats of the Adirondacks are relatively disjunct and many are located in remote and roadless areas, our design precluded a completely random selection of study sites. The best possible effort was made to include a mix of known boreal wetlands in which some of these species had been documented in the past and numerous sites that had never been surveyed.

" *Cxkcp" oqpkvqtkpi*. WCS conducted unlimited-distance point counts to assess presence/absence of our target species along transects of 5 points spaced at least 250 m apart within boreal wetland habitats (Ralph et al. 1995). In a small number of particularly large wetlands or wetland complexes, multiple transects were placed in order to adequately represent the bird community present, but spaced with a minimal distance separation of 300 m to maintain independence. All points were surveyed for 10-minutes between the hours of 5:00 and 9:00 am. Survey start and end dates for each year varied with weather conditions and song activity. All sampling occurred during the primary breeding season on survey dates ranging from the last week of May to the third week of July, with the majority of sites sampled in June. At each sample point, birds were recorded by species, time period of detection (i.e., 0–3 minutes, 3–5 minutes, 5–10 minutes), and activity (i.e., singing, calling, individual seen). Point counts were conducted by trained observers, the majority of whom conducted counts at the same locations for 3 or more of the project years. During counts, we recorded the date, start and end time for each survey, ambient temperature, and sky and wind conditions. We measured sky conditions on a scale from 0 to 6 ranging from clear or a few clouds to rain, and wind on a Beaufort scale from 0 to 5 ranging from calm to small trees swaying. Surveys were halted in the event of wind or sky conditions

the experimental units for the purposes of analysis. Estimation of parameters from spatial, rather than temporal replication is also employed by the BBS (Hines et al. 2010). In most cases, the sites were large and uniform enough to accommodate a linear transect of 5 points, but in some cases points were placed in a nonlinear fashion, maintaining a minimal distance separation of 250 m. We have sampled more than 80 locations over the course of the project; 58 of those were sampled consistently for the period between 2007 and 2011 and are the subject of the current analysis (Table 1).

### **Analysis**

*GIS datasets.* I used 3 primary GIS datasets to calculate variables of hypothesized importance to boreal bird dynamics: wetland cover-type maps, a regional



associated with human settlement, access, land-use change, and electrical power infrastructure. This dataset provides a relative measurement of human transformation of the natural landscape across the park. I used the average human-footprint score across each of the 5 points along each study transect to characterize human impact at each study wetland.

I obtained information on elevation of study wetlands from a digital elevation model also provided by the Adirondack Park Agency, and calculated a latitude for each transect by mapping their UTM coordinates and using ArcMap 10 to determine the latitude of the centroid for each transect. Together, these datasets resulted in 5 variables used in occupancy models to characterize study wetlands: area (wetarea),

*Occupancy modeling.* To investigate dynamics of boreal birds in the Adirondacks, I used the multi-season model implemented in program Presence (Hines 4228+"vq"ecnewncvg"fgvgevkvqpp"\*r+."qeewrcpe{"\* +."eqnqpk|cvkqp"\* +."cpf"gzvkpevkqp"\* + probabilities for 2007–2011 for each of the species for which adequate data were obtained (detections at 15% or more of study locations; George and Zack 2008).

Vjqg"kpewfgf"Dncem/dcemgf"Yqqfrgemgt."Qnkxg/ukfgf"Hn{ecvejgt." [gmnqy/dgnkqgf" Hn{ecvejgt." Itc{"Lc{"Dqtgc" Ejkemc fgg." Rcn o" Yctdngt." Nkpeqpøu" Urcttqy." cpf" Rusty Blackbird. Data for the other 4 target species (Three-toed Woodpecker, Tenpguugg" Yctdngt." Ecrg" Oc{" Yctdngt." cpf" Dc{/dtgcuvgf" Yctdngt+" eqpuvkvwvgf" Ö34" detections of each species in the entire 5-year dataset and therefore could not be used in an occupancy-modeling framework.

" Qeewrcpe{" rtqdcdknkv{"ku" fgLpgf"cu"vjg" rtqdcdknkv{"qh" c" ukvg" dgkpi" qeewrkqf" within a given season, while detection probability denotes the probability of a spe-  
ekgu"dgf" cpf" gvevf." ikxgp"kvu" rtgugpeg0" Bqnpk|kqpp"rtqdcdknk "rtvEtack \_ Y gpe `O'



at equilibrium, and (4) probability of occupancy and local extinction are dependent on patch size, as predicted by metapopulation theory.

Using support for metapopulation dynamics and Markovian changes in occupancy from the initial model set, I next modeled the impacts of 5 covariates (wetland area, connectivity, latitude, elevation, and human footprint) on extinction and colonization dynamics for each species over the 5-year period between 2007 and 2011, incorporating the best predictor for detection. This model set also included 2 equilibrium models for comparison against dynamic models: one in which equilibrium y cu" fgŁpgf" kp" vgt o u" qh" eqpuvcpv" qeewrcpe{ " rtqdcdknk{ " \*Uvcvkqpct{ " Octmqx+" cpf" qpg"kp" y jke j"kv" y cu" fgŁpgf" kp" vgt o u" qh" eqpuvcpv" eqnqpk | cvkqp" cpf" gzvkpevkqp" rtq-dabilities (MacKenzie et al. 2006). I did not place any covariates on occupancy itself, cuuw o kpi "kv"vq"dg"tg Ĩ gevkxg"qh" rcuv" f { pc o keu" \*U13/4 i tgp/ I wnxg" cpf" J cpumk"4222+" cpf" c fgs wcvgn{ " ecrvwtgf" d{ " eqxctkcvgu" rncegf" qp" eqnqpk | cvkqp" cpf" gzvkpevkqp) Hkpgt/uecng" habitat quality is also likely to impact occupancy dynamics of these species, but past analyses of these data have demonstrated much greater support for large-scale factors in controlling occupancy (M.J. Glennon, unpubl. data). The purpose of the second rctv"qh"v jg"cp cn{ uku" y cu" ur gekŁecm{ "vq"cuuguu"v jg" k" o rcev"qh"ncp fuec r g/uecng" ftkxgtu"qp" short-term dynamics of these birds in the Adirondacks.

In this second phase of the analysis, I tested a set of models whereby I asked if (1) occupancy and/or rates of colonization and extinction are constant, (2) colonization dynamics depend on wetland area, connectivity, latitude, elevation, and human infrastructure, and (3) extinction dynamics depend on wetland area, connectivity, latitude, elevation, and human infrastructure. I did not have plausible biological explanations for modeling every possible combination of covariates and chose, for simplicity, to hold one rate constant and vary the other within the model set, resulting in a set of 12 models for each species (Table 3). It is possible, of course, that both colonization and extinction rates vary at the same time and, as such, I draw in-htgpegu"htq o "v jg" dgvcu" cpf" o qfgn/cxgtc igf" guvk o cvgu"qh" " cpf" "hqt" cnn" o qfgnu0" O { " rtgfkevkqpu" y gtg"v jcv" \*3+" y gvncpf" ctgc" cpf" eqppgevkxkv { " y qwnf" rqukvxgn { " kp Ĩ wgpeg" eqnqpk | cvkqp" cpf" pgi cvkxgn { " kp Ĩ wgpeg" gzvkpevkqp ô dki igt." o qtg/eqppgevgf" y gv-lands are expected to be of higher quality for birds than smaller, more-isolated sites, \*4+"ncvkwfg" cpf" gngxcvkqp" y qwnf" rqukvxgn { " kp Ĩ wgpeg" eqnqpk | cvkqp" cpf" pgi cvkxgn { "

---

Vcdng"40" Pkpg" o qfgnu"qh" qeewrcpe{ "\*" +."eqnqpk | cvkqp" \* +."cpf"gzvkpevkqp" \* +rtqdcdknk{ "wugf"vq"gzc o -ine metapopulation structure and equilibrium assumptions for 8 bird species in boreal wetlands of the Adirondack Park, NY, 2007–2011. Covariates are explained in Methods.

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Oqfgn"	Rtgfkevgf" f { pc o keu"tg Ĩ gevkxg"qh
"*0+"	Uvcvke"qeewrcpe{ "&" "&" "&" R x      c p f   k e l o c

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habitats and/or be outcompeted by more abundant, generalist species near human-occupied areas. We calculated occupancy rates for each of the years between 2007 and 2011 in order to examine trends over time. The default model parameterization calculates colonization probabilities, respectively (MacKenzie et al. 2006).

$$p_{t+1} = \frac{p_t + 3}{t + 3}$$

extinction probabilities, respectively (MacKenzie et al. 2006).

## Results

A total of 1305 detections were made for all species over the 5-year time frame, including 52% of the population of the Yellow Palm Warbler (23%), and far fewer detections of the Boreal Chickadee (3%), and Rusty Blackbird (2%). Wetland area ranged from 0.04–6 km<sup>2</sup> and latitude ranged from 43°40'8"N–44°41'40"N. Most wetlands (90%) were associated with positive values for Moran's *I*, indicating that they were within clusters. Z scores calculated from Moran's *I* values for these wetlands indicated that the majority of them (83%) were large wetlands within clusters of other large wetlands ( $P < 0.05$ ). Human-footprint values for individual wetlands ranged from 3.8–47.5

I found that no single variable best predicted detection probability for all boreal species. Time of day and observer were the best predictors of detection probability for 2 species each, while detection probabilities for the 4 remaining species were best predicted by wind, sky, date, and temperature, respectively (Table 4). The re-uwvnu"qh"vqr" o qfgnu"kp"vjg"Łtuv" o qfgn"ugv"kp fkecvgf"vjcv"ejcpi gu"kp"qeewrcpe{"ygtg" driven by Markovian, rather than random changes. Though constant-occupancy models were supported for some species, the majority of models supported for 6 of 8 species were dynamic models, indicating that occupancy was not constant over the 5-year period. Most species also demonstrated some support for area-driven extinction, as predicted by metapopulation theory (Table 4). These results provided lwuvkŁecvkqp"hqt"vjg"uvtwevwtg"qh"vjg"ugeqpf" r j cug"qh"vjg"cpn{uku." y j ke j"gzrnkekvn{" examined drivers of colonization and extinction, and which assumed Markovian changes in occupancy.

Results of the second model set indicated that most species were controlled more strongly by extinction rather than colonization dynamics (Table 5). Among drivers of extinction and colonization dynamics, the strongest predictors by total model weight across all species were the effect of elevation on colonization and latitude

Table 4. Summary of model selection results from analysis of underlying dynamics for 8 bird species monitored in boreal wetlands in the Adirondack Park, NY, 2007–2011. Covariates are explained kp"Ogvjqfu-"qpn{"vjg"tguwvnu"qh"vqr" o qfgnu"ctg"ujqyp"\* CKE"Ö"402+0"N"?"nkmgnkjqqf="%"?"pw o dgt"qh" rctc ovgtu0"Urgekgu<"D/d"Y"?"Dncem/dcemgf"Yqqf rgemgt."Q/u"H"?"Qnkxg/ukfgf"Hn{ecvejgt."[/d"H"?" [gnmqy/dgnkkgf"Hn{ecvejgt."I"L"?"I tc{"Lc{"D"E"?"Dqtgcn"Ejkemc fgg."R"Y"?"Rcn o"Yctdngt."N"U"?"Nkp-coln's Sparrow.

Species	Oqfgn"	CKE"	CKE"	CKE"y v"	N"	%/4NqiNkmg
B-b W	*y gvctgc+." *0+." *y gvctgc+."p(wind)	713.23	0.00	0.4754	1.0000	7 699.23
"	*0+." *0+." *y gvctgc+."p(wind)	713.27	0.04	0.4660	0.9802	6 701.27
O-s W	*0+." *0+."p(time)	571.9	0.00	0.3448	1.0000	4 563.90
"	*0+." *0+." *0+."p(time)	572.18	0.28	0.2998	0.8694	5 562.18
"	*0+." *0+." *y gvctgc+."p(time)	573.39	1.49	0.1637	0.4747	6 561.39
[/d"H"	*0+." *0+."p(date)	1461.88	0.00	0.4878	1.0000	4 1453.88
"	*0+." *0+." *0+."p(date)	1463.68	1.80	0.1983	0.4066	5 1453.68
I"L"	*0+." *0+." *y gvctgc+."p(obs)	687.78	0.00	0.298	1.0000	6 675.78
"	*y gvctgc+." *0+." *y gvctgc+."p(obs)	688.21	0.43	0.2404	0.8065	7 674.21
"	*0+." *0+."p(obs)	688.41	0.63	0.2175	0.7298	4 680.41
"	*0+." *0+." *0+."p(obs)	689.49	1.71	0.1267	0.4253	5 679.49
D"E"	*y gvctgc+." *0+." *y gvctgc+."r*qdu+	586059"	2022"	20:347"	302222"	9" 572059
R"Y"	*y gvctgc+." *0+." *y gvctgc+."p(temp)	998.42	0.00	0.2811	1.0000	7 984.42
"	*0+." *0+." *y gvctgc+."p(temp)	998.7	0.28	0.2444	0.8694	6 986.70
"	*0+." *0+." *0+."p(temp)	999.39	0.97	0.1731	0.6157	5 989.39
"	*0+." *y gvctgc+."p(temp)	999.46	1.04	0.1671	0.5945	5 989.46
"	*0+." *0+."p(temp)	999.97	1.55	0.1295	0.4607	4 991.97
N"U"	*0+." *{gct+." *{gct+."p(time)	1240.98	0.00	0.7285	1.0000	11 1218.98
T"D"	*0+." *0+."p(sky)	235.16	0.00	0.3972	1.0000	4 227.16
"	*0+." *y gvctgc+."p(sky)	236.16	1.00	0.2409	0.6065	5 226.16
"	*0+." *0+." *0+."p(sky)	236.85	1.69	0.1706	0.4296	5 226.85

on extinction processes. In both cases, however, agreement with predictions was mixed (Table 6). In general, no single covariate had strong effects on colonization or extinction dynamics across species, and there was high variability among species in their response to individual covariates. With respect to colonization, the strongest responses by species were as follows: Black-backed Woodpecker to wetland area; Warbler to elevation; and Boreal Chickadee and Lincoln’s Sparrow to latitude. In addition, Black-backed Woodpecker and Rusty Blackbird by connectivity; Olive-backed Woodpecker and Rusty Blackbird by connectivity; and Rusty Blackbird by connectivity. In addition, Black-backed Woodpecker and Rusty Blackbird by connectivity; Olive-backed Woodpecker and Rusty Blackbird by connectivity; and Rusty Blackbird by connectivity.

In addition to examining model weights, it is also of value to examine signs of the betas to determine the degree of consistency with which species responded to covariates and the degree of agreement with predictions. Human footprint and wetland area were the most consistent predictors of colonization probability across species, and human footprint and wetland area were the most consistent predictors of extinction probability (Table 6).

Trends calculated from modeled colonization and extinction probabilities indicated that 4 of the 8 species modeled are demonstrating a pattern of declining occupancy in boreal wetlands in the Adirondacks, although the relative rate of decline is variable among them (Table 7). Rusty Blackbird and Yellow-bellied Sapsucker demonstrated a pattern of increasing occupancy. In no

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Table 5. Summary of model selection results from analysis of drivers of dynamics for 8 bird species monitored in boreal wetlands in the Adirondack Park, NY, 2007–2011. Covariates are explained by the model. The best model is indicated by a boldface font. The Akaike weights (w<sub>i</sub>) are given in parentheses. The model selection criteria are given in the following order: AIC, ΔAIC, and the number of parameters (K). The model selection criteria are given in the following order: AIC, ΔAIC, and the number of parameters (K). The model selection criteria are given in the following order: AIC, ΔAIC, and the number of parameters (K).

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Vcdhg'9l"Oqf gni/cxgfcigf"rcic o gvgt"gunk ociguv'qih'qeewr cpe{ "\*" + "eqiqpk|cikqp" \* + "cpf"gzv'kpe'kqp" \* + "hqt" : "dit f"ur'ge'ku"lp"dq'gcn"y g'wncp fu"lkp"vj"g"C fktqpf ccm"  
Park, NY, 2007-2011.

Rctc o gvgt"	Black-backed Yqq fr gemgt"	Olive-sided Hn{ecvejgt"	Yellow-bellied Hn{ecvejgt"	I tc f"lcf"	Boreal Ej keme fgg"	Rcno " Yctdngt"	Lincoln's Urectqy"	Rusty Dncemdktf
2007	0.71 ± 0.12	0.55 ± 0.12	0.77 ± 0.08	0.71 ± 0.13	0.36 ± 0.11	0.39 ± 0.07	0.63 ± 0.09	0.22 ± 0.11
2008	0.64 ± 0.12	0.49 ± 0.12	0.75 ± 0.08	0.68 ± 0.13	0.32 ± 0.11	0.44 ± 0.07	0.65 ± 0.09	0.22 ± 0.11
2009	0.58 ± 0.12	0.45 ± 0.12	0.75 ± 0.08	0.67 ± 0.13	0.29 ± 0.11	0.48 ± 0.07	0.67 ± 0.09	0.23 ± 0.11
2010	0.54 ± 0.12	0.43 ± 0.12	0.75 ± 0.08	0.67 ± 0.13	0.27 ± 0.11	0.51 ± 0.07	0.68 ± 0.09	0.23 ± 0.11
2011	0.50 ± 0.12	0.42 ± 0.12	0.75 ± 0.08	0.66 ± 0.13	0.26 ± 0.11	0.53 ± 0.07	0.69 ± 0.09	0.23 ± 0.11
"	2 2 : "Ö"2 34"	2 36"Ö"2 2 ; "	2 66"Ö"2 36"	2 59"Ö"2 4 ; "				



largely at their southern range extent in the Adirondacks, I expected that these birds may move northward and up in elevation over time given observed and predicted changes in distribution and abundance of other northern bird species across the globe in response to climate change (Virkkala and Rajasärkkä 2011, Virkkala et al. 2008, Waite and Strickland 2006, Zuckerberg et al. 2009). Both latitude and elevation were strong predictors of colonization and extinction dynamics, but only for a few species, and with inconsistent results. Some species did have higher probability of extinction at southern sites and at sites of lower elevation, while others demonstrated opposite patterns. The inconsistency of responses among species to these 2 predictor variables suggests that other factors may be playing a larger role in controlling these species' dynamics than does climate change over this small window of time, and that the responses of individual species to climate change are not likely to be uniform or highly predictable. Though these species are at their southern range extent and expected to be sensitive to climate change, the short duration of the dataset in comparison to climate-driven processes may preclude detection of changes driven solely by warming. Zuckerberg et al. (2011) pointed out the importance of urbanization and behavioral adaptation in modifying the impact



abundance (Greenberg and Matsuoka 2010). It is possible that competitive interactions around food or other resources between several of these species and more widespread family members (e.g., Gray Jay and *Cyanocitta cristata* L. [Blue Jay], Boreal Chickadee and *Poecile atricapillus* L. [Black-capped Chickadee]) may impact their success in wetlands more proximal to human-dominated areas; such species are commonly detected in the study wetlands described here (M.J. Glennon, 2014). Interactions with predators and competitors and effects to population variability as a critical knowledge gap for boreal bird species.

I suspect that isolated wetland populations of boreal birds are functioning as



of human impacts nearby to boreal wetlands, and maintaining the smaller, isolated fringe habitats that probably provide important stepping stones for boreal birds in this landscape will probably best serve their long-term maintenance. Minimizing the likelihood of invasion by synanthropic species with which these birds may compete. Climate change may render the long-term persistence of these species in the park uncertain. On shorter time scales, however, additional research to understand the importance of maintaining their functional connectivity through protection and management will

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