

University of Vermont

UVM ScholarWorks

UVM Honors College Senior Theses

Undergraduate Theses

2021

A Model of Olive-sided Flycatcher (*Contopus cooperi*) Occupancy in the Northeastern United States

Kayley J. Dillon

Follow this and additional works at: <https://scholarworks.uvm.edu/hcoltheses>

Recommended Citation

Dillon, Kayley J., "A Model of Olive-sided Flycatcher (*Contopus cooperi*) Occupancy in the Northeastern United States" (2021). *UVM Honors College Senior Theses*. 426.
<https://scholarworks.uvm.edu/hcoltheses/426>

This Honors College Thesis is brought to you for free and open access by the Undergraduate Theses at UVM ScholarWorks. It has been accepted for inclusion in UVM Honors College Senior Theses by an authorized administrator of UVM ScholarWorks. For more information, please contact donna.omalley@uvm.edu.

**A Model of Olive-sided Flycatcher (*Contopus cooperi*) Occupancy in the Northeastern
United States**

Kayley Dillon
Rubenstein School of Environment and Natural Resources

Primary Thesis Advisor

Dr. Allan Strong, Professor of Wildlife Biology

Secondary Thesis Advisor

Dr. James Murdoch, Associate Professor of Wildlife Biology

Committee Members

Dr. Brittany Mosher, Assistant Professor of Wildlife Biology

University of Vermont
May 2021

Abstract

The Olive-sided Flycatcher (*Contopus cooperi*) is a migratory bird species that breeds in coniferous forests and bogs. Over the past few decades, they have shown significant population declines across their range, particularly at the southern edge. These declines have prompted many government agencies to list them as a Species of Special Concern and have renewed interest in conservation. Therefore, tools are needed to better understand their habitat relationships and guide potential conservation actions in the northeastern United States. In this project, a presence-only occupancy model was developed to examine the impacts of habitat factors on Olive-sided Flycatcher occupancy in Maine, Massachusetts, New Hampshire, and Vermont. Olive-sided Flycatcher observations from year to year were obtained from eBird, a large community science database. Habitat covariates were chosen based on existing knowledge of the species' habitat requirements and these were derived from the National Land Cover Database. Multiple models were considered including proportion of coniferous forests, wetlands, developed areas, canopy cover, and distance to the nearest road. I used the R-package maxlike to assess how well these habitat variables predicted the occurrence of Olive-sided Flycatchers. The top model received overwhelming empirical support and showed that Olive-sided Flycatcher occupancy in the northeastern United States is best represented by the proportion of wetlands in the surrounding area. These results suggest that wetlands, bogs, and beaver meadows could provide important habitat for Olive-sided Flycatchers. The conservation, restoration, and creations of wetlands may help support their declining populations in the Northeast.

Acknowledgements

First and perhaps most importantly, I would like to thank Dr. Allan Strong for serving as my primary advisor on this project. His insight, guidance, and patience allowed me to not only complete this project, but to engage with and contribute to a current conservation issue in our region. Furthermore, I would like to say thank you to Dr. James Murdoch for serving as my secondary advisor and providing his support with the technical and analytical components of this project. Without his experience in occupancy modeling, this project may not have come to fruition. Thank you to Dr. Brittany Mosher for serving as my final committee member and bringing her own expertise and perspective to the project.

Next, I am grateful for the support of the Office of Fellowships, Opportunities, and Undergraduate Research at the University of Vermont and the Carl Reidel Award, who provided funding for me to conduct this research over the summer of 2020. Their financial support allowed me to dedicate the time and attention my research required.

Thank you to James Duncan, who provided access to a computer with the processing power and memory needed to run these models; this project could not have been completed without your help. I am also extremely grateful for the guidance of Jarlath O'Neil-Dunne. Your expertise helped me work through many issues, and your instruction in GIS was essential to completing this project.

Lastly, thank you very much to all of my friends and family who supported me throughout this process. Your patience and encouragement was deeply appreciated.

Table of Contents

Abstract	2
Acknowledgements	3
Introduction	5
Methods	7
<i>eBird Observations</i>	7
<i>Environmental Covariates</i>	8
<i>Model Set and Covariates</i>	9
<i>Model Validation</i>	12
Results	12
Discussion	17
Literature Cited	23

Introduction

Boreal forests and wetlands cover a large portion of northern North America and reach their southern edge within the northeastern United States (Stralberg et al. 2019). These areas provide essential habitat for a wide variety of boreal species who similarly reach the southern extent of their range in this region (Glennon et al. 2019, Stralberg et al. 2019). Many of these species, however, have experienced significant declines in recent years and may be further threatened by continued land use and environmental changes (Glennon et al. 2019).

The Olive-sided Flycatcher (*Contopus cooperi*) is one such species: a large flycatcher that inhabits northern wetlands and forest gaps (Altman and Sallabanks 2012; Renfrew 2013). Currently, Olive-sided Flycatchers can be found across northern North America, from the Rocky Mountains and coastal California to the northern reaches of New England (Altman and Sallabanks 2012). Historically, they ranged farther south into West Virginia, Pennsylvania, and Maryland (Bent 1963). Their range has since retracted northward into Massachusetts, Vermont, New Hampshire, and Maine, and their numbers have continued to decline overall (Altman and Sallabanks 2012; Committee on the Status of Endangered Wildlife in Canada 2018). They are now listed as a Species of Special Concern in Vermont, New Hampshire, and across Canada (Renfrew 2013, Hunt 2016, Committee on the Status of Endangered Wildlife in Canada 2018). In Maine, they are considered a Species of Greatest Conservation Need (Maine 2015 Action Plan Revision 2016). The International Union for Conservation of Nature lists them as near threatened (BirdLife International 2017). These widespread declines have fueled interest in flycatcher conservation, and further research is necessary to inform potential management actions.

Most research on Olive-sided Flycatcher habitat has been conducted in the west, where they occur in gaps left by natural disturbances, such as fires or blowdowns, and areas impacted

by timber harvest (Hutto and Young 1999, Altman and Sallabank 2012). Because fire suppression has also reduced the availability of naturally disturbed stands (Hannon and Drapeau 2005, Altman and Sallabanks 2012), timber harvest has been suggested as a method for mimicking natural disturbances and creating habitat (Hutto and Young 1999, Robertson and Hutto 2007). Preliminary research, however, suggests that low rates of nest success in harvested forests may lead these sites to act as an ecological trap for Olive-sided Flycatchers (Robertson and Hutto 2007). These findings complicate the issue of effective conservation and management strategies for Olive-sided Flycatchers in the west.

By contrast, little research has been done on Olive-sided Flycatcher habitat in eastern North America (Renfrew 2013, Hunt 2016). Existing literature has shown that Olive-sided Flycatchers often occur in both disturbed areas and various wetland communities such as bogs, peatlands, beaver meadows, and marshy edges of streams and lakes (Altman and Sallabanks 2012, Renfrew 2013, Hunt 2016). Previous studies have sought to describe Olive-sided Flycatcher habitat in more detail, but conclusions have been limited by small sample sizes, even when this species is specifically targeted in surveys (Hunt 2016, Zlonis et al. 2017). While they are relatively easy to detect, a sparse distribution and large territories make them difficult to survey in large numbers through traditional sampling protocols (Renfrew 2013, Hunt 2016).

In recent years, community science platforms have proliferated, which allow individuals to submit scientific data to larger databases (Sullivan et al. 2009, Walker and Taylor 2017). These databases can offer greater sample sizes covering wider geographic areas and time spans than are feasible for a single research team (Sullivan et al. 2017, Walker and Taylor 2017). Therefore, they may represent a valuable tool to answer research questions that require larger volumes of data to address conservation issues (Sullivan et al. 2009, Sullivan et al. 2017).

One such community science project is eBird, a large platform that encourages users to submit bird sightings and has grown to include tens of millions of observations (Sullivan et al. 2017, Walker and Taylor 2017). Data collected from eBird have been successfully used to examine various patterns, including changes in temporal patterns, distribution, and abundance (Sullivan et al. 2009, Walker and Taylor 2017). While eBird datasets do have their own limitations, the platform can serve as a useful source of information for sparsely distributed, declining, and vulnerable species (Sullivan et al. 2009).

To plan and implement conservation actions to protect Olive-sided Flycatchers, we need an effective approach to evaluate their habitat relationships within the northeastern United States. I utilized eBird, alongside nationwide datasets such as the National Land Cover Database, to construct a presence-only model to predict Olive-sided Flycatcher occupancy across the northeastern United States.

Methods

eBird Observations

Olive-sided Flycatcher observations were downloaded from eBird from 2010 to 2019 for Maine, Massachusetts, New Hampshire, and Vermont (eBird Basic Dataset 2021). Only confirmed observations were included in the analysis to limit any potential false positives (Sullivan et al. 2009). One of the limitations of eBird data is that I could not assume a user detected all birds presented at a location or that all locations are surveyed (Sullivan et al. 2009). Therefore, these data were treated as presence-only; I did not assume that Olive-sided Flycatchers were absent, even if they were not reported.

Olive-sided Flycatcher observations were then proofed to only include observations between June 5th and August 1st, restricting the sample to birds on their breeding grounds (Renfrew 2013). These dates should effectively exclude migrating individuals, which may make use of different habitat than breeding individuals (Renfrew 2013). Additionally, data were proofed to remove duplicate observations, so only one point from each individual location would be included in the final dataset (Appendix 1, Figure 3).

These data were converted to points in ArcGIS Pro (Environmental Systems Research Institute, Inc., Redlands, California) for formatting alongside geospatial covariates. Points were assigned a value of one to indicate presence. All other points were assigned a value of “NoData.”

Environmental Covariates

Land cover and canopy cover data were obtained from the 2016 National Land Cover Database (Dewitz 2019; USDA Forest Service 2019). Covariates were selected based on existing knowledge of habitat requirements and included coniferous forest, wetlands, development, and percent canopy cover. The proportion of land cover types of interest and average canopy cover were then calculated within 300 meters of each Olive-sided Flycatcher observation across the landscape of interest. The 300-meter radius was based on estimates of both Olive-sided Flycatcher home ranges and detection distance to account for the space the bird may be using and the ability of an observer to detect an individual bird (Altman and Sallabanks 2012).

To account for mixed forests as potential habitat, these pixels were weighted at 0.5 to represent the average proportion of coniferous trees, based on the National Land Cover Database’s definition of mixed forests (USDA Forest Service 2019). These data were also incorporated into the proportion of coniferous forests. Similarly, the National Land Cover

Database includes multiple classes of development; only medium and high intensity development were incorporated into the proportion of developed land.

Lastly, I considered distance to the nearest road as a covariate due to potential spatial biases in the dataset. Areas near roads may be more accessible to birders, and the locations provided by eBird can be based on where a checklist was started (Sullivan et al. 2009).

Therefore, I incorporated distance to roads to potentially address these biases. These data were obtained from the USGS National Transportation Datasets for Maine, Massachusetts, New Hampshire, and Vermont (US Geological Survey 2020a-d). Roads were then merged into a single vector layer and converted to a raster to align with all other covariates. Distance to the nearest road in meters was then calculated in ArcGIS.

All raster datasets were clipped to the state boundaries to exclude areas beyond the scope of this project and areas which would not act as habitat, such as oceans. Areas outside of these boundaries were given a value of “NoData.” All data were converted to raster datasets using the standard coordinate systems and cell size of the National Land Cover Database to minimize distortion. These data were then exported from ArcGIS Pro for use in R (R version 3.5.1, <https://www.r-project.org/>, accessed 19 April 2021).

Model Set and Covariates

The model set was determined *a priori* based on available information about habitat requirements and potential biases in the data (Table 1). I also hypothesized the effects of each covariate based on available information about Olive-sided Flycatcher habitat (Table 1).

Coniferous forests and wetlands were expected to have a positive effect as commonly observed features of Olive-sided Flycatcher habitat (Table 1). By contrast, intensive human development

was expected to negatively impact occupancy (Table 1). I predicted that the percent canopy cover would have a nonlinear effect where occupancy probability was highest near the center (Table 1). This relationship would represent the need for some trees to act as cover and perches as well as gaps for foraging. To account for this possibility, a linear and quadratic model were both run (Table 1). The distance to the nearest road was predicted to have a negative effect due to potential spatial biases in eBird data; points may be more likely to occur in more accessible areas or be reported close to roads, where a checklist was likely started. Due to time restrictions, only single covariate models were run.

Table 1: Habitat variables used to predict Olive-sided Flycatcher occupancy probability in the northeastern United States.

Covariate	Scale	Predicted Effect	Citations
Coniferous Forests	Proportion	Positive	Altman and Sallabanks 2012, Renfrew 2013
Wetlands	Proportion	Positive	Altman and Sallabanks 2012, Hunt 2016, Glennon et al. 2019
Development	Proportion	Negative	Altman and Sallabanks 2012, Zlonis et al. 2019
Canopy Cover	Proportion	Nonlinear (see quadratic model)	Robertson and Hutto 2007, Committee on the Status of Endangered Wildlife in Canada 2018
Canopy Cover ²	Proportion	Greatest at intermediate values	Robertson and Hutto 2007, Committee on the Status of Endangered Wildlife in Canada 2018
Distance to Roads	Meters	Negative	Sullivan et al. 2009

The package maxlike was used to create all occupancy models. Maxlike is designed to produce a probability of occupancy specifically from presence-only data when given an adequately large sample size, and it has been found to be comparable to previously used presence-only modeling tools such as MaxEnt (Royle et al. 2012, Fitzpatrick et al. 2013). Unlike

previous tools, maxlike is able to directly produce a probability of occupancy, rather than a related metric such as a habitat suitability index (Royle et al. 2012). Due to an error in recent versions of maxlike and its dependencies which resulted in incomplete results, models were run in R version 3.5.1, which did not exhibit the same issue.

Models were compared using Akaike's Information Criterion (AIC), a relative metric frequently used to compare models and determine which best represents the given set of data (Wagenmakers and Farrell 2004). Additionally, model parameters were evaluated based on their standard errors and a 95% confidence interval to determine whether the proposed effects were biologically meaningful.

Model Validation

A new set of eBird data from 2020 was downloaded and proofed, using the same procedures as the primary dataset, for potential model validation (eBird Basic Dataset 2021). Validation would test the proposed model against an independent set of data not used to construct the model. This process could then determine whether the top model is able to accurately predict a new set of data, in this case sites that Olive-sided Flycatchers occupy. Due to complications and time constraints, I was ultimately not able to use these data to validate the model. In the future, these data could still be used for model validation.

Results

The top-ranking model in the set indicates that the proportion of wetlands within 300 meters best represents Olive-sided Flycatcher occupancy in the northeastern United States (Table 2). This model had strong empirical support compared to the other models in the set as the only

model with an AIC < 2 and a weight of 0.93 (Table 2). The nonlinear canopy cover model had weak empirical support as indicated by a Δ AIC of 5.06, despite being the only model in the set with multiple parameters (Table 2). All other models had very little empirical support (Table 2).

A 95% confidence interval was used to evaluate the parameters of the top model, and no parameters crossed 0, which indicates a meaningful relationship (Table 3). The proportion of wetlands had a strong positive effect on occupancy, resulting in a high probability of occupancy where the majority of the surrounding landscape was wetlands (Figure 1). The top model was then used to predict Olive-sided Flycatcher occupancy across the study area (Figure 2).

Table 2: Model selection results for Olive-sided Flycatchers in the northeastern United States.

Model Name	AIC	Δ AIC	AIC Weight	No. of Parameters
Ψ (wetlands)	30236.2	0	0.93	2
Ψ (canopy + canopy ²)	30241.26	5.06	0.07	3
Ψ (roads)	30333.94	97.74	0.00	2
Ψ (coniferous)	30426.92	190.72	0.00	2
Ψ (development)	30439.31	203.11	0.00	2
Ψ (canopy cover)	30442.71	206.51	0.00	2

Table 3: Parameter estimates for the top model of Olive-sided Flycatcher occupancy probability in the northeastern United States, $\Psi(\text{wetlands})$.

Parameter	β estimate	SE	UCI	LCI
Intercept	-1	0.129	-0.747	-1.253
Wetlands	10.4	1.947	14.22	6.584

Table 4: Slope coefficients for all other models of Olive-sided Flycatcher occupancy in the northeastern United States, in order according to AIC.

Parameter	β estimate	SE	UCI	LCI
Canopy (quadratic)	-45	7.02	-31.241	-58.759
Canopy ²	12.7	3.20	18.972	6.428
Distance to Roads	-0.615	0.069	-0.480	-0.750
Coniferous	4.965	2.072	9.026	0.904
Development	-7.12	6.16	4.954	-19.194
Canopy (linear)	2.586	3.76	9.956	-4.784

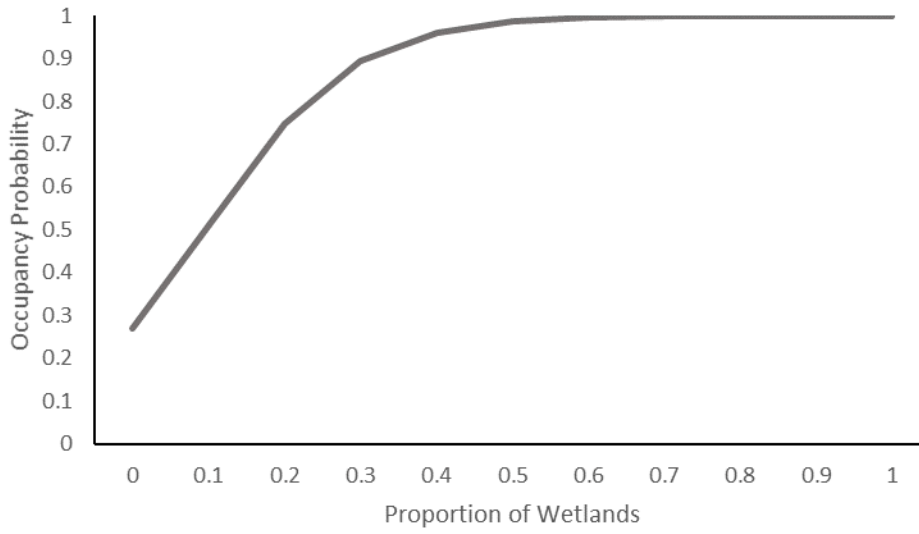


Figure 1: Occupancy probability of Olive-sided Flycatchers as a function of the proportion of wetlands within 300 meters in the northeastern United States.

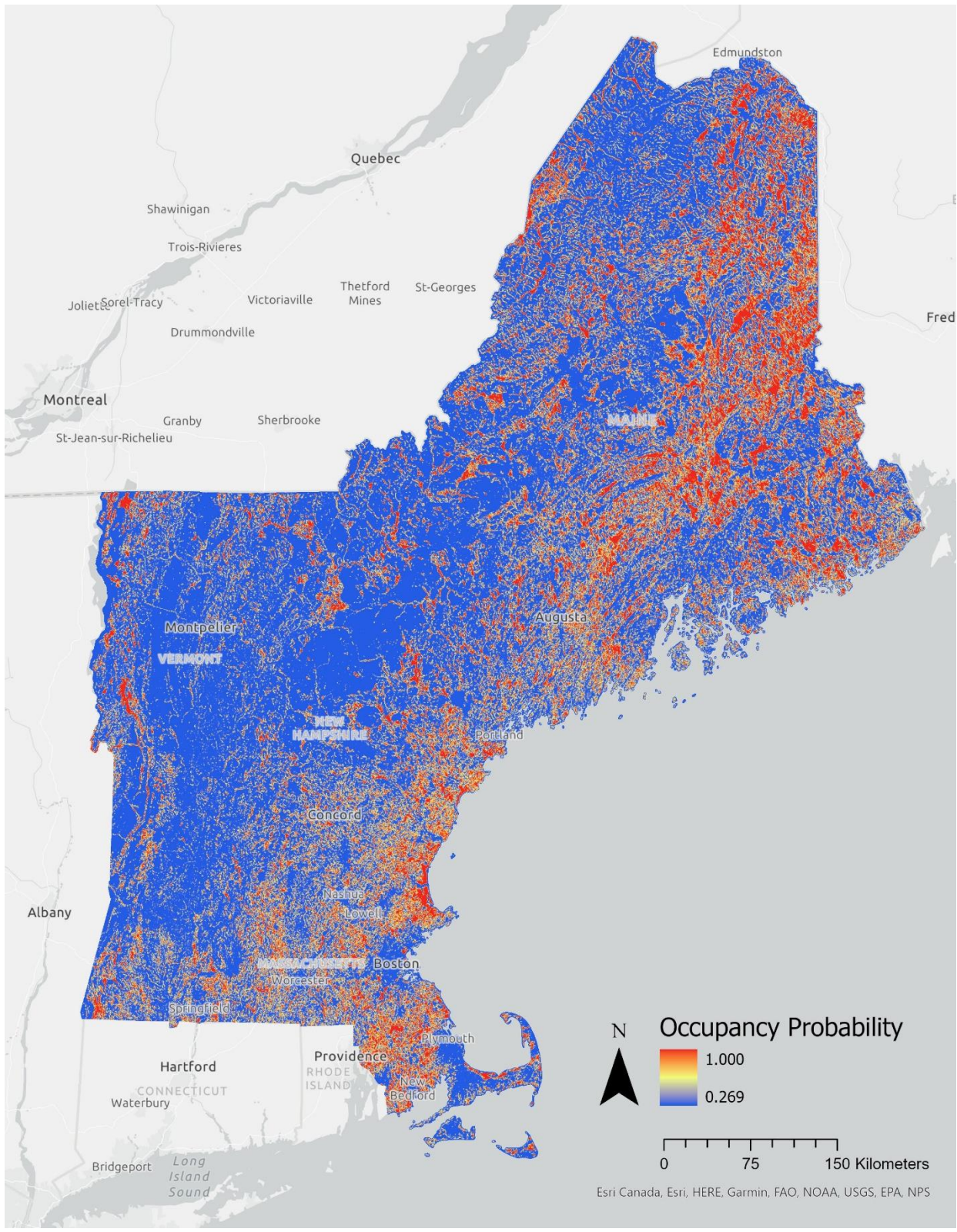


Figure 2: A map of Olive-sided Flycatcher occupancy probability in Maine, Massachusetts, New Hampshire, and Vermont based on the top-ranking model, $\Psi(\text{wetlands})$.

Discussion

Olive-sided Flycatcher occupancy probability was strongly and positively correlated with the proportion of wetlands within 300 meters, which suggests that wetlands serve as key habitat for this species within the eastern portion of their range. The top model suggests that Olive-sided Flycatchers should be found in areas with a large proportion of wetlands, such as Maine (Figure 2). Notably, it also suggests that Olive-sided Flycatchers could occupy a variety of areas farther to the south, where many states have seen significant declines in recent years (Renfrew 2013, Hunt 2016).

No other models in the set had strong empirical support, and the nonlinear canopy cover model was the only one to receive weak empirical support. The canopy cover model best aligned with previous findings in the western parts of Olive-sided Flycatcher's range, where they are commonly associated with forest gaps created by disturbance (Robertson and Hutto 2007, Altman and Sallabanks 2012). A lack of strong support suggests that wetlands serve as key habitat rather than forest gaps in the Northeast. These findings are especially interesting in terms of the ecological trap hypothesis because they would suggest that Olive-sided Flycatchers may utilize wetlands over harvested gaps in the Northeast, rather than selecting harvested stands and potentially suffering from lower nest success rates (Robertson and Hutto 2007).

A lack of empirical support for the coniferous model may be explained by how widespread coniferous and mixed forests are in total. Olive-sided Flycatchers may utilize areas dominated by coniferous trees, but all areas dominated by conifers are not suitable if they lack other key features, such as wetlands or gaps for foraging. The development model likely experienced a similar issue. Many areas without development may still lack key habitat features for Olive-sided Flycatchers, even if they do tend to prefer areas away from major development.

Therefore, neither variable effectively predicts occupancy on its own. By contrast, a lack of support for the distance to roads model suggests a lack of significant bias introduced by the eBird data. Points were not significantly biased towards easily accessible areas or influenced by slight variations in the exact location of the point reported to eBird.

Multiple hypotheses have been proposed to explain Olive-sided Flycatcher occurrence in wetlands. For example, wetland habitats may offer greater insect abundance and therefore provide more plentiful food resources (Altman and Sallabanks 2012). The suppression of fire in the Northeast may have also reduced the availability of suitable, naturally disturbed stands for Olive-sided Flycatchers, causing them to seek out habitat in wetlands (Hannon and Drapeau 2005, Altman and Sallabanks 2012).

Research on Olive-sided Flycatchers in other parts of their range has emphasized the role of natural and anthropogenic disturbance in creating forest gaps to serve as habitat (Robertson and Hutto 2007, Altman and Sallabanks 2012). Based on these findings, current management recommendations have focused on allowing natural disturbance or replicating it through forestry practices (Renfrew 2013). By contrast, these results suggest that wetlands may represent important Olive-sided Flycatcher habitat in the northeastern United States. Therefore, the conservation, restoration, and creation of wetlands may be a key step in protecting Olive-sided Flycatchers in this region.

Furthermore, such conservation efforts could align with other vulnerable and endangered species. Wetlands host a significant proportion of threatened and endangered species across taxa (Vermont Department of Environmental Conservation 2021). Other bird species which utilize northern wetlands, such as the Rusty Blackbird (*Euphagus carolinus*) have also exhibited severe declines in recent years and similarly sparked interested in conservation efforts (Avery 2013,

Renfrew 2013). Wetlands are also important habitat for amphibians, and northern species such as the mink frog (*Lithobates septentrionalis*) may benefit from such protections in states such as Vermont and New Hampshire, where they are uncommon or threatened with extirpation (Megyesy and Marchand 2015, Vermont Reptile and Amphibian Atlas 2021). Furthermore, large and charismatic species such as the moose (*Alces alces*) also make use of wetland habitats for thermoregulation, which may be increasingly important due to climate change (Jennewein et al. 2020). Conservation of wetlands may therefore offer an opportunity to protect not only Olive-sided Flycatchers, but also a variety of other vulnerable species that rely on wetland habitats.

Historically, a significant portion of natural wetlands were degraded or converted to other land uses across the United States (Sucik and Marks 2017). This perspective only began to change in the 1970s as we gained an understanding of the important ecosystem services that wetlands provide, including wildlife habitat (Sucik and Marks 2017). Many states, however, had already lost a significant portion of their wetlands. Massachusetts has lost approximately one third of its wetlands, (Massachusetts Department of Environmental Protection 2021), and Vermont has similarly lost an estimated 35% of its wetlands (Thompson et al 2019). In stark contrast, Maine contains more wetlands than any other state in New England by a significant margin, and a full 25% of the state is classified as wetlands (Maine Department of Environmental Protection 2003).

Rates of wetland losses have slowed across the country, in part due to regulations on the development of wetlands (Sucik and Marks 2017). All four states considered in this project have passed restrictions on the development of wetlands which incorporate protections for wildlife habitat (Maine Department of Environmental Protection 2003, Vermont Department of Environmental Conservation 2020, Massachusetts Department of Environmental Protection

2021, New Hampshire Department of Environmental Protection 2021). Additionally, American beaver (*Castor canadensis*) populations have been reintroduced and recovered across New England (Vermont Fish and Wildlife Department 2009, New Hampshire Fish and Game). Beavers act as a keystone species and create wetland habitats through damming. These beaver meadows can be beneficial to a wide variety of other species (Vermont Fish and Wildlife Department 2009). Despite these factors, Olive-sided Flycatcher numbers have continued to decline in recent decades, even after such conservation and restoration efforts had been implemented.

Multiple factors may be contributing to Olive-sided Flycatcher population declines. Widespread declines have been observed in aerial insectivores more broadly, including flycatchers (Renfrew 2013, Glennon et al. 2019). These declines could be linked to changes in food supplies, increased use of pesticides, changes in the time of insect emergence, and changes in climate (Renfrew 2013, Glennon et al. 2019). It remains unclear why aerial insectivores specifically are declining, however, as opposed to insectivores more generally (Renfrew 2013).

Additionally, Olive-sided Flycatchers may be at further risk as long-distance migrants. Long-distance migrants have seen considerable declines in multiple ecological systems, including migrants to South America such as Olive-sided Flycatchers (Nebel et al. 2010, Laaksonen and Lehikoinen 2013). Land use change or pesticide use on their wintering grounds in South America or important migratory stopovers, could be negatively impacting their populations (Altman and Sallabanks 2012, Renfrew 2013). This hypothesis has been proposed in previous studies, but adequate data for evaluation are lacking (Altman and Sallabanks 2012, Renfrew 2013). Long distance migrants may also be more vulnerable to phenological mismatches driven by climate change (Visser et al. 2004, Laaksonen and Lehikoinen 2013).

Climate change could further contribute to Olive-sided Flycatcher declines, especially in the northeastern United States. Boreal ecosystems are expected to experience dramatic shifts and retract northward as a result of climate change (Stralberg et al 2019). Along their southeastern edge, boreal ecosystems are expected to convert to temperate forests which may not provide necessary habitat for boreal species (Stralberg et al. 2019). Species that are already declining, such as Olive-sided Flycatchers, may be less able to adapt to the changing environment and more vulnerable to stochastic environmental events (Stralberg et al. 2019).

Large wetland ecosystems, however, may offer a refuge for boreal species facing a changing climate (Glennon et al. 2019). Upland ecosystems, in contrast, are expected to lose more boreal bird species as the climate changes (Glennon et al. 2019). These findings suggest that investments in wetland conservation could provide valuable habitat into the future, even in the face of major environmental changes.

Interestingly, upland habitats were also favored by nest predators such as red squirrels (*Tamiasciurus hudsonicus*) (Glennon et al. 2019). These findings align well with the ecological trap hypothesis, which suggests that harvested forests host more nest predators and therefore impact Olive-sided Flycatcher nest survival (Robertson and Hutto 2007). Both of these findings suggest that large, intact wetlands could serve as refugia for Olive-sided Flycatchers.

Based on my results, wetland conservation and restoration in the northeastern United States may be an essential step to ensure the persistence of Olive-sided Flycatchers in the region. The top model supported the importance of these habitats, but it also indicated that Olive-sided Flycatchers should likely occur farther south than current records suggest. Other environmental factors, such as the amount and types of surrounding forest, could render these areas unsuitable for Olive-sided Flycatchers. This study was also limited to single covariate models and was

therefore unable to evaluate potential combinations of habitat factors. An additive model or interaction between multiple covariates may be able to account for this variation.

My models also had a few notable limitations which should be considered in the interpretation of results. I was not able to validate the model due to time constraints. Validation of presence-only models represents a continuing challenge for researchers in general (Fitzpatrick et al. 2013). eBird data from 2020 could still be used for model validation in the future. Second, maxlike assumes a random sample of presence points (Royle et al. 2012). As a community science project, eBird data may not represent a random sample of the landscape, and Olive-sided Flycatchers may be sought after by birders in areas where they are uncommon. To minimize this potential bias, duplicate points were removed to avoid biasing models towards frequently visited locations. The large number of points offered by eBird should also help counteract the potential issues of a non-random sample. Additionally, I included the distance to the nearest road in my model set to account for the accessibility of different locations. This model did not receive empirical support, which implies that such bias was not a major contributing factor (Table 2).

Although these limitations are important to consider, my analysis shows that large, community science datasets have the potential to answer key questions about sparsely distributed species which are difficult to survey with standard methodologies. These datasets may therefore represent a valuable conservation tool and should not be overlooked.

Literature Cited

- Altman, B. and R. Sallabanks. 2012. Olive-sided Flycatcher (*Contopus cooperi*). Birds of the World. <<https://birdsoftheworld-org.ezproxy.uvm.edu/bow/species/olsfly/cur/introduction>>. Accessed 29 April 2021.
- Avery, M. L. 2013. Rusty Blackbird (*Euphagus carolinus*). Birds of the World. <<https://birdsoftheworld-org.ezproxy.uvm.edu/bow/species/rusbla/cur/introduction>>. Accessed 4 May 2021.
- Bent, A. C. 1963. Life histories of North American flycatchers, larks, swallows, and their allies. Dover Publications, New York, New York, USA.
- BirdLife International. 2017. *Contopus cooperi*. The IUCN Redlist of Threatened Species. <<https://www.iucnredlist.org/species/22699787/110734937>>. Accessed 3 May 2021.
- Committee on the Status of Endangered Wildlife in Canada. 2018. Olive-sided Flycatcher (*Contopus cooperi*): COSEWIC assessment and status report 2018. Government of Canada. <<https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/cosewic-assessments-status-reports/olive-sided-flycatcher-2018.html#toc0>>. Accessed 3 May 2021.
- Dewitz, J. 2019. National Land Cover Database (NLCD) 2016 Products: U.S. Geological Survey data release. <<https://doi.org/10.5066/P96HHBIE>>.
- eBird Basic Dataset. Version: EBD_relJan-2021. Cornell Lab of Ornithology, Ithaca, New York. Jan 2021.
- Fitzpatrick, M. C., Gotelli, N. J., and A. M. Ellison. 2013. MaxEnt versus MaxLike: empirical comparisons with ant species distributions. *Ecosphere* 4:1-15.

- Glennon, M. J., Langdon, S. F., Rubenstein, M. A., and M. S. Cross. 2019. Temporal changes in avian community composition in lowland conifer habitats at the southern edge of the boreal zone in the Adirondack Park, NY. PLoS One 14(8). <<https://www-proquest-com.ezproxy.uvm.edu/docview/2275930537?OpenUrlRefId=info:xri/sid:primo&accountid=14679>>. Accessed 4 May 2021.
- Hannon, S. J. and P. Drapeau. 2005. Bird responses to burning and logging in the boreal forest of Canada. Pages 97-115. Fire and avian ecology in North America. Cooper Ornithological Society, Camarillo, California, USA.
- Hunt, P. 2016. Assessment of Olive-sided Flycatcher (*Contopus cooperi*) Status and Distribution in New Hampshire. Audubon Society of New Hampshire, Concord, New Hampshire, USA.
- Hutto, R. L. and J. S. Young. 1999. Habitat relationships of landbirds in the Northern Region, USDA Forest Service. <https://www.fs.fed.us/rm/pubs/rmrs_gtr032.pdf>. Accessed 3 May 2020.
- Jennewein, J. S., Hebblewhite, M., Mahoney, P., Gilbert, S., Meddens, A. J. H., Boelman, N. T., Joly, K., Jones, K., Kellie, K. A., Brainerd, S., Vierling, L. A., and J. U. H. Eitel. 2020. Behavioral modifications by a large-northern herbivore to mitigate warming conditions. Movement Ecology 8. <<https://doi-org.ezproxy.uvm.edu/10.1186/s40462-020-00223-9>>. Accessed 17 May 2021.
- Laaksonen, T. and A. Lehikoinen. 2013. Population trends in boreal birds: Continuing declines in agricultural, northern, and long-distance migrant species. Biological Conservation 168:99-107.

Maine 2015 Wildlife Action Plan Revision. 2016.

<https://www.maine.gov/ifw/wildlife/reports/pdfs/SGCN_Reports/SGCN/Olive-sided%20Flycatcher_Contopus%20cooperi.pdf>. Accessed 3 May 2021.

Maine Department of Environmental Protection. 2003. Wetlands protection: A federal, state, and local partnership. <<https://www.maine.gov/dep/land/nrpa/ip-wet-protectionl.html#:~:text=Over%20five%20million%20acres%20of,beds%2C%20beaches%20and%20reefs>>. Accessed 4 May 2021.

Massachusetts Department of Environmental Protection. 2021. Protecting Wetlands in Massachusetts. Mass.gov. <<https://www.mass.gov/guides/protecting-wetlands-in-massachusetts>>. Accessed 4 May 2021.

Megyesy, J. and M. Marchand. 2015. Mink Frog (*Lithobates septentrionalis*). <<https://www.wildlife.state.nh.us/wildlife/profiles/wap/amphibian-minkfrog.pdf>>. Accessed 17 May 2021.

Nebel, S., Mills, A., McCracken, J. D., and P. D. Taylor. 2010. Declines of aerial insectivores in North America follow a geographic gradient. *Avian Conservation & Ecology* 5(2). <<http://www.ace-eco.org/vol5/issue2/art1/>>. Accessed 4 May 2021.

New Hampshire Department of Environmental Services. 2021. Wetlands. <<https://www.des.nh.gov/water/wetlands>>. Accessed 4 May 2021.

New Hampshire Fish and Game. Beaver (*Castor canadensis*). <<https://www.wildlife.state.nh.us/wildlife/profiles/beaver.html>>. Accessed 4 May 2021.

Renfrew, R. B. 2013. *The Second Atlas of Breeding Birds of Vermont*. University Press of New England, Lebanon, New Hampshire, USA.

- Robertson, B. A. and R. L. Hutto. 2007. Is Selectively Harvested Forest an Ecological Trap for Olive-Sided Flycatchers? *The Condor* 109:109-121.
- Royle, J. A., Chandler, R. B., Yackulic, C., and J. D. Nichols. 2012. Likelihood analysis of species occurrence probability from presence-only data for modelling species distributions. *Methods in Ecology and Evolution*.
- Stralberg, D., Berteaux, D., Ronnie Drever, C., Drever, M., Naujokaitis-Lewis, I., Schmiegelow, F. K. A., and J. A. Tremblay. 2019. Conservation planning for boreal birds in a changing climate: A framework for action. *Avian Conservation & Ecology* 14(1). <<http://web.b.ebscohost.com.ezproxy.uvm.edu/ehost/pdfviewer/pdfviewer?vid=2&sid=81452352-4eec-4156-af61-c237f210b104%40sessionmgr103>>. Accessed 5 May 2021.
- Sucik, M. T. and E. Marks. 2017. The status and recent trends of wetlands in the United States. USDA Natural Resources Conservation Service. <https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1262239.pdf>.
- Sullivan, B. L., Wood, C. L., Iliff, M. J., Bonney, R. E., Fink, D., and S. Kelling. 2009. eBird: A citizen-based bird observation network in the biological sciences. *Biological Conservation* 142:2282-2292.
- Sullivan, B. L., Phillips, T., Dayer, A. A., Wood, C. L., Farnsworth, A., Iliff, M. J., Davies, I. J., Wiggins, A., Fink, D., Hochachka, W. M., Rodewald, A. D., Rosenberg, K. V., Bonney, R., and S. Kelling. 2017. Using open access observational data for conservation action: A case study for birds. *Biological Conservation* 208:5-14.
- Thompson, E. H., Sorenson, E. R., and R. J. Zaino. 2019. Woodland, wetland, wildland: A guide to the natural communities of Vermont. Chelsea Green Publishing, White River Junction, Vermont.

- USDA Forest Service. 2019. NLCD 2016 Tree Canopy Cover (CONUS). Salt Lake City, Utah.
- US Geological Survey, National Geospatial Technical Operations Center. 2020a. USGS National Transportation Dataset (NTD) for Maine. Reston, Virginia.
- US Geological Survey, National Geospatial Technical Operations Center. 2020b. USGS National Transportation Dataset (NTD) for Massachusetts. Reston, Virginia.
- US Geological Survey, National Geospatial Technical Operations Center. 2020c. USGS National Transportation Dataset (NTD) for New Hampshire. Reston, Virginia.
- US Geological Survey, National Geospatial Technical Operations Center. 2020d. USGS National Transportation Dataset (NTD) for Vermont. Reston, Virginia.
- Vermont Department of Environmental Conservation. 2020. Vermont Wetland Rules.
<https://dec.vermont.gov/sites/dec/files/documents/wsmd_VermontWetlandRules.pdf>.
Accessed 4 May 2021.
- Vermont Department of Environmental Conservation. 2021. Wetland functions and values: Rare, threatened, and endangered species habitat.
<<https://dec.vermont.gov/watershed/wetlands/functions/sensitive>>. Accessed 4 May 2021.
- Vermont Fish and Wildlife Department. 2009. Beaver (*Castor canadensis*).
<<https://dec.vermont.gov/sites/dec/files/wsm/wetlands/docs/Beaver%20FactSheet.pdf>>.
Accessed 4 May 2021.
- Vermont Reptile and Amphibian Atlas. 2021. Mink Frog (*Lithobates septentrionalis*).
<<https://www.vtherpatlas.org/herp-species-in-vermont/lithobates-septentrionalis/>>.
Accessed 17 May 2021.

- Visser, M. E., Both, C., and M. M. Lambrechts. 2004. Global climate change leads to mistimed avian reproduction. *Advances in Ecological Research* 35:89-110.
- Wagenmakers, E. and S. Farrell. 2004. AIC model selection using Akaike weights. *Psychonomic Bulletin & Review* 11:192-196.
- Walker, J. and P. D. Taylor. 2017. Using eBird data to model population change of migratory bird species. *Avian Conservation & Ecology* 12(1). <<https://doi.org/10.5751/ACE-00960-120104>>. Accessed 4 May 2021.
- Zlonis, E. J., Panci, H. G., Bednar, J. D., Hamady, M., and G. J. Neimi. 2017. Habitats and landscapes associated with bird species in a lowland conifer-dominated ecosystem. *Avian Conservation & Ecology* 12(1). <<https://doi.org/10.5751/ACE-00954-120107>>. Accessed 4 May 2021.

Appendix I: Olive-sided Flycatcher Points

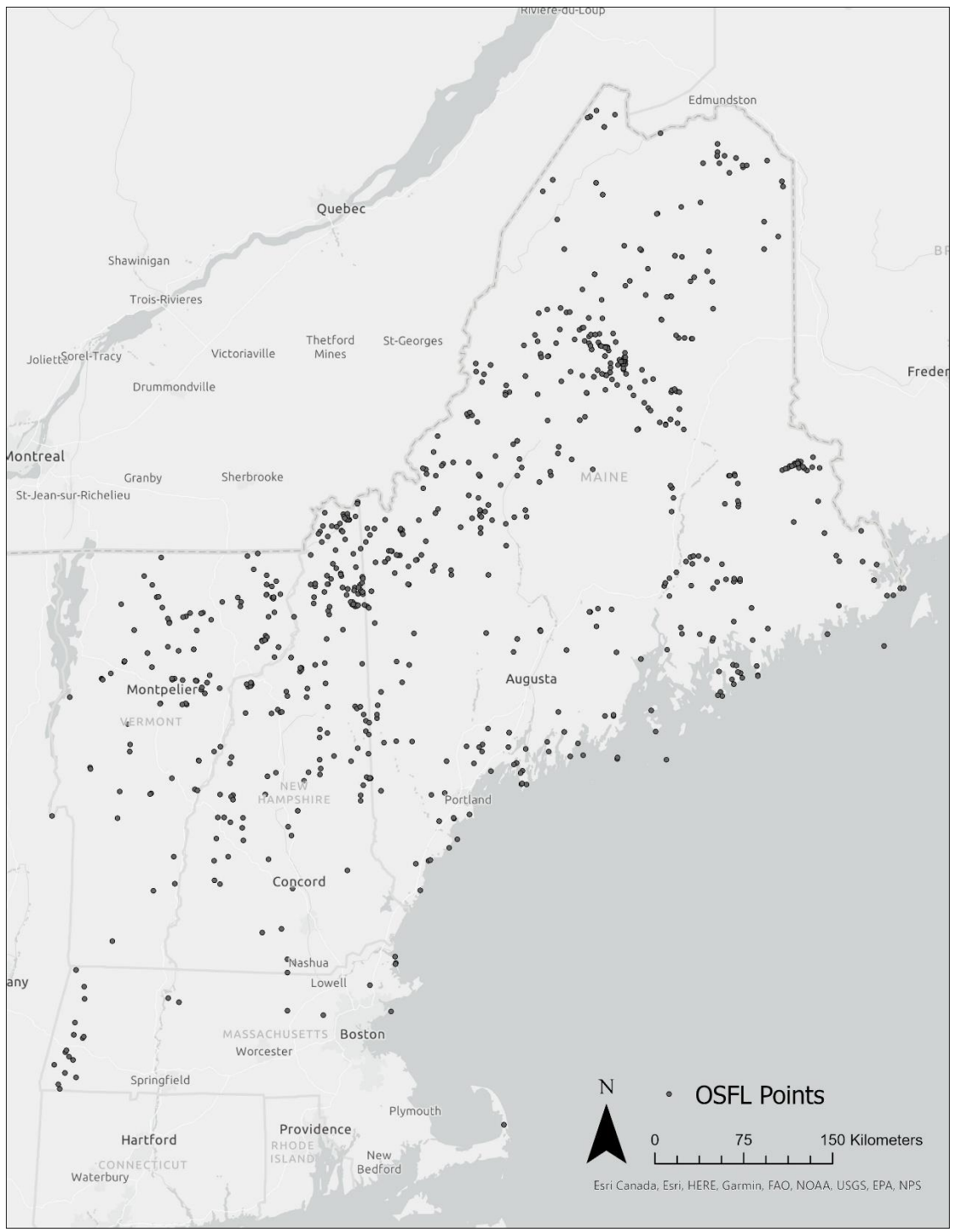


Figure 3: Proofed Olive-sided Flycatcher detections from eBird from 2010 to 2019 between June 5th and August 1st used to create occupancy models.