A Habitat Suitability Model for Ruffed Grouse (Bonasa umbellus) in New York State Department of Environmental Conservation Region 8

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A Habitat Suitability Model for Ruffed Grouse
(Bonasa umbellus) in New York State Department
of Environmental Conservation Region 8

by

Austin Groff

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Environmental Science

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College of Science

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ABSTRACT

Shrubland, young forest, and other types of early successional habitats have historically declined due to a lack in anthropogenic and natural disturbances. This decline in disturbance-dependent habitats has impacted the populations of a variety of species, with some of conservation concern, such as the Ruffed Grouse (*Bonasa umbellus*). Using an iteration-reduction method for this project, a Habitat Suitability Model was created in ArcGIS Pro to assess NYSDEC Region 8 for potential habitat, and to assist with determining where the potential habitat was located within the area of interest. These potential habitat areas were ranked from “POOR” to “PRIME” based on literature-derived habitat parameters such as the presence of: 1) significant shrubland habitat, 2) significant urban areas, 3) a significant water source, and 4) significant coniferous forest. The model identified 11,047 potential sites distributed as “PRIME” (3550), “GOOD” (3543), “FAIR” (1462), and “POOR” (2492). eBird data used for verification had 585 eBird sightings that “hit”, or intersected with the model results, with 458 (78%) within “PRIME” sites, 50 (9%) within “GOOD” sites, 46 (8%) within “FAIR” sites, and 31 (5%) within ”POOR” sites. Sensitivity tests based on a maximum literature-derived home range were able to capture an additional 153 eBird sightings of the 467 eBird sightings that missed the model entirely, which increased the model sighting accuracy from 56% (585 eBird sighting hits) to 70% (738 eBird sighting hits). Although several factors associated with the verification data, National Land Cover Database (2011), and model constraints may be reducing the overall accuracy of the model, the results suggest that the model accurately identified “PRIME” habitat, but a majority of this habitat is on private land. Conservation efforts will need to focus on recruiting private landowners into managing shrubland, as well as to continue managing publicly owned lands, as part of the conservation strategy for the Ruffed Grouse.
AKNOWLEDGEMENTS

A special thanks to Karl Korfmacher for providing guidance, support, and knowledge throughout the entire process of completing my classwork and my thesis.

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INTRODUCTION

Trends in Population of Shrubland Birds

Over the past 40 years, world bird populations have declined due to a variety of factors, including a decrease in viable habitat (Ford et al., 2009). Of the over 800 species that are found in the United States, 15% rely on early successional and disturbance-dependent habitats, such as grassland, shrubland, and young forest (Ford et al., 2009). The populations of most bird species that are associated with these disturbance-dependent habitats (grassland, shrubland, and other early successional habitat) have declined since the 1950s (Hunter et al., 2001). Many of these species and subspecies are now extinct, globally rare, threatened, or endangered, primarily due to the lack of abundance of disturbance-dependent habitat (Hunter et al., 2001). Some species near extinction include the Heath Hen (*Tympanuchus cupido*), Greater Prairie-chicken (*T. c. pinnatus*), Attwater’s Prairie-chicken (*T. c. attwateri*), and the Bachman’s Warbler (*Vermivora bachmanii*). Species that are endangered, or on the watch list, include the Golden-winged Warbler (*Vermivora chrysoptera*), Kirtland’s Warbler (*Dendroica kirtlandii*), Henslow’s Sparrow (*Ammodramus henslowii*), and the Cerulean Warbler (*Dendroica cerulea*) (Hunter et al., 2001).

The Ruffed Grouse (*Bonasa umbellus*) needs very similar habitat to some of the species listed above, making it a species of conservation importance (decrease in population). Ruffed Grouse populations have annually declined by 2% in the northeastern United States, which amounts to a greater than 60% decrease in total population from 1970-2000 (Sauer et al., 2014). Ruffed Grouse populations in New York have declined by 83% since 1966, according to NYSDEC’s Young Forest Initiative (NYSDEC, 2016) and Breeding Bird Survey. Listed in Figure 1 are other species that are of conservation concern due to the dramatic overall decline in population linked to shrubland loss since 1966.
Figure 1. Percent decline since 1966 in shrubland habitat species of concern. Recreated from the NYSDEC Young Forest Initiative (NYSDEC, 2016). Based on Breeding Bird Survey (Sauer et al., 2014)

Conserving shrubland will also potentially impact all of the 100 New York plant and animal species that inhabit these habitats (Defined by NYSDEC Bureau of Bird and Mammal Team, Reptile and Amphibian Diversity Team, Furbearer Team, and their Invertebrate Biologist) (NYSDEC, 2016). The conservation of shrubland, young forest, and other early successional habitats will reach 39 bird species, including the Ruffed Grouse, and 61 other species in New York that inhabit these areas. Of the 39 bird species, 1 is endangered, 4 are of Special Concern, 5 are a Species of Greatest Conservation Need (SGCN), and 10 are of High Priority Species of Greatest Conservation Need (HPSGCN) in New York. Of the rest of the species that inhabit these habitats, 7 are endangered, 3 are threatened, 10 are of Special Concern, 16 are HPSGCN, 25 are SGCN, and 11 are Species of Potential Conservation Need (SPCN) (See Table 1).
Table 1. This is a table summary of the New York listed species as well as the SGCN status. The information from the table is derived from the NYSDEC Young Forest Initiative (NYSDEC, 2016). There are 8 species that will be impacted that are of undefined status.

<table>
<thead>
<tr>
<th></th>
<th>Endangered</th>
<th>Threatened</th>
<th>Special Concern</th>
<th>High Priority SGCN</th>
<th>SGCN</th>
<th>SPCN</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birds</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>10</td>
<td>5</td>
<td>1</td>
<td>21</td>
</tr>
<tr>
<td>Mammals</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>7</td>
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<tr>
<td>Reptiles and Amphibians</td>
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<td>3</td>
<td>7</td>
<td>9</td>
<td>12</td>
<td>1</td>
<td>35</td>
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<tr>
<td>Invertebrates</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>11</td>
<td>10</td>
<td>29</td>
</tr>
<tr>
<td>Total</td>
<td>7</td>
<td>3</td>
<td>14</td>
<td>26</td>
<td>30</td>
<td>12</td>
<td>92</td>
</tr>
</tbody>
</table>

**Shrubland Habitat History and Decline**

Shrubland and early successional habitats are characterized by small trees and shrubs age 20 years or less (Brooks, 2003). The New York State Department of Environmental Conservation (NYSDEC) defines these habitats as having trees less than 10 years old. Less than 15% of the total land cover in the United States is shrubland or early successional habitat (Dettmers, 2003). These habitats rely on natural disturbances such as fire, wind, floods, and beavers for their establishment, as well as anthropogenic disturbances including clear cutting for timber and pioneer farming practices (Brooks, 2003). In the late 19th century, and early 20th century, much of the northeastern United States was dominated by young forest and early successional habitats, primarily due to logging, land clearing, fuel wood utilization, fires, and farmland abandonment (Lorimer and White, 2003), but since the 1950s there has been a historical decrease (Brooks, 2003). In the southern northeastern states, shrubland and early successional habitats currently comprises 5% of total timberland cover, which is a dramatic
decline from 36% in the 1950s (Brooks, 2003). In New York and Pennsylvania, the shrubland and early successional habitats have decreased from the 4.4 million ha in the 1970s to 2 million ha (16% of the total timberland). The decrease is largely attributed to habitat change caused by increased human land development for residential and commercial purposes, lack of human disturbances (clear cutting and logging operations), and reduced natural disturbance stemming from a lack of land management and conservation efforts (Blomberg et al., 2012). In order to preserve disturbance-dependent habitats, as well as the species that inhabit them, land management practices and conservation efforts are needed to create the required disturbance (Lorimer and White, 2003).

Forestry practices seem to work well in creating early successional habitat and forest habitat diversity for shruband bird species (DeGraaf and Yamasaki, 2003). Sustainable forest management practices provide forest habitat diversity for the shrubland bird species and can slow, or even reverse, the decline of bird species population due to the habitat decline by reintroducing or promoting early successional habitat growth (DeGraaf and Yamasaki, 2003; Ford et al., 2009; Brooks, 2003). Due to the human suppression of many types of natural disturbances, regular disturbance cycles have been disrupted or minimized, leading to a degradation of disturbance-dependent habitats. Because of this, human intervention by means of forestry management practices, such as clear cutting, selective cutting, and understory growth, is necessary in order to help reintroduce and conserve disturbance-dependent habitats (Brooks, 2003; NYSDEC, 2016).
Ruffed Grouse (*Bonasa umbellus*) Natural History: Literature Review

*Physical Description*

The Ruffed Grouse is classified as an uncommon* upland game bird that typically is 43.2 cm in length (17 inches), has a wingspan of 55.9 cm (22 inches), and weighs 1.3 lb (580 grams) (Sibley, 2016). Its plumage ranges from mottled gray to brown and black, and is identified by a dark band by the tip of its tail and tufts of feathers on the side of its neck that can be erected into a “ruff” (Rusch et al., 2000) (Figure 2).

![Ruffed Grouse](https://www.flickr.com/photos/seabamirum/3447982213/) Photo credit to Time Lenz. The picture was located at [https://www.flickr.com/photos/seabamirum/3447982213/](https://www.flickr.com/photos/seabamirum/3447982213/) in the public domain

*Range*

The Ruffed Grouse (*Bonasa umbellus*) is predominantly found in most of the New England states, in some of the northwestern states, as well as most of the Canadian Provinces (Bump et al., 1978; Sibley, 2016). The home range of the Ruffed Grouse varies. The male

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1. Found in small numbers and usually—but not always—found with some effort in appropriate habitat at the right time of year (Cannings et al., 2005).
Ruffed Grouse, which tends to be territorial, has a significantly smaller home range compared to the female (Blomberg et al., 2012). The average Ruffed Grouse home range recently used in a NYSDEC related study, and that will be used for this study is 28.44 ha (Fearer, 1999; Skirp et al., 2011). The maximum home range for this study representing a female Ruffed Grouse is 91.2 ha (Fearer, 1999; Skirp et al., 2011). Figure 3 shows the abundance distribution determined by the number of Ruffed Grouse observations along the Breeding Bird Survey observation routes (Sauer et al., 2014).

Figure 3. This distribution map (Sauer et al., 2014) was obtained from the Breeding Bird Survey website (http://www.mbr-pwrc.usgs.gov/id/framlst/i3000id.html). The units in this map are observations along the BBS routes. For example the “One and Below” unit means that there were observations of one or 0 Ruffed Grouse, on average, along the routes in these areas in a specific timeframe, in this case the 2014 collection year. The “None Counted” means that there was no observation.

Habitat

According to current research, the Ruffed Grouse prefer early successional forest and shrubland habitats, which occur when there has been a recent disturbance such as wind, fire, or
active forestry (Post, 2005). Since the primary cause of mortality in Ruffed Grouse is due to predation by the Northern Goshawk (*Accipiter gentillis*) and the Great Horned Owl (*Bubo virginianus*), they seek out protection in dense shrubs and canopies of young trees (Rusch, 2000). The ideal habitat includes a mixed or deciduous forest with a diverse mosaic of clearings, dense brush, and young trees (Sibley, 2016), especially aspens (Kouffeld et al., 2013). Deciduous plants found in these early successional forests also provide food in the form of buds, leaves, and fruits, especially from aspens (Rusch et al., 2000; Kouffeld et al., 2013). Cover differs from season to season, and Ruffed Grouse tend to prefer forests areas that contain evergreen trees. Evergreen trees provide year round cover and protection from predators, especially during the winter months when the foliage of deciduous trees has fallen (Bump et al., 1978). Like the majority of species found in the U.S, water resources are also considered a key characteristic to survival for the Ruffed Grouse (Tirpak and Guilano, 2010). Although the Ruffed Grouse are able to live in most forest types, early successional forest (shrubland habitat) is deemed to be the most consistent component of Ruffed Grouse habitat selection (Blomberg et al., 2009).

Since the Ruffed Grouse have a relatively high mortality rate (deaths per period of time) and short life span (7 to 8 years), chick survival is key to sustaining the population (Jones et al., 2008). In a study of 186 brood selection sites, Jones et al. (2008) found that brood selection sites have a high percentage of herbaceous ground cover and vertical vegetation cover, as well as a high invertebrate density, suggesting that Ruffed Grouse also choose shrubland and early successional habitats for broods (Jones et al., 2008). The clutch size in each brood ranges from 9-14 eggs (Rusch et al., 2000)

There are also factors with negative correlation to habitat preference. Areas in proximity to human disturbances, such as roads and infrastructure, are areas Ruffed Grouse tend to avoid
(Kouffeld et al., 2013). Ruffed Grouse also tend to avoid open areas such as agriculture and old forests with no cover due to risk of predation (Kouffeld et al., 2013; Tirpak and Guilano, 2010).

In order to promote future population growth for the Ruffed Grouse, research suggests that habitat management efforts should attempt to maintain 3-4 percent of the landscape in young forest cover that is less than 20 years of age, and have the areas evenly distributed throughout the landscape (Tirpak et al., 2010). Each early successional and shrubland habitat patch size should be at least 0.8 ha, and regenerated every 10-15 years (DeGraaf and Yamasaki, 2003). The stand management interval ranges from 10-15 years where Ruffed Grouse have become common in an area after clear cutting. If management takes place 15 years after clear cutting or later, the population of the Ruffed Grouse tends to decline due to forest maturation (DeGraaf and Yamasaki, 2003). The NYSDEC Young Forest Initiative aims to address the decrease in early successional habitat by using forestry management practices such as selective cutting and tree planting (NYSDEC, 2016)

**Geographic Information Systems and Habitat Suitability Models: Literature Review**

The uses and capabilities of geospatial technology have dramatically increased over the past ten years. Geographic Information Systems (GIS) are geospatial computer software systems that can generate models and maps to analyze and display trends in spatial data (Brambilla et al., 2009). Several focused on the use of GIS and other geospatial technology to create habitat suitability models with relation to the Ruffed Grouse, as well as other wildlife, such as songbirds (Blomberg et al., 2009; Blomberg et al., 2012; Correa-Berger, 2007; Dong et al., 2013; Fearer and Stauffer, 2003; Rubenstein, 2016; Store et al., 2003; Tirpak and Giuliano, 2010; Van Horne and Wiens, 1991). Table 2 summarizes these selected articles with respect to the use of
Geospatial Technology for Habitat Modeling and their effectiveness, as well as the methodological approach of each study to assist with determining the model approach that will be taken for this study. Effectiveness for the articles below, for this literature review, is defined as the success and capability of the geospatial software to complete the tasks or projects outlined in the studies.

Table 2. This table summarizes the articles cited with respect to the use of geospatial technology for habitat modeling for a variety of target species.

<table>
<thead>
<tr>
<th>Article</th>
<th>Format</th>
<th>Target Species</th>
<th>Application of Technology</th>
<th>Methodological Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blomberg et al. (2009)</td>
<td>GIS</td>
<td>Ruffed Grouse</td>
<td>Ruffed Grouse Habitat Distribution</td>
<td>Multi-criteria approach (Mahalinobis D2) with heat map proximity based on Ruffed Grouse density</td>
</tr>
<tr>
<td>Blomberg et al. (2012)</td>
<td>GIS</td>
<td>Ruffed Grouse</td>
<td>Population Dynamics and Habitat Modeling</td>
<td>Multi-criteria approach (used above study to predict decline)</td>
</tr>
<tr>
<td>Correa-Berger (2007)</td>
<td>GIS</td>
<td>Spotted Turtle</td>
<td>Habitat Suitability Modeling</td>
<td>Hybrid multi-criteria approach (Iteration-Reduction)</td>
</tr>
<tr>
<td>Dong et al. (2013)</td>
<td>GIS</td>
<td>Songbirds</td>
<td>Habitat Suitability Index and Modeling</td>
<td>Multi-criteria approach “fuzzy” model (habitat parameters in ranges or weights)</td>
</tr>
<tr>
<td>Rubenstein (2016)</td>
<td>GIS</td>
<td>Golden-Winged Warbler</td>
<td>Habitat Suitability Modeling</td>
<td>Multi-criteria approach (Iteration-Reduction)</td>
</tr>
<tr>
<td>Store et al. (2003)</td>
<td>GIS</td>
<td>N/A</td>
<td>Habitat Suitability Modeling</td>
<td>Multi-criteria approach “fuzzy” model (weighting method)</td>
</tr>
<tr>
<td>Tirpak and Guilano (2010)</td>
<td>GIS and RS</td>
<td>Ruffed Grouse</td>
<td>Forest Habitat Characterization Modeling</td>
<td>Analyzed ground truth data to create the Habitat Characterization Model</td>
</tr>
<tr>
<td>Van Horne and Wiens (1991)</td>
<td>GIS</td>
<td>Forest Birds</td>
<td>Habitat Suitability Modeling</td>
<td>Multi-criteria Habitat Suitability Index using weights (without generating maps)</td>
</tr>
</tbody>
</table>

Knowing the effectiveness of the technologies in each of the articles was critical in determining if this project, regarding detection of early successional forest and assessment of Ruffed Grouse habitat, would be feasible. From the table, all nine applications of the
technologies in the select articles were effective in their studies, which was a good indication that creating a habitat suitability model for Ruffed Grouse using geospatial software is feasible and worthwhile.

Eight of the nine selected articles used a multi-criteria approach for their analysis. Four articles used a “weight” approach, three used ground truth data (both GPS tracking data as well as habitat data), and two used an “Iteration-Reduction” method. Based on the lack of usable resources such as available ground truth data, as well as limited time to collect ground truth data or to create a weighted classification, this study adopted the multi-criteria “Iteration-Reduction” method, relying on publically available spatial data linked to literature values to determine habitat parameters.

The use of GIS for wildlife habitat evaluation has the definite advantages of quickness and cost effectiveness over conventional survey methods, such as ground surveying, due to the use of available data for initial analyses without numerous hours of fieldwork (Kushwaha et al., 2002). As time progresses, spatial data become more accurate, resulting in a potentially better habitat model (Kushwaha et al., 2002). Although GIS is able to create accurate models, limitations include the availability, age, and accuracy of the data available for use, so the model created in a GIS is only as good as the data used to generate it (Brambilla et al., 2009). Some fieldwork, or ground truthing is still recommended for increased accuracy. In some cases, ground truthing data are already publicly available through citizen science collection efforts, such as eBird observations used in this study (Sullivan et al., 2009).

GIS can also help to analyze data regarding spatial patterns and property ownership and conservation status in order to determine areas of conservation priority (Geneletti, 2004). ArcGIS highlights boundaries and displays patterns of public and private land holding in a specific area.
Public lands are logistically easier to manage in comparison to private land, due to property ownership and access rights. State-run organizations, such as the NYSDEC, have access to the public state lands and have a high level of control on what is done with the land, whereas private land management is up to the owner, potentially increasing the difficulty of management.

In order to generate the habitat model for this study using the multi-criteria “Iteration Reduction” method, parameters of habitat preference such as elevation, land cover, food availability and water proximity, must be known for the target species. When creating a model for the Ruffed Grouse, the specific habitat preferences must be accounted for to be able to create an accurate model. In this model, based on the Ruffed Grouse natural history literature review, shrubland and young forest with deciduous forest containing conifer patches, distance from human disturbance, and proximity to water will be used as some of the habitat parameters (Bump et al. 1978; DeGraaf and Yamasaki, 2003; Gullion, 1984; Kouffeld et al., 2013; Rusch, 2000; Sibley, 2016; Tirpak and Guilano, 2010).

Current Data Available

Some of the current data available for the GIS model include the National Land Cover Database (provides land cover classification over an entire region) (Homer et al., 2015) as well as sighting/observation databases such as eBird (Sullivan et al., 2009), Breeding Bird Survey (Sauer et al., 2014) and NYSDEC Hunting Logs. In order to use the parameter of proximity to water, a hydrologic database, such as the National Hydrography Database (USGS, 2013) can be used as a layer for streams and water bodies in ArcGIS. In order to determine property ownership, parcel (tax) data for each of the counties included within the NYSDEC Region 8 boundary was be retrieved from the NYS GIS Clearinghouse (https://gis.ny.gov/gisdata) as well as public land
layers such as Wildlife Management Areas, Bird Conservation Areas, and Parks can be added for additional data.

**Area of Study**

The extent of this study will be within the boundaries of New York State Department of Environmental Conservation (NYSDEC) Region 8. Figure 4 shows the layout of the Region and identifies all of the counties that lie within the boundary. These counties are: Chemung, Genesee, Livingston, Monroe, Ontario, Orleans, Schuyler, Seneca, Steuben, Wayne, and Yates.

![Figure 4. NYSDEC Region 8. Dots located at Bath and Elmira are regional offices. The star located at Avon is the NYSDEC Region 8 headquarters. NYSDEC Regional Website](https://gis.ny.gov/gisdata/inventories/member.cfm?organizationID=529)

**Project Goal**

The goal of this study is to use ArcGIS Pro to create a model of seed sites (current habitat and potential reintroduction sites) for the Ruffed Grouse. If the model is deemed accurate through the use of eBird verification data, then the model will be able to accurately assist in conservation efforts by identifying current and potential habitat, as well as regional gaps where
targeted shrubland development could support Ruffed Grouse reintroduction. The model will be
based on primary key habitat parameters found throughout the literature. After the preliminary
seed sites are created, a home range buffer will be added to each site, and then using an iteration-
reduction method adopted from Correa-Berger (Correa-Berger, 2007), suitable sites will be
narrowed down based on additional key habitat attributes. The model will aim to: 1) use
literature-derived habitat preferences to aid with identifying potential reintroduction sites, 2)
determine where in NYSDEC Region 8 these areas are located, and 3) rank areas that should be
of conservation concern (or importance) based on a combination of site rank, sighting data, and
property ownership. Because public land provides observers easy access, the verification data
should line up strongly with “PRIME” sites located within public holdings. If this trend is seen,
and if additional eBird sightings line up on predicted “PRIME” private holdings, then the model
results without field verification data should accurately reflect potential habitat. These would be
area targeted for field observation.

The proposed research, focused on promoting the conservation of the Ruffed Grouse and
eyearly successional habitat, will benefit not only conservation scientists, but also the recreational
public. The Ruffed Grouse, American Woodcock, and Wild Turkey are all game birds that
require licenses to hunt, as well as a few other game animals on the species list that inhabit these
areas. The conservation of these species for recreational purposes will continue to fund
conservation through the purchase of hunting licenses and other recreational equipment. Of the
approximate 50 million dollars in the New York State Conservation Expenditure, 43 million was
covered through license revenue (DiNapoli, 2015). This total does not include the total revenue
of all of the recreational equipment purchased for hunting and many other recreational activities,
including bird watching and hiking.
METHODS

Model Approach (Iteration Reduction Method)

The model approach for this study was partially adopted from a previous habitat suitability model that utilized a process called iteration-reduction (Correa-Berger, 2007). This method was chosen because it follows a common logic in GIS analyses, a multi-criteria approach and it is suitable for use with the available data and the time available to complete the model (Refer to Table 2). The iteration-reduction starts with critical habitat areas, in this case a defined home range buffer around shrubland habitat, identified as analysis seed sites. These seed sites contain the most important key habitat characteristics for the Ruffed Grouse (shrubland), as defined in the literature review, and through each additional iteration (additional habitat requirement) either exclude or include each site until only “PRIME” sites that contain all of the key habitat characteristics remain after the last iteration (lack of urban, presence of water, presence of deciduous forest, presence of coniferous forest).

By introducing additional habitat requirements at each step, or iteration, sites that do not contain the additional characteristics will be excluded and ranked lower. This process continues until all of the identified habitat characteristics are added during separate iterations, leaving only sites that meet all of the user-defined habitat parameters, and these sites for this study would be considered “PRIME” existing habitat for the Ruffed Grouse. Sites that did not contain only the second to last characteristic (coniferous forest) would be ranked as “GOOD” and would be considered “PRIME” habitat if the missing parameter could be introduced. Sites that miss the third to last characteristic (presence of water) would be ranked as “FAIR”, reflecting a more difficult or extensive habitat restoration process. Any sites that were excluded before the “FAIR” iteration ranking would be ranked as “POOR”, indicating a low possibility of restoring the area
as usable habitat due to presence of urban land cover. This model approach was completed using ArcGIS Pro and Microsoft Excel software. The defined parameters for each of the iterations are based on the literature review of the Ruffed Grouse presented in the introduction. The specific parameters and descriptions for each of the iterations are displayed in Table 3.

Table 3 displays the data sets/layers used, parameters and brief description for each of the iterations used in the Iteration Reduction process. National Land Cover Database = NLCD; NHD = National Hydrography Dataset

<table>
<thead>
<tr>
<th>Step</th>
<th>Data/Layers Used</th>
<th>Description</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Seed Sites</td>
<td>NLCD (code 52), 1.1 ha area of contiguous shrubland minimum (Schlossberg &amp; King, 2007) and home range buffer of 28.44 ha (Fearer, 1999; Skirp et al., 2011)</td>
<td>Large shrubland areas surrounded by a home range buffer (most important habitat characteristic found in the literature)</td>
<td>Shrubland plots of at least 1.1 hectares surrounded by a home range buffer radius of 300 m (Skirp et al., 2011)</td>
</tr>
<tr>
<td>Iteration 1</td>
<td>NLCD (codes: 22, 23, and 24)</td>
<td>Code 22: Low-Intensity Urban</td>
<td>Exclude remaining sites that contain urban of any type that is larger than 1000 square meters (approximately 0.25 acres)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Code 23: Med-Intensity Urban</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Code 24: High-Intensity Urban</td>
<td></td>
</tr>
<tr>
<td>Iteration 2</td>
<td>NLCD (codes 11, 90, and 95) and NHD stream network</td>
<td>Code 11: Open Water</td>
<td>Exclude remaining sites that do not contain a water source (code 11, 90, and 95 or a stream) of at least 1000 square meters (approximately 0.25 acres)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Code 90: Woody Wetlands</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Code 95: Emergent Wetlands</td>
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<td></td>
<td></td>
<td>NHD: Stream network</td>
<td></td>
</tr>
<tr>
<td>Iteration 3</td>
<td>NLCD (code 41)</td>
<td>Code 41: Deciduous Forest</td>
<td>Exclude remaining sites that do not contain deciduous forest of at least 1000 square meters</td>
</tr>
<tr>
<td>Iteration 4</td>
<td>NLCD (code 42)</td>
<td>Code 42: Coniferous Forest</td>
<td>Exclude remaining sites that do not contain coniferous trees of at least 1000 square meters</td>
</tr>
</tbody>
</table>
Data Sets Used for the Model

National Land Cover Database (NLCD)

The National Land Cover Database (Homer et al., 2015) was the data backbone of this study. This database contains assigned information about the land cover across an area. 30 m pixels are assigned a code for each specific land cover based on satellite imagery and imaging spectroscopy classification. Figure 5 displays the National Land Cover Database classification legend, along with a map layout of the National Land Cover Database (2011) within the NYSDEC Region 8 Boundary.

Figure 5. National Land Cover Database land classification categories (legend), as well as the total land cover classification of NYSDEC Region 8. (Refer to Table 3 for Land Covers Used)
The National Hydrography Dataset (U.S. Geological Survey, 2013) contains stream networks within specified boundaries such as counties, states, etc. The merged stream networks for all of the Region 8 counties were used in part to determine if there was a water source within the Ruffed Grouse home range buffer sites. Figure 6 displays the stream network within NYSDEC Region 8.

Figure 6. NHD Stream network within the NYSDEC Region 8 boundary.
**eBird for Sighting Verification**

eBird (Sullivan et al., 2009) was the significant Ruffed Grouse sighting verification dataset. The data used included the NYS total Ruffed Grouse eBird sightings from 2011 to present. This dataset was in the form of geographic point data displaying where the public has seen a specific species. eBird (https://ebird.org/home) is a citizen science organization created and managed by the Cornell Lab of Ornithology that aims to provide the public with a platform to post bird sightings for open access for other birders, as well as scientists.

**New York State Parcel Ownership Database**

New York State Parcel data (Gehrer, 2017) were necessary for determining whether or not land was public or privately owned (http://gis.ny.gov/parcels/). Since some of the parcel (tax) boundary data were not publicly available for some of the Region 8 counties, centroid ownership points were used and queried for public or private ownership. These data were important in determining ease of access to lands that the model aided in identifying as areas of conservation importance. These data were added after the last iteration as a final step to determine focus areas.

**NYSDEC Region 8 Boundary**

The New York State Department of Environmental Conservation Region 8 boundary was used as the processing extent for this study. The boundary of Region 8 was a NYSDEC layer acquired from the New York Geographic Information Systems Clearinghouse (https://gis.ny.gov/) (NYSDEC, 2011). With a few conversions and visual alterations, the boundary could be imported into ArcGIS Pro.
NYSDEC WMA Boundaries and NYS Bird Conservation Areas

Both the NYSDEC Wildlife Management Area boundaries (NYSDEC, 2018) and the NYS Bird Conservation Areas (NYSDEC, 2008) were obtained from the New York Geographic Information Systems Clearinghouse (https://gis.ny.gov/).

Model Steps

Initial Seed Sites and Home Range Buffers

The initial sites for the iteration-reduction process were defined using the National Land Cover Database (Homer et al., 2015) to identify areas of shrubland (NLCD code 52) of at least 1.1 hectares within the New York State Department of Environmental Conservation Region 8. Shrubland areas less than 1.1 hectares are considered edge (Schlossberg & King, 2007), thus they are not considered as a home area for Ruffed Grouse for this study. Figure 7 displays all of the shrubland habitat, defined by the 2011 National Land Cover Database.

After finding all of the shrubland sites of at least 1.1 hectares within the NYSDEC Region 8 boundary, a home range buffer (300 m radius) was created around each of the shrubland plots. The 300 m radius buffer was calculated from the area of a circle formula using a home range area of 28.44 hectares (Fearer, 1999; Skirp et al., 2011). These initial sites were considered the seed sites for the iteration-reduction process. To be able to determine the land cover with each of the seed sites, these initial seed sites were then intersected with the NLCD 2011 using the intersect command in ArcGIS Pro.
Figure 7. Shrubland land cover (NLCD grid code 52) of at least 1.1 contiguous hectares in red. The Region 8 boundary is displayed as a dashed black outline.

The iterations were completed in order of the most binding to least binding in terms of conservation efforts. For example, it would be of higher difficulty to remove an urban landscape than it would be to introduce a water feature, and it would be easier still to introduce coniferous trees than it would be to introduce water. Therefore, the iterations are implemented in the following order: 1) exclude seed sites containing a significant urban area, 2) exclude areas without a water source, 3) exclude areas without deciduous forest, and 4) exclude areas without coniferous forest.
Iteration 1 (Exclusion of Sites That Contained Urban)

Since the literature stated that the Ruffed Grouse tend to inhabit areas that are secluded or separated from any type of urban, developed, or residential areas, except for remote cabins or houses, the first iteration aimed to exclude sites that contained at least 1000 square meters (the approximate area of a average small house) of the National Land Cover Database codes 22 (Low-Intensity Urban), 23 (Medium-Intensity Urban), and 24 (High-Intensity Urban) within the home range buffer. Sites determined to have either codes 22, 23, or 24 were given a value of “1” per code (recorded on an Excel Sheet). Sites that did not contain any of these urban codes were given a value of “0” for each code. After adding the values for each buffer site, any that had a value greater than “0” were excluded for the next iteration and ranked as “POOR”.

Iteration 2 (Exclusion of Sites That Did Not Contain a Water Source)

Because the Ruffed Grouse need water to survive, the second iteration aimed to exclude any of the remaining sites from the first iteration that did not contain any type of significant water source (greater than 1000 square meters). A water source in this step was defined by either a stream from the National Hydrologic Database (NHD) (U.S. Geological Survey, 2013), or NLCD codes 11 (Open Water), 90 (Woody Wetlands), and 95 (Emergent Wetlands). Sites that contained codes 11, 90, and/or 95 were given a value of “0” for each code, and sites that did not contain each of these water codes were given a value of “1” for each code. After adding the values for each of the codes, sites that had a value of “3” (sites with no water according to the 2011 NLCD) were then analyzed in ArcGIS Pro to determine if a stream from the NHD intersected within the home range buffer of each site. Sites that were then determined to have a
value of “3”, and did not contain a stream from the NHD were then excluded for the next
iteration and ranked as “FAIR”.

**Iteration 3 (Exclusion of Sites That Do Not Contain Deciduous Forest)**

The third iteration focused on the importance of deciduous forest as a habitat
characteristic. This iteration aimed to exclude any remaining sites that did not contain at least
1000 square meters of NLCD code 41 (Deciduous Forest) within the home range buffer. Sites
that contained the required amount of deciduous forest were given the value of “0”, and sites that
did not contain the required amount were given the value of “1”. No sites were excluded during
this iteration (all of the sites given a value of “0”), rendering this step null.

**Iteration 4 (Exclusion of Sites That Do Not Contain Coniferous Forest)**

After determining that all sites contained a sufficient amount of deciduous forest, the next
iteration focused on excluding remaining sites that did not contain at least 1000 square meters of
coniferous forest (NLCD code 42). Coniferous forest is a key habitat characteristic for winter
survival of the Ruffed Grouse. Remaining sites that contained code 42 were given a value of “0”
for each code. Sites that did not contain code 42 were given the value of “1” for each code. The
sites valued “1” were excluded for the next iteration and ranked “GOOD”.

**Final Model**

The final sites for this model that met all of the user defined parameter requirements were
ranked as “PRIME”. These final sites contained shrubland, did not contain urban, contained a
water source, contained deciduous forest, and contained coniferous forest.
Data Verification

To analyze whether or not the model correlated with actual Ruffed Grouse sightings, eBird sightings of Ruffed Grouse from 2011-2017 in the form of point data were added on top of the model as a new layer (Sullivan et al., 2009). The years 2011-2017 were used to include the generation and growth of shrubland, as well as the degeneration of shrubland in years post 2011 when the NLCD was generated for this model. In order to obtain the eBird point data, the user needed to obtain permission from the organization for specific species, date, and area. After gaining access, the point data were downloaded and added as event data to the map, and then converted into a point shapefile. Points were then intersected with the “PRIME” sites, as well as the other ranked habitat areas.

Public vs. Private

To be able to further analyze sites for potential conservation efforts, determining property ownership was important. Gaining access to private lands presents a barrier, but public lands are easily accessible from a management perspective. New York State property ownership data (Gehrer, 2017) and NYSDEC Wildlife Management Areas (NYSDEC, 2018) were also added to the model as well to aid with identifying target areas for future management efforts through intersect commands.
RESULTS

Model Ranks

Identifying sites with at least 1.1 ha of shrubland yielded 11,047 initial seed sites. Adding additional constraints reduced this number of sites down to 3550 “PRIME” sites in the final iteration (Figure 8), with intermediate step totals shown in Table 4.

![Habitat Suitability Model for Ruffed Grouse in NYSDEC Region 8](image)

Figure 8. The entire habitat model showing the compilation of all 11,047 seed sites ranking from “PRIME” to “POOR”.

Table 4 displays the number of sites assigned to each rank as well as the rank’s percentage of the total sites.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Number of Sites (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRIME (Met All Requirements)</td>
<td>3550 (32%)</td>
</tr>
<tr>
<td>GOOD (Lack of Significant Coniferous Forest)</td>
<td>3543 (32%)</td>
</tr>
<tr>
<td>FAIR (Lack of Water)</td>
<td>1462 (13%)</td>
</tr>
<tr>
<td>POOR (Contained Urban)</td>
<td>2492 (23%)</td>
</tr>
</tbody>
</table>
POOR (sites excluded due to urban)

From the total number of possible shrubland seed sites, 2492 sites were removed during the first iteration because the seed sites contained urban land use of at least 1000 square meters within the home range buffer. Figure 9 displays these “POOR” sites.

Figure 9. All of the sites within the NYSDEC Region 8 boundary that were excluded and ranked as “POOR” because they contained urban, developed, or residential land cover (NLCD Grid Codes 22, 23, 24)
FAIR (sites excluded due to lack of water)

Of the sites remaining after the first iteration, 1462 sites were excluded during the second iteration because they did not contain a water source. Figure 10 displays the seed sites that were excluded and ranked as “FAIR”.

Figure 10. The few sites within the NYSDEC Region 8 boundary that were excluded in the second iteration and ranked as “FAIR” because they did not contain a water source (NLCD Grid Codes 11, 90, and 95) or a section of a stream (National Hydrologic Dataset).
GOOD (sites excluded due to no coniferous trees for cover during the winter months)

Of the sites remaining after the second iteration, 3543 sites were excluded because they did not contain a sufficient amount of coniferous forest. Figure 11 displays the sites that were excluded during the third iteration and ranked “GOOD”.

Figure 11. All of the sites within the NYSDEC Region 8 boundary that were excluded during the fourth iteration and ranked as “GOOD” because they did not contain coniferous trees (NLCD grid code 42). The third iteration is not displayed because all sites contained sufficient deciduous forest (NLCD grid code 41).
PRIME (sites that meet all of the user defined parameters)

The remaining 3550 sites were ranked as “PRIME” because they met all of the defined habitat characteristic standards in the model. These remaining sites are displayed in Figure 12.

Figure 12. All of the “PRIME” habitat for the Ruffed Grouse within the NYSDEC Region 8 boundary. These sites contained all of the needed characteristics for Ruffed Grouse as defined by the model and literature parameters.

Data Verification

Figure 13 displays the eBird sightings of Ruffed Grouse from 2011-2017 (Sullivan et al., 2009) displayed as red dots on top of “PRIME” and “GOOD” habitat rankings. 458 eBird sightings fell within “PRIME”, 50 sightings fell within “GOOD”, 46 sightings fell within “FAIR”, and 31 sightings fell within “POOR” habitat. The results of the verification analysis are
displayed in Table 5 below. The high percentage of model hits, or sightings that intersected with the model, in the “PRIME” category suggest good model fit for habitat layers used, although 467 eBird points missed the predicted habitat entirely. A sensitivity analysis using the maximum home range from the literature found that 153 of these 467 misses, or sightings that did not intersect with the model, were within an additional 238 m of predicted habitat, indicating potential issues with accuracy of eBird points, accuracy of the 2011 National Land Cover Database, defied model parameters or a conservative home range estimate. These issues are further discussed in the next section.

Due to the high percentage of private land throughout the region, verification through eBird may be sparse in certain areas due to access issues. With this in mind, “PRIME” and “GOOD” sites that did not have a sighting within the area of interest may not indicate that there is an absence of Ruffed Grouse, but an absence of observations. If nearby public lands contain eBird sightings, these private lands would be recommended areas to target additional surveys and observations.

Another issue with using eBird data is that anyone can create an eBird account and report that they saw a Ruffed Grouse. This can lead to potential false sightings impacting model results. Some of the sightings downloaded for use as verification were found to be located in the middle of urban areas or on a street where it would be abnormal habitat for a Ruffed Grouse. Thirty random points from verification misses were examined in detail, and it was found that 70% of these misses were associated with land covers not considered ideal habitat by the literature (cropland, urban, and wetlands). 100% sighting accuracy when using open source data is unrealistic, but eBird does represent the most viable source of verification data for this project.
Figure 13. Comparison of eBird Ruffed Grouse sighting reference data (red dots) with “GOOD” and “PRIME” sites.

Table 5 displays the number of eBird sightings per rank as well as the number of sites that contained a Ruffed Grouse sightings. Sightings were determined based on reported eBird locations (Sullivan et al., 2009). The total number of sightings that intersected the model was 585.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Sightings</th>
</tr>
</thead>
<tbody>
<tr>
<td>“PRIME”</td>
<td>458</td>
</tr>
<tr>
<td>“GOOD”</td>
<td>50</td>
</tr>
<tr>
<td>“FAIR”</td>
<td>46</td>
</tr>
<tr>
<td>“POOR”</td>
<td>31</td>
</tr>
<tr>
<td>MISSED THE MODEL</td>
<td>467</td>
</tr>
</tbody>
</table>
Ownership Status

Ease of access to the sites that were determined to be of high conservation focus ("GOOD" and "PRIME") is considered to be important when looking at the areas from a land and habitat conservation standpoint. Public lands owned by the state (Wildlife Management Areas, Parks, etc.) are easier to gain access to, especially if the conservation efforts are headed by state run agencies such as the NYSDEC. Private lands would not be quite as easy to gain access to due to permission from a multitude of different owners that may or may not be willing to allow their land to be altered or accessed. Table 6 displays the statistics for public vs. private lands.

Table 6 displays the total number of sites that contained private land per rank (based on the NYS Parcel Database centroid points). The private land percentage of each rank is displayed as well.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Total Sites</th>
<th>Private</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;PRIME&quot;</td>
<td>3550</td>
<td>3363 (95%)</td>
</tr>
<tr>
<td>&quot;GOOD&quot;</td>
<td>3543</td>
<td>3386 (96%)</td>
</tr>
<tr>
<td>&quot;FAIR&quot;</td>
<td>1462</td>
<td>1373 (94%)</td>
</tr>
<tr>
<td>&quot;POOR&quot;</td>
<td>2492</td>
<td>2373 (95%)</td>
</tr>
</tbody>
</table>
DISCUSSION

This study aimed to identify areas that could be used for future Ruffed Grouse reintroduction seed sites, areas of conservation importance, and to create a habitat suitability model to aid with the location of the areas of importance. If the habitat suitability model was determined to be accurate for this study, then the majority of the eBird reference sightings should hit mostly within the “PRIME” habitat areas. The predicted ownership of the majority of the “PRIME” sites that contained Ruffed Grouse sightings would be public lands, owing to ease of access for the birding community. After the model was completed, to determine if the model was accurate, and to assess the predictions, as well as address the project goals, all of the sites were analyzed based on indicators of conservation importance using literature-derived habitat parameter requirements, presence or absence of eBird sightings, and ownership status.

Model Accuracy

1052 eBird points were obtained for verification purposes within the AOI. Of the 585 (56% of total) sightings that hit the predicted habitat, 458 (78% of hits) of these sightings fell within “PRIME” sites. If “GOOD” sites are also considered (those needing only coniferous forest), this number increases to 508 (87% of hits), and if “FAIR” sites are included as well (those needing a water source, which could be present, but not detected such as puddles and small creeks) this number further increases to 554 (95%).

To address the 467 (44% of total) eBird sightings that missed the model, a sensitivity analysis was conducted using the maximum literature derived home range of a female Ruffed Grouse (91.2 ha) (Fearer, 1999). This home range results in a 538 m home range buffer, an additional 238 m beyond the original 300 m average home range buffer used for the model. The
additional 238 m captured an additional 153 eBird sightings, which increased the total eBird sightings that hit the model to 738 (70% of the total eBird sightings). Of the additional 153 sightings, 113 were within 238 m of “PRIME” sites, 21 were within 238 m of “GOOD” sites, 11 were within 238 m of “FAIR” sites, and 8 were within 238 m of “POOR” sites. By adding the eBird sightings that were captured by the additional 238 m, rank totals increased to: 571 (77% of hits) within “PRIME”, 71 (10% of hits) within “GOOD”, 57 (8% of hits) within “FAIR”, and 39 (5% of hits) within “POOR”. The results from this sensitivity analysis, as well as the results from the original model suggest that the habitat suitability model created for this study is generally accurate, but parameters may need ranges, rather than absolute values, to account for parameter uncertainty. Figure 14 shows the steps used to derive model accuracy using eBird sightings.

Figure 14. Flow chart displaying the steps and process in which the model was assessed for accuracy using eBird verification data.
Conservation Focus Based on Ranks

After the model was determined to be accurate, each rank was defined in terms of conservation importance to aid with identifying areas of conservation importance within NYSDEC Region 8.

“PRIME”

Prime areas were areas that met all of the producer defined habitat characteristic requirements. These areas would be also of high conservation importance because they would be areas that could be used for reintroduction sites, if eBird records show no observations. These sites also are areas that could currently contain a viable, unobserved population of Ruffed Grouse. A viable population of Ruffed Grouse to be introduced within the “PRIME” sites would be 2 males to 5 females per 28.44 ha (modified from the 4M to 10F per 100 ha) (Woolf and Adams, 2003). Keeping these areas would be the least cost and effort because there is no restoration required, but would be very important to maintain. 3550 sites fell into this rank, and 458-571 eBird sightings hit the model within “PRIME” sites, depending on the home range used.

“GOOD”

Sites that were given the rank of “GOOD” would be relatively easy to convert into “PRIME” areas by simply planting coniferous trees, which would cost less than converting the “POOR” and “FAIR” sites. These “GOOD” areas would be of high conservation focus along with the “PRIME” areas. Priority should be given to sites connected to the fringe of “PRIME” areas, or areas isolated from “PRIME” containing eBird sightings, or areas of sparse “PRIME” habitat to improve habitat extent. Increasing contiguous “PRIME” habitat could present an increased number of sites that could support viable Ruffed Grouse populations (see viable
population ratio above). 3543 sites fell into this rank, and 50-71 eBird sightings hit the model within “GOOD” sites, depending on the home range used.

“FAIR”

Sites ranked as “FAIR” would require less effort to restore than commercial or residential areas, but are still of higher cost due to the need to add in water resources, compared to sites that were ranked as “GOOD” or “PRIME”. It would be easier to create a water source, such as an artificial pond or a mitigation wetland, than it would be to completely renovate areas that were previously commercial or residential areas. 1462 sites fell into this rank, and 46-57 eBird sightings hit the model within “FAIR” sites, depending on the home range used.

“POOR”

Sites ranked as “POOR” would be difficult to restore, due to the presence of established commercial and residential areas. Roads, traffic, landscaping, and landscape modifications, and the presence of humans all act as barriers for this species. With this in mind, sites that are ranked as poor would not be considered important for conservation purposes. 2492 sites fell into this rank, and 31-39 eBird sightings hit the model within “POOR” sites depending on the home range used.

PRIVATE vs. PUBLIC

The model results showed that 96% (187,805 ha) of the “GOOD” and 95% (183,211 ha) of the “PRIME” sites contained privately owned property, leaving 4% (9945 ha) of “GOOD” and 5% (8369 ha) of “PRIME” areas publicly accessible. Of the 89 sites that contained a Ruffed
Grouse sighting, 45% (2484 ha) fell within public lands, leaving 55% (2759 ha) of the “PRIME” sites on private lands that contained sightings. The percentage of public land was less than expected for this study, but adds to the importance of considering ownership for future conservation focus. The conservation of shrubland habitat requires habitat maintenance (such as selective cutting, logging, planting, etc.). These practices, within public land only, will limit expansion and creation of new viable habitat for Ruffed Grouse as well as other species that inhabit shrubland and early successional habitats to the within the 18,314 ha of publicly available “PRIME” and “GOOD” sites.

Although areas that are public or state owned would be areas of easy access for conservation efforts and would have minimal barriers to implementing conservation practices, gaining access to expand conservation practices on private lands is of high enough importance that government entities will offer incentive packages to landowners who choose participate with conservation efforts (Goldstein et al., 2006). Yet enticements such as incentives and financial reimbursement offer challenges such as upfront costs, limited funding from the government, and some uncertainty of whether or not the projects will ultimately prove to be effective (Goldstein et al, 2006).

Due to these barriers and potential financial costs of conservation on private lands, it is important to reach out and educate private landowners about the positive potential of conservation projects. Landowners who witness environmental conservation progress on land offered for conservation efforts are more likely to communicate positively with other landowners, as well as to continue such efforts, in comparison to landowners that do not see any progress (Farmer et al., 2017). With this in mind, it is important to focus on lands that will have a higher likelihood of succeeding, and the model results can help guide selecting target areas.
Some of the highlighted areas in the next section were user-identified areas that could yield high potential for Ruffed Grouse habitat conservation on private, as well as public lands. These areas were identified based on current Ruffed Grouse sightings, large fragmented quantities of public land separated by private land, conservation cost, and future conservation potential.

**Visual Analysis of Specific Areas Within the Region 8 Boundary**

Within the New York State Department of Environmental Conservation Region 8, four areas of identified conservation importance, as well as areas that were of particular interest were identified due to correlation between sightings (or lack thereof), “PRIME” or “GOOD” habitat (or lack thereof), and presence of DEC lands. In Figure 15, discussion areas were identified based on size, for example the southernmost box was named Area A (smallest), and the easternmost box Area D (largest).
Figure 15 shows “PRIME” and “GOOD” sites, verification eBird data, and major areas that are publicly owned. This helps illustrate the amount of potential habitat in private holdings as well as display areas of defined focus.

Area A illustrates an area of conservation importance because it has separate pieces of state lands with private lands in between. The area also falls within “PRIME” habitat. The privately owned land that falls between the two pieces of public land could be managed to be a wildlife corridor for Ruffed Grouse to travel if constructed properly. The creation of wildlife corridors is a conservation practice that connects, or links, larger areas of important habitat through the management of forest, or creation of new habitat between the large habitats (Lees and Peres, 2008). If properly managed, these areas could create safe passage for multiple species.
within the areas of focus. Much like other conservation practices, management of these corridor areas is important as well; deteriorating corridors are less effective (Lees and Perez, 2008).

Within the private land in Area A below (Figure 16), there are no current Ruffed Grouse sightings, which could be because no one observed any Ruffed Grouse, birders did not have access to these areas, or there were no Ruffed Grouse seen during surveys in this area. If wildlife corridors were created (more “PRIME” habitat) in this area, Ruffed Grouse could have access to larger pieces of “PRIME” areas.

Figure 16. Area A illustrates a region with “PRIME” and “GOOD” habitat intersecting with DEC managed areas surrounded by private lands. Areas that are blue are areas that are public, any other land besides blue areas are privately owned. This area is of importance because it could be a potential corridor between two areas of DEC lands if properly managed.
Areas B (left) and C (right) (Figure 17) follow the similar pattern of A, where they are sections of public lands with private land separating the pieces (potential wildlife corridor). The difference between B, C, and A is that both B and C have Ruffed Grouse sightings in the “PRIME” habitat that is privately owned. In order to keep the current population of Ruffed Grouse within this area, and areas similar with a high concentration of Ruffed Grouse sightings on private lands, owners need to be educated and encouraged to follow management practices mentioned in the NYSDEC Young Forest Initiative (NYSDEC, 2016) to conserve shrubland and early successional habitats. Without proper management on these areas, shrubland and early successional habitats will age and lose the ability to support a healthy Ruffed Grouse population.
Figure 17. Areas B (left) and C (right) are surrounded by both “PRIME” and “GOOD” habitat and, if properly managed on the private lands, the public lands could be connected through wildlife corridors expanding viable contiguous habitat for Ruffed Grouse.

Area D (Figure 18) is different from all of the other areas in that it has very little DEC WMA lands (at least in the database), but has a large quantity of other publicly owned lands surrounded by private land with Ruffed Grouse sightings within “PRIME” areas. Area D is significant due to the high concentration of Ruffed Grouse Sightings within this public land. In order to maintain the viable habitat that is supporting this Ruffed Grouse population, management practices mentioned in the introduction as well as in the NYDEC Young Forest Initiative (NYSDEC, 2016) should be implemented. Area D also shows how “PRIME” sites in the model lined up will with the sighting data.
Figure 18. Area D. Teal circles are ArcGIS Pro generated approximate buffer boundaries for the non-DEC owned lands that are still public. Surrounding this area is a large number of private lands with few sightings. The model lined up well with the sighting data here in Area D.

Population Viability

When considering reintroduction of Ruffed Grouse to the areas above, as well as throughout the region, the minimum ratio (population viability) is 4 males to 10 females per 100 ha (Woolf and Adams, 2003). A generated “heat map” (Figure 19) displays areas of high eBird sighting density aligning well within “PRIME” sites, public land, as well as within the Areas of Conservation Importance (ACOI) A, B, C, and D. This high eBird sighting density within all of the identified AOCIs, “PRIME” sites, and public lands suggest that these areas currently contain
a viable population of Ruffed Grouse and that the areas have enough viable habitat support Ruffed Grouse populations.

Figure 19. A heat map that shows the density of Ruffed Grouse sightings in relation to “PRIME” sites, public lands, and the identified Areas of Conservation Importance. All of the Areas of Conservation Importance have a “cloud” of Ruffed Grouse sightings within their boundaries. Other high-density areas suggest a presence of a viable population of Ruffed Grouse. Areas of public lands also correlate with the sighting density “clouds”, suggesting that birders generally report sightings within public lands.
Contiguous “PRIME” sites surrounding the “clouds” within the heat map would also be areas to potentially target for Ruffed Grouse reintroduction, given there is enough viable habitat (100 ha) to support a population of 14 Ruffed Grouse (4 males to 10 females ratio). Satellite, non-contiguous “PRIME” sites would not be of high priority, even though they could potentially support 7 Ruffed Grouse (2 males to 5 females ratio), unless additional “PRIME” habitat (converted from “GOOD”) can be introduced to create contiguous 100 ha habitat for increased population numbers.

Possible “PRIME” Habitat Expansion: “GOOD” to “PRIME”

There are large quantities of area that are classified as “PRIME” habitat that have connecting or nearby “GOOD” habitat areas. These areas could be converted into “PRIME” by introducing coniferous forest by planting conifer trees. By doing this, the “PRIME” habitat areas could be expanded to the necessary 100 ha needed to support a viable Ruffed Grouse population (mentioned above), as well as provide essential winter habitat for Ruffed Grouse (Caron, 2009). Figure 20 below displays possible expansion.
Expansion of “PRIME” habitat from “GOOD” areas that are otherwise devoid of viable habitat (“GOOD” sites that are not connected, or contiguous with “PRIME” in Figure 20) may not prove to be quite as effective, with regards to wildlife population retention or reintrogression, in comparison with “GOOD” areas that are connected or contiguous with “PRIME” areas. So, it may be most effective to focus coniferous planting efforts to contiguous areas with known sightings, at least initially.

Although planting coniferous trees to convert “GOOD” to “PRIME” sites to expand wildlife habitat may seem like a simple fix, 96% of these “GOOD” areas contain privately owned lands. Without cooperation from private landowners towards projects such as the
NYSDEC Young Forest Initiative (NYSDEC, 2016) within areas that have potential for habitat expansion, as well as within areas A, B, C, and D, the “PRIME” habitat areas could be lost, expansion of current “PRIME” habitat would not happen, and the potential for success would decrease.

Limitations and Errors

Although this model seemed to correlate fairly well with the eBird verification points, and was concluded to be accurate, there were a few limitations and errors that were encountered throughout the project as well as ways to improve the analysis. Some of the more critical limitations and errors included: 1) a limited amount of usable verification data (actual observations as well as spatial distribution), 2) gaps in the verification data where there were no reported sightings at all, 3) an average home range estimate was used, rather than a maximum reported home range value potentially capturing fewer reported eBird Ruffed Grouse sightings within the model, 4) too tight or too loose of habitat constraints were used that resulted in either excluding sites that should not have been or including sites that should not have been, 5) the National Land Cover Database may not be completely accurate, compounding omission and commission errors in the model, and 6) the conflict between private and public land conservation.

Of the 1052 total reported eBird sightings within the region, 314 missed the model entirely even with the addition of the sensitivity analysis. After the investigation of 30 sightings that were not within the additional 238 m beyond the original 300 m home range buffer radius, results suggest that errors mentioned in this limitations section could have resulted in these sighting misses. Of the 30 investigated sightings, 6 were within agricultural fields, 6 were within
residential areas, 9 were within wetland areas, 8 were within areas that did not have the required 1.1 ha minimum shrubland plot size, and 1 was just beyond the additional 238 m buffer. Based off the literature: the 12 total sightings that were within agricultural fields and within urban areas would most likely be eBird database errors (Ruffed Grouse tend to avoid urban and agricultural areas); the 9 sightings that were within wetland areas could be due to misclassification by the NLCD (contains no shrubland-wetland category); the 8 sightings that were within areas that did not have a contiguous 1.1 ha of shrubland could have been captured by the model if the initial habitat patch size requirement was decreased. The single sighting that fell outside the additional 238 m expanded home range represents a miss for a variety of reasons. Each limitation found during the further investigation of the 30 eBird sites that missed the model entirely, as well as the limitations and errors for this project are examined below.

1) Limited Amount of Usable Verification Data: Accuracy With eBird

During the analysis, limited verification data of Ruffed Grouse sightings were found. The only readily available verification resource that contained sufficient point data throughout the study area was eBird. Other potential data sources, such as Breeding Bird Survey and NYSDEC hunting logs, did not provide sufficient point data, sufficient spatial resolution, or sufficient coverage to be useful. Hunting logs are not reported with (X,Y) coordinates (flush numbers per Wildlife Management Unit and Ecozone), which does not help in determining predicted site accuracy. The Breeding Bird Survey (BBS) (Pardieck, 2018) routes were limited to only fourteen routes that were not evenly distributed across the region and only three contained at least one Ruffed Grouse sighting. Therefore, BBS did not provide enough data to be useful for this study to verify widely across the NYSDEC Region 8 (see Figure 21).
Figure 21. Total BBS Routes (Pardieck, 2018) in NYSDEC Region 8 (Left) and validated Ruffed Grouse Sighting Routes (Right) with relation to shrubland land cover (NLCD code 52). BBS data retrieved from [https://doi.org/10.5066/F76972V8](https://doi.org/10.5066/F76972V8)

With only one sighting verification source, compound accuracy of the model using different sighting resources was not possible.

Because eBird is an open source citizen science database, there are potential identification and spatial accuracy issues. Adding an additional 238 m to the home range buffers improved the model hits from 585 to 738 (70% accuracy). The majority of these hits were within “PRIME” sites (458-571, 508-642 if “GOOD” sites were combined with “PRIME” sites). While this suggests that the model is reasonably accurate, it still leaves 314 sighting “misses”, which a sensitivity analysis indicates are primarily due to verification points within land covers not considered suitable habitat (see beginning of Discussion). These sightings that missed the model beyond the additional 238 m included in the sensitivity analysis could be due to birdwatcher error, National Land Cover Database errors (later in limitations), or model parameter constraints.
(See “Set Home Range” limitation for potential sighting misses due to the set home range; See “Errors in the NLCD” for potential sighting misses due to errors in the NLCD)

2) Gaps in Verification Data

When overlaying the usable eBird point verification on top of the habitat model, there seemed to be areas of low point counts that created gaps in “PRIME” habitat areas that potentially contain Ruffed Grouse sightings. After analyzing the areas that contained few verification points, it was determined that most of these particular areas contained significant private land holdings. Since eBird data originates from birdwatchers, both hobby and experts, most of the eBird sighting data comes from places that are publicly accessible (parks, WMA’s, and state owned lands) and not necessarily from areas of private ownership. Figure 22 illustrates an area with a large number of “PRIME” sites, but little public land within the study area and few reported eBird sightings. In contrast, the NYSDEC lands outside the study area boundary do contain reported Ruffed Grouse eBird sightings (not shown to avoid confusion), indicating that the birds are in the general area. To potentially improve sighting accuracy, and to potentially address this limitation, fieldwork to generate GPS ground truth sighting data could be collected in a future study.
Figure 22 displays an area that contains very few Ruffed Grouse sightings despite the abundance of “PRIME” habitat. This could be due to the density of private ownership in this area, or it could be that there are no Ruffed Grouse in this area. Field study to collect ground truth sighting points could potentially help address this limitation.

3) Set Home Range Parameter

Another factor that could have impacted the model was selecting the 28.44 ha area estimate as the set home range buffer (300 m radius) surrounding the initial seed sites. Due to this home range size, the Region 8 area that was covered by the model was “spotty” and the diversity and quantity of land cover types within the buffer boundaries was limited. This could explain why some of the eBird sightings missed the model. In contrast, if the buffer were set too high, there could have been errors of exclusion or inclusion too early in the iteration-reduction
process, such as residential or commercial areas on the edge of the buffer. Smaller home range constraints could have included more sites from the beginning, as well as excluding fewer sites that had disadvantageous land covers on the perimeter of the buffer during the iteration process, but including too small of a home range would potentially exclude “PRIME” sites and omit eBird sightings. To address the limitation, a sensitivity analysis was completed to determine the quantity of eBird sightings that fell within an additional 238 m outside the initial (300 m) home range seed site buffer (see beginning of Discussion). Simulating a total 538 m home range buffer reflects the largest home range of a female Ruffed Grouse (91 ha) documented in the same article that the average Ruffed Grouse home range was adopted from for this study (Fearer, 1999). Within the additional 238 m, an additional 153 sightings were included in the model totaling 738 (70%) sightings that would have hit the model with this more liberal home range parameter. Future studies could address the limitation by running three sets of home range models (minimum, average, and maximum areas).

4) Too Tight or Too Loose of Habitat Parameter Constraints

Too loose or too tight of habitat parameter constraints could have had a similar effect as too large of a home range. Too loose of habitat parameter constraints could have caused an error of commission, and too tight of parameter constraints could have had errors of omission. This could be an additional reason that eBird sightings missed the model entirely. To address this limitation, a “fuzzy” classification based on assigned habitat parameter weights could be completed, rendering the model less rigid. This is a suggestion for a future study.
5) National Land Cover Database Errors (Landsat Imagery)

Errors in the National Land Cover Database classification as well spatial and temporal differences in the Landsat imagery used to create the 2011 NLCD could have had an impact on the model as well. The distinct line in the shrubland habitat located in the southern portion of the study area appears to be due to spectral differences in the two Landsat scenes from different dates used to generate the 2011 database. Errors of both omission and commission when classifying the land cover could have impacted whether or not sites were excluded or included during the iteration-reduction process. Errors within the Landsat imagery, including cloud cover during data collection, may have had an impact on the National Land Cover Database classification as well. There does appear to be some misclassification of land cover in the 2011 NLCD. Shrubland and herbaceous could be difficult to differentiate between, as well as some shrub-wetlands. The NLCD does not have a land cover code for shrub-wetlands, which could be why the NLCD coded some potential viable shrubland as “wetland”. This limitation could be improved through 2 methods: 1) independently reclassifying the entire NYSDEC Region 8 land cover, or 2) re-run the analysis with a potentially more accurate and up to date land cover database (NLCD 2016) expected to be available late 2018.

6) Private vs. Public Lands

One of the larger limitations to this project is access to land for conservation purposes. Whether or not landowners would be willing to join or follow management guidelines according to the New York State Department of Environmental Conservation Young Forest Initiative (NYSDEC, 2016) is a significant limitation to progress with young forest habitat conservation. As stated previously, 96% of the “GOOD” and 95% of the “PRIME” habitat are privately
owned, leaving 4% of “GOOD” and 5% of “PRIME” areas publicly accessible. Of the 89 sites that contained a Ruffed Grouse sighting, 40 (45%) of them fell within public lands, leaving 55% of the “PRIME” sites that contained sightings, privately owned. This was less than expected for this study, but adds to the importance of considering ownership for future conservation focus.

Figure 23 displays all of the available public land in blue, the rest of the area is considered private.

Figure 23. Public lands within NYSDEC Region 8 displayed in blue. See Table 6 in the Results for the totals per rank.
Future Studies

In terms of initial model input accuracy, a newer National Land Cover Database (2016) is scheduled to be released late 2018. With the updated 2016 NLCD, the model would be more current to existing aerial photos of the region with potentially more accurate classifications. These imagery databases may be able to pick up potential habitat, such as powerline and pipeline right of ways maintained by energy and power companies. Using field verification data in collaboration with eBird sighting data would also aid with increasing accuracy and analysis. An additional future recommendation to further increase sighting accuracy would be to create a “fuzzy” habitat suitability model where, habitat parameter ranges, rather than absolute values (Boolean format), are used to assess an area’s suitability ranking.

Independent Remote Sensing analyses could also be incorporated into this project or in future projects. Presence or absence of shrubland, as well as other habitat characteristics is important, but if they are unhealthy, Ruffed Grouse may not use these areas. Normalized Difference Vegetation Index (NDVI), a remote sensing analysis, helps the user analyze health of vegetation by using the ratio between Landsat bands 4 and 3 (brightness in the image correlates with healthy vegetation). Images from a series of seasonal times would be used to assess plant community health. The model could be further refined past “PRIME” using more habitat requirements such as slope and elevation, and along with the NDVI analysis to exclude sites that were not identified as “healthy”, as well as rank areas higher that were identified as healthy to aid with conservation focus.

Reasons for Ruffed Grouse population decline beyond habitat degradation such as disease, predation, and environmental imbalances could also be investigated to enhance this
CONCLUSIONS

Due to the historic decline in shrubland habitat, and the associated shrubland-dependent species, including the Ruffed Grouse (*Bonasa umbellus*), it is imperative to target conservation efforts towards early successional habitats such as shrubland and young forest. The model created in ArcGIS Pro for this study used an iteration-reduction method based on the presence or absence of literature-derived habitat characteristics was able to identify “PRIME” to “POOR” habitat within NYSDEC Region 8. The model was initially generally consistent with eBird sightings, with a majority within “PRIME” sites, but some missed the model entirely. The results from a sensitivity test suggest that using a maximum home range estimate will increase model accuracy up to 70% from the initial 56%, with 77% of the hits within “PRIME” habitat. Several factors associated with using open source verification data may have reduced the overall accuracy of the model, but the use of eBird sighting data for this model was appropriate considering the initial results. The limitations in the model that could account for the missed sightings could be addressed through additional field study, improved NLCD (2016), and/or an altered method approach that creates a fuzzy model, where habitat parameter ranges, rather than the potentially too restrictive Boolean format used in this model, are used to assess an areas suitability ranking.

The high percentage of private lands that envelop the model presents the largest barrier towards the future conservation implications of this study. Education of private landowners suggesting management strategies with or without access to their land is crucial to the
conservation of the shrubland habitat and the species associated with them, especially since 95% (187,805 ha) of the “PRIME” sites and 96% (183,211 ha) of the “GOOD” sites within this model are privately owned.

Complete focus on private lands is also not necessarily the best approach. Of the 89 “PRIME” sites that contained reported eBird Ruffed Grouse sightings, 45% (2484 ha) were publicly owned, and 55% (2759 ha) were privately owned. These results were lower than expected for public land ownership because birders generally report eBird sightings from public land due to unrestricted access, but this suggests that management should also focus on public lands. Collaboration between both public and private landowners is imperative to the success of preservation of current shrubland and early successional habitat, as well as land management efforts to promote future shrubland habitat throughout the region.

This model suggests that the Areas of Conservation Importance identified within NYSDEC Region 8 could be targeted for future conservation efforts with the goal to preserve shrubland habitat and shrubland-dependent species. With follow-up field verification, a fuzzy model approach, and a more recent version of the NLCD (2016) to address the limitations mentioned in this study, in combination with additional research regarding factors beyond habitat degradation that impact the decline in the populations of shrubland-dependent species, this model could be recreated with potentially increased accuracy, and possibly used to aid with targeting conservation efforts at a larger scale.
REFERENCES


