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Department of Environmental Studies

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The Impact of "Forestry for the Birds" Management on the Avian Community at Kensan-Devan Wildlife Sanctuary in Marlborough, NH after the First Year

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The Impact of "Forestry for the Birds" Management on the Avian Community at Kensan-Devan Wildlife Sanctuary in Marlborough, NH after the First Year

A Thesis

Presented to the Department of Environmental Studies

Antioch University New England

In Partial Fulfillment

Of the Requirements for the Degree of

Master of Science

By Chad J. Witko

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DEDICATION

This work is dedicated to the countless wild birds I have encountered in my lifetime. From them I have been given a lens to view the world, purpose to my actions, and wings for my dreams.

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This thesis would not have been possible without the love, support, and encouragement provided from several key people. I would first like to thank my thesis advisor, Liz Willey, for her continuous support throughout the process of my thesis and my time at Antioch University. I am particularly grateful for her patience and understanding as I pushed through personal and academic barriers. I would also like to express my thanks to Pam Hunt who served as the sole external committee member for my thesis and provided necessary commentary throughout.

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ABSTRACT

Nearly a quarter of all temperate forest bird species in North America are in a state of high conservation concern, many the result of habitat alteration. Since 2008, "forestry for the birds" programs have been developed across New England to manage habitat for birds, integrating timber harvest and songbird management schemes. During the winter of 2016-2017, the Ecosystem Management Company implemented the first in a series of timber harvests at New Hampshire Audubon's Kensan-Devan Wildlife Sanctuary aimed at improving forest habitat for both early-successional and mature forest-breeding bird species. During the summers of 2016 and 2017, an intensive point count study was conducted to assess the avian community at Kensan-Devan. The two objectives of this study were to obtain baseline knowledge on the entire breeding avian community and to assess the impact of forestry on the forest bird community in the first-year, post-harvest. To achieve these objectives, the avian community was assessed at 45 point count stations, including a series of points that fell within forestry-treated zones. Measurements of abundance, relative abundance, and species diversity were then analyzed through paired *t*-tests to evaluate any changes in the first-year post-harvest. During the study, overall abundance of the avian community at the sanctuary decreased while species diversity exhibited no significant change. Forest bird species targeted for management experienced no significant change in abundance in the first year. Ovenbird (*Seiurus aurocapilla*), the sanctuary's most abundant species, experienced significant decreases across the sanctuary while Red-eyed Vireo (*Vireo olivaceus*), the sanctuary's second-most abundant species exhibited significant decreases in the section receiving forestry management only, and these changes in the two most abundant species likely drove changes in the overall abundance metrics. Due to the short term and limited scope of the study, it is not possible to assess whether observed differences were due to annual fluctuation or forestry practices over the first year, though the target forest birds did not

appear to be negatively affected by forestry in the first year. Long-term studies should be conducted on the avian community at Kensan-Devan Wildlife Sanctuary in order to evaluate the impact of forestry at this site over time, and the results of this thesis can be used as a reference point to assess potential changes.

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INTRODUCTION

Birds are among the most well-studied vertebrates on Earth with an estimated 95% of their biodiversity having been described (Barrowclough et al. 2016). Globally, some 10,585 species of birds are recognized in *The Clements Checklist of Birds of the World (v2018)* and are found in nearly every ecosystem on Earth (Clements et al. 2018). As members of these ecosystems, birds provide ecological services critical to the health of our planet, ecosystem stability, and human well-being, including pest control, weed seed control, disease control, seed dispersal, pollination, and nutrient cycling (García & Martínez 2012; Mikusinski et al. 2018; Whelan et al. 2015).

Birds also serve as ecological indicators for the environments they inhabit, particularly at broad scales and during the extremes of habitat degradation (Bradford et al. 1998; O'Connell et al. 2000). By collecting and analyzing data on avian ecology, researchers and conservation biologists may save considerable resources when compared to researching other ecological processes or biota that are difficult to study or costly to measure (Pérez-García et al. 2016).

Regrettably, many species of birds are declining across their ranges. According to the 2016 *State of the Birds Watch List*, some 37.4% (432 species) of native birds found across Canada, the continental United States, and Mexico were noted as needing urgent conservation action and categorized above the threshold for "high concern" (NABCI 2016). In the United States alone, 230 species of birds, approximately 25% of the native avifauna, were listed on the 2014 *State of the Birds Watch List* as "presently endangered or at risk of becoming endangered without significant conservation action" (NABCI 2014).

In New Hampshire, 191 species of breeding birds can be found across diverse habitats, from Saltmarsh Sparrows (*Ammodramus caudacutus*) nesting just above the high tide line along the Seacoast region to American Pipits (*Anthus rubescens*) above timberline atop Mount

Washington (Hunt 2009). Unfortunately, many are experiencing similar trends as native avifauna across the country with 42% (81) of New Hampshire’s breeding species in a state of decline and another 9% (18) having unknown status (Hunt, P., personal communication, August 21, 2019).

Located in the heart of the Atlantic Northern Forest, which spans from the Adirondack Mountains of New York to the Maritime Provinces of Canada, New Hampshire hosts some of the best remaining breeding habitat for forest birds in this region. Providing a meta-population source for many species, the forests of New England are globally significant to many breeding species of neotropical migrant birds (AVVDFPR 2012; Hunt et al. 2011). According to the *Managing Your Woods with Birds in Mind*, the northern forests are home to the highest concentration of bird species breeding in the continental United States (AVVDFPR 2012). If the prairie pothole region is the “duck factory” of the United States, then the forests of Vermont, New Hampshire, and Maine are the “breeding bird factory” for countless species of thrushes, vireos, and warblers (Ballard et al. 2014; McLean et al. 2016).

Not surprisingly, New Hampshire’s forest birds are facing many of the same threats that forest birds experience on a global scale. These include chemical pollution, pesticides, invasive species, acid deposition, and climate change (Birdlife International n.d; Hunt et al. 2011). However, no threat contributes to their decline as much as habitat alteration with habitat destruction, degradation, and fragmentation being perhaps the largest contributors to the decline of forest bird species (AVVDFPR 2012; Hunt et al. 2011; Lichstein et al. 2002; Maine Audubon 2017). For neotropical migrant species, this is particularly concerning as they are thus subject to full-annual-cycle threats imposed by habitat destruction across large geographic ranges and many geopolitical entities including those on the breeding grounds, at stop-over sites, and on the wintering grounds, an area of their lifecycle that is often overlooked.

Over the last 300 years, New Hampshire has witnessed drastic anthropogenic alterations to the landscape with fluctuations back and forth between forested and pastoral settings. By 1840, approximately 75% of New England's landscape had been converted from mature forests to open fields for agricultural use and sheep pasture (Wessels 1997). This was beneficial for grassland and early successional species, providing thousands of hectares of suitable habitat, but detrimental for forest breeding species at that time. By 2005, 89% of New Hampshire's landscape was covered by forests once again, the most forest cover of any continental state in the Lower 48 (Nowak & Greenfield 2012).

However, much of this reestablished forested habitat is now fragmented as a product of urbanization, and long-distance Nearctic migrants such as the Wood Thrush (*Hylocichla mustelina*) and Ovenbird (*Seiurus aurocapillus*) are being negatively impacted on the breeding grounds (Lampila et al. 2005). In the case of the Wood Thrush, one consequence of forest fragmentation is decline due to nest parasitism by Brown-headed Cowbirds (*Molothrus ater*), which are otherwise found in more open habitats Phillips et al. 2005). White-tailed Deer (*Odocoileus virginianus*), whose populations are artificially high across fragmented landscapes are also a major contributing factor in the decline of many of our native songbirds. The resulting deer browse, so evident in many of our forests with exceedingly high deer populations, directly impacts food resource availability and nest site quality, factors that ultimately negatively impact bird abundance (Allombert et al. 2005; Chollet et al. 2015; Tymkiw et al. 2013). Despite these trends, with proper management, the forests of northern New England can play a critical role in providing the life requisites of forest-breeding birds while alleviating limiting factors (Klaus et al. 2005).

In 2008, the Foresters for the Birds conservation project was introduced in the state of Vermont (Maine Audubon 2017). Established through a partnership between Audubon Vermont and the Vermont Department of Forests, Parks, and Recreation, it aimed to integrate timber and songbird management schemes into a singular conservation model to maintain and manage forestlands while keeping common species of forest birds common (Audubon Vermont n.d.a). Through dynamic partnerships between environmental researchers, foresters, and landowners, highly collaborative work, and interdisciplinary approaches, Foresters for the Birds has become a guiding resource in the realm of forest-based avian conservation within the region, being shared with hundreds of foresters and landowners (Maine Audubon 2017). Furthermore, many landowners participating in "forestry for the birds" efforts are now realizing that this form of conservation can offset the costs of land ownership from the sale of timber, providing a supplemental, yet critical type of incentive to join such programs (AVVDFPR 2012; Maine Audubon 2017).

Seeing the success of the Foresters for the Birds program and understanding the need to improve existing forests as an essential component of conservation, similar projects were started throughout neighboring states in New England (Bakermans et al. 2012). For example, Maine Audubon's Forestry for Maine Birds program, which published the technical guide, *Forestry for Maine Birds: A Guidebook for Foresters Managing Woodlots "With Birds in Mind"* (Maine Audubon 2017) was established in 2017. It was around this time that New Hampshire Audubon (NHA) also began studying the impact of forestry on both forest and early-successional birds within their sanctuary system, starting first with the Kensan-Devan Wildlife Sanctuary. In August 2015, the *Forest Management Plan for the New Hampshire Audubon Kensan-Devan Wildlife Sanctuary* was prepared by The Ecosystem Management Company (TEMC) of New

London, New Hampshire. The 171-page document outlines everything from property attributes, natural communities, and anthropogenic land-use histories to forest management approaches and operational considerations and objectives.

As outlined in the forest management plan, the objectives of NHA were multiple, multifaceted, and interrelated. These objectives included responsible stewardship, protection of water and wetland resources, managing for sustainable production of quality wood products to generate income for NHA, providing wildlife viewing opportunities, and providing education and interpretation resources for the public (TEMC 2015). Most importantly among these was the objective to “Maintain, protect, enhance and create bird habitat, especially: Protect interior forest habitat, create early successional habitat, [and] protect interior forest wetlands” (TEMC 2015). To achieve these objectives, habitat management at the Kensan-Devan Wildlife Sanctuary included the following considerations to account for the needs of multiple species: vegetative species composition, edge habitat, understory vegetation, midstory vegetation, coarse and fine woody material, snags and cavity trees, perch trees, deciduous leaf litter, canopy height, canopy closure, and the various streams, wetland, and riparian systems throughout the sanctuary (TEMC 2015).

Most of the management decisions for this property from TEMC were based, in part, on the guidelines created by Audubon Vermont to manage forestlands while keeping birds in mind. Although initially developed for Vermont, many of the guidelines within the Audubon Vermont *Forest Bird Initiative* are transferable to parts of New Hampshire, particularly, the southwestern part of the state where the Kensan-Devan Wildlife Sanctuary is located. Among these management guidelines was the adoption of “The Birder’s Dozen”- 12 species among 40 forest birds that: 1) have a high percentage of their global breeding population in the Atlantic Northern

Forest, 2) use a variety of forest types and conditions for different life history requirements, 3) exhibit critical long-term declines within their global populations, and 4) are easy to identify by sight and sound (Audubon Vermont 2013).

Of the 12 species that make up the Birders Dozen, eight were selected by NHA as targets for management, along with Eastern Towhee, and presented in the *Forest Management Plan for the New Hampshire Audubon Kensan-Devan Wildlife Sanctuary.* The nine target species were believed to be linked to the type of habitat that is not only currently available at the Kensan-Devan Wildlife Sanctuary but also meets the management objectives of NHA for the site. They included: 1) Eastern Wood-Pewee (*Contopus virens*), 2) Blue-headed Vireo (*Vireo solitarius*), 3) Wood Thrush, 4) Eastern Towhee, 5) Chestnut-sided Warbler (*Setophaga pensylvanica*), 6) Black-throated Blue Warbler (*Setophaga caerulescens*), 7) Black-throated Green Warbler (*Setophaga virens*), 8) Canada Warbler (*Cardellina canadensis*), and 9) Scarlet Tanager (*Piranga olivacea*) (TEMC 2015).

In March 2016, NHA supported the inception of this thesis, which had two main research objectives: 1) to establish baseline knowledge of the avian community at the sanctuary through a series of point count stations in 2016, and 2) to analyze the impact of forestry on the forest-breeding bird community, particularly NHA's suite of target species, which took place during the winter of 2016-2017. For the latter, the analysis on the impact of forestry is strictly limited to the first year through the same series of point count stations in the summer of 2017. It should be noted that the avian response to active forestry takes at a minimum 3-5 years for early-successional species in patch cuts and up to 16 years for mature-forests (Duguid et al. 2016; Perry et al. 2018). Given the timing of management, we expect that the abundance of mature-forest species may decline in the first-year post-harvest whereas early-successional species will not yet be present due to the limited length of time since harvest.

METHODS

Study Area

The Kensan-Devan Wildlife Sanctuary is a 231-hectare (ha) property in Marlborough, New Hampshire, USA, located 8.9 kilometers to the east-southeast of Keene in the heart of the Monadnock Region (Figure 1). It is comprised of seven different lots existing over two distinct, non-contiguous sections, including the Meetinghouse Pond section (111-ha) to the west and the Hunt Road section (120- ha) to the east (TEMC 2015).

Ranging in elevation from 335 meters along Meetinghouse Pond to 414 meters within the Hunt Road section, the Kensan-Devan Wildlife Sanctuary is dominated by south and west facing aspects providing a landscape favoring tree species that persist on warmer sites such as Northern Red Oak (*Quercus rubra*) and Eastern White Pine (*Pinus strobus*). (TEMC 2015). However, the lower terrains are not as well-drained and tend to hold some of the larger stands of Eastern Hemlock (*Tsuga canadensis*) within the sanctuary.

Like so many of the properties and parcels that subdivide New Hampshire's landscape, Kensan-Devan has a long and storied history of both land use and ownership. From the heavily forested landscape of the early 18th century to the open farmland of the mid-19th century, Kensan-Devan experienced significant changes to its natural vegetative communities much the same as many other New England locations have over the past three centuries. While the anthropogenic history of the sanctuary's land dates to the Native Americans of the Monadnock Region, it is the post-colonization and contemporary use and ownership of these lands that have most greatly shaped the sanctuary boundaries and natural communities into what they are today (TEMC 2015).

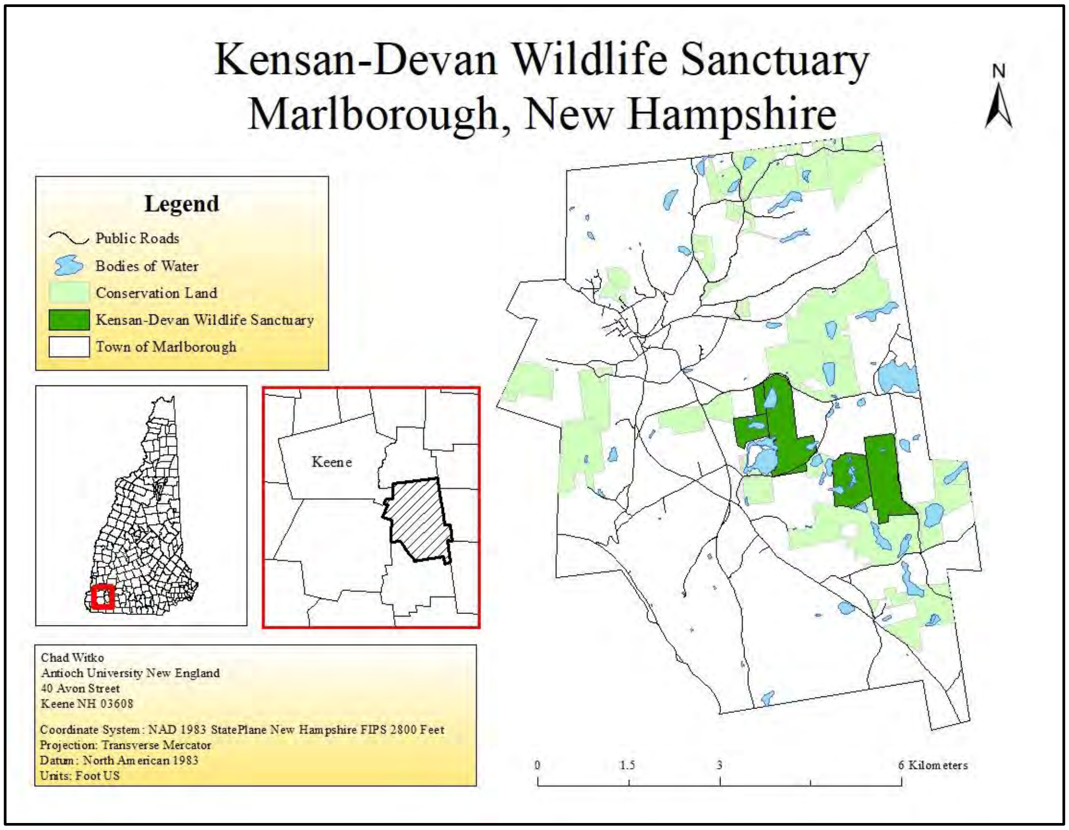

Figure 1. Locator map for Kensan-Devan Wildlife Sanctuary. Map shows the area of interest in the context of Marlborough, NH. Within the sanctuary, the Meetinghouse Pond section is the western parcel, while the Hunt Road section lies to the East. Unless otherwise noted, all map base layers were retrieved from the New Hampshire Geographically Referenced Analysis and Information Transfer System (NH GRANIT).

Starting with European settlers during the 1760s, recorded history for Kensan-Devan indicates that this area of Marlborough was first subdivided into 50 separate parcels, most of which were eventually cleared for agriculture and timber (TEMC 2015). By 1801, the land that would become the sanctuary, owned by the local ministry and school, was divided into three lots and sold (TEMC 2015). As was standard during the early- to mid-1800s, agriculture and livestock, particularly sheep, dominated these new clear-cut parcels. This would be a contributing factor to the eventual shaping of Kensan-Devan's natural communities, along with the natural communities of the surrounding landscape.

During the first half of the 19th century, nearly 75% of central New England's forested landscape was converted to open pasture for sheep to support the production of merino wool during the famed sheep boom (Wessels 1997). Evidence of this land use history can still be found at the sanctuary in the form of several large pasture trees, resultant from pasture succession, including one Eastern Hemlock dating back to 1845, and the presence of stone walls built around 1800 (New Hampshire Audubon 2016). Eventually, the sheep boom which shaped the forested New England landscape into a pastoral setting during the early1800s began to disappear and by the 1840s, sheep-farms were abandoned in earnest (Wessels 1997). A half-century later, as the result of natural succession, these pasturelands were soon growing back to forests, and by the early 1900s, extensive logging was taking place on the large legacy pines that dominated the overgrown pastures and fields of Kensan-Devan (TEMC 2015). Since then, over the last 100 years, the land that would comprise the Kensan-Devan Wildlife Sanctuary would see less active management and logging, and the forest progressed into its current state of natural communities (TEMC 2015).

Between the 1980s and the early 2000s, NHA procured the tracts and parcels that make up the Kensan-Devan Wildlife Sanctuary as it now stands (TEMC 2015). In 1986, a core piece of land making up the Meetinghouse Pond section was offered via the generous support of Marlborough resident, Cia Devan (New Hampshire Audubon 2016). This donation helped to form the original 68-ha sanctuary and was the integral first parcel acquired by NHA which was added onto in subsequent years.

Aside from the 231 hectares, which are conserved within Kensan-Devan itself, the sanctuary is nestled within a matrix of several thousand hectares of minimally fragmented conserved forestland within the Monadnock Region (TEMC 2015). Bordering Kensan-Devan and Meetinghouse Pond is land owned by the town of Marlborough and the Monadnock Conservancy in the form of easements and fee-owned parcels. Additionally, the New England Forestry Foundation holds easements for land in the nearby town of Dublin while the Society for the Protection of New Hampshire Forests owns and manages nearby Monadnock Reservation, just a few kilometers away (TEMC 2015).

Anthropogenic land use and ownership are among the leading influences upon the existing natural communities of Kensan-Devan, shaping how they are ultimately expressed over the short-term. However, it is the biophysical environment—climate, geology, and soils— that primarily determines the initial distribution of plants and their subsequent communities across the landscape and their long-term status (Sperduto & Kimball 2011). Weather conditions have been measured annually across the region since the late 1800's. Classified as cool-temperate, the average annual high temperature for Keene, New Hampshire (1893-2018), based on a weather station 13.7 kilometers to the northwest of Kensan-Devan, is 14.4°C with an average annual low temperature of 1.1°C (Sperduto & Kimball 2011). Annually, temperatures peak during the summer month of July, with an average high temperature of 28.2°C. Conversely, the temperature drops to an average low of -11.8°C in January. Average annual precipitation (non-snow) is 104.2 centimeters (cm) while annual snowfall is 157.5 cm (NRCC 2017).

Soils, the substrate from which natural vegetative communities grow, is the result of bedrock and surface deposits following the retreat of glaciers and the subsequent geophysical breakdown of them due to the actions of water, flora, and fauna (Sperduto & Kimball 2011). At Kensan-Devan, most of the forest soils belong to Forest Groups IA and IB as determined by the Natural Resources Conservation Service (NRCS) (TEMC 2015). These soil groups tend to favor a series of successional plant species that trend towards climax-stands of shade-tolerant hardwoods due to the deeper, loamy, well-drained soils (TEMC 2015). These soils are extremely supportive of the hardwood community that is present at Kensan-Devan, including Sugar Maple (*Acer saccharum*), Red Maple (*Acer rubrum*), American Beech (*Fagus grandifolia*), Gray Birch (*Betula populifolia*), White Birch (*Betula papyrifera*), and Northern Red Oak. Some of the indicator species within the hardwood forests of the site include: White Ash (*Fraxinus americana*) and Yellow Birch (*Betula alleghaniensis*), indicating rich and/or moist soil and substrate. Softwoods are generally less abundant at Kensan-Devan, mixing in with the hardwood stands in varying combinations, and primarily include Red Spruce (*Picea rubens*), Balsam Fir (*Abies balsamea*), Eastern Hemlock, and Eastern White Pine.

The sanctuary is comprised of four distinct forested communities along with several wetland communities. These communities are defined by their floral composition, vegetative structure, and physical surroundings (Sperduto & Kimball 2011). At Kensan-Devan, the forested natural communities include: 1) Eastern Hemlock- dominated lowlands that surround several interior wetlands, 2) northern hardwood on low- to mid-elevation slopes, 3) hemlock-beech-oak-pine forests in varying combinations of their components on the intermediate slopes of the property, and 4) pine-oak dominated uplands (TEMC 2015).

Due to NHA's objectives, the sanctuary is not entirely unaltered in its composition. In addition to management-linked access roads and skid trails, recreational footpaths have been created and maintained throughout the Meetinghouse Pond section, which are open throughout the year during daylight hours (New Hampshire Audubon 2016; TEMC 2015). However, most of the trail system within the Meetinghouse Pond section has been altered since the inception of this study due to forestry efforts that were conducted to improve bird habitat at the sanctuary. New Hampshire Audubon plans for reestablishment of the trail system in the near future. Other anthropogenic features on the site include an old road that bisects the Hunt Road section as well as two old farmstead sites (TEMC 2015).

Hydrologically, the sanctuary is part of the Middle Connecticut Watershed (NHDES 2012). There are four major wetland and water features within Kensan-Devan, totaling 19-ha including: 1) Meetinghouse Pond and associated wetlands, 2) a Shaker Brook-fed shrub wetland on the eastern edge of the Meetinghouse Pond section, 3) a Stone Pond-fed brook, wetlands, and beaver pond complex on the western half of the Hunt Road section and 4) a small series of non-contiguous wetlands on the southern tier of the Hunt Road section (TEMC 2015). Most of these mapped wetland resources are significant in the context of wildlife and are classified by the New Hampshire Wildlife Action Plan (2015) as either "Highest Ranked Habitat in New Hampshire" or "Highest Ranked Habitat in the Biological Region" (NHFGD 2015b). Ecologically, Meetinghouse Pond is significant to the sanctuary and the region because it contains a floating bog mat and is host to several bog-obligate plant species such as sphagnum moss (Sphagnaceae), pitcher plants (Sarraceniaceae), sundews (Droseraceae), Leatherleaf (*Chamaedaphne calyculata*), Bog Rosemary (*Andromeda polifolia*), and Black Spruce (*Picea mariana*).

During the winter of 2016-2017, TEMC conducted a series of timber harvests on the property as prescribed in their forest management plan to NHA, including group selection (29 hectares), overstory removal (5.6 hectares), and seed tree (5.6 hectares) (Appendix A). In total, 843,357 board feet were harvested, which included low grade wood (50.3% of the harvest), softwood logs (39.1%), and hardwood logs (10.6%). Spatially, all three treatments were confined to the eastern edge of the Meetinghouse Pond section (Figure 2). These are the first in a proposed series of forestry treatments between 2016 and 2025, which will include the following: small patches, group selection, crop tree release, patch cut, modified shelterwood, free thinning, expanding gap, modified overstory removal, and natural progression.

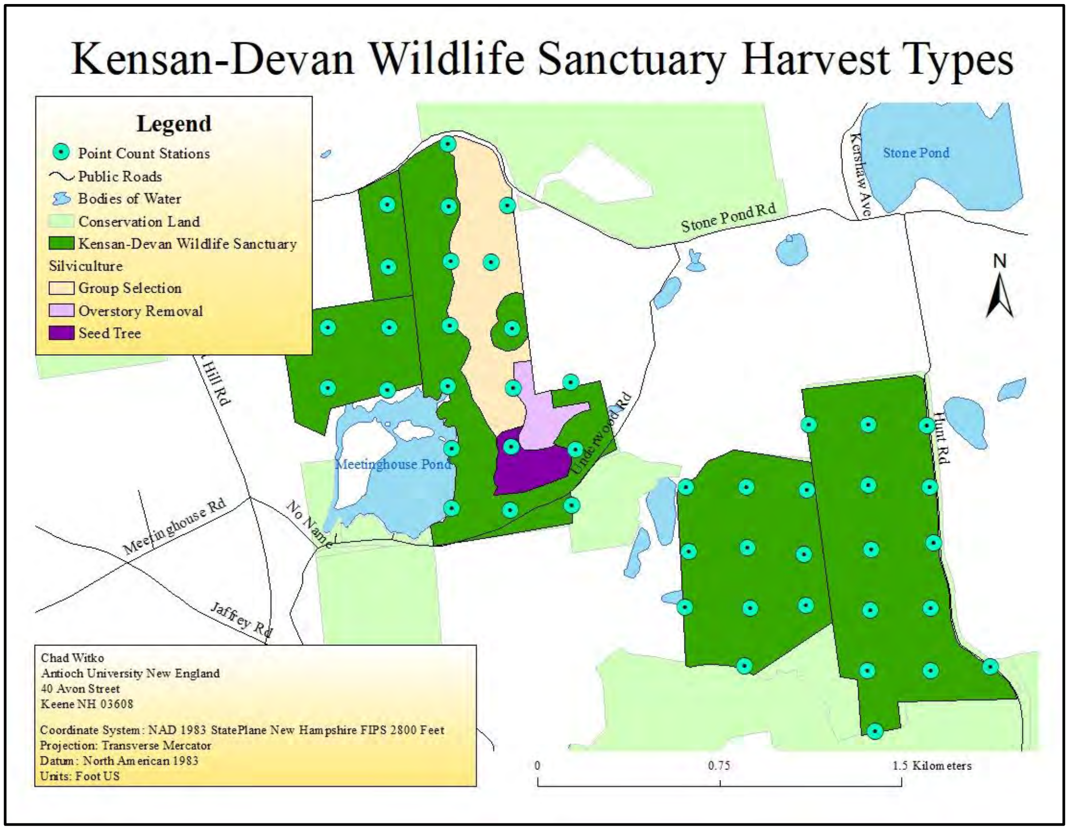

Figure 2. Forestry efforts at Kensan-Devan Wildlife Sanctuary. Map illustrates the spatial location and silviculture harvest types that took place at the Kensan-Devan Wildlife Sanctuary during the winter of 2016-2017.

Data Collection

Avian Surveys

For the inventory of the avifauna at Kensan-Devan, an adapted version of a Variable Circular Plot (VCP) point count method as established by Ralph et al. (1995) and popularized by PRBO Conservation Science (California Avian Data Center 2003) was utilized. Observations took place at 45 point count stations, which were established along a 250-meter cell grid throughout the property (Figure 3). The exact placement of the grid was finalized in a manner to maximize the number of accessible points falling within a forested setting of the property to best monitor forest birds. In total, 22 sites were established in the Meetinghouse Pond section and 23 were established in the Hunt Road section.

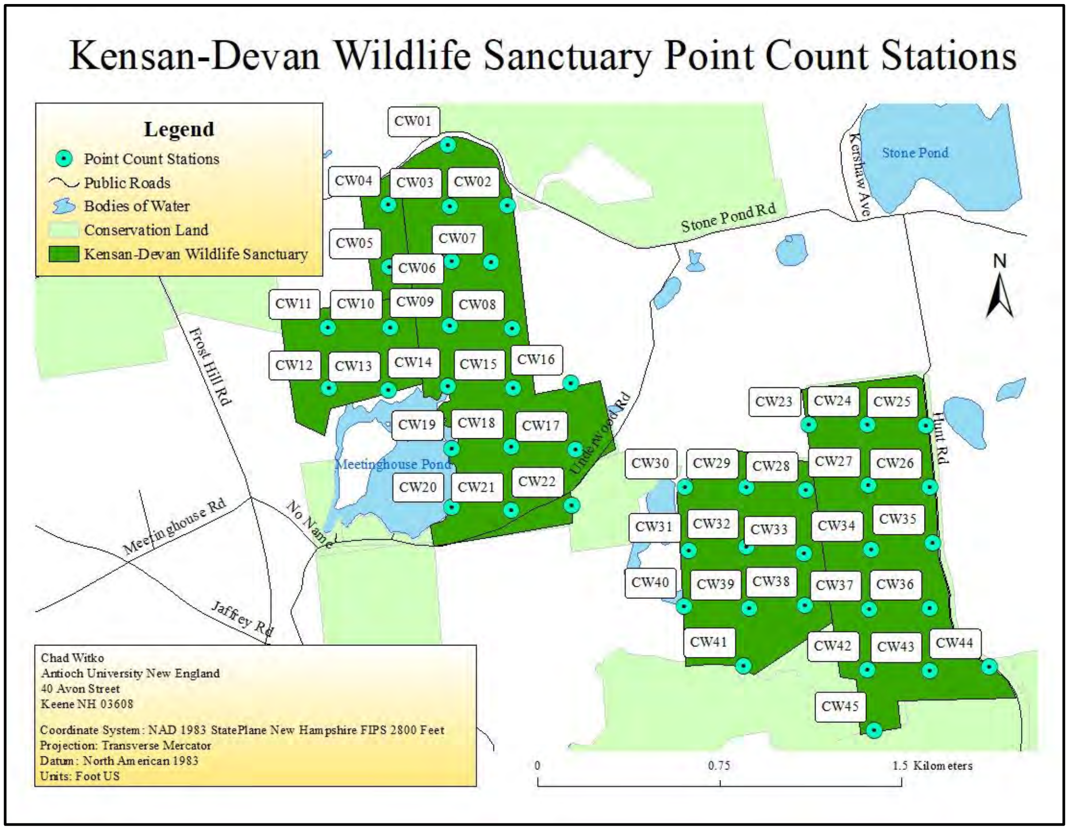

Figure 3. Locator map for Kensan-Devan Wildlife Sanctuary point count stations (with point count station numbers). Map illustrates the spatial distribution of the 45 point count stations across the Kensan-Devan Wildlife Sanctuary in both the Meetinghouse Pond (west) and Hunt Road (east) sections.

An *Etrek Venture HC* GPS unit by Garmin (1200 E. 151st St., Olathe, KS 66062-3426) was used to navigate to all 45 points. The original points generated by NHA via ArcMap and affixed to a 250-meter cell grid were named in the following convention, "KDXX", representing Kensan-Devan points 01-45 (e.g., KD23 represents point count station 23). Once established in the field, all point count stations were marked with bright orange vinyl flagging at eye-level to assure ease in relocating for future surveys and to standardize the location for future research. Each point count center (always a sizeable tree) was double- to triple-wrapped around the trunk with a large piece of orange flagging hanging off where the point count station ID was marked (e.g., "NHA KD 02"). Flagging at each of the point count stations was left in the field at the end of the study to be managed by NHA. To assist in navigational efforts to the point center, a series of orange flagging was suspended 10-25 meters outside of the point center on prominent pieces of vegetation in different directions depending upon topography, line of sight, and the ever-present high density of foliage.

To capture the height of the local breeding season for neotropical migrant passerines, three rounds of surveys were conducted each year between June 8 and July 17, and each of the 45 points were surveyed three times (replicates) over the course of a given season. To cover all 45 points in both the Meetinghouse Pond and Hunt Road sections, four mornings of surveys were necessary in each round, covering 11-13 points each morning. This resulted in a total of 12 visits made to the sanctuary each year. Each survey started as close to local sunrise as possible and ended no more than four hours after local sunrise to capture the peak of bird activity. Weather permitting, the four mornings of surveys would be conducted consecutively to minimize the effect of time as a variable across a given round. If this was not possible due to the variable weather of late spring and summer (e.g., rain and wind), all 45 points were aimed to be surveyed within a single week. Each point was surveyed for a total of five minutes per visit with each visit starting at a randomly selected point adjacent to the parking areas. A two-minute waiting period was utilized at each point count station and preceded each survey allowing bird activity to resume to more normal levels after the disturbance of walking to the point count station.

At each point, all unique individual birds that were detected either by sight or sound (call, song, and non-vocal sounds made by wings or drumming) were tallied on the field data sheet (Appendix B), paying special attention to avoid double counting individuals along the way.

Aside from a tally (count) of each species, each unique individual was marked with a behavior code to denote how it was first detected (e.g., C=Call, S=Song, V=Visual, D=Drumming).

Additional data were also taken on weather for both the start and end of the survey day, including temperature (degrees Celsius), cloud cover (%), wind direction, and wind speed (kph). For point counts of birds to be effective, it is imperative that they be conducted under appropriate weather conditions that facilitate the detection of birds. While a constant heavy rain has the greatest impact on bird counts, the number of songbirds detected is also generally inversely related to wind speed whereas cloud cover and light fog have little influence (Robbins 1981). Ralph et al. (1995) suggests that birds not be surveyed during heavy rain, dense fog, and high wind, particularly in highly vegetated areas that create wind-blown noise. In general, this protocol was followed with surveys rescheduled to the next available date if weather conditions included steady rain or winds over 12 kph at the start of a survey. In order to complete a full round of surveys on time for all 45 points, several exceptions to this had to be made on the days in which the windspeed increased at the end of the survey period and exceeded 12 kph for the last several points.

All birds detected during the time of study (not just during the official point counts) were also entered into eBird (www.ebird.org), an online checklist database for bird sightings. All submitted checklists utilized one of two locations created for the survey, either the “Kensan-Devan Wildlife Sanctuary- Hunt Road Section” or “Kensan-Devan Wildlife Sanctuary-Meetinghouse Pond Section”. This was done to encourage future data collection at the sanctuary by birders with the goal of increasing the total data available.

Natural Community Surveys

While TEMC did extensive habitat surveys for their management plan ahead of this research, the grid of points utilized for these did not match those of the avian point count centers that were initially established by NHA and used for this study. Thus, to assess habitat characteristics at the site, I collected data at each avian point count location in both 2016 and 2017 using *Forestry for the Birds* protocol (Audubon Vermont n.d.b) (Appendix C). This methodology and its associated data sheet were used because the planned habitat management at Kensan-Devan was based, at least in part, on the *Foresters for Birds* protocol established by Audubon Vermont.

Through this protocol, percent cover, general vegetative distribution (e.g., patchy or uniform), and tree type in the overstory, midstory, and understory are measured categorically. Per the *Bird Habitat Data Field Sheet*, additional data were collected on the presence of soft mass, invasive plants, leaf litter, and the quantity of course and fine woody debris. A photo was taken at each point count station facing north for future reference of habitat change (Appendix D). To further quantify the habitat associated with each of the 45 avian point count stations, the Variable Radius Plot sampling method to tally all trees by species was employed using a 10-basal area factor Bitterlich wedge prism. Data for this were collected on a separate field sheet. This method allowed quick retrieval of basic information regarding basal area of overstory trees at each point across the landscape.

<u>Data Analysis</u>

Avian Communities

To first gain insight into the avian community at Kensan-Devan, relative abundance was calculated for all species (both years), across several different spatial scales. These scales included: 1) the entire Kensan-Devan Wildlife Sanctuary (all 45 point count stations), 2) both sections independently (Meetinghouse Pond (22 points) and Hunt Road (23 points)), and 3) all points within the Meetinghouse Pond section that were directly associated with one of the various forest treatment types: no treatment (16 points), group selection (5 points), overstory removal (0 points), and seed tree (1 point).

Relative abundance was calculated by taking the total number of detections for each species (sum of all points across all replicates as needed per the spatial scales above in a given year) divided by the total number of detections for all species for a given year of the study for the same spatial scale (relative abundance = (n/N) x 100). Percent change in total relative abundance at the site level (Kensan-Devan Wildlife Sanctuary) was also compared for all species between the 2016 and 2017 seasons.

To quantify the diversity of the avian community at Kensan-Devan, the Simpson's Diversity Index (Simpson 1949) was employed across both sections (Meetinghouse Pond and Hunt Road) as well as across the different treatment types of the Meetinghouse Pond section (Group, Seed, None). Measuring the probability that two individuals randomly selected from a larger community will belong to different species, the following formula is used: $D= 1-\{\Sigma n(n-1)/N(N-1)\}$ where n= the total number of birds of a given species and N=the total number of birds of all species. General abundance in each year (total number of detections at each point summed across all visits for that year) was also analyzed at the site and section scales for the entire avian community, the entire forest bird community, for NHA's target species (pooled together), for each target species individually where data allowed, and for Ovenbird and Red-eyed Vireo individually, the sanctuary's two most common species.

To measure the significance of changes in both relative abundance and diversity, along with general abundance of target species across various spatial scales during the study, paired *t*-tests were conducted in RStudio (RStudio Team 2015). The paired *t*-test is used to test the null hypothesis that the mean difference of paired measurements is equal to a specific value (Whitlock & Schluter 2015). To assess assumptions of the paired *t*-tests, the Shapiro-Wilk test was first used to evaluate the goodness of fit of a normal distribution (R Core Team 2016). For target species individually, data did not meet the normality assumption for *t*-test, and therefore, a Wilcoxon Signed-Rank Test was used instead, using the wilcox.test function in R (R Core Team 2019).

Natural Communities

To gain insight into the forested community at Kensan-Devan, the habitat data collected at the point count stations were summarized at the following scales, just as they were for the avian community: 1) the entire Kensan-Devan Wildlife Sanctuary, 2) both sections that comprise the sanctuary (Meetinghouse Pond and Hunt Road) independently, and 3) all points within the Meetinghouse Pond section that were directly associated with one of the various forest treatment types. Specifically, categorical data (e.g., overstory uniformity (uniform or patchy) were calculated as the percent frequency for each category represented. Continuous data were measured and/or averaged across the aforementioned scales and compared across years at the seven points within or adjacent to active management areas using a paired t-test.

RESULTS

Avian Communities

Sixty-one species of birds were detected during point counts at Kensan-Devan over the course of the 2016 and 2017 field seasons. This included 987 individual detections of 54 species in 2016 and 806 individual detections of 49 species in 2017, of which 42 were observed in both years (Table 1). This avian community consists of common species as well as those listed as Species of Greatest Conservation Need (SGCN) in the state of New Hampshire. SGCN that were detected at Kensan-Devan during this study include Black-billed Cuckoo (*Coccyzus erythropthalmus*), Canada Warbler, Common Loon (*Gavia immer*), Eastern Towhee, Purple Finch (*Haemorhous purpureus*), Ruffed Grouse (*Bonasa umbellus*), Scarlet Tanager, and Veery (*Catharus fuscescens*) (NHFGD 2015a). Common Loon, a confirmed breeding species at Kensan-Devan on Meetinghouse Pond, is also listed as State Threatened, the only species detected during this study to have that designation (NHFGD 2015a).

Two taxa were removed from this study as they were not identified to species in the field: 1) unknown gull (*Larus* sp.) and 2) unknown woodpecker (*Picoides* sp.). The gull was represented by two flyovers on June 15, 2016 that were not using any of Kensan-Devan’s habitat while the unknown woodpeckers (15 total over two years) were heard drumming and the identification down to species (either Downy or Hairy based on drumming pattern and presence on the property) could not be determined.

Table 1. Alphabetical list of all bird species identified at Kensan-Devan Wildlife Sanctuary in 2016 and 2017 during the study. Numbers for each year represent total number of detections across all points for a given year and relative abundance (%).

Species	2016	2017
Alder Flycatcher	6 (0.61)	7 (0.87)
American Crow	14 (1.42)	7 (0.87)
American Goldfinch	2 (0.2)	11 (1.36)
American Robin	4 (0.41)	3 (0.37)
Barn Swallow	5 (0.51)	2 (0.25)
Barred Owl	1 (0.1)	1 (0.12)
Black-and-white Warbler	8 (0.81)	5 (0.62)
Black-billed Cuckoo*	0 (0)	1 (0.12)
Blackburnian Warbler	3 (0.3)	1 (0.12)
Black-capped Chickadee	70 (7.09)	47 (5.83)
Black-throated Blue Warbler	22 (2.23)	20 (2.48)
Black-throated Green Warbler	56 (5.67)	52 (6.45)
Blue Jay	70 (7.09)	62 (7.69)
Blue-headed Vireo	34 (3.44)	33 (4.09)
Bobolink*	1 (0.1)	0 (0)
Broad-winged Hawk	3 (0.3)	3 (0.37)
Brown Creeper	1 (0.1)	1 (0.12)
Canada Warbler*	1 (0.1)	3 (0.37)
Cedar Waxwing	2 (0.2)	0 (0)
Common Loon*^{T}	6 (0.61)	1 (0.12)
Common Raven	14 (1.42)	0 (0)
Common Yellowthroat	30 (3.04)	17 (2.11)
Downy Woodpecker	2 (0.2)	2 (0.25)
Eastern Kingbird	3 (0.3)	2 (0.25)
Eastern Phoebe	0 (0)	1 (0.12)
Eastern Towhee*	1 (0.1)	0 (0)
Eastern Wood-Pewee	14 (1.42)	13 (1.61)
Golden-crowned Kinglet	1 (0.1)	0 (0)
Green Heron	1 (0.1)	0 (0)
Hairy Woodpecker	16 (1.62)	10 (1.24)
Hermit Thrush	69 (6.99)	66 (8.19)
House Wren	1 (0.1)	0 (0)
Least Flycatcher	0 (0)	1 (0.12)
Mallard	1 (0.1)	1 (0.12)
Mourning Dove	7 (0.71)	17 (2.11)

Species	2016	2017
Northern Flicker	1 (0.1)	2 (0.25)
Northern Parula	3 (0.3)	0 (0)
Northern Waterthrush	0 (0)	3 (0.37)
Ovenbird	154 (15.6)	89 (11.04)
Pileated Woodpecker	6 (0.61)	8 (0.99)
Pine Warbler	18 (1.82)	20 (2.48)
Purple Finch*	4 (0.41)	11 (1.36)
Red-bellied Woodpecker	1 (0.1)	0 (0)
Red-breasted Nuthatch	56 (5.67)	26 (3.23)
Red-eyed Vireo	97 (9.83)	85 (10.55)
Red-shouldered Hawk	0 (0)	1 (0.12)
Red-winged Blackbird	12 (1.22)	19 (2.36)
Rose-breasted Grosbeak	1 (0.1)	0 (0)
Ruffed Grouse*	1 (0.1)	0 (0)
Scarlet Tanager*	14 (1.42)	18 (2.23)
Song Sparrow	13 (1.32)	17 (2.11)
Swamp Sparrow	16 (1.62)	11 (1.36)
Tree Swallow	9 (0.91)	0 (0)
Tufted Titmouse	17 (1.72)	11 (1.36)
Veery*	15 (1.52)	6 (0.74)
White-breasted Nuthatch	20 (2.03)	5 (0.62)
Winter Wren	15 (1.52)	15 (1.86)
Wood Duck	0 (0)	14 (1.74)
Yellow-bellied Sapsucker	10 (1.01)	15 (1.86)
Yellow-billed Cuckoo	0 (0)	2 (0.25)
Yellow-rumped Warbler	35 (3.55)	38 (4.71)

Species listed in **bold** represent target species. * = NH Species of Greatest Conservation Need (n = 169), NH Wildlife Action Plan 2015. T = NH threatened (List revised 2017).

Relative Abundance

Kensan-Devan Wildlife Sanctuary.

Ovenbird and Red-eyed Vireo (*Vireo olivaceus*) were the two most abundant species at Kensan-Devan across both seasons based on total detections, with an overall decrease in the relative abundance of Ovenbird (-29.23%) in 2017 but a slight increase in the relative abundance of Red-eyed Vireo (7.31%) in 2017 (Table 1). The next seven most abundant species of birds in terms of relative abundance for both years at Kensan-Devan, albeit in different rankings for each year, were Blue-headed Vireo, Blue Jay (*Cyanocitta cristata*), Black-capped Chickadee (*Poecile atricapillus*), Red-breasted Nuthatch (*Sitta canadensis*), Hermit Thrush (*Catharus guttatus*), Black-throated Green Warbler, and Yellow-rumped Warbler (*Setophaga coronata*). Several other NHA target species were also detected including Eastern Wood-Pewee, Black-throated Blue Warbler, Canada Warbler, and Scarlet Tanager (Table 2). Two target species, Wood Thrush and Chestnut-sided Warbler, were not detected during point counts.

Table 2. Alphabetical list of target species determined by New Hampshire Audubon that were identified at Kensan-Devan Wildlife Sanctuary along with total detections and relative abundance (%) for 2016 and 2017.

Species	2016	2017
Black-throated Blue Warbler	22 (2.23)	20 (2.48)
Black-throated Green Warbler	56 (5.67)	52 (6.45)
Blue-headed Vireo	34 (3.44)	33 (4.09)
Canada Warbler	1 (0.1)	3 (0.37)
Eastern Towhee	1 (0.1)	0 (0)
Eastern Wood-Pewee	14 (1.42)	13 (1.61)
Scarlet Tanager	14 (1.42)	18 (2.23)

Hunt Road and Meetinghouse Pond Sections.

Within the Hunt Road (non-managed) section of Kensan-Devan, Ovenbird and Red-eyed Vireo were again the two most abundant species, although they did flip their order between 2016 and 2017 (Table 3). Just as it was for the entire Kensan-Devan Wildlife Sanctuary, in the Hunt Road section, there was a decrease in the relative abundance of Ovenbirds (-32.10%) and an increase in the relative abundance of Red-eyed Vireos (46.25%) in 2017. Five target species were observed within the Hunt Road section in both years: Eastern Wood-Pewee, Blue-headed Vireo, Black-throated Blue Warbler, Black-throated Green Warbler, and Scarlet Tanager, while Canada Warbler was only detected in 2017.

Table 3. Alphabetical list of bird species detected within the Hunt Road section in 2016 and 2017, showing total detections and relative abundance (%).

Species	2016	2017
Alder Flycatcher	4 (0.81)	5 (1.34)
American Crow	6 (1.21)	1 (0.27)
American Robin	0 (0)	3 (0.8)
Black-and-white Warbler	3 (0.61)	3 (0.8)
Blackburnian Warbler	2 (0.4)	0 (0)
Black-capped Chickadee	45 (9.09)	26 (6.97)
Black-throated Blue Warbler	8 (1.62)	12 (3.22)
Black-throated Green Warbler	21 (4.24)	25 (6.7)
Blue Jay	42 (8.48)	25 (6.7)
Blue-headed Vireo	16 (3.23)	13 (3.49)
Bobolink	1 (0.2)	0 (0)
Broad-winged Hawk	2 (0.4)	1 (0.27)
Canada Warbler	0 (0)	2 (0.54)
Cedar Waxwing	2 (0.4)	0 (0)
Common Raven	11 (2.22)	0 (0)
Common Yellowthroat	11 (2.22)	10 (2.68)
Downy Woodpecker	1 (0.2)	1 (0.27)
Eastern Kingbird	2 (0.4)	2 (0.54)
Eastern Wood-Pewee	6 (1.21)	3 (0.8)
Green Heron	1 (0.2)	0 (0)
Hairy Woodpecker	8 (1.62)	4 (1.07)
Hermit Thrush	38 (7.68)	42 (11.2)
House Wren	1 (0.2)	0 (0)
Least Flycatcher	0 (0)	1 (0.27)
Mourning Dove	2 (0.4)	2 (0.54)
Northern Flicker	1 (0.2)	0 (0)
Ovenbird	86 (17.37)	44 (11.80)
Pileated Woodpecker	2 (0.4)	5 (1.07)
Pine Warbler	6 (1.21)	14 (3.75)
Purple Finch	0 (0)	2 (0.54)
Red-bellied Woodpecker	1 (0.2)	0 (0)
Red-breasted Nuthatch	27 (5.45)	12 (3.22)

Species	2016	2017
Red-eyed Vireo	49 (9.9)	54 (14.48)
Red-shouldered Hawk	0 (0)	1 (0.27)
Red-winged Blackbird	3 (0.61)	6 (1.07)
Scarlet Tanager	5 (1.01)	2 (0.54)
Song Sparrow	0 (0)	2 (0.54)
Swamp Sparrow	9 (1.82)	6 (1.61)
Tree Swallow	1 (0.2)	0 (0)
Tufted Titmouse	10 (2.02)	5 (1.34)
Veery	7 (1.41)	6 (1.61)
White-breasted Nuthatch	18 (3.64)	3 (0.8)
Winter Wren	8 (1.62)	9 (2.41)
Yellow-bellied Sapsucker	10 (2.02)	12 (3.22)
Yellow-rumped Warbler	19 (3.84)	12 (3.22)

Species listed in **bold** represent target species.

For the Meetinghouse Pond section (the parcel that underwent timber harvest during 2016-2017), Ovenbird remained the most abundant species over both years while Red-eyed Vireo was the second most abundant species in 2016 and third most in 2017 (replaced by Blue Jay) (Table 4). In the second year of the study, Ovenbirds decreased in relative abundance (-24.81%) while Red-eyed Vireo experienced a greater rate of decrease (-26.62%). Six target species were observed within the Meetinghouse Pond section in both years: Eastern Wood-Pewee, Blue-headed Vireo, Black-throated Blue Warbler, Black-throated Green Warbler, Canada Warbler, and Scarlet Tanager while Eastern Towhee was only detected in 2016.

Table 4. Alphabetical list of bird species detected within the Meetinghouse Pond section in 2016 and 2017, showing total detections and relative abundance (%).

Species	2016	2017
Alder Flycatcher	2 (0.41)	2 (0.46)
American Crow	8 (1.63)	6 (1.39)
American Goldfinch	2 (0.41)	11 (2.54)
American Robin	4 (0.81)	0 (0)
Barn Swallow	5 (1.02)	2 (0.46)
Barred Owl	1 (0.20)	1 (0.23)
Black-and-white Warbler	5 (1.02)	2 (0.46)
Black-billed Cuckoo	0 (0)	1 (0.23)
Blackburnian Warbler	1 (0.20)	1 (0.23)
Black-capped Chickadee	25 (5.08)	21 (4.85)
Black-throated Blue Warbler	14 (2.85)	8 (1.85)
Black-throated Green Warbler	35 (7.11)	27 (6.24)
Blue Jay	28 (5.69)	37 (8.55)
Blue-headed Vireo	18 (3.66)	20 (4.62)
Broad-winged Hawk	1 (0.20)	2 (0.46)
Brown Creeper	1 (0.20)	1 (0.23)
Canada Warbler	1 (0.20)	1 (0.23)
Common Loon	6 (1.22)	1 (0.23)
Common Raven	3 (0.61)	0 (0)
Common Yellowthroat	19 (3.86)	7 (1.62)
Downy Woodpecker	1 (0.20)	1 (0.23)
Eastern Kingbird	1 (0.20)	0 (0)
Eastern Phoebe	0 (0)	1 (0.23)
Eastern Towhee	1 (0.20)	0 (0)
Eastern Wood-Pewee	8 (1.63)	10 (2.31)
Golden-crowned Kinglet	1 (0.20)	0 (0)
Hairy Woodpecker	8 (1.63)	6 (1.39)
Hermit Thrush	31 (6.30)	24 (5.54)
Mallard	1 (0.20)	1 (0.23)
Mourning Dove	5 (1.02)	15 (3.46)
Northern Parula	3 (0.61)	0 (0)
Ovenbird	68 (13.82)	45 (10.39)
Pileated Woodpecker	4 (0.81)	4 (0.92)
Northern Flicker	0 (0)	2 (0.46)
Northern Waterthrush	0 (0)	3 (0.69)
Pine Warbler	12 (2.44)	6 (1.39)
Purple Finch	4 (0.81)	9 (2.08)

Red-breasted Nuthatch	29 (5.89)	14 (3.23)
Red-eyed Vireo	48 (9.76)	31 (7.16)
Red-winged Blackbird	9 (1.83)	15 (3.46)
Rose-breasted Grosbeak	1 (0.20)	0 (0)
Ruffed Grouse	1 (0.20)	0 (0)
Scarlet Tanager	9 (1.83)	16 (3.70)
Song Sparrow	13 (2.64)	15 (3.46)
Swamp Sparrow	7 (1.42)	5 (1.15)
Tree Swallow	8 (1.63)	0 (0)
Tufted Titmouse	7 (1.42)	6 (1.39)
Veery	8 (1.63)	0 (0)
White-breasted Nuthatch	2 (0.41)	2 (0.46)
Winter Wren	7 (1.42)	6 (1.39)
Wood Duck	0 (0)	14 (3.23)
Yellow-bellied Sapsucker	0 (0)	3 (0.69)
Yellow-billed Cuckoo	0 (0)	2 (0.46)
Yellow-rumped Warbler	16 (3.25)	26 (6.0)

Species listed in **bold** represent target species.

Forestry Treatments.

Relative abundance of avian species was calculated for group selection and seed tree treatment types, as well as untreated areas, by pooling all the points found within each treatment type. However, because zero points fell within the overstory removal treatment zone, no relative abundances were calculated for this type.

No Treatment.

Within the Meetinghouse Pond section, a large portion of the forest received no forest management during the study. For the 16 points within the Meetinghouse Pond section that received no treatment, Ovenbird and Red-eyed Vireo were among the most abundant species yet again (Table 5). In 2017, both Ovenbird (-24.6%) and Red-eyed Vireo (-21.0%) declined within the no treatment zone just as they did at the Meetinghouse Pond section scale.

Table 5. Alphabetical list of bird species detected within the No Treatment Zone of Meetinghouse Pond section in 2016 and 2017, showing total detections and relative abundance (%).

Species	2016	2017
Alder Flycatcher	2 (0.55)	2 (0.61)
American Crow	7 (1.91)	4 (1.22)
American Goldfinch	2 (0.55)	11 (3.36)
American Robin	3 (0.82)	0 (0)
Barn Swallow	5 (1.37)	2 (0.61)
Barred Owl	1 (0.27)	1 (0.31)
Black-and-white Warbler	2 (0.55)	2 (0.61)
Black-billed Cuckoo	0 (0)	1 (0.31)
Blackburnian Warbler	1 (0.27)	0 (0)
Black-capped Chickadee	17 (4.64)	13 (3.98)
Black-throated Blue Warbler	12 (3.28)	7 (2.14)
Black-throated Green Warbler	28 (7.65)	24 (7.34)
Blue Jay	22 (6.01)	30 (9.17)
Blue-headed Vireo	9 (2.46)	14 (4.28)
Brown Creeper	1 (0.27)	0 (0)
Canada Warbler	1 (0.27)	1 (0.31)
Common Loon	5 (1.37)	1 (0.31)
Common Raven	3 (0.82)	0 (0)
Common Yellowthroat	19 (5.19)	7 (2.14)
Downy Woodpecker	1 (0.27)	0 (0)
Eastern Kingbird	1 (0.27)	0 (0)
Eastern Phoebe	0 (0)	1 (0.31)
Eastern Towhee	1 (0.27)	0 (0)
Eastern Wood-Pewee	0 (0)	3 (0.92)
Hairy Woodpecker	3 (0.82)	3 (0.92)
Hermit Thrush	21 (5.74)	17 (5.2)
Mallard	1 (0.27)	1 (0.31)
Mourning Dove	4 (1.09)	11 (3.36)
Northern Parula	3 (0.82)	0 (0)
Northern Waterthrush	0 (0)	3 (0.92)
Ovenbird	46 (12.57)	31 (9.48)
Pileated Woodpecker	3 (0.82)	2 (0.61)
Pine Warbler	8 (2.19)	4 (1.22)
Purple Finch	4 (1.09)	8 (2.45)
Red-breasted Nuthatch	21 (5.74)	10 (3.06)

Species	2016	2017
Red-eyed Vireo	34 (9.29)	24 (7.34)
Red-winged Blackbird	9 (2.46)	15 (4.59)
Rose-breasted Grosbeak	1 (0.27)	0 (0)
Ruffed Grouse	1 (0.27)	0 (0)
Scarlet Tanager	7 (1.91)	14 (4.28)
Song Sparrow	13 (3.55)	15 (4.59)
Swamp Sparrow	7 (1.91)	5 (1.53)
Tree Swallow	8 (2.19)	0 (0)
Tufted Titmouse	6 (1.64)	4 (1.22)
Veery	6 (1.64)	0 (0)
White-breasted Nuthatch	1 (0.27)	1 (0.31)
Winter Wren	6 (1.64)	2 (0.61)
Wood Duck	0 (0)	14 (4.28)
Yellow-bellied Sapsucker	0 (0)	2 (0.61)
Yellow-billed Cuckoo	0 (0)	2 (0.61)
Yellow-rumped Warbler	10 (2.73)	15 (4.59)

Species listed in **bold** represent target species.

Group Selection Treatment.

While the majority of Meetinghouse Pond received no forestry, a series of three treatment types were applied within the section including group selection, overstory removal, and seed tree. For the group selection treatment (five points), Ovenbird remained the most abundant species despite another large decrease between years (Table 6). Red-eyed Vireo ranked much lower in 2016 and 2017 for this treatment type than others, ranking the fifth and ninth most abundant species respectively while declining 38.2% between years. In both years, five target species were observed within the group selection treatment zone of the Meetinghouse Pond section: Eastern Wood-Pewee, Blue-headed Vireo, Black-throated Blue Warbler, Black-throated Green Warbler, and Scarlet Tanager.

Table 6. Alphabetical list of bird species detected within the Group Selection Treatment of the Meetinghouse Pond section in 2016 and 2017, showing total detections and relative abundance (%).

Species	2016	2017
American Crow	1 (0.95)	2 (2.35)
American Robin	1 (0.95)	0 (0)
Black-and-white Warbler	2 (1.90)	0 (0)
Blackburnian Warbler	0 (0)	1 (1.18)
Black-capped Chickadee	6 (5.71)	8 (9.41)
Black-throated Blue Warbler	2 (1.90)	1 (1.18)
Black-throated Green Warbler	7 (6.67)	3 (3.53)
Blue Jay	6 (5.71)	5 (5.88)
Blue-headed Vireo	8 (7.62)	6 (7.06)
Broad-winged Hawk	0 (0)	2 (2.35)
Brown Creeper	0 (0)	1 (1.18)
Common Loon	1 (0.95)	0 (0)
Downy Woodpecker	0 (0)	1 (1.18)
Eastern Wood-Pewee	4 (3.81)	5 (5.88)
Golden-crowned Kinglet	1 (0.95)	0 (0)
Hairy Woodpecker	5 (4.76)	3 (3.53)
Hermit Thrush	10 (9.52)	6 (7.06)
Mourning Dove	1 (0.95)	2 (2.35)
Northern Flicker	0 (0)	2 (2.35)
Ovenbird	19 (18.10)	11 (12.94)
Pileated Woodpecker	1 (0.95)	1 (1.18)
Pine Warbler	3 (2.86)	1 (1.18)
Red-breasted Nuthatch	8 (7.62)	4 (4.71)
Red-eyed Vireo	8 (7.62)	4 (4.71)
Scarlet Tanager	2 (1.90)	1 (1.18)
Tufted Titmouse	1 (0.95)	0 (0)
Veery	1 (0.95)	0 (0)
Winter Wren	1 (0.95)	4 (4.71)
Yellow-rumped Warbler	6 (5.71)	11 (12.94)

Species listed in **bold** represent target species.

Seed Treatment.

For point 18, the only point that fell within the seed tree treatment type, Red-eyed Vireo was the most abundant species in 2016 and the second most abundant species in 2017, although its total relative abundance declined 50% between years (Table 7). Ovenbird, the third most abundant species in 2016, had zero change in its relative abundance in 2017, but increased to the most abundant species for all points within the seed tree treatment type that year (Table 7). In the seed treatment type, Eastern Wood-Pewee was the only NHA target species observed in this treatment type across both years. Complementing this were Blue-headed Vireo in 2016 and Scarlet Tanager in 2017 (Figure 4).

Table 7. Alphabetical list of bird species detected within the Seed Treatment Zone of the Meetinghouse Pond section in 2016 and 2017, showing total detections and relative abundance (%).

Species	2016	2017
Black-and-white Warbler	1 (4.76)	0 (0)
Black-capped Chickadee	2 (9.52)	0 (0)
Blue-headed Vireo	1 (4.76)	0 (0)
Blue Jay	0 (0)	2 (9.52)
Broad-winged Hawk	1 (4.76)	0 (0)
Eastern Wood-Pewee	4 (19.05)	2 (9.52)
Hermit Thrush	0 (0)	1 (4.76)
Mourning Dove	0 (0)	2 (9.52)
Ovenbird	3 (14.29)	3 (14.29)
Pileated Woodpecker	0 (0)	1 (4.76)
Pine Warbler	1 (4.76)	1 (4.76)
Purple Finch	0 (0)	1 (4.76)
Red-eyed Vireo	6 (28.57)	3 (14.29)
Scarlet Tanager	0 (0)	1 (4.76)
Tufted Titmouse	0 (0)	2 (9.52)
Veery	1 (4.76)	0 (0)
White-breasted Nuthatch	1 (4.76)	1 (4.76)
Yellow-bellied Sapsucker	0 (0)	1 (4.76)

Species listed in **bold** represent target species.

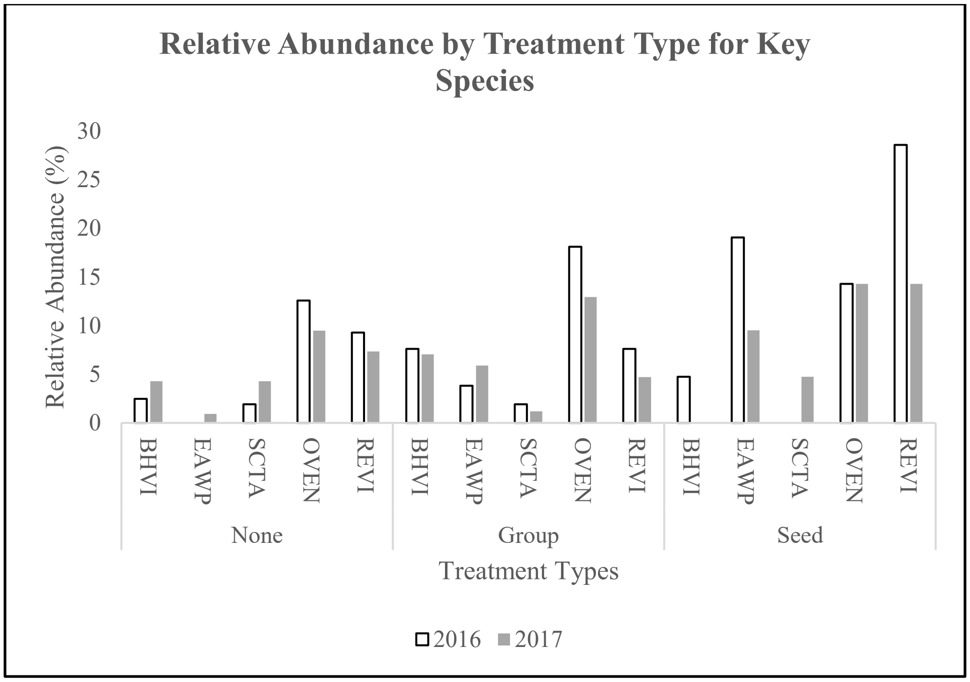

Figure 4. Relative avian abundance of key species for all treatment types within the Meetinghouse Pond section for both years. Only the most abundant species (Ovenbird and Red-eyed Vireo) and target species that were detected across five of the six years/treatment combinations (None, Group, Seed in 2016 and 2017) are shown. Four-letter codes for all species can be found in Appendix E.

Avian Diversity

The diversity of birds at Kensan-Devan was relatively similar among all 45 points, ranging on the Simpson's Diversity Index from 0.79 to 0.95 in 2016 and 0.76 to 0.98 in 2017 (values closer to 1 indicate greater species diversity) (Table 8). Diversity was also calculated for the various forestry treatment types which comprise the Meetinghouse Pond section (points 1-22) (Table 9). These include group selection (points 1, 2, 6, 7, and 15) and seed tree (point 18), as well as those which did not receive any treatment, categorized as none (points 3, 4, 5, 8, 9, 10, 11, 12, 13, 14, 16, 17, 19, 20, 21, 22). To calculate diversity for these treatments, all points that comprised a treatment were summed together for a given year. Point 18, the only point that fell within the seed tree treatment, had a Simpson's Diversity Index value of 0.88 in 2016 and 0.95 in 2017 (Table 8). The group selection treatment saw the Species Diversity Index rise slightly from 0.93

in 2016 to 0.96 in 2017. The avian diversity of the collective points that received no treatment in the Meetinghouse Pond section remained steady at a value of 1.0.

Table 8. Total avian diversity for all 45 points in both 2016 and 2017 as well as the percent change. Values closer to 1 indicate greater species diversity.

Section	Point	2016	2017	% change	Treatment
Meetinghouse Pond	1	0.91	0.90	-0.91	Group
Meetinghouse Pond	2	0.93	0.89	-4.63	Group
Meetinghouse Pond	3	0.89	0.95	6.43	None
Meetinghouse Pond	4	0.93	0.89	-5.10	None
Meetinghouse Pond	5	0.88	0.89	0.83	None
Meetinghouse Pond	6	0.88	0.95	7.78	Group
Meetinghouse Pond	7	0.93	0.94	1.13	Group
Meetinghouse Pond	8	0.92	0.94	2.17	None
Meetinghouse Pond	9	0.92	0.94	1.59	None
Meetinghouse Pond	10	0.92	0.94	1.59	None
Meetinghouse Pond	11	0.91	0.91	-0.43	None
Meetinghouse Pond	12	0.93	0.96	3.88	None
Meetinghouse Pond	13	0.94	0.95	1.09	None
Meetinghouse Pond	14	0.95	0.84	-11.78	None
Meetinghouse Pond	15	0.93	0.96	2.93	Group
Meetinghouse Pond	16	0.85	0.89	5.23	None
Meetinghouse Pond	17	0.95	0.96	1.55	None
Meetinghouse Pond	18	0.88	0.95	8.11	Seed
Meetinghouse Pond	19	0.93	0.96	2.80	None
Meetinghouse Pond	20	0.95	0.92	-2.69	None
Meetinghouse Pond	21	0.85	0.92	8.18	None
Meetinghouse Pond	22	0.85	0.89	4.59	None
Hunt Road	23	0.86	0.90	5.39	None
Hunt Road	24	0.85	0.97	14.38	None
Hunt Road	25	0.95	0.94	-1.12	None
Hunt Road	26	0.93	0.90	-3.35	None
Hunt Road	27	0.88	0.85	-3.71	None
Hunt Road	28	0.79	0.84	5.56	None
Hunt Road	29	0.87	0.88	1.69	None
Hunt Road	30	0.91	0.90	-1.52	None
Hunt Road	31	0.91	0.98	7.95	None
Hunt Road	32	0.94	0.95	1.40	None

Section	Point	2016	2017	% change	Treatment
Hunt Road	33	0.89	0.86	-3.68	None
Hunt Road	34	0.86	0.92	6.44	None
Hunt Road	35	0.87	0.82	-4.86	None
Hunt Road	36	0.82	0.88	7.66	None
Hunt Road	37	0.91	0.91	0.77	None
Hunt Road	38	0.90	0.93	3.28	None
Hunt Road	39	0.86	0.94	9.72	None
Hunt Road	40	0.93	0.96	3.03	None
Hunt Road	41	0.88	0.86	-2.04	None
Hunt Road	42	0.90	0.76	-15.94	None
Hunt Road	43	0.84	0.80	-4.56	None
Hunt Road	44	0.87	0.94	8.39	None
Hunt Road	45	0.92	0.81	-12.37	None

Table 9. Total avian diversity for each of the three treatment types (Meetinghouse Pond) in both 2016 and 2017 that avian point count circles fell within. Values closer to 1 indicate greater species diversity.

Treatment	2016	2017
None (n=16)	1.00	1.00
Group (n=5)	0.93	0.96
Seed (n=1)	0.88	0.95

Changes in the Avian Community

Avian Abundance (Total Detections).

For the following results, all data presented met the normality assumption of the paired *t*-test based on the Shapiro-Wilk test, unless otherwise stated. This was also checked visually and those that did not meet the normality assumption did not greatly violate it. During the study, avian abundance, measured as total detections of all species for each point count station, exhibited significant decreases across the sanctuary ($t = 4.63$, $df = 44$, p-value <0.001), Hunt Road ($t = 4.18$, $df = 22$, p-value <0.001), and Meetinghouse Pond ($t = 2.34$, $df = 21$, p-value $= 0.029$) section scales (Figures 5-7). Within Meetinghouse Pond, points that are spatially within the treatment zones in one of the forestry practices (all points pooled together due to sample size) ($t = 1.64$, $df = 5$, p-value = 0.161) and those that received no treatment ($t = 1.74$, $df = 15$, p-value = 0.103), exhibited non-significant decreases in avian abundance (total detections).

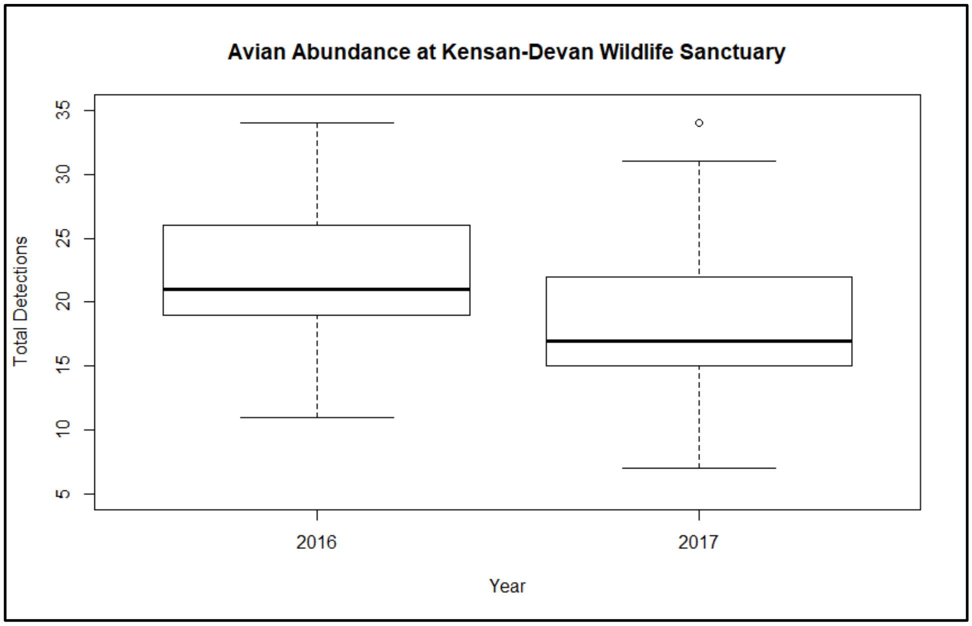

Figure 5. Boxplot showing a significant decrease in avian abundance at Kensan-Devan Wildlife Sanctuary during the study. Total detections represent the summed number of detections at each of the point count stations.

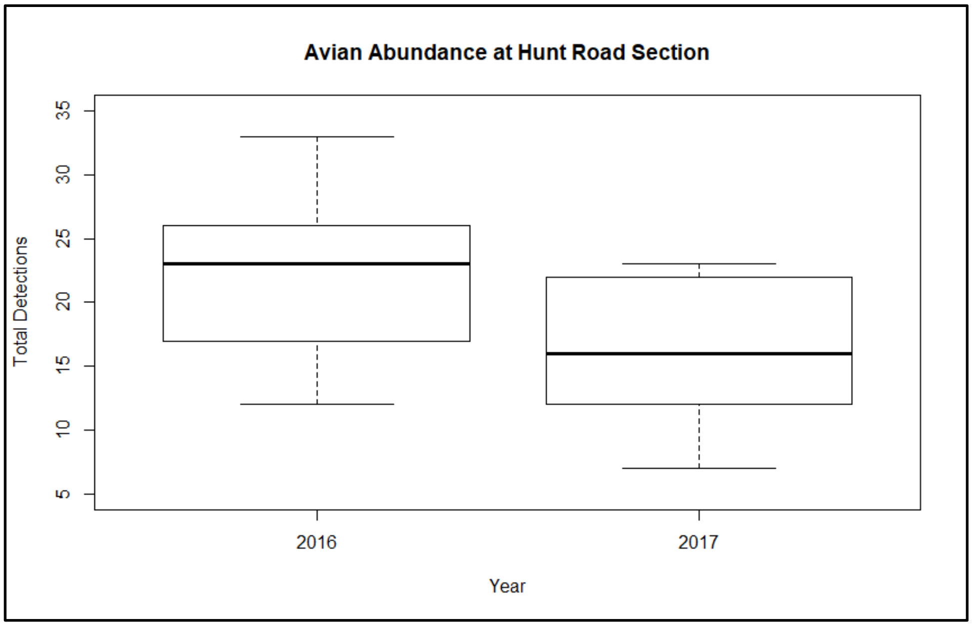

Figure 6. Boxplot showing a significant decrease in avian abundance at Hunt Road section during the study. Total detections represent the summed number of detections at each of the point count stations.

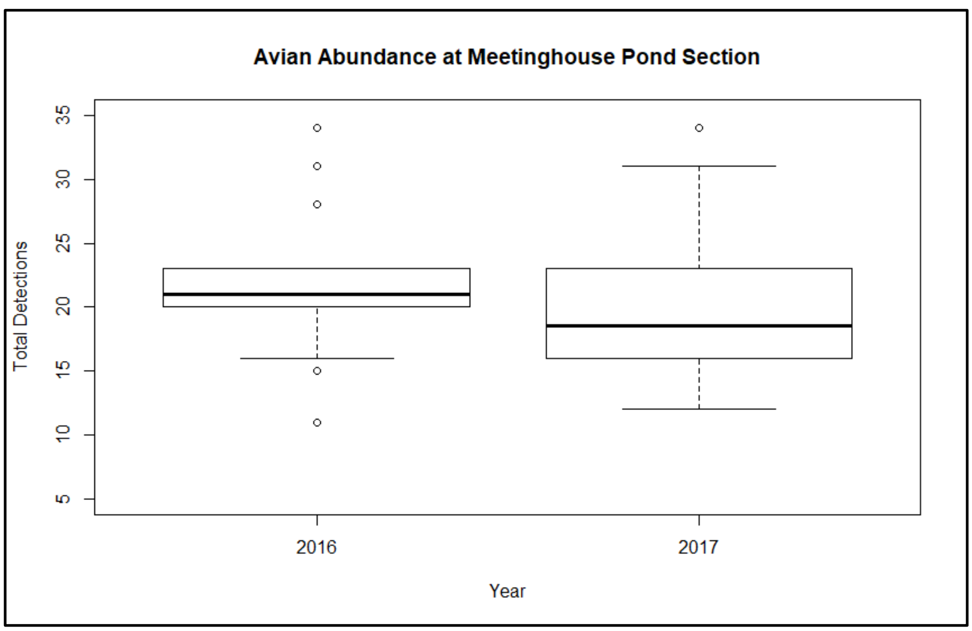

Figure 7. Boxplot showing a significant decrease in avian abundance at Meetinghouse Pond section during the study. Total detections represent the summed number of detections at each of the point count stations.

Target Species Abundance.

To examine the changes on target species (i.e., the six forest species representative of NHA's management efforts at Kensan-Devan) between 2016 and 2017, all target forest species detected were initially pooled together for analysis. Overall abundance of the target species community, based on total detections, exhibited no significant change during the study across the sanctuary ($t = 0.22$, $df = 44$, p-value = 0.828), as well as within the Hunt Road section ($t = -0.11$, $df = 22$, p-value = 0.912) and Meetinghouse Pond section ($t = 0.38$, $df = 21$, p-value = 0.710).

Because distributions for individual target species were not normally distributed, target species with greater than 10 detections each year were individually analyzed using Wilcoxon Signed Rank Tests to assess changes in the first year. Thus, using this level of sufficiency, Black-throated Blue Warbler, Black-throated Green Warbler, Blue-headed Vireo, Eastern Wood-Pewee, and Scarlet Tanager were all analyzed in this manner. Excluded from this test were Canada Warbler and Eastern Towhee, an early-successional species, as they only totaled four and one sightings across both years respectively. Using Wilcoxon Signed Rank Tests, none of the five assessed target species underwent significant change in abundance in the first year ($P>0.05$ in all cases).

Ovenbird and Red-eyed Vireo Abundance.

To further insight into changes in abundance and relative abundance on a species level, Ovenbird and Red-eyed Vireo were selected for closer examination due to two criteria: 1) they both occupy large, mature broadleaf or mixed forests with shrubby understories, thus are representative of Kensan-Devan's habitats, and 2) they were the two most abundant species (total detections) during the study. Overall abundance of Ovenbird, based on total detections, exhibited significant decreases during the study across the sanctuary ($t = 3.50$, $df = 44$, p-value = 0.001) and Hunt Road (unmanaged) section (t = 2.87, df = 22, p-value = 0.009) (Figures 8 and 9). Non-significant decreases were detected for Ovenbird within the managed Meetinghouse Pond section (t = 2.01, df = 21, p-value = 0.057) as well all sites within the latter treated with forestry (t = 2, df = 5, p-value = 0.102) and untreated (t = 1.38, df = 15, p-value = 0.188). Relative abundance of Ovenbirds, a measure of their percentage of the total avian community at each point count station, also exhibited significant decreases at the sanctuary (t = 2.56, df = 44, p-value = 0.014) and Hunt Road section (t = 2.23, df = 22, p-value = 0.036) scales (Figures 10 and 11). Just as it was for total abundance by detections, Ovenbirds exhibited non-significant decreases across the managed Meetinghouse Pond section (t = 1.31, df = 21, p-value = 0.204) as well as sites treated with forestry (t = 2.01, df = 5, p-value = 0.101) and without forestry (t = 0.85, df = 15, p-value = 0.41).

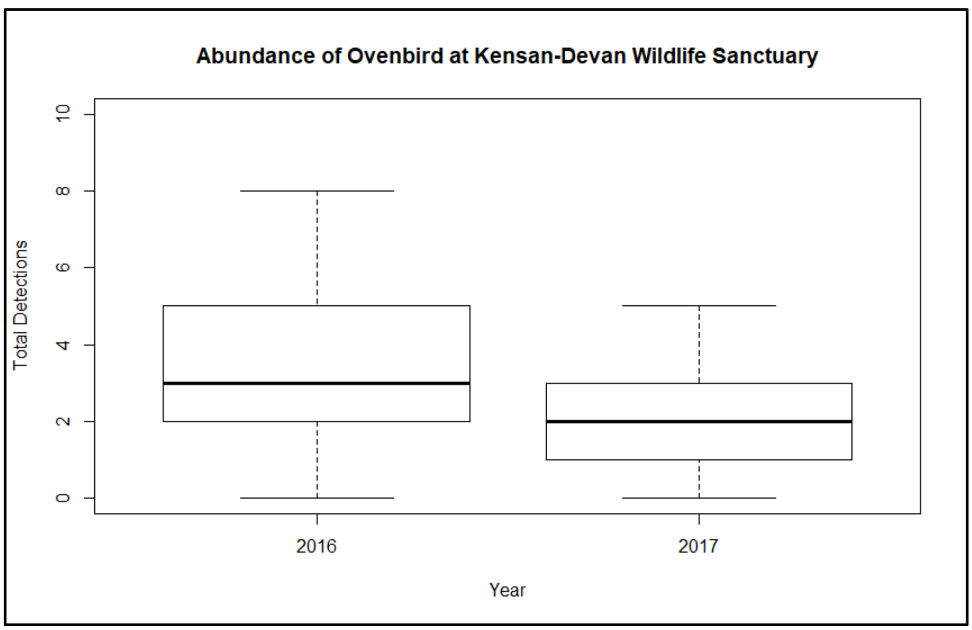

Figure 8. Boxplot showing a significant decrease in Ovenbird abundance at Kensan-Devan Wildlife Sanctuary during the study. Total detections represent the summed number of detections at each of the point count stations.

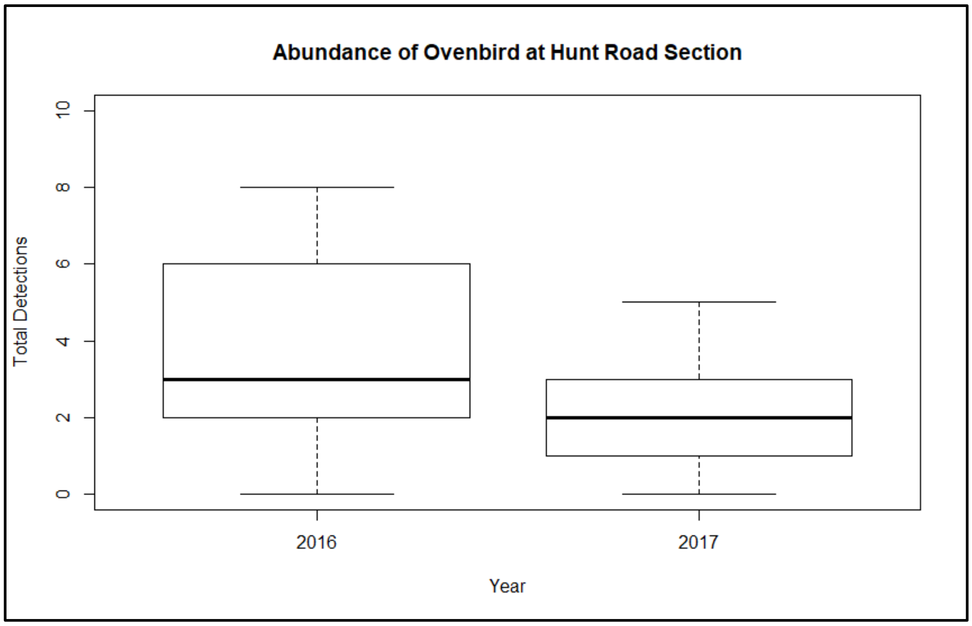

Figure 9. Boxplot showing a significant decrease in Ovenbird abundance at Hunt Road section during the study. Total detections represent the summed number of detections at each of the point count stations.

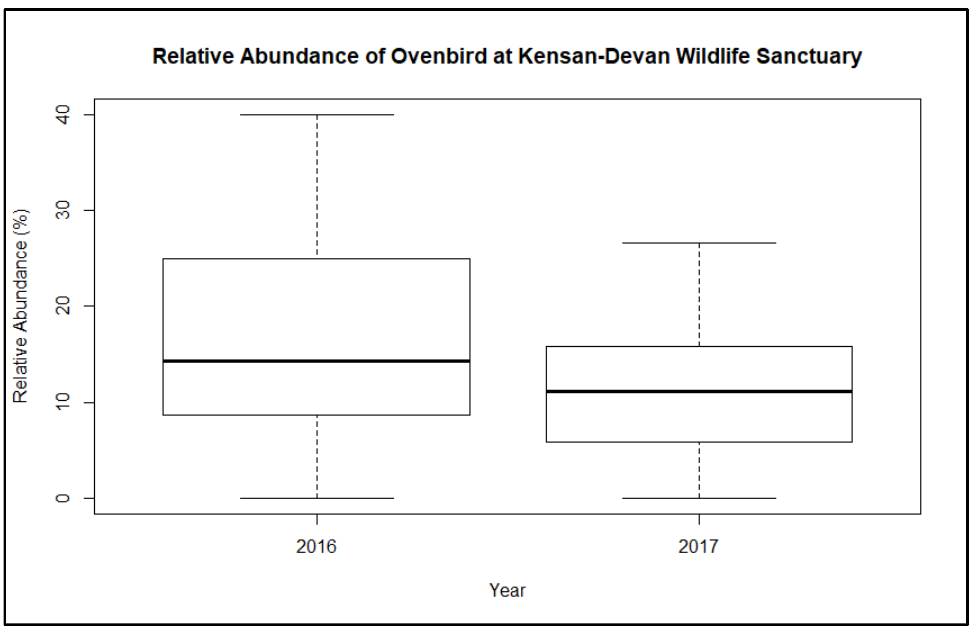

Figure 10. Boxplot showing a significant decrease in Ovenbird relative abundance at Kensan-Devan Wildlife Sanctuary during the study. Relative abundance represents a measure of the percentage of Ovenbirds relative to the total avian community at each point count station.

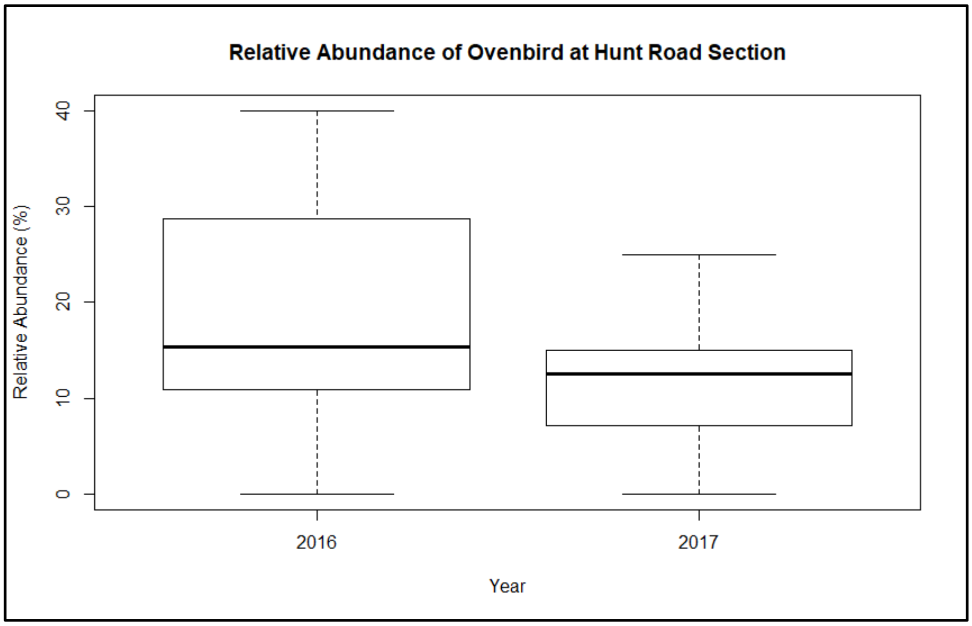

Figure 11. Boxplot showing a significant decrease in Ovenbird relative abundance at Hunt Road section during the study. Relative abundance represents a measure of the percentage of Ovenbirds relative to the total avian community at each point count station.

Based on total detections, Red-eyed Vireo abundance exhibited no significant change across the sanctuary ($t = 0.85$, $df = 44$, p-value = 0.400). However, in the Meetinghouse Pond (managed) section, Red-eyed Vireos experienced a significant decrease ($t = 2.40$, $df = 21$, p-value = 0.026), though they experienced non-significant decreases when examining treated ($t = 1.94$, $df = 5$, p-value = 0.11) and untreated ($t = 1.62$, $df = 15$, p-value = 0.126) points within Meetinghouse Pond separately. Red-eyed Vireos showed no significant change within the (control) Hunt Road section ($t = -0.42$, $df = 22$, p-value = 0.679). Relative abundance of Red-eyed Vireo, a measure of their percentage of the total avian community at each point count station, showed no significant change at the sanctuary ($t = -0.14$, $df = 44$, p-value = 0.889) and Hunt Road section ($t = -1.32$, $df = 22$, p-value = 0.201) scales, and experienced non-significant decreases in relative abundance across the Meetinghouse Pond section ($t = 1.92$, $df = 21$, p-value

= 0.069) and the two forestry treatment types within this section: treated ($t = 1.63$, $df = 5$, p-value = 0.165) and untreated ($t = 1.28$, $df = 15$, p-value = 0.221).

Avian Diversity.

Diversity as measured by the Simpson's Diversity Index exhibited no significant changes at any spatial scale including the sanctuary ($t = -1.34$, $df = 44$, p-value = 0.187), Hunt Road ($t = -0.55$, $df = 22$, p-value = 0.59), and Meetinghouse Pond ($t = -1.56$, $df = 21$, p-value = 0.134) section scales. Diversity within the forestry treatment types including treated zones ($t = -1.21$, $df = 5$, p-value = 0.289) and non-treated ($t = -1.05$, $df = 15$, p-value = 0.311) also exhibited no significant change.

Natural Communities

The Kensan-Devan Wildlife Sanctuary is comprised of four main habitat types according to the 2015 New Hampshire Wildlife Action Plan Wildlife Habitat Land Cover map: 1) hemlock-hardwood-pine, 2) northern swamp, 3) wet meadow/shrub wetland, and 4) open water (NHFGD 2015a) (Figure 12). Of these, the hemlock-hardwood-pine habitat type is by far the most frequent habitat type with 89% of all point count stations falling within it (Table 10). Based on localized variables such as species locations, landscape context, and human influences, many of these habitat types are critically important to birds and other wildlife in both New Hampshire and the biological region (Figure 13 and Table 10).

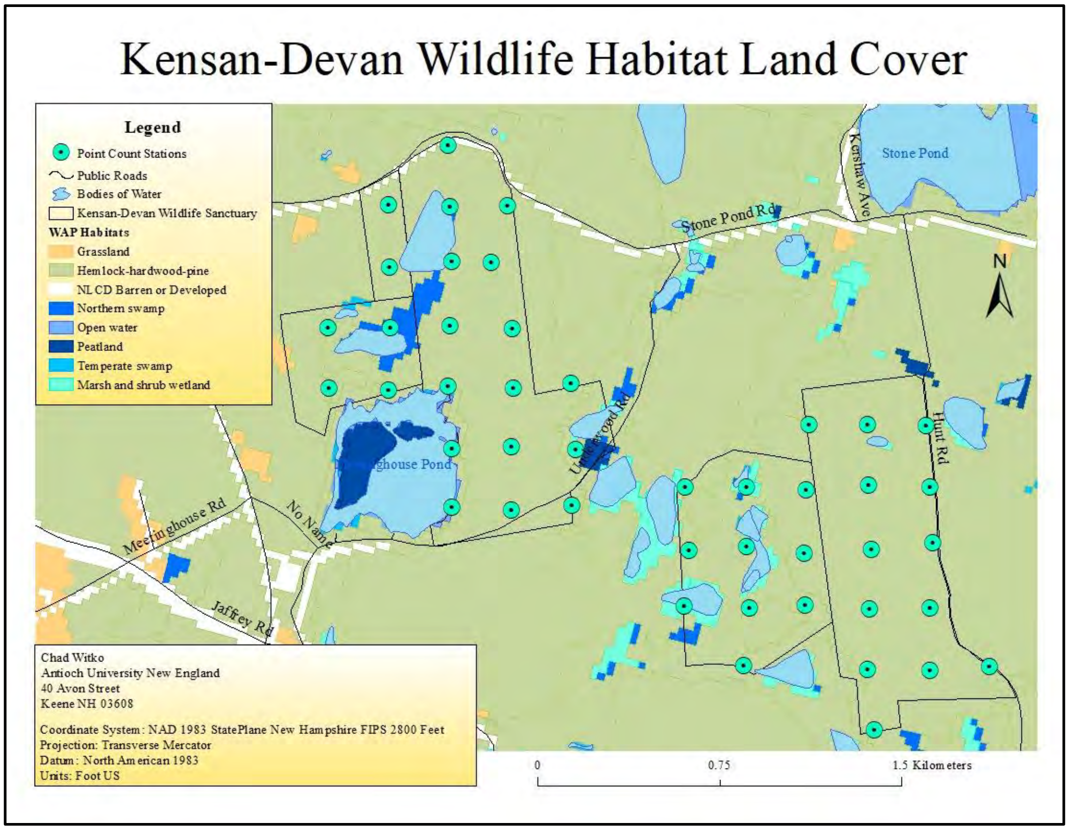

Figure 12. Locator map for wildlife habitat land cover at the Kensan-Devan Wildlife Sanctuary. Map illustrates wildlife habitat land cover for Kensan-Devan and surrounding areas as determined by the New Hampshire Wildlife Action Plan (2015). Legend indicates all land cover shown within the extent of the map.

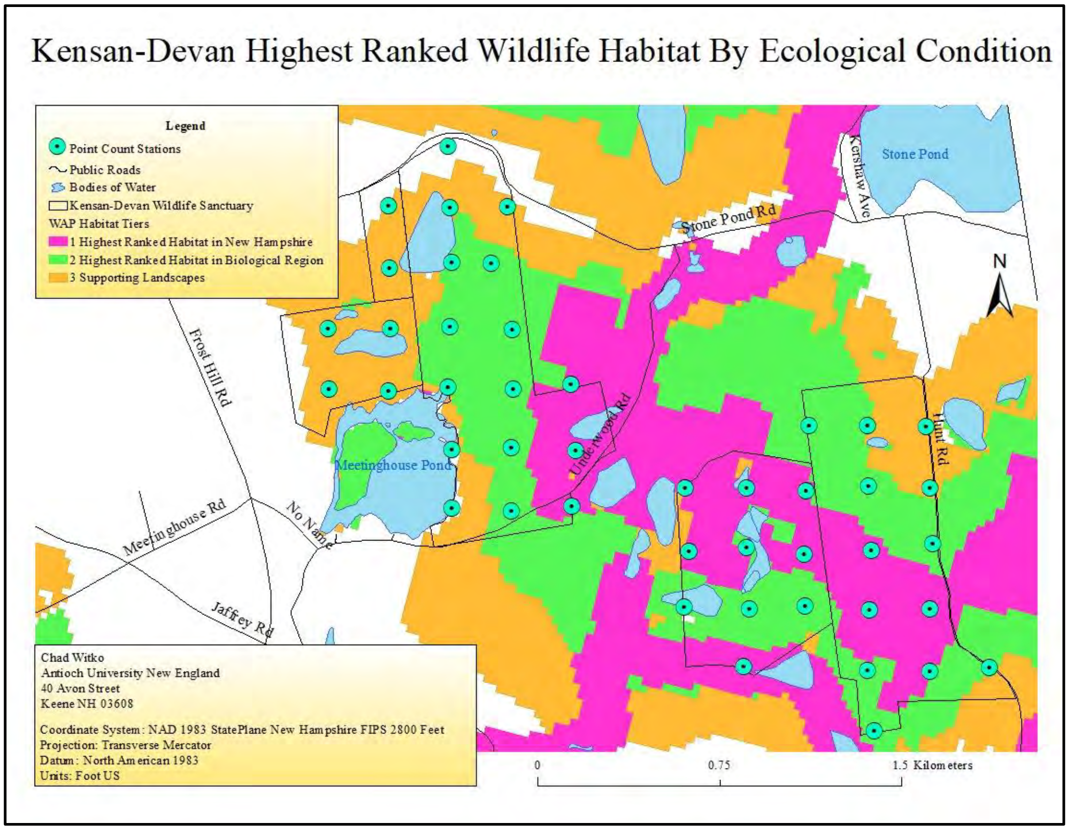

Figure 13. Locator map for highest ranked wildlife habitat by ecological condition at the Kensan-Devan Wildlife Sanctuary. Map illustrates highest ranked wildlife habitat by ecological condition at the Kensan-Devan Wildlife Sanctuary and surrounding areas as determined by the New Hampshire Wildlife Action Plan (2015). Legend indicates all wildlife habitat rankings shown within the extent of the map.

Table 10. Wildlife Habitat Land Cover and Wildlife Habitat Ranking by Ecological Condition at the Kensan-Devan Wildlife Sanctuary's 45 avian point count stations.

Point	Habitat Land Cover	Habitat Ranking by Ecological Condition
1	Hemlock-hardwood-pine	Not Ranked
2	Hemlock-hardwood-pine	Supporting Landscapes
3	Hemlock-hardwood-pine	Supporting Landscapes
4	Hemlock-hardwood-pine	Not Ranked
5	Hemlock-hardwood-pine	Supporting Landscapes
6	Hemlock-hardwood-pine	Highest Ranked Habitat in Biological Region
7	Hemlock-hardwood-pine	Highest Ranked Habitat in Biological Region
8	Hemlock-hardwood-pine	Highest Ranked Habitat in Biological Region
9	Hemlock-hardwood-pine	Highest Ranked Habitat in Biological Region
10	Northern swamp	Supporting Landscapes

Point	Habitat Land Cover	Habitat Ranking by Ecological Condition
11	Hemlock-hardwood-pine	Supporting Landscapes
12	Hemlock-hardwood-pine	Supporting Landscapes
13	Hemlock-hardwood-pine	Supporting Landscapes
14	Hemlock-hardwood-pine	Highest Ranked Habitat in Biological Region
15	Hemlock-hardwood-pine	Highest Ranked Habitat in Biological Region
16	Hemlock-hardwood-pine	Highest Ranked Habitat in New Hampshire
17	Hemlock-hardwood-pine	Highest Ranked Habitat in New Hampshire
18	Hemlock-hardwood-pine	Highest Ranked Habitat in Biological Region
19	Open water	Not Ranked
20	Open water	Not Ranked
21	Hemlock-hardwood-pine	Highest Ranked Habitat in Biological Region
22	Hemlock-hardwood-pine	Highest Ranked Habitat in New Hampshire
23	Hemlock-hardwood-pine	Highest Ranked Habitat in Biological Region
24	Hemlock-hardwood-pine	Highest Ranked Habitat in Biological Region
25	Hemlock-hardwood-pine	Supporting Landscapes
26	Hemlock-hardwood-pine	Supporting Landscapes
27	Hemlock-hardwood-pine	Highest Ranked Habitat in Biological Region
28	Hemlock-hardwood-pine	Highest Ranked Habitat in New Hampshire
29	Wet meadow/shrub wetland	Highest Ranked Habitat in New Hampshire
30	Hemlock-hardwood-pine	Highest Ranked Habitat in New Hampshire
31	Hemlock-hardwood-pine	Highest Ranked Habitat in New Hampshire
32	Hemlock-hardwood-pine	Highest Ranked Habitat in New Hampshire
33	Hemlock-hardwood-pine	Highest Ranked Habitat in New Hampshire
34	Hemlock-hardwood-pine	Highest Ranked Habitat in New Hampshire
35	Hemlock-hardwood-pine	Highest Ranked Habitat in Biological Region
36	Hemlock-hardwood-pine	Highest Ranked Habitat in New Hampshire
37	Hemlock-hardwood-pine	Highest Ranked Habitat in New Hampshire
38	Hemlock-hardwood-pine	Highest Ranked Habitat in Biological Region
39	Hemlock-hardwood-pine	Highest Ranked Habitat in Biological Region
40	Wet meadow/shrub wetland	Highest Ranked Habitat in Biological Region
41	Hemlock-hardwood-pine	Highest Ranked Habitat in New Hampshire
42	Hemlock-hardwood-pine	Highest Ranked Habitat in Biological Region
43	Hemlock-hardwood-pine	Highest Ranked Habitat in New Hampshire
44	Hemlock-hardwood-pine	Highest Ranked Habitat in Biological Region
45	Hemlock-hardwood-pine	Highest Ranked Habitat in Biological Region

Habitat Land Cover and Habitat Ranking by Ecological Condition classifications extracted from New Hampshire Wildlife Action Plan GIS layer.

Within the overarching habitats, there are four distinct natural communities found within and subdividing the forests at Kensan-Devan: 1) Eastern Hemlock, 2) mixed hardwood, 3) hemlock-beech-oak-pine forests, and 4) pine-oak dominated uplands (TEMC 2015). Vegetation within the natural communities consists of canopy-dominant trees (overstory), a tree- and shrub-filled midstory, an understory filled with small shrubs, tree saplings, and herbaceous plants, and ground cover comprised of leaf litter and woody debris.

Throughout Kensan-Devan, as measured from the 45 point count stations, 13 species of trees were identified during the habitat inventory using variable radius plot as the sampling method (Table 11). From this short list of identified species, Red Maple, Eastern Hemlock, Northern Red Oak, Eastern White Pine, Paper Birch (*Betula papyrifera*), and American Beech were the most frequently observed (based on presence/absence at point count stations) (Table 11). This ranking corresponds with the importance value for each, a measure of how dominant a species is in each forested area, with Red Maple, Eastern Hemlock, Northern Red Oak, Eastern White Pine, Paper Birch, and American Beech leading the way (Table 12).

Table 11. Alphabetical list (common name) of tree species present at the Kensan-Devan Wildlife Sanctuary's 45 avian point count stations along with their frequency (percentage of points detected).

Species	**Latin name**	**Percentage of points present**
American Beech	*Fagus grandifolia*	28.89
American Chestnut	*Castanea dentata*	2.22
Balsam Fir	*Abies balsamea*	4.44
Black Birch	*Betula lenta*	20
Black Cherry	*Prunus serotina*	6.67
Eastern Hemlock	*Tsuga canadensis*	71.11
Eastern White Pine	*Pinus strobus*	53.33
Northern Red Oak	*Quercus rubra*	64.44
Paper Birch	*Betula papyrifera*	35.56
Red Maple	*Acer rubrum*	88.89
Red Spruce	*Picea rubens*	13.33
White Ash	*Fraxinus americana*	4.44
Yellow Birch	*Betula alleghaniensis*	11.11

Table 12. Alphabetical list (common name) of tree species present at the Kensan-Devan Wildlife Sanctuary along with their importance value across all point count stations.

Species	**Total count**	**Stand BA(ft2/A)**	**Rel. BA**	**# of occ.**	**Freq.**	**Rel. freq.**	**Importance value**
American Beech	21	4.67	3.17	13	0.29	7.26	5.22
American Chestnut	1	0.22	0.15	1	0.02	0.56	0.35
Balsam Fir	1	0.22	0.15	1	0.02	0.56	0.35
Black Birch	12	2.67	1.81	8	0.18	4.47	3.14
Black Cherry	5	1.11	0.75	3	0.07	1.68	1.22
Eastern Hemlock	182	40.44	27.47	32	0.71	17.88	22.67
Eastern White Pine	98.5	21.89	14.87	24	0.53	13.41	14.14
Northern Red Oak	97.5	21.67	14.72	29	0.64	16.20	15.46
Paper Birch	24.5	5.44	3.70	16	0.36	8.94	6.32
Red Maple	191	42.44	28.83	40	0.89	22.35	25.59
Red Spruce	17	3.78	2.57	5	0.11	2.79	2.68
White Ash	2	0.44	0.30	2	0.04	1.12	0.71
Yellow Birch	10	2.22	1.51	5	0.11	2.79	2.15

The overstory was measured categorically at each of the 45 point count stations for height, percent cover, and distribution (patchy versus uniform) across the site (Table 13). Components of the midstory were measured similarly, including categorical estimates of percent cover and distribution (Table 14). Each midstory was also categorized into whether it was primarily comprised of mixed, hardwood, or softwood components. In only one case was a point largely absent of a discernable midstory. Midstory species included saplings of American Beech, American Chestnut (*Castanea dentata*), American Witch-hazel (*Hamamelis virginiana*), Balsam Fir, Black Birch (*Betula lenta*), Eastern Hemlock, Eastern White Pine, Northern Red Oak, Paper Birch, Red Maple, Red Spruce, Striped Maple (*Acer pensylvanicum*), White Ash, and Yellow Birch.

Table 13. Overstory habitat summarized for points at Kensan-Devan. Total count equals the number of point count stations that have listed habitat characteristics (n=45). Relative frequency is the percentage of point count stations (out of 45).

		Total count	**Relative frequency**
Height (ft)	< 20	3	6.67
	20-60	4	8.89
	> 60	38	84.44
Percent Cover	0-25	1	2.22
	26-50	4	8.89
	51-75	24	53.33
	76-100	16	35.56
Distribution	Patchy	30	66.67
	Uniform	15	33.33

Table 14. Midstory habitat summarized for points at Kensan-Devan. Total count equals the number of point count stations that have the listed habitat characteristics (n=45). Relative frequency is the percentage of point count stations (out of 45).

		Total count	**Relative frequency**
Type	Mixed	34	75.56
	Hardwood	3	6.67
	Softwood	7	15.56
	None	1	2.22
Percent Cover	0	1	2.22
	25	15	33.33
	50	22	48.89
	75	7	15.56
Distribution	Patchy	38	84.44
	Uniform	7	15.56

While only two point count stations (points 11 and 45) had no understory, the remainder showcased varying amounts of undergrowth (Table 15). Understory species included seedlings of American Beech, American Chestnut, American Witch-hazel, Balsam Fir, Eastern Hemlock, Eastern White Pine, Red Spruce, Striped Maple, and unidentified hardwood species. Other common components of the understory included several species of ferns, Hobblebush (*Viburnum lantanoides*), and Lowbush Blueberry (*Vaccinium angustifolium*). Leaf litter is abundant across the entirety of the sanctuary, while coarse woody material (not shown in table) was present at 43 point count stations (95.56% of points), ranging in number from 1 to 13 stems in a 0.04 hectare subplot, averaging 5.69 per point count station. Fine woody material (also not in table) was present at 44 point count stations (97.78% of points), ranging from 1 to 58 stems in a 0.04 hectare subplot with an average of 14.49 stems per station. At the point count stations, Lowbush Blueberry was the most evident soft mast-producing vegetation.

Table 15. Understory habitat summarized for points at Kensan-Devan. Total count equals the number of point count stations that have the listed habitat characteristics (n=45). Relative frequency is the percentage of point count stations (out of 45).

		Total count	Relative frequency
Type	Mixed	30	66.67
	Hardwood	5	11.11
	Softwood	7	15.56
	Sedge	1	2.22
	None	2	4.44
Percent Cover	0	2	4.44
	25	32	71.1
	50	7	15.56
	75	3	6.67
	100	1	2.22
Distribution	Patchy	40	88.89
	Uniform	5	11.11
Soft Mast	Absent	34	75.56
	Present	11	24.44
Leaf Litter	Adequate	43	96.56
	Inadequate	2	4.44

Habitat remained relatively unchanged over the course of one year at all sites receiving no treatment (in both Meetinghouse Pond and Hunt Road) and were not included here. At seven points that were either adjacent to skid trails and cuts (<100 meters) or fell directly within them, the difference was marked in a few areas. This included an average decrease in the continuously measured overstory of 22%, which was which was significant using a paired t-test ($t= 2.90$, $df=6$, $P=0.027$). Categorically measured, there was an increase in understory percent cover while the midstory remained relatively unchanged (Table 16). The best example of change was at point count station 18 where the percent cover of overstory decreased by 55% and course woody material on the forest floor increased to a level too high to accurately count (listed as '999' on the data form).

Table 16. Percent cover of overstory, midstory, and understory at all points that were adjacent to (n=6) or in (n=1) cuts and skidtrails.

		Overstory %		**Midstory %**		**Understory %**	
Notes	**Point**	**2016**	**2017**	**2016**	**2017**	**2016**	**2017**
Adjacent to skid trail	1	75	75	50	50	25	0
Adjacent to cut	3	85	75	50	50	25	50
Adjacent to cut	6	85	40	50	25	75	50
Adjacent to skid trail	8	80	60	50	75	25	75
Edge of skid trail	9	85	75	50	50	25	25
Adjacent to cut	15	75	60	50	75	25	75
Within cut	18	75	20	25	25	25	75

DISCUSSION

Overview

Contemporary research suggests that managing local forest attributes, such as canopy gaps, is an effective strategy to increase both forest bird density and nest success (Bakermans et al. 2012; Keller et al. 2018). First implemented in Vermont in 2008, the "forestry for the birds" style of habitat management was applied to the Kensan-Devan Wildlife Sanctuary during the winter of 2016-2017 when a series of forestry cuts were executed. To establish baseline knowledge of the avian community ahead of the cuts, including NHA's target species, a series of point counts were conducted during the summer of 2016. A year later, another series of point counts were administered to investigate the impact of forestry efforts on the avian community at Kensan-Devan, including NHA's suite of target species. This baseline knowledge and analysis of the avian community during the first-year post-harvest is important to the long-term management of the avian community at Kensan-Devan and may help guide future management.

In the first year, a decrease in total avian abundance and an increase in diversity was detected for the entire avian community across Kensan-Devan. As a group, NHA's target species experienced no significant change in abundance during the first year at the sanctuary or section levels. Using Wilcoxon Signed-Rank Test to analyze target species that exhibited sufficient counts for individual analysis (i.e., above 10 detections per year across Kensan-Devan), no significant change was detected in the first year. Conversely, Kensan-Devan's two most abundant species experienced noteworthy changes with Ovenbird experiencing significant decreases across Kensan-Devan while Red-eyed Vireo exhibited significant decreases in Meetinghouse Pond only. Because these two species were the most abundant across the sanctuary, the changes they experienced likely drove the changes measured across the entire avian community. Due to the limited scope and inconclusive findings of the study, it is not possible to evaluate whether observed differences were due to annual variations or forestry practices. However, it should be noted that target forest birds did not appear to be negatively impacted by forestry over the first year.

Species Analysis

As previously stated, none of the assessed target species underwent significant change in abundance in the first year. Nevertheless, several interesting observations were noted during this study. Of all the targets that were detected, Canada Warbler was the detected the least, occurring just four times over two years at two sites (point count stations 17 and 40) (Figure 14). This lack of detections likely owes to their range-wide declining population and specialized habitat requirements (Reitsma et al. 2009). While the exact forest type Canada Warblers prefer changes based on latitude, from the rhododendron forests of Appalachia to spruce forests in Canada, they invariably inhabit moist, mixed, riparian or cedar swamp forests with a dense understory dominated by shrubs and an irregular forest floor with a well-developed moss layer (Audubon Vermont 2013; Laughlin & Kibbe 1985; Reitsma et al. 2009). In New Hampshire, research has shown males Canada Warblers select territories based on its vegetative structure, including low canopy height, high foliar density in the midstory, the number of available perch trees, and the number of shrub stems taller than a meter in height that are less than 8 centimeters in diameter at breast height (Hallworth et al. 2008). Because of their specific life history requirements during the breeding season, it is not surprising Canada Warblers were so rare at Kensan-Devan, owing to the limited number of moist sites paired with high foliar density of the midstory.

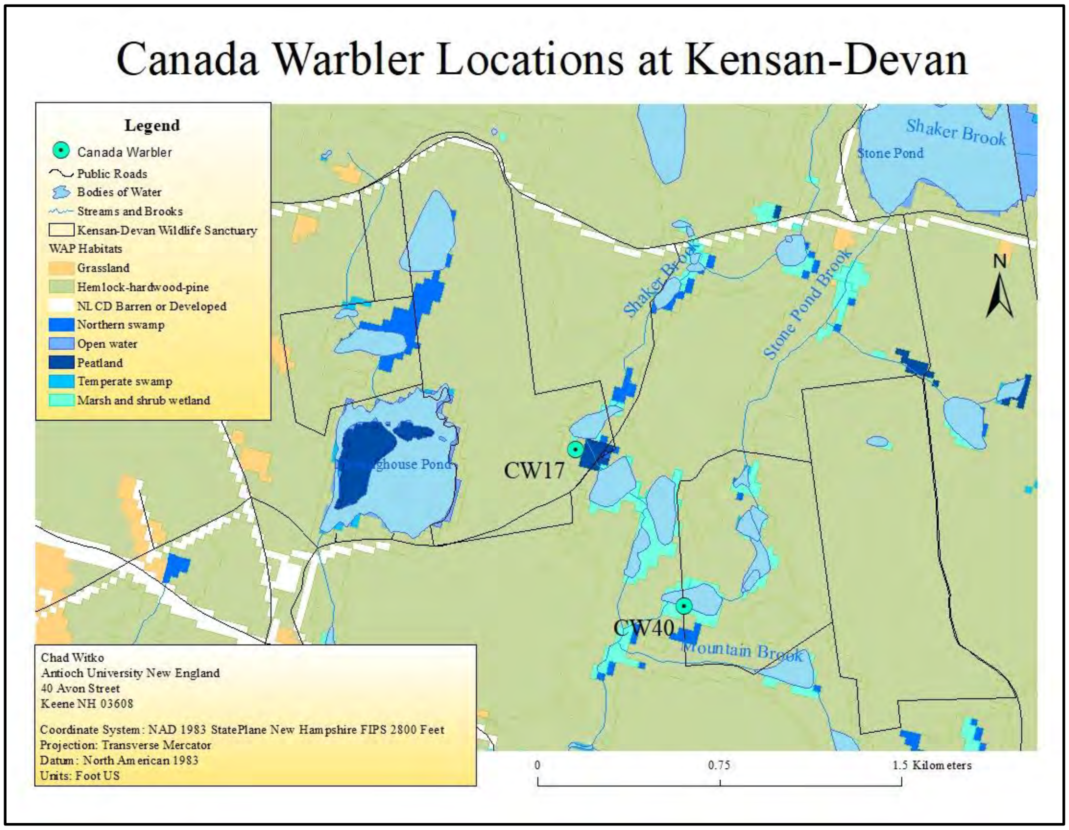

Figure 14. Locator map illustrating the spatial distribution of Canada Warbler detections at Kensan-Devan Wildlife Sanctuary. Point 17 lies west of Shaker Brook and its associated shrub-wetlands while point 40 lies directly adjacent to wetlands north of Mountain Brook.

As rare as Canada Warbler was during this study, there were two target species (Wood Thrush and Chestnut-sided Warbler) that were not detected at all. Preferring habitat characteristics that are seemingly present at Kensan-Devan: shady, moist forests with closed canopies of 15 meters or taller, a moderate to dense understory with a heavy layer of leaf litter, sometimes adjacent to water, Wood Thrush was surprisingly absent (Audubon Vermont 2013; Evans et al. 2011). However, it should be noted that three Wood Thrush were reported from Kensan-Devan within the Meetinghouse Pond section by another observer on July 15, 2017. This was the third to last date of surveys for this study and the same date that NHA led a “Birds and Forestry” field trip to the sanctuary showcasing a “recently harvested forest with bird populations in mind”. Unfortunately, there is no data from the eBird checklist that contained the three Wood Thrush detections that further validates their presence or describes their location at the sanctuary. If the three Wood Thrush were correctly identified, these are the only detections at the sanctuary during the summer breeding season to date.

Of the nine target species listed by NHA, only Eastern Towhee and Chestnut-sided Warbler are early-successional. Due to the absence of early-successional habitat at Kensan-Devan, the absence of Chestnut-sided Warbler and rarity of Eastern Towhee were predictable as forest maturation has a negative relationship with their required habitat’s availability (Klaus et al. 2005). Eastern Towhee was detected only once during point counts, represented by a single detection of a singing male less than 50 meters away from point count station eight on June 8, 2016. Even during the summer of 2017, six months after harvest, early-successional vegetation did not have enough time to fill in any of the larger harvest gaps in a meaningful way to recruit early-successional species, which peak three to five years post-harvest (Kellner et al. 2016; Perry & Thrill 2013). During the summer of 2019, reports from Phil Brown, the Director of Land Management, indicate vegetation is growing within the gaps but is still a few years away from being reaching peak stem density.

At the species level, Ovenbird and Red-eyed Vireo were additionally chosen for statistical analysis and used as a proxy for measuring the changes to Kensan-Devan’s avian community at the species level. These two were selected for this type of analysis because they were by far the most numerous species at Kensan-Devan and exhibited normally distributed data on a species level (all target species showcased non-normally distributed data and were subsequently pooled and analyzed individually using a Wilcoxon Sign Test). Additionally, it was deemed important to remove Ovenbird and Red-eyed Vireo from any community-level analysis as their numbers would drive subsequent results.

Ovenbird, the sanctuary's most abundant species, exhibited significant decreases across the sanctuary and Hunt Road section, which served as a control, and a non-significant decrease across Meetinghouse Pond, the managed section. This pattern generally reflects that of the avian community, suggesting the decreases observed across the sanctuary and in both treated and non-treated sections were the result of annual variation or detection, and not the result of forestry efforts at Kensan-Devan. Due to their substantial contribution to the overall numbers of birds at Kensan-Devan, the significant decrease in Ovenbirds was a major contributing factor to the changes shown in relative abundance for the avian community as a whole. This highlights a recognized weakness of using relative abundance as a metric to measure the avian community.

Among birds classified as mature-forest specialists, Ovenbirds are very sensitive to edge effects created by timber harvests, regardless of disturbance level, and require relatively large contiguous areas of undisturbed forest for successful nesting (Kellner et al. 2016; Perry et al. 2018). At Kensan-Devan, Ovenbirds experienced declines in the first-year post-harvest at all measured spatial scales except within the Seed Treatment, which is just a single point (18). The declines across Meetinghouse Pond where forestry efforts took place were non-significant. As an outcome of these results, there is no evidence that the decreases experienced by Ovenbirds in the first-year post-harvest are linked to forestry measures that took place.

Red-eyed Vireo, the next most-abundant species, exhibited different changes in total detections, significantly decreasing in the managed Meetinghouse Pond section but increasing non-significantly in the control, Hunt Road section. There is evidence in the literature that Red-eyed Vireos prefer a landscape containing a mixture of stand ages and is equally abundant in both selectively cut and mature, even-aged stands (Annand & Thompson 1997; Lichstein et al. 2002). Additional studies indicate that Red-eyed Vireos significantly decline at points associated with clearcuts but are generally not impacted by other regeneration methods (Kellner et al. 2016; King & DeGraaf 2000; Perry et al. 2018). Findings from this study appear to be consistent with that of other studies with Red-eyed Vireo experiencing a non-significant decrease in total detections across the sanctuary, a significant decrease in the Meetinghouse Pond section where forestry took place, and a slight, non-significant increase at Hunt Road, which served as a control.

Management Implications

Historically, it was thought that managing for early-successional and mature forest-breeding species are mutually exclusive. However, contemporary findings indicate differently, showing the total abundance of mature-forest birds on a local scale to be positively correlated to the presence of early-successional habitat patches within a landscape (Chandler et al. 2012). For example, research indicates that the creation of canopy gaps, which increases the number of small trees, may increase the density of Wood Thrush (Bakermans et al. 2012). Additionally, it has been shown that the total number of mature-forest species can rival that of early-successional species in an early-successional clearcut (Vitz & Rodewald 2006). This is directly linked to mature-forest birds' extensive use of early-successional forest patches during the post fledgling period (Chandler et al. 2012; Perry et al. 2018; Vitz & Rodewald 2006). These results by other studies have important implications for NHA in the management of both mature-forest habitats and early-successional patches at Kensan-Devan.

With the use of these patches by adult and juvenile individuals seeking food and protection from predators during the post-fledgling stage, the importance of early-successional patches is equal to or greater than mature forest stands during the nesting period within the life cycle of an individual (Chandler et al. 2012). Specifically, Wood Thrush, Blue-headed Vireo, Red-eyed Vireo, Black-throated Green Warbler, and Black-throated Blue Warbler are all known to move from nesting sites to areas of early- and mid-successional forests created by clearcuts or wildlife openings, while Ovenbirds move from mature-forests to mixed-aged forests with denser understories (Chandler et al. 2012). Even Scarlet Tanagers are sometimes linked to early successional clearcuts and their edges, visiting these habitats to feed on fruit that often regenerates in these areas (Vitz & Rodewald 2006).

When managing for early-successional forests, NHA should consider elements of patch size, shape, and distribution. Evidence shows that early-successional species prefer patches large enough to contain suitable breeding areas >50-80 meters from edges (Rodewald & Vitz 2005). By making these patch cuts square or round, NHA can maximize the interior of these habitats without increasing harvest area. For the larger cuts, this appears to have been done as best as possible around local land features. This has management implications when considering mature-forest management as it will minimize the impact of edge on the landscape, which is negatively correlated to the presence and density of some ground-nesting, mature-forest species (Rodewald & Vitz 2005). In New Hampshire, there was a negative correlation between patch size and density of breeding Chestnut-sided Warblers, but no relationship to the number of young fledged per territory (King & DeGraaf 2004). It is expected that many of the smaller cuts and thinning that occurred throughout the northern portion of Meetinghouse Pond will support breeding Chestnut-sided Warbler, if there is little to no overstory. Conversely, Eastern Towhee is positively associated with larger cut sizes, such as the largest cut which took place in the southeastern quadrant of Meetinghouse Pond (Askins et al. 2007).

Limitations of Study

In the context of this study, the greatest limitation to understanding the response of the avian community to implemented forestry practices was time. While there is utility in understanding the response of the avian community in the first year, peak rates of recolonization and recruitment by mature-forest (e.g., Ovenbird) and early-successional species (e.g, Chestnut-sided Warbler) is several years to a decade away. In the case of early-successional species, detection rates peak three to seven years after harvest with an increased presence lasting a total of 7-12 years (Duguid et al. 2016; Kellner et al. 2016; Perry & Thrill 2013). Alternatively, recolonization by mature forest-obligates can take much longer. In the case of ground-nesting birds such as the Ovenbird, it may take as long as 13-16 years after initial single-tree harvests for population numbers to approach that of unharvested controls (Duguid et al. 2016; Perry et al. 2018).

Another major limitation in this study was the lack of an extensive habitat assessment and its correlation to the avian community through metrics such as abundance and diversity. As previously mentioned, TEMC conducted a complete forest inventory ahead of their forestry plan to evaluate habitat for birds and other wildlife, as well as timber types, forest composition, stocking potential, and total volume for merchantable timber (TEMC 2015). To collect these data, points were established by TEMC on a systematic grid, which were not available at the onset of this study and is different than the 250-meter avian point count grid established by NHA. To best model habitat-influenced changes in avian composition, future studies should use the same points whenever possible so direct comparisons can be made. For future work at Kensan-Devan, it is highly advised that the 45 established point count stations remain and be used due to the baseline established by this study. However, special considerations should be made to try and incorporate the habitat data collected by TEMC whenever possible by analyzing the spatial distribution of the two grids.

To fully determine the impact of forestry on the avian community at Kensan-Devan and to shape future management at this site and others, it is imperative that future iterations of the study be conducted in a manner so that results can be compared over time. It is highly recommended that future studies look to measure habitat variables on a continuous scale for all metrics. Utilizing the *Forestry for the Birds* protocol was an important first step in studying the forest bird community at Kensan-Devan, but there are definitive limitations to measuring habitat characteristics and assigning them a category for their value. Even with experienced observers, it is hard to discount the potential for introducing error into a study by trying to estimate percent cover around categorical bins (e.g., 0-24% or 25-49%). While it is true that birds are likely selecting habitat based on their own categorical assessment to some small degree, there is no definitive way to assign a measured change within the avian community to a concrete habitat value, which will be important over time when managing the system as time progresses and the avian community responds. Additionally, discrete measurements from continuous data allow for threshold relationship assessments, whereas categorical does not.

While many points within Kensan-Devan did not fall within actual treatments, it was nevertheless important to measure them for this and future studies. In areas where point count stations lie adjacent to but not directly within a cut or its associated skid trails, there could still be discernable impacts from the nearby treatments on the very localized bird community. Many species of forest birds, even those with relatively low territory sizes such as the Red-eyed Vireo, utilize the forest on a scale that is larger than the point count station and its measured habitat. This has a direct impact on how habitat measurements might not directly reflect changes in the avian community. As such, it will be incredibly important for future iterations of this study to invest more time and resources into the measurement of habitat, particularly regarding elements such as distance to cuts, if possible

It is also highly recommended that future studies of this system obtain spatial information on the various forestry efforts at the sanctuary. For this thesis, TEMC provided shapefiles for the various forestry treatment zones within Meetinghouse Pond (see Figure 3). However, these zones only tell part of a picture as they only show areas that various forestry treatments fell within, not the actual cuts themselves (Figure 15). This is particularly challenging for smaller cuts, which may still have a sizeable impact. While there would be both sample size and scale challenges due to some cut sizes being too small, having shapefiles for the individual cuts might allow future iterations of this research to study the impact of ‘cut size’ along with ‘distance to cut’ as factors that might impact the avian community and target species at Kensan-Devan. This is particularly relevant for point count stations where there is no discernable change in habitat at the station itself from small, neighboring cuts just out of view, which nevertheless impact the presence and abundance of forest birds that are selecting for habitat characteristics on a spatial scale larger than the point count station itself.

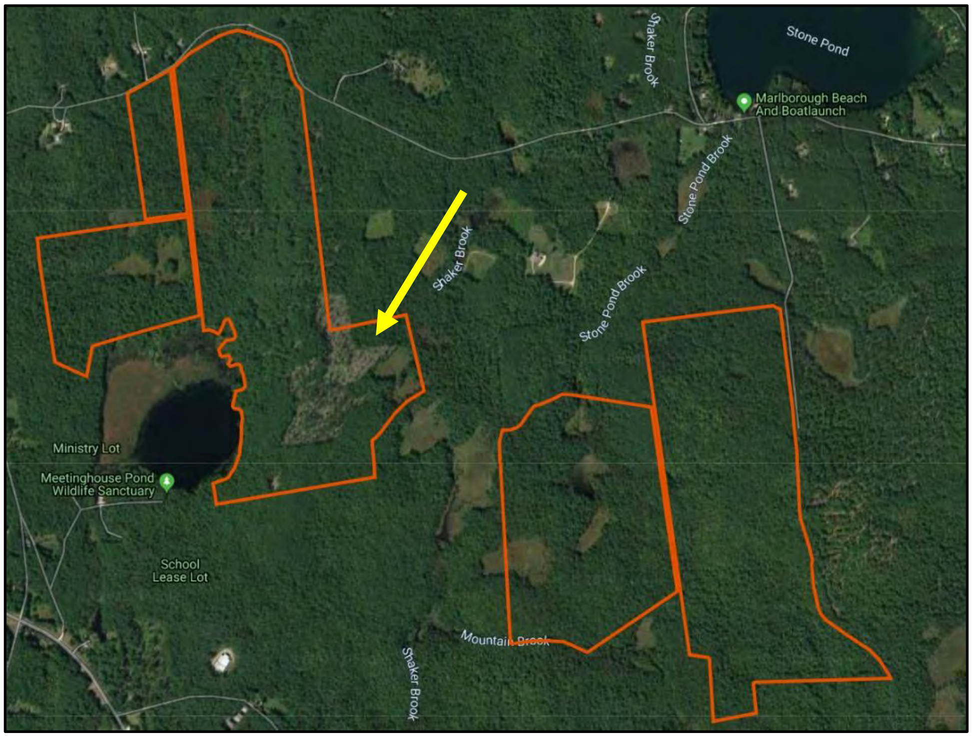

Figure 15. Kensan-Devan Wildlife Sanctuary boundary satellite imagery. Note the forestry efforts in the southeastern quadrant of the Meetinghouse Pond section as indicated by the yellow arrow. Satellite imagery provided by Google Maps (2019). Shapefiles provided by New Hampshire Audubon.

Future Suggestions

When choosing management methods based around forestry, forest managers should consider the balance between timber production and the conservation of native fauna and flora, including birds (Kellner et al. 2016). While "forestry for the birds" is aimed at conserving birds using forestry as a conservation tool, these efforts will ultimately impact more than just a property's avifauna. As such, it is critical that NHA continue to consult TEMC to reevaluate management goals during different stages of this process. It is also imperative that NHA understands how local biodiversity is affected by forestry efforts in order to have effective integrated forest management approaches (Bascille et al. 2019). Management suggestions for all nine target species, along with Ovenbird and Red-eyed Vireo, can be found in the Appendix F. The suggestions are based on management practices proposed by TEMC, the life history requirements for these species, and the exhaustive literature that surrounds many of the "forestry for the birds" programs in New England.

Multiple goals are often associated with timber harvest as it relates to forest bird conservation. In the case of forest management at Kensan-Devan this includes the regeneration of new trees, developing well-developed mid-stories, and creating early-successional habitat (TEMC 2015). Research indicates that on the local, forest-stand scale, no one method to achieve this appears optimal for the entire forest bird community. For example, while some species would benefit from routine management, some species of ground-nesting birds, such as Ovenbirds, are negatively impacted by the greater disturbance caused by continually maintained logging roads and skid trails (Kellner et al. 2016). As such, important considerations should be made to the timing of timber harvests across a sanctuary as continued activity could contribute to decline in some species.

As stated in the hypothesis, the abundance of mature-forest species such as Ovenbird and Red-eyed Vireo declined in the first-year post-harvest, whereas early-successional species were not yet detected. However, this study cannot confirm that the effect of forestry has directly affected the abundance of mature-forest species. Nevertheless, during the 2016 and 2017 seasons, the avian community at Kensan-Devan appears healthy and robust. The noted changes that took place are likely linked to expected annual variation and stochastic events such as weather (e.g., wet springs, drought, snow depth, ice storms) and food supply.

While I would expect the total detections of Ovenbird at Kensan-Devan to routinely fluctuate in subsequent years, it would not be surprising if they remained suppressed due to their sensitivity around forestry efforts and their long recolonization rates. Conversely, I would expect an increase of Chestnut-sided Warbler within the larger cuts of Kensan-Devan in the next five years, as this species has a propensity to find its way into early-successional gaps within the forest. With continued management of the forest as prescribed by NHA and the species-specific recommendations presented in the Appendices, target species selected by NHA should continue to be present and increase in density in the short- and mid-term.

Not unexpectedly, further research is still required to provide a more robust understanding of the avian community at Kensan-Devan, particularly when it comes to maintaining an abundant and diverse avian community along with a suite of target species, many of which have different life history requirements. It is imperative that this study be repeated in the future throughout the management and timber harvest process to assess the effect of current and future management in relation to avian abundance and diversity. While annual breeding bird surveys at Kensan-Devan would be ideal, the logistics of this make this option less feasible. Instead, future surveys should be conducted in a timeframe where the entire property (all 45 established point count stations) can be surveyed in a single season while considering the typical response times of the avian communities to forestry efforts in mature-forest and the newly developed early-successional stands. Based on the known response times of peak avian density to harvest, early-successional communities are best surveyed every 2-4 years to capture the growth, peak, and eventual change of avian composition and densities. Because the recolonization rates in mature-forests occur over a broader timeframe, including up to 16 years for some ground-nesting species, surveys are best conducted every 3-5 years. To balance this out, we recommend official surveys of Kensan-Devan occur every 2-3 years due to the different avian response times and habitat types managed for at the sanctuary. This would allow researchers to collect avian occurrence data at key junctures when forest regeneration within the various harvest types is most likely to attract or maximize the presence and density of target species.

To facilitate this study, routine maintenance of the 45 point count stations should be upheld to assure they do not degrade over time and become lost in the landscape. One suggestion is for NHA to affix small aluminum tags to the trees indicating the point count stations. These would require less maintenance over time and would also decrease the extensive use of unsightly vinyl flagging on the landscape which invariably breaks down but isn't biodegradable. Birding checklists submitted to eBird at the two hotspots for the sanctuary could also be used as supplemental occurrence data between official surveys.

Finally, as future iterations of management take place, NHA would be well advised to incorporate findings from contemporary studies based on "forestry for the birds"-style studies. With "forestry for the birds" becoming an increasingly utilized conservation tool across New England, there will be more and more research to draw inferences upon as these practices mature. As such, it is critical that regular data collection take place at Kensan-Devan to best inform the direction and magnitude of future harvests with both the avian community and target species in mind. To reflect moving targets of management, particularly considering climate change, it is suggested that other target species be considered as future data are collected. Examples at Kensan-Devan include Prairie Warbler and American Woodcock, two species in decline across their range. While each of these species have their own unique habitat requirements as it relates to forest management, such as relatively large patch size and complete cuts for Prairie Warbler (>1.1 hectares), these are two species that are often impacted positively by timber harvests and their subsequent successional growth (Audubon Vermont 2013; Hunt et al. 2011; Maine Audubon 2017; Shake et al. 2012). To better model the changes within the avian community as it relates to forestry, special consideration to which species are included in future analysis is highly suggested. The aim of this is to avoid the inclusion of species represented in the overall avian community that may use Kensan-Devan tangentially but are not directly linked to mature or early-successional forests. Future studies on occupancy, detection rates, and closer associations to the individual clearings are also suggested and would help establish a stronger baseline that will be useful at this and other properties.

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APPENDICES

Appendix A: Photos of Forestry at Kensan-Devan Wildlife Sanctuary

Figure A1. Post-timber harvest at Kensan-Devan Wildlife Sanctuary (Meetinghouse Pond section- June 9, 2017).

Figure A2. Post-timber harvest at Kensan-Devan Wildlife Sanctuary (Meetinghouse Pond section- June 9, 2017).

Figure A3. Post-timber harvest at Kensan-Devan Wildlife Sanctuary (Meetinghouse Pond section- June 9, 2017).

Figure A4. Skid trail at Kensan-Devan Wildlife Sanctuary (Meetinghouse Pond section- June 9, 2017).

Appendix B: Kensan-Devan Wildlife Sanctuary Point Count Data Sheet

Kensan-Devan Wildlife Sanctuary Point Count Data Form Page____of_____

Start Weather Information (to be taken at first point count station)
Temp:______° F or ° C (circle one) **Cloud Cover**______% **Wind Speed**______mph, knots, or kmph (circle one)

Month Day Year Visit # Observer Name Phone Number

Point #		Time				Species				≤ 50 m	> 50 m	Fly-overs	Breed?

End Weather Information (to be taken at last point count station)
Temp:______° F or ° C (circle one) **Cloud Cover**______% **Wind Speed**______mph, knots, or kmph (circle one)

Data Entry (Initial): Entered: _______________Proofed: _____________eBird:_____________

Appendix C: Bird Habitat Data Field Sheet (by Audubon Vermont)

Silviculture with Birds in Mind
Bird Habitat Data Field Sheet

Property: ______ Plot ID: ______ GPS ID: ______
Technician: ______ Date: ______ BAF: ______

Photo(s)					
Canopy Height:	<20 ft	20-60 ft	>60 ft		
Overstory (30'+)					
% cover					
distribution:	uniform	patchy			
Midstory (5-30')					
% cover:	0%	25%	50%	75%	100%
distribution:	uniform	patchy			
type:	hdwd	softwd	mixed		
Understory (0-5')					
cover	0%	25%	50%	75%	100%
distribution:	uniform	patchy			
type:	hdwd	softwd	mixed		
Soft mast					
presence:	present	absent			
species:					
Non-native invasive woody plants					
cover:	0%	25%	50%	75%	100%
species:					
Leaf litter	adaquate	inadaquate			
Coarse woody material (CWM) (# of pieces >10 in diameter and >3 ft long in 1/10 acre sub-plot)					
Fine woody material (FWM) (# of piles and tops in 1/10 acre sub-plot)					
Birds Observed	**Notes**				

Silviculture with Birds in Mind
Bird Habitat Data Field Sheet

Property: ______ Plot ID: ______ GPS ID: ______
Technician: ______ Date: ______ BAF: ______

Photo(s)					
Canopy Height:	<20 ft	20-60 ft	>60 ft		
Overstory (30'+)					
% cover					
distribution:	uniform	patchy			
Midstory (5-30')					
% cover:	0%	25%	50%	75%	100%
distribution:	uniform	patchy			
type:	hdwd	softwd	mixed		
Understory (0-5')					
cover	0%	25%	50%	75%	100%
distribution:	uniform	patchy			
type:	hdwd	softwd	mixed		
Soft mast					
presence:	present	absent			
species:					
Non-native invasive woody plants					
cover:	0%	25%	50%	75%	100%
species:					
Leaf litter	adaquate	inadaquate			
Coarse woody material (CWM) (# of pieces >10 in diameter and >3 ft long in 1/10 acre sub-plot)					
Fine woody material (FWM) (# of piles and tops in 1/10 acre sub-plot)					
Birds Observed	**Notes**				

Data sheet available at: http://vt.audubon.org/sites/default/files/birdhab_field_sheet.pdf

Appendix D: Photos of Point Count Stations (Facing North from Point Count Center)

Figure D1. Point Count Station 01 (Meetinghouse Pond section- July 26, 2016).

Figure D2. Point Count Station 02 (Meetinghouse Pond section- July 26, 2016).

Figure D3. Point Count Station 03 (Meetinghouse Pond section- July 26, 2016).

Figure D4. Point Count Station 04 (Meetinghouse Pond section- July 26, 2016).

Figure D5. Point Count Station 05 (Meetinghouse Pond section- July 26, 2016).


Figure D6. Point Count Station 06 (Meetinghouse Pond section- July 26, 2016).

Figure D7. Point Count Station 07 (Meetinghouse Pond section- July 26, 2016).

Figure D8. Point Count Station 08 (Meetinghouse Pond section- July 28, 2016).

Figure D9. Point Count Station 09 (Meetinghouse Pond section- July 28, 2016).

Figure D10. Point Count Station 10 (Meetinghouse Pond section- July 28, 2016).

Figure D11. Point Count Station 11 (Meetinghouse Pond section- July 28, 2016).

Figure D12. Point Count Station 12 (Meetinghouse Pond section- July 28, 2016).

Figure D13. Point Count Station 13 (Meetinghouse Pond section- July 28, 2016).

Figure D14. Point Count Station 14 (Meetinghouse Pond section- July 28, 2016).

Figure D15. Point Count Station 15 (Meetinghouse Pond section- July 27, 2016).

Figure D16. Point Count Station 16 (Meetinghouse Pond section- July 27, 2016).

Figure D17. Point Count Station 17 (Meetinghouse Pond section- July 27, 2016).

Figure D18. Point Count Station 18 (Meetinghouse Pond section- July 27, 2016).

Figure D19. Point Count Station 19 (Meetinghouse Pond section- July 27, 2016).

Figure D20. Point Count Station 20 (Meetinghouse Pond section- July 27, 2016).

Figure D21. Point Count Station 21 (Meetinghouse Pond section- July 27, 2016).

Figure D22. Point Count Station 22 (Meetinghouse Pond section- July 27, 2016).

Figure D23. Point Count Station 23 (Hunt Road section- October 17, 2016).

Figure D24. Point Count Station 24 (Hunt Road section- October 17, 2016).

Figure D25. Point Count Station 25 (Hunt Road section- October 17, 2016).

Figure D26. Point Count Station 26 (Hunt Road section- October 11, 2016).

Figure D27. Point Count Station 27 (Hunt Road section- October 17, 2016).

Figure D28. Point Count Station 28 (Hunt Road section- October 16, 2016).

Figure D29. Point Count Station 29 (Hunt Road section- October 17, 2016).

Figure D30. Point Count Station 30 (Hunt Road section- October 17, 2016).

Figure D31. Point Count Station 31 (Hunt Road section- October 17, 2016).

Figure D32. Point Count Station 32 (Hunt Road section- October 16, 2016).

Figure D33. Point Count Station 33 (Hunt Road section- October 17, 2016).

Figure D34. Point Count Station 34 (Hunt Road section- October 17, 2016).

Figure D35. Point Count Station 35 (Hunt Road section- October 11, 2016).

Figure D36. Point Count Station 36 (Hunt Road section- October 12, 2016).

Figure D37. Point Count Station 37 (Hunt Road section- October 11, 2016).

Figure D38. Point Count Station 38 (Hunt Road section- October 11, 2016).

Figure D39. Point Count Station 39 (Hunt Road section- October 11, 2016).

Figure D40. Point Count Station 40 (Hunt Road section- October 12, 2016).

Figure D41. Point Count Station 41 (Hunt Road section- October 11, 2016).

Figure D42. Point Count Station 42 (Hunt Road section- October 11, 2016).

Figure D43. Point Count Station 43 (Hunt Road section- October 11, 2016).

Figure D44. Point Count Station 44 (Hunt Road section- October 11, 2016).

Figure D45. Point Count Station 45 (Hunt Road section- June 11, 2016).

Appendix E: Key for the American Ornithological Society (AOS) Designated Alpha Codes

Common Name	Scientific Name	Alpha Code
Alder Flycatcher	*Empidonax alnorum*	ALFL
American Crow	*Corvus brachyrhynchos*	AMCR
American Goldfinch	*Spinus tristis*	AMGO
American Robin	*Turdus migratorius*	AMRO
Barn Swallow	*Hirundo rustica*	BARS
Barred Owl	*Strix varia*	BADO
Black-and-white Warbler	*Mniotilta varia*	BAWW
Black-billed Cuckoo	*Coccyzus erythropthalmus*	BBCU
Blackburnian Warbler	*Setophaga fusca*	BLBW
Black-capped Chickadee	*Poecile atricapillus*	BCCH
Black-throated Blue Warbler	*Setophaga caerulescens*	BTBW
Black-throated Green Warbler	*Setophaga virens*	BTNW
Blue Jay	*Cyanocitta cristata*	BLJA
Blue-headed Vireo	*Vireo solitarius*	BHVI
Bobolink	*Dolichonyx oryzivorus*	BOBO
Broad-winged Hawk	*Buteo platypterus*	BWHA
Brown Creeper	*Certhia americana*	BRCR
Canada Warbler	*Cardellina canadensis*	CAWA
Cedar Waxwing	*Bombycilla cedrorum*	CEDW
Common Loon	*Gavia immer*	COLO
Common Raven	*Corvus corax*	CORA
Common Yellowthroat	*Geothlypis trichas*	COYE
Downy Woodpecker	*Picoides pubescens*	DOWO
Eastern Kingbird	*Tyrannus tyrannus*	EAKI
Eastern Phoebe	*Sayornis phoebe*	EAPH
Eastern Towhee	*Pipilo erythrophthalmus*	EATO
Eastern Wood-Pewee	*Contopus virens*	EAWP
Golden-crowned Kinglet	*Regulus satrapa*	GCKI
Green Heron	*Butorides virescens*	GRHE
Hairy Woodpecker	*Leuconotopicus villosus*	HAWO
Hermit Thrush	*Catharus guttatus*	HETH
House Wren	*Troglodytes aedon*	HOWR
Least Flycatcher	*Empidonax minimus*	LEFL
Mallard	*Anas platyrhynchos*	MALL
Mourning Dove	*Zenaida macroura*	MODO
Northern Flicker	*Colaptes auratus*	NOFL
Northern Parula	*Setophaga americana*	NOPA
Northern Waterthrush	*Parkesia noveboracensis*	NOWA
Ovenbird	*Seiurus aurocapilla*	OVEN
Pileated Woodpecker	*Hylatomus pileatus*	PIWO

Common Name	Scientific Name	Alpha Code
Pine Warbler	*Setophaga pinus*	PIWA
Purple Finch	*Haemorhous purpureus*	PUFI
Red-bellied Woodpecker	*Melanerpes carolinus*	RBWO
Red-breasted Nuthatch	*Sitta canadensis*	RBNU
Red-eyed Vireo	*Vireo olivaceus*	REVI
Red-shouldered Hawk	*Buteo lineatus*	RSHA
Red-winged Blackbird	*Agelaius phoeniceus*	RWBL
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	RBGR
Ruffed Grouse	*Bonasa umbellus*	RUGR
Scarlet Tanager	*Piranga olivacea*	SCTA
Song Sparrow	*Melospiza melodia*	SOSP
Swamp Sparrow	*Melospiza georgiana*	SWSP
Tree Swallow	*Tachycineta bicolor*	TRES
Tufted Titmouse	*Baeolophus bicolor*	TUTI
Veery	*Catharus fuscescens*	VEER
White-breasted Nuthatch	*Sitta carolinensis*	WBNU
Winter Wren	*Troglodytes hiemalis*	WIWR
Wood Duck	*Aix sponsa*	WODU
Yellow-bellied Sapsucker	*Sphyrapicus varius*	YBSA
Yellow-billed Cuckoo	*Coccyzus americanus*	YBCU
Yellow-rumped Warbler	*Setophaga coronata*	YRWA

Appendix F: Target Species Requirements

Black-throated Blue Warbler

Across New England, Black-throated Blue Warblers inhabit large tracts of relatively undisturbed interior deciduous and mixed forests (Audubon Vermont 2013, Holmes et al. 2017). With territory size ranging from 1.01-4.05 hectares with diverse understory, this well-studied warbler prefers larger contiguous tracts (>101 hectares) with 50-80% canopy cover, and trees mixed in size and age over 12 meters in height (Maine Audubon 2017). In New Hampshire, Black-throated Blue Warblers are most abundant in northern hardwood forests dominated by maples, birches, and beech trees at elevations of 400-700 meters (Holmes et al. 2017). Black-throated Blue Warblers prefer a dense understory of deciduous or broad-leaved evergreen shrubs including Hobblebush and other small saplings of Sugar Maple, American Beech, Striped Maple, Red Spruce, and Balsam Fir (Audubon Vermont 2013; Holmes et al. 2017; Maine Audubon 2017).

Research has provided evidence that vegetation structure, specifically shrub density, was integral to the reproductive performance of Black-throated Blue Warblers in fragmented forests, suggesting this species responds to localized forest characteristics during the breeding season (Cornell & Donovan 2010). Black-throated Blue Warblers do not normally occur in young clearcuts or second growth stands, but readily use forestry treatments that include group selection and selective logging (Webb et al. 1977). Forest management suggestions across the region for Black-throated Blue Warbler include creating a dense understory under a broken canopy for nesting (Audubon Vermont 2013; Jobes et al. 2004). At Kensan-Devan there is already a fair amount of understory across the sanctuary at the site scale. Nevertheless, active management is recommended to keep a dense understory of Hobblebush and small saplings of Sugar Maple, American Beech, Striped Maple and various softwoods within mixedwood habitats (TEMC

2015). During the study Black-throated Blue Warbler was detected 42 times (22 in 2016 and 20 in 2017).

Black-throated Green Warbler

Across the Northeast in coniferous, mixed, and even pure deciduous forests, the Black-throated Green Warbler is often among the most common breeding species (Audubon Vermont 2013; Morse & Poole 2005). Territory size for this species varies depending upon habitat type, ranging from 0.24 hectares in preferred spruce forests to 0.65 hectares in hemlock-beech stands (Maine Audubon 2017). In New Hampshire and other parts of non-coastal New England, Black-throated Green Warbler has a tight association with Eastern Hemlock during the breeding season (Morse & Poole 2005). Overall, Black-throated Green Warblers prefer multi-layered, closed canopy (>80% cover) forests in tracts greater than 101 hectares with trees over 15 meters in height and a dense midstory (Maine Audubon 2017). At the end of the breeding season, both first year offspring and adults have been known to shift from feeding in evergreen foliage to foraging in Paper Birch when they contain large populations of insects (Morse & Poole 2005). Anecdotal evidence for foraging Black-throated Green Warblers in both Paper Birch and Yellow Birch is high at the end of the summer period.

Future management at Kensan-Devan should consider leaving large blocks undisturbed to maintain forest interior for this species as fragmentation, thinning, and creating forest gaps 24-40 meters in width often leads to the disappearance of Black-throated Green Warblers in small plots and reduced breeding densities (Audubon Vermont 2013; Freedman et al. 1981; Hagan et al. 1996). Additional management suggestions include retaining, releasing, and regenerating Yellow Birch whenever possible. During the study Black-throated Green Warbler was detected 108 times (56 in 2016 and 52 in 2017). Black-throated Green Warblers are well represented at

Kensan-Devan and the sanctuary's natural state appears to be well suited for strong, viable populations without much management.

Blue-headed Vireo

Widely distributed across New England at mid-elevation levels in extensive forests, the Blue-headed Vireo occupies moist coniferous forests, although will occupy deciduous forests at times (Audubon Vermont 2013; Morton & James 2014). Across their range, Blue-headed Vireos are tightly associated with closed canopy cover. As such, forest management suggestions include maintain a closed canopy cover as even partial clearing due to group selection harvest may seriously impact breeding density and the ability of individuals to find mates (Audubon Vermont 2013; Meehan 1996). At Kensan-Devan, easy management would be to maintain large stands with a closed canopy of Eastern Hemlock and other softwoods whenever possible. During the study Blue-headed Vireo was detected 67 times (34 in 2016 and 33 in 2017).

Canada Warbler

During the breeding season, the Canada Warbler inhabits cool, moist, mixed forests, complete with dense understory, multifaceted ground cover, and often standing water (Reitsma et al. 2009). More specifically, Canada Warblers prefer moist, mixed woods with 50-70% canopy cover complete with a dense understory and midstory (Maine Audubon 2017). Present in 10- and 20-year old clear cuts and selectively cut areas, Canada Warblers are typically not present in recent clear cuts or uncut mature forests (Reitsma et al. 2009). Forest management suggestions across New England include providing forested wetlands with small gaps through management to 50-70% canopy cover, while improving vertical structure in mixed forests (Audubon Vermont 2013; Maine Audubon 2017). It should be noted that evidence suggests Canada Warblers are sensitive to reduction of vegetative undergrowth by forest ungulates (DeGraaf et al. 1991).

At Kensan-Devan, future management will be directly tied to low-lying wet areas of the property with 50-80% canopy cover (TEMC 2015). In these areas it will be critical to retain a sizeable softwood component in the understory of hardwood (deciduous) stands and to help maintain an uneven forest floor through the presence of coarse woody debris. It might also be advantageous to Canada Warbler management to allow hunting of White-tailed Deer to assist in maintaining lower deer densities which could aid in breeding opportunities due to a healthier understory. During the study Canada Warbler was only detected four times (one in 2016 and three in 2017). Using the breeding habitat requirements of Canada Warbler as a guide, by managing vegetative structure of the forest around moist sites, the increased presence and abundance of this species at Kensan-Devan is likely.

Chestnut-sided Warbler

Closely associated with young forests or old fields with dense shrub cover, the Chestnut-sided Warbler is a frequent target species for management across New England where it was once essentially absent (Byers et al. 2013; Audubon Vermont 2013). With territory sizes ranging from 0.4-1.21 hectares, this species has historically relied on natural disturbances that created patches of young forest within a landscape of mature forests that New England is famous for (Maine 2017). In disturbed or managed areas with a canopy of less than 30%, Chestnut-sided Warbler becomes present in areas 1-3 years post-harvest and most abundant in open patches 5-15 years into regeneration (Byers et al. 2013).

Management suggestions across the region include creating and maintaining 0.4-1.21-hectare gaps in mature forests with dense shrubs and saplings 1-3 neters high (Audubon Vermont 2013; Maine Audubon 2017). Chestnut-sided Warbler was not detected at Kensan-Devan Wildlife Sanctuary during this study. At Kensan-Devan, a series of 0.4-1.21-hectare gaps, along with larger patches (in balance with other forestry management needs) is recommended. Through the activity of forestry and the resulting succession that takes place, Chestnut-sided Warbler, a banner species for shrubland restoration, has a viable future at Kensan-Devan but will require rotating patches of desirable habitat to maintain their presence.

Eastern Towhee

A large member of the sparrow family, Eastern Towhees are edge-associated generalists that prefer gaps with dense brushy understory and a thin leaf litter layer (Audubon Vermont 2013; Greenlaw 2015). In New Hampshire, Eastern Towhees are most common in regenerating forests, power line cuts, regenerating fields and associated edges, and pine barrens (NHFGD 2015a). While overstory conditions are less critical to their presence, open-canopy woodlands are preferred (Greenlaw 2015). Management recommendations include maintaining habitat diversity within a region, including secondary succession as well as collecting data at sites already managed for New England Cottontail, American Woodcock and Karner Blue Butterfly (Greenlaw 2015; NHFGD 2015a). Eastern Towhee was detected once during this study in 2016. Through the activity of forestry and the resulting succession that takes place, Eastern Towhee has a viable future at Kensan-Devan but will require rotating patches to maintain their presence.

Eastern Wood-Pewee

Heard in the canopy of forests throughout the Northeast, this slender flycatcher is an overall generalist, associated with small gaps and forest edges within deciduous forests with 50-70% canopy cover and an open midstory (Audubon Vermont 2013; Maine Audubon 2017). Interestingly, Eastern Wood-Pewees may best be adapted to open woodland habitats at the landscape scale with higher densities paired with high levels of canopy cover and low levels of forest cover on the landscape (Watt et al. 2017). In some areas, peak Eastern Wood-Pewee density was associated with shelterwood cuts, shortly after partial clearing (Newell & Rodewald 2012). Forest management suggestions across portions of their range include creating canopy gaps and dense understory (Audubon Vermont 2013). At Kensan-Devan, it will be crucial to maintain dense deciduous forests with a strong canopy cover and an open midstory adjacent to natural openings and man-made gaps. During the study Eastern Wood-Pewee was detected 27 times (14 in 2016 and 13 in 2017).

Scarlet Tanager

Preferring interior hardwood forests with dense canopy of tall oak trees, Scarlet Tanagers are extremely sensitive to forest fragmentation and its associated risks (Maine Audubon 2017; Mowbray 1999). In New Hampshire, Scarlet Tanager has declined at 0.66% per year since 2003 (NHFGD 2015a). With a territory size of 0.41-9 hectares, Scarlet Tanagers are highly dependent on sizeable tracts of forests greater than 101 hectares with large deciduous trees of considerable height and do best with a significant oak component (Maine Audubon 2013; Mowbray 1999).

Forest management suggestions include creating and maintaining well-stocked uneven-aged sawtimber stands of at least 16.19 hectares in size, nestled within an extensive forested matrix with limited edge, greater than 80% canopy cover and large amounts of oaks (Audubon Vermont 2013; Maine Audubon 2017; Mowbray 1999). To maintain Scarlet Tanager abundance at Kensan-Devan, it is necessary to preserve the existing large tracts of unbroken forest, particularly those with tall trees, uniform canopy cover, and a large presence of Northern Red Oak. Because Scarlet Tanagers also occur in young-successional forests, maintaining the oak component around any cuts is paramount. During the study Scarlet Tanager was detected 32 times (14 in 2016 and 18 in 2017).

Wood Thrush

Closely associated with mature, moist deciduous forests with dense understory and heavy leaf litter, Wood Thrush have declined 4.77% per year since 2003 in New Hampshire (Audubon Vermont 2013; Evans et al. 2011; NHFGD 2015a). With a territory size up to 2.83 hectares, Wood Thrush prefer diverse, mid-successional, interior hardwood forests with a canopy greater than 15 meters in height, a moderately dense midstory, and an open forest floor with a thick, moist leaf litter layer (Evans et al. 2011; Maine Audubon 2017; NHFGD 2015a).

Forest management suggestions include creating and maintaining well-stocked, diverse, uneven-aged sawtimber stands with a closed canopy greater than 80%, and plentiful moist leaf litter within larger contiguous forest blocks greater than 101 hectares. Wood Thrush was not detected at Kensan-Devan Wildlife Sanctuary during this study. Through active management focused on maintaining a closed canopy and providing well-developed vertical structure and a moist leaf litter within deciduous stands, it is likely that Wood Thrush can officially be noted during the breeding season at Kensan-Devan Wildlife Sanctuary in the future. Special considerations should be made in heavily forested areas where logging takes place to limit the width of any logging roads and skid trails to not create unnecessary fragmentation.

Ovenbird

The Ovenbird is a common denizen of mature deciduous or mixed forests across eastern North America and much of the boreal zone (Burke & Nol 2000). Ovenbirds occupy territory sizes of 0.4-1.41 hectares, preferring mature forest patches >101 hectares (Robbins 1979; Mazerolle & Hobson 2004; Maine Audubon 2017; Ortega & Capen 1999; Van Horn et al. 1995). Territory size is largely correlated to individual male characteristics as well as an inverse relationship with distance to road (Mazerolle & Hobson 2004; Ortega & Capen 1999). It is also a well-studied species for understanding the impacts of forest fragmentation and timber harvest (Porneluzi et al. 2011). Ovenbirds prefer older forests with 60-90% canopy closure and canopy heights >15 meters (Maine Audubon 2017; Thompson & Capen 1988). On the forest floor, Ovenbirds prefer less ground cover, abundant, deep leaf litter and which serves as a source of food and nesting sites, and aggregated piles of both course and fine woody material (Maine Audubon 2017).

Several studies have shown the utility of having early-successional habitat within a matrix of mature-forests as it relates to species such as Ovenbird, which commonly uses regenerating, even-aged stands in the weeks post-fledging (Chandler et al. 2012; Maine Audubon 2017; Perry et al. 2018; Vitz & Rodewald 2006). Nevertheless, NHA would be wise to limit the number of early-successional patches in relation to managing for Ovenbird, leaving as many large stands as possible and avoiding excessive logging roads and skid trails (Kellner et al. 2016). Preferring tall overstories with dense canopy cover in mature forests, multi-aged management schemes will help maintain medium to high overstory cover over the long haul (Maine Audubon 2017). However, this needs to be balanced against Ovenbirds' requisite of deep ground cover which often comes in mature, even-aged systems (Maine Audubon 2017). During the study Ovenbird was detected 243 times (154 in 2016 and 89 in 2017)

Red-eyed Vireo

Throughout the eastern half of North America, Red-eyed Vireos are one of the most common breeding songbirds (Cimprich et al. 2018). Breeding in deciduous and mixed forests, Red-eyed Vireos are largely absent from stands where understory shrubs are sparse or absent (Lawrence 1953; Ross 1976). Territory size for Red-eyed Vireo is relatively small, ranging from 0.53-0.69 hectares, consisting of a cylinder extending from the forest canopy to the understory (Williamson 1971). While the overall presence of Red-eyed Vireos is positively correlated to forest area, they have been known to breed in forest patches as small as 0.48 hectares (Robbins et al. 1989). Red-eyed Vireos are gleaners, foraging at all vertical levels of the forest in areas where canopies and understories are both densely present (Ross 1976; Williamson 1971).

While not an initial target species for NHA, due to their overall abundance within the avian community, Red-eyed Vireos should be carefully managed at Kensan-Devan just the same. Much like Ovenbirds, Red-eyed Vireos are known for relatively long recolonization rates following disturbance. While some of the studies that catalogued their rates of return were not directly applicable to forestry (e.g., strip mining, farming), Red-eyed Vireos have been measured moving into hardwood timber stands as young as eight years in age (Morgan & Freedman 1985). Sensitive to isolated forest fragments, this species has responded relatively well to small canopy openings (1.21-2.02 hectares), tolerant of forestry practices such as group selection cuts, narrow clearcuts, and single-tree selection (Robbins et al. 1989). Management at Kensan-Devan should prioritize larger stands as well as a matrix of small cuts. During the study Red-eyed Vireo was detected 182 times (97 in 2016 and 85 in 2017).