Habitat and landscape associations of breeding birds in forested peatlands, Minnesota, USA.

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Dedication

This thesis is dedicated to all other researchers who have worked in and represented this unique landscape throughout the past.

Abstract

I compared breeding bird habitat use and community metrics among ten lowland conifer cover types in northern Minnesota. Breeding birds were sampled at 130 points distributed throughout black spruce, tamarack and white cedar forests within the Agassiz Lowland Subsection (ALS), Minnesota. Birds were sampled three times in the spring and summer of 2013 and twice during the spring and summer of 2014. I identified ten lowland conifer cover types using hierarchical clustering then identified distinctive breeding bird species of the ten lowland conifer cover types through indicator species analyses-percent perfect indication (PPI). Connecticut Warbler (*Oporornis agilis*) was most distinctive in semi-productive black spruce-tamarack bog cover types (PPI=40, P<0.01). Boreal Chickadee (*Poecile hudsonicus*) was most distinctive in productive black-spruce-tamarack bog cover types (PPI=8, p<0.01). Species such as the Nashville Warbler (*Leiothlypis ruficapilla*), Yellow-rumped Warbler (*Setophaga coronata*) and White-throated Sparrow (*Zonotrichia albicollis*) were ubiquitous across many lowland conifer cover types. The cluster analysis identified two bird communities that responded to differences in vegetation at the landscape level. Results from the Canonical Correspondence Analysis (CCA) showed significant relationships between breeding birds and vegetation variables (p<0.01). The results from the CCA ordination support the ten cover types identified from the hierarchical cluster analysis. These findings can inform forest and wildlife management decisions that will benefit the conservation and management of breeding birds in lowland conifer forests of the ALS. Disturbances such as logging, insect outbreaks, fire and climate change have the capacity to significantly alter bird communities within these lowland coniferous forests. Data presented here can improve our predictions of how the ALS avifauna will change given future changes to lowland conifer forests in the ALS.

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INTRODUCTION

Boreal forest – Forested peatlands

The boreal forest of North America is primarily found in Canada, with portions that extend into Minnesota and the northern United States (Figure 1). The breeding distributions of many bird species associated with the boreal forest extends south into northern Minnesota, northern Wisconsin and northern Michigan. One major ecological component of the boreal forests is the forested peatlands. The vast majority of forested peatlands are found throughout the northern part of North America, primarily in Canada. In the lower 48 states, no other state has a peatland complex that compares to Minnesota, totaling around 2.4 million hectares (6 million acres) (Wright et al. 1992). Lowland conifer tree species such as black spruce (*Picea mariana*), tamarack (*Larix laricina*) and white cedar (*Thuja occidentalis*) are the primary conifer species found in forested peatlands. Lowland conifers in

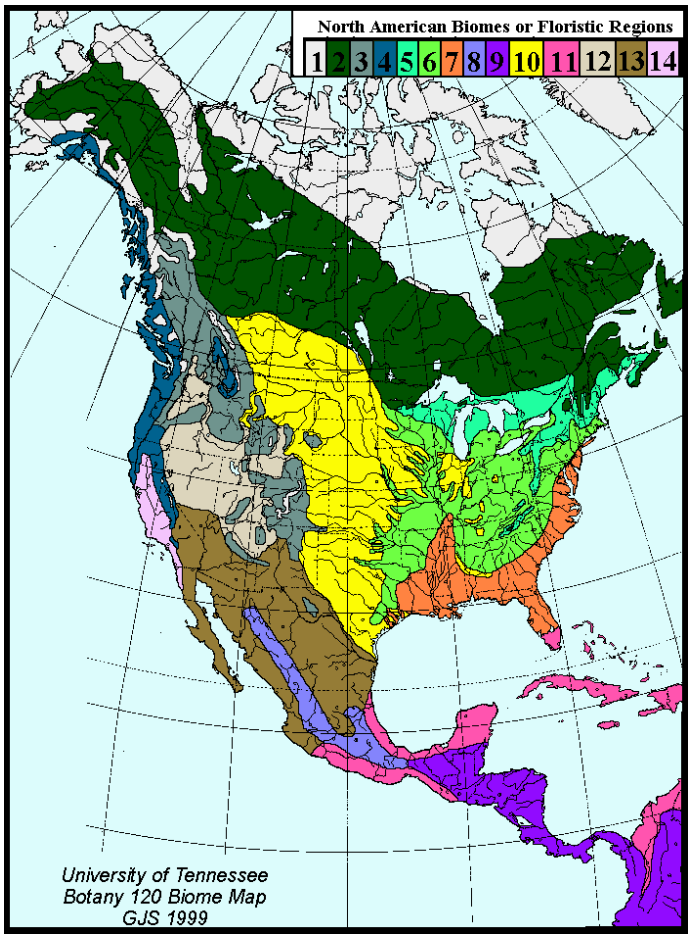

Figure 1. North American Biomes or Floristic Regions (Tundra- 2-Taiga (boreal forest) 3- 4 Mountain Forest 5-6-7 Temperate Deciduous) showing the extent of the boreal forest in Canada and its southern limit in Northeast Minnesota (Schmidt 1999).

Minnesota make up 20% of the estimated 6.7 million hectares (16.5 million acres) of forested lands or 1.34 million hectares (3.3 million acres) (Miles et al. 2007, Wright et al. 1992). About 28% of Minnesota's lowland conifer forest or 650,000 hectares (1.6 million acres) are classified as commercial forest (Wright et al. 1992). The most extensive areas of lowland conifers within Minnesota are located in the Agassiz Lowlands Subsection (ALS) and the Tamarack Lowlands Subsection (Minnesota Department of Natural Resources, MNDNR 2006). Ecological subsections are part of a hierarchical, nationwide, ecological classification system used to identify, describe and map progressively smaller areas of land with increasingly uniform ecological characteristics (Cleland et al. 1997, MNDNR 2016). Nationwide, there are eight hierarchical levels, with Minnesota containing six of the eight levels (MNDNR 2016). The top level in Minnesota, called a Province, has four classes containing prairies and deciduous and coniferous forests, while the second level has 10 Ecological Sections and the third level has 26 Ecological Subsections, which were developed by the MNDNR and U.S. Forest Service.

Natural disturbances in the boreal forest include fire, insect infestation, disease, wildlife and wind (Pastor et al. 1996). Currently, many of these same disturbances continue to alter the composition of lowland conifers in Minnesota. For instance, more than 105,000 hectares (260,000 acres) (Dana Carlson – MNDNR Forester, *pers. comm.*) of tamarack out of the 400,000 hectares (1 million acres) of tamarack in Minnesota have been effected due to infestations of Eastern larch beetle (ELB) (*Dendroctonus simplex LeConte*). ELB infests larger, mature tamarack forests, typically killing trees that have diameter breast heights (DBHs) larger than 10 cm. The severity and magnitude of the

current outbreak is unprecedented in previous outbreaks in Minnesota (Crocker et al. 2016).

Anthropogenic disturbances such as farming, peat mining (Wright et al. 1992) and more recently, logging, have altered the composition of lowland conifers in the ALS. Since the turn of the century, increased logging in the ALS and harvesting techniques such as clear cutting have made the composition and trajectory of lowland conifers in the ALS unclear. Currently, lowland conifer regeneration is poorly understood and paludification or swamping of recently harvested stands has been documented. Finally, Minnesota has seen increased temperatures and changes in precipitation that will likely affect peatland hydrology and vegetation. In Minnesota, black spruce, tamarack and white cedar are predicted to be three of the state's top eight losers of suitable habitat by 2100 (Iverson et al. 2008). The boreal biome is likely to be lost in Minnesota (Galatowitsch et al. 2009) with black spruce, tamarack and white cedar moving northward under high carbon emission scenarios (Iverson et al. 2008). Increases in tree mortality from insect infestations (Galatowitsch et al. 2009, Crocker et al. 2016), droughts, blowdowns from thunderstorms, and fire is expected under high carbon emission scenarios, leaving drought and fire tolerant species to prevail (Galatowitsch et al. 2009). In addition, climate change has already influenced the spread of the ELB (Venette and Walter 2008). How breeding bird species will respond to these disturbances in the ALS are poorly understood.

Breeding birds

The ALS has been identified as an important region for wildlife because many bird

species listed as Species of Greatest Conservation Need (SGCN) are found nesting there (MNDNR 2006, 2016). Many of these species have experienced significant population declines in national forests of Minnesota (Zlonis et al. 2015, Niemi et al. 2016). In Minnesota, a >20 year breeding bird monitoring program for the Superior and Chippewa National Forests has detected significant declines in at least one national forest for the following species that use lowland conifers: Chipping Sparrow (*Spizella passerine*), Connecticut Warbler, Evening Grosbeak (*Coccothraustes vespertinus*), Swainson's Thrush (*Catharus ustulatus*), Winter Wren (*Troglodytes hiemalis*), Yellow-bellied Flycatcher (*Empidonax flaviventris*) and Yellow-rumped Warbler (Zlonis et al. 2015, Niemi et al. 2016). The Connecticut Warbler (-8% per year), Evening Grosbeak (-8%) and Swainson's Thrush (-3%) have documented annual population declines in the Superior National Forest from 1995-2015, while in the Chippewa National Forest, species such as the Connecticut Warbler (-7%), Yellow-bellied Flycatcher (-5%) and Yellow-rumped Warbler (-2%) have shown annual population declines over the same period (Zlonis et al. 2015).

Species that have shown significant local (Minnesota), regional (BCR 12), or continental declines respectively, on an annual basis from the Breeding Bird Survey (BBS) monitoring program (Sauer 2014) from 1966 to 2013 include (percent decline per year in parenthesis): Dark-eyed Junco (*Junco hyemalis*) (-3%, -2%, -1%), Ruby-crowned Kinglet (*Regulus calendula*) (state: -3%, regional: -3%), Connecticut Warbler (-2%, -3%, -2%), Swainson's Thrush (regional: -1%, continental: -1%), Olive-sided Flycatcher (*Contopus cooperi*) (-5%, -3%, -4%) and Purple Finch (*Haemorhous purpureus*) (-2%, -2%, -1%). In Minnesota, SGCN are defined as "native animals, nongame and game,

whose populations are rare, declining, or vulnerable to decline and are below levels desirable to insure their long-term health and stability. Also included are species for which Minnesota is suggested to having stewardship responsibility" (MNDNR 2006, 2015). Species that occur in lowland conifer forests and are listed as SGCN in Minnesota are: Olive-sided Flycatcher, Spruce Grouse (*Falcipennis canadensis*), Purple Finch, Connecticut Warbler, Black-backed Woodpecker (*Picoides arcticus*), Boreal Chickadee and Winter Wren.

Breeding birds that occur in lowland conifer habitat types have been described by many studies in Canada, including Erskine (1977), Kirk et al. (1996), Imbeau et al. (1999, 2001), Hobson and Scheick (1999), Drapeau et al. (2000) and Hannon and Drapeau (2005). Fewer have been completed in Minnesota, especially in lowland conifer habitats within the Agassiz Lowlands Subsection (e.g., Hanowski and Niemi 1983, Niemi and Hanowski 1984, and Warner and Wells 1984). These studies provided a background on species breeding in the ALS and their associated habitats; however, these studies were restricted to small areas within this vast subsection. In addition, these studies included all habitat types from fens to forested bogs. No studies have been completed within the ALS over the past 30 years that primarily focus on habitat associations of breeding birds in lowland conifer forests.

Objectives

The goal of this research was to provide baseline data on breeding bird species use of lowland conifer types and identify habitats of high conservation value. My specific objectives were to address the following questions: 1) Are there differences in breeding

bird communities among lowland conifer forest types? 2) What forest types are most important to breeding bird species and communities in the ALS? 3) What vegetation characteristics at the stand and landscape scale are associated with these breeding bird relationships? These findings will be useful for resource managers in natural resource agencies to conserve species, communities, and lowland conifer habitats.

METHODS

Study area

The ALS is found in the northwest part of Minnesota (approximately 48.4° N, 94.7° W, 15,000 $km^{2,}$ Figure 2) and is comprised of open and forested peatland and upland forests. It contains approximately 42% forests, 46% open water/wetlands, and 12% agriculture (MNDNR 2006). The ALS encompasses approximately 7% of the total land area in the state (MNDNR 2006) and contains 55% of the state-owned lowland conifers, in which 33% is classified as productive forests (Joel Perrington, MNDNR-Forestry, *pers. comm.*).

Selection of survey stands

I identified 65 forest stands (Figure 2) that met the criteria of 1) state land, 2) stand age (0 to > 90 years), 3) site index (productivity), 4) minimum stand size of 20 acres (the minimum size to accommodate two replicate 100 m radius point counts), and 5) within 500 m of a suitable access point. Stands selected for sampling were distributed across five state forest districts in the ALS to insure coverage across the study area: Littlefork (24 stands), Deer River (3), Blackduck (8), Baudette (16) and Warroad (14) (Figure 2). Of the 65 stands, six stands were selected that contained ELB infestations. These stands

provided a range of stand size conditions that naturally occur within the ALS and included eight stands that I had previously sampled in 2011. The 65 forest stands were initially grouped into five categories of varying ages, species, site indices (productivity), and stand sizes.

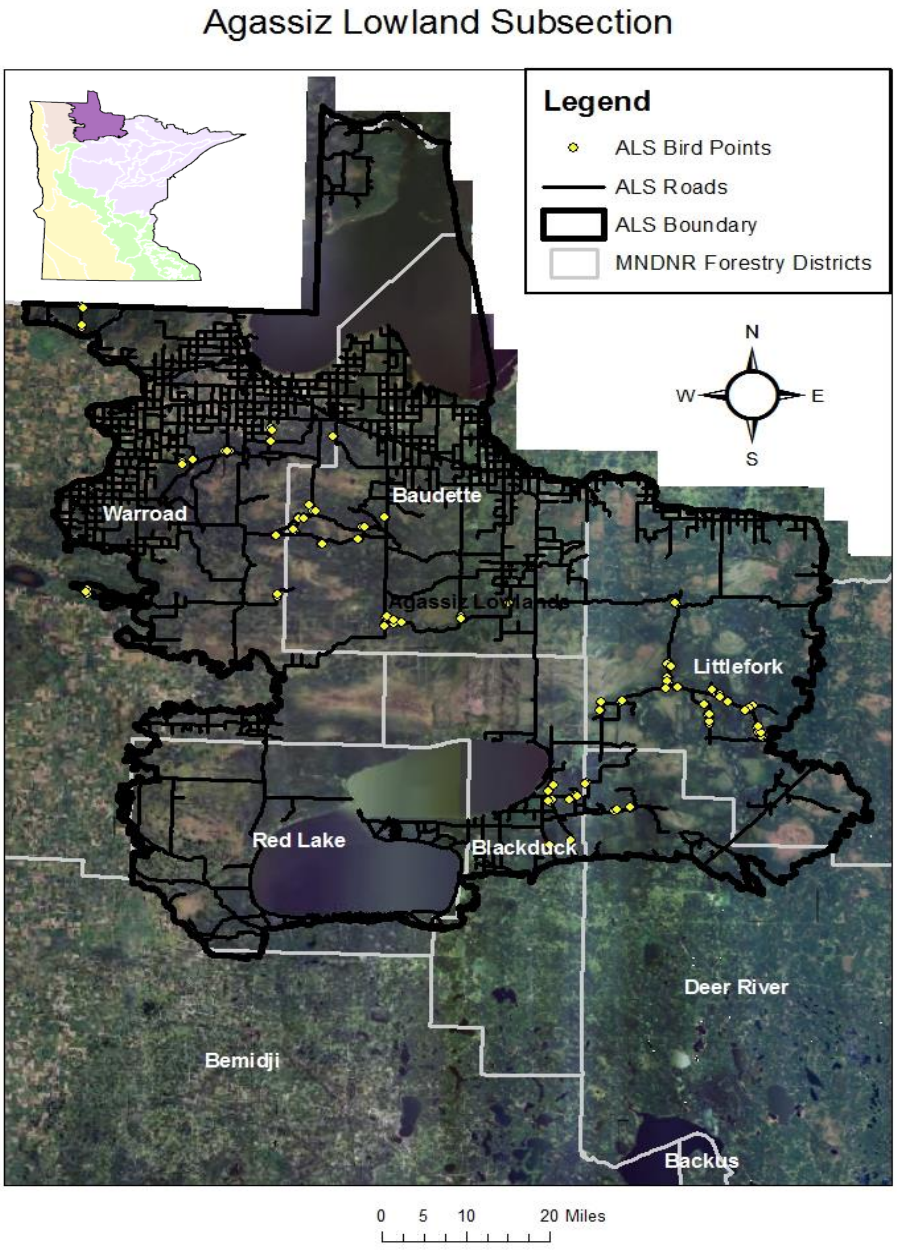

Figure 2. Distribution of 65 (130 points) forest stands across five forest districts within the ALS. Areas immediately north and west of the Red Lake district were not sampled due to limited road access.

Breeding bird sampling design

Each stand was sampled five times. Three surveys were completed in 2013, including an early spring survey from 9 May to 18 May, an early breeding bird survey from 2 June to 11 June, and a late breeding bird survey from 20 June to 1 July. Two surveys were completed in 2014 including an early spring survey from 10 May to 18 May, and a breeding bird survey from 11 June to 7 July. The stands were sampled in a general southeast to northwest direction (starting in Big Falls, MN, and ending in Roseau, MN). For the second round of surveys in 2013 and 2014, observers were rotated so that no points were sampled twice by the same observer. Within the second sampling periods of 2013 and 2014, I also randomized the sampling of forest stands so no stands were consistently sampled early or late in the morning. For the third sampling period in 2013, I randomized the observer and the order the stands were sampled.

Each stand was sampled with two, ten-minute unlimited distance point counts (Howe et al. 1997, Hanowski et al. 2005, Etterson et al. 2009) during each survey period. For each observation, observers estimated the distance from the sampling point, the minute interval when first detected, and behavior (e.g., singing, calling, fly-over, or any nesting activity observed) were also included. Surveys were completed from 0.5 hrs before to 4 hrs after sunrise on days with no or low wind (<15 km/hr) and light or no precipitation. Weather data at the time of the survey were recorded including temperature, wind speed, cloud cover, presence of any precipitation, and noise level. All counters were required to pass a song test of 86 bird songs and had their hearing tested to insure they were within the normal ranges (125 to 8,000 hertz).

To summarize bird data, I limited the bird detections to those within 100 m to insure the observations were within the forest stand of interest. Depending on migration strategy, I included a species in the summary for either three (June and July only) or all five sampling periods (May to July). Five surveys were used for species that were permanent residents (e.g., Boreal Chickadee), semi-permanent residents (e.g., Blue Jay, *Cyanocitta cristata*), or short-distance migrants (e.g., White-throated Sparrow). Three surveys were used (June to July counts) for long-distance migrants when individuals of these species were on the breeding grounds within the ALS. Abundance was summarized using either all individuals (e.g. all observations except flyovers) or territorial individuals (e.g., singing males).

Habitat covariates

I summarized habitat variables at three spatial scales for each stand: point, stand and landscape. Site level variables were collected by observers at each census point and were used to describe vegetative structure within 100 m of the census point. Variables were visually estimated by observers and included tree species composition, cover, diameter at breast height (DBH), height, density and richness. Coverage variables (e.g., ground, canopy, sub-canopy, black spruce, etc.) were estimated in 10% intervals, while other variables such as DBH and height were estimated in metric units. For coverage variables that were combined (e.g., black spruce-tamarack DBH), I weighted the DBH and height for each respective tree species to obtain average estimates. Stand level data were derived from the MNDNR's Forest Inventory Management (FIM) database. FIM data such as cover type, site index (productivity), DBH (reclassified) and basal area (reclassified) are

representative of both points in a stand, and were collected by MNDNR foresters. FIM variables such as DBH and basal area that were inventoried prior to 1985 were reclassified based on a regression analysis of more current, reliable FIM data in the ALS. Greater emphasis was placed on data collected by observers versus FIM data due to the improved accuracy of the recently collected data. For example, correlations from DBH's of disturbed stands (e.g., ELB infestations) for observer collected DBH's and the reclassified DBH's are R^2=0.34, whereas, the correlations with the DBH's improved to R^2=0.70 when disturbed stands were removed from the analysis.

Habitat variables at three landscape spatial scales (Zlonis et al. 2017) were derived from the Upper Midwest Gap Analysis Program (GAP) land cover database. GAP land-cover is a 30 m tiled raster spanning all of Minnesota and consists of four distinct hierarchical levels of land cover classification, ranging from broad classes such as 'forest' (level 1) to more detailed classes such as 'stagnant tamarack forest' (level 4). Additional data included MNDNR estimates of ELB induced tamarack mortality (polygon). All datasets were received from MNDNR personnel or downloaded via the MNDNR Data Deli (MNDNR 2012).

Land cover and other landscape variables were derived at three spatial scales (200, 500, and 1000 m) surrounding each count location. Additional metrics of landscape pattern such as patch richness and number of patches at each landscape scale were included in the analysis. Environmental predictor variables were processed in ArcGIS Version 10.2.2 (© esri.com), Geospatial Modelling Environment Version 0.7.3.0 (Beyer 2012), and Fragstats Version 4 (McGarigal et al. 2012).

Statistical analyses

Habitat types - Community analyses.- Most FIM data available were collected in the early 1980s and interpretation of growth rings for these slow growing trees is difficult. In addition, productivity (site index) of these forest stands can be altered rather quickly due to hydrologic fluctuations (e.g., beaver dams), and stand boundaries are subject to considerable variation in interpretation by individual foresters. Due to these inconsistencies, I focused on an alternative approach to understanding the relationships of bird species and their habitat preferences without initially linking the forest stands to predetermined habitat categories. I applied hierarchical cluster analysis (Sneath and Sokal 1973, McCune and Grace 2002) using mean log-transformed bird species abundances from 130 sample points to identify relationships among points based on bird species community composition. The cluster algorithm used Ward's method (hierarchical grouping) based on Euclidean distances (Wishart 1969) and implemented in the statistical program R (R Core Team 2014). Species occurring at fewer than 7 sites (<5%) and with fewer than 10 observations (34/82) were excluded from the analysis to minimize spurious group assignments.

Bird habitat affinities.- Once the clusters were identified I used DuFrene and Legendre's (1997) indicator species analysis to identify the most characteristic bird species for each community assemblage. The percent perfect indication (PPI) represents the degree of affinity to a habitat type using a combination of abundance (e.g., total number of individuals per 10-minute/100 m radius point count) and frequency (e.g., number of sites a species was present within a habitat type). PPI values can range from 0-100, where 100

represents a situation where all individuals of a species were counted in just one category (regenerating lowland conifers) and the species was always present in samples of that category. PPI values were calculated by PCORD v6.08 (McCune and Mefford 2006). I defined "distinctive" species as those whose PPI value for a given habitat type was at least twice as large as its PPI value for every other habitat (Niemi et al. 2016). This was a conservative criterion (Niemi et al. 2016) because the Monte Carlo randomization test described by DuFrene and Legendre (1997) and McCune and Mefford (2006) yielded a significant maximum PPI (in most cases $p < 0.01$) for 35/48 species included in the analysis. The p-value from the randomization test represents the fraction of times that the maximum PPI from a randomized data set equals or exceeds the maximum PPI from the actual data set. In other words, the null hypothesis is that maximum PPI is no larger than would be expected by chance. In all cases the criterion to identify “distinctive species” for a given habitat type was much stricter than the $p < 0.05$ standard. This habitat-independent method of bird community analysis is therefore complementary to more traditional analysis of habitat associations. In addition to PPI values, I calculated abundances (average number of territorial observations per 100 m point count) to determine the most abundant species for each cover type.

Community metrics.- I also calculated species richness and both Shannon’s and Simpson’s species diversity indices. I calculated two different species richness metrics: 1) overall species richness for birds and 2) species richness for 20 lowland conifer-associated species in this study (Table 1). Generalized linear models (GLMs) with a Poisson error were used to model the differences in each species richness metric between

cover types. From the GLMs I obtained estimated species richness and standard errors for each cover type. I used Spearman's rank correlations to examine patterns between cover types and species diversity or species richness.

Table 1. Lowland conifer species (20) that are associated with lowland conifers in Minnesota. Criteria used to identify lowland conifer species (20) came from Green (1995) and Niemi et al. (2016).

Spruce Grouse (*Falcipennis canadensis*)	Golden-crowned Kinglet (*Regulus satrapa*)
American Three-toed Woodpecker (*Picoides dorsalis*)	Ruby-crowned Kinglet (*Regulus calendula*)
Black-backed Woodpecker (*Picoides arcticus*)	Swainson's Thrush (*Catharus ustulatus*)
Olive-sided Flycatcher (*Contopus cooperi*)	Hermit Thrush (*Catharus guttatus*)
Yellow-bellied Flycatcher (*Empidonax flaviventris*)	Connecticut Warbler (*Oporornis agilis*)
Blue-headed Vireo (*Vireo solitarius*)	Palm Warbler (*Setophaga palmarum*)
Gray Jay (*Perisoreus canadensis*)	Yellow-rumped Warbler (*Setophaga coronata*)
Boreal Chickadee (*Poecile hudsonicus*)	Chipping Sparrow (*Spizella passerina*)
Brown Creeper (*Certhia americana*)	Dark-eyed Junco (*Junco hyemalis*)
Winter Wren (*Troglodytes hiemalis*)	Purple Finch (*Haemorhous purpureus*)

Multivariate Analyses.- Canonical Correspondence Analysis (CCA) was also used to explore the relationships between forested bird species and site level habitat variables. Multivariate analyses of vegetation and bird data were conducted in PC-ORD (McCune and Mefford 2006). Habitat variables that were highly correlated ($R^2 \geq 0.70$) with other variables were eliminated from ordination analyses. If two variables were highly correlated, the variable that was easier to interpret was retained in the analysis. For example, if "understory deciduous cover (%)" was correlated with "black spruce cover (%)," black spruce cover (%) was retained for the analysis. Of the 48 common bird species, four species (Sedge Wren (*Cistothorus platensis*), Swamp Sparrow (*Melospiza georgiana*), Mourning Dove (*Zenaida macroura*) and Ruffed Grouse (*Bonasa umbellus*)) not known to regularly use forested lowland conifers, were removed. To emphasize

lowland conifer forests, I included 122/130 sites in the analysis, removing eight sites that had inconsistent lowland conifer regeneration (e.g., high proportion of sedge). A randomization test (Monte Carlo permutations test, 999 runs) was used to test the significance of bird-vegetation correlations (McCune and Mefford 2006).

RESULTS

A total of 130 points, sampled five times each, yielded 10,419 individuals of 106 species for unlimited distance counts. A total of 4,930 individuals of 77 species were detected for limited distance counts. The summer counts for limited distance surveys averaged 7.2 territorial individuals per census, while the spring counts had 4.6 territorial individuals per census. The average number of observations for the 2013 breeding season was 5.9 individuals per census while 2014 yielded 6.0 individuals per census.

Clusters

I used a combination of observations of the bird species in the ALS, field experience, and prior knowledge from the published literature on breeding birds to identify 10 clusters of breeding bird communities using hierarchical cluster analysis (Figure 3). The 10 clusters representing the bird communities (hereafter called "cover types" when referring to vegetative characteristics) were identified by the following lowland conifer forest cover types in the ALS (number of census points included in cluster): *mixed lowland white cedar* (17*), Eastern larch beetle disturbance forests* (9), *northern white cedar* (5), *stagnant black spruce-tamarack bog* (10), *semi-productive black spruce-tamarack bog* (12), *mixed tamarack swamp conifer* (15), *mixed lowland conifer* (*landscape,* 19),

productive (mature) black spruce-tamarack bog (12), *mixed lowland conifer* (25) *and recently harvested lowland conifers* (6). The 10 cover types were empirically described by their dominant cover and structure, but supported by vegetation measurements. Sixty-six of the 130 points sampled, or approximately 50% of the points, remained in the same cluster (cover type) as its replicate point count.

Community metrics

Total species richness and both the Shannon's and Simpson's species diversity were highest in *mixed lowland white cedar* cover types (Table 2). Species richness for the 20 lowland conifer associated breeding bird species (Table 1) were greatest in *productive (mature) black spruce-tamarack bogs* and lowest in the *recently harvested lowland conifers* (Table 2). Spearman rank correlations yielded significant relationships among all community metrics except for the 20 lowland conifer associated species (r_s>0.77, p<0.01). Values for Spearman rank correlations for the 20 lowland conifer associated species and all other community metrics were (r_s=-0.13:-0.18, p>0.05).

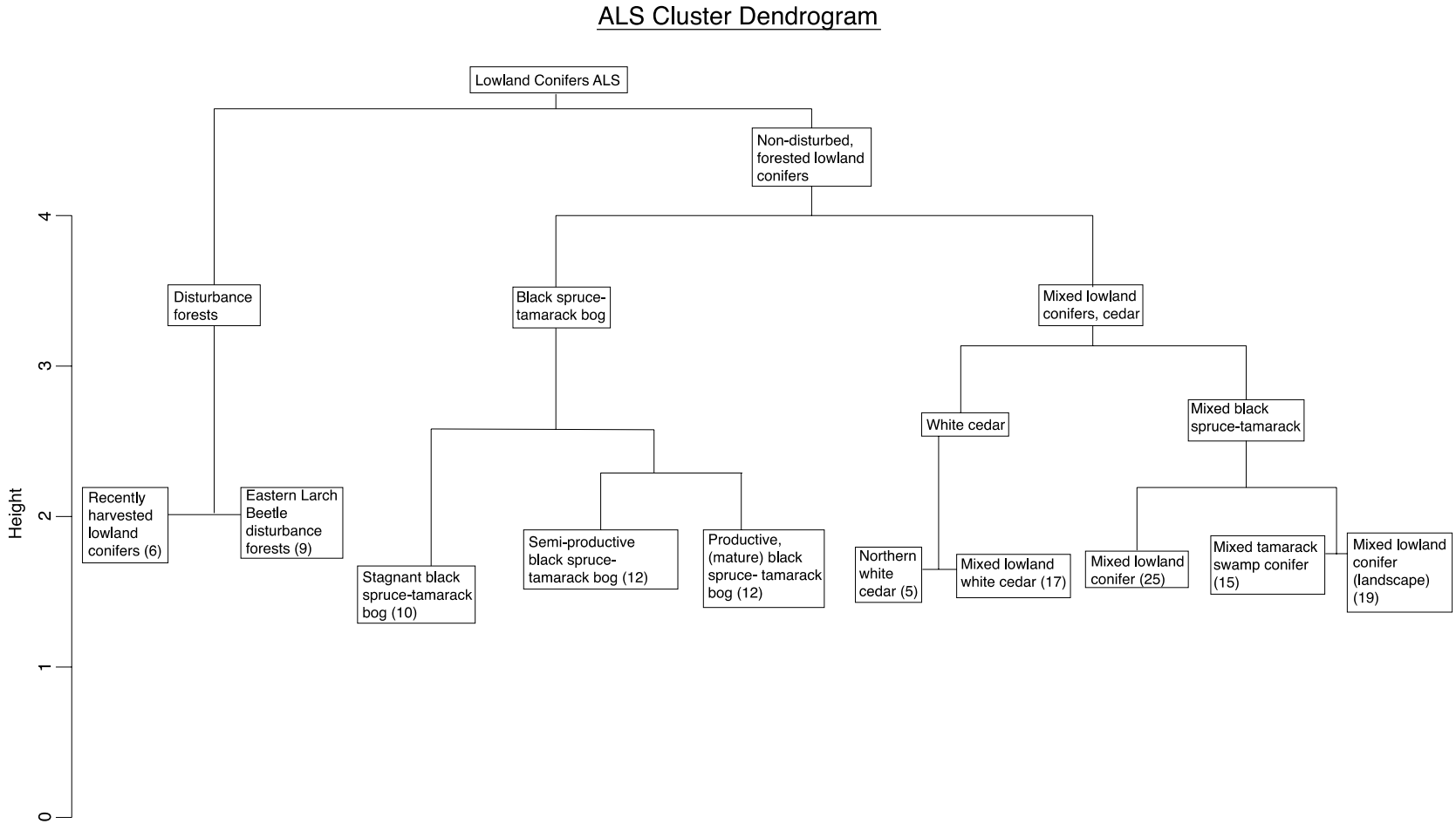

Figure 3. Hierarchical dendrogram for 130 original census points located in the Agassiz Lowland Subsection (ALS), MN. The cluster algorithm used Ward's method (hierarchical grouping) based on Euclidean distances (Wishart 1969) of mean log-transformed bird abundances. The ten clusters or bird communities at the bottom of the dendrogram represent forest cover types found within the ALS. Interpretations of cover types are provided in text boxes in the dendrogram and the number of point count locations in parentheses.

Table 2. Species richness and species diversity indices for 10 cover types (n of stands in parentheses) within the Agassiz Lowland Subsection (ALS), MN. Predicted species richness was calculated using generalized linear models (GLMs) and Poisson errors for ten cover types in the Agassiz Lowland Subsection (ALS), MN. Predicted species richness was modeled using all species. Predicted species richness was calculated for the 20 lowland conifer-associated species (Table 1). Predicted standard errors for species richness are listed in parenthesis. Diversity indices were calculated for each point within a cover type, and then averaged for each cover type (standard errors in parentheses).

Cover Type	Species Richness	Species Richness (20)	Shannon's H Diversity Index	Simpson's Diversity Index
Mixed lowland white cedar (17)	15.8 (1.0)	6.9 (0.6)	2.51 (0.05)	10.16 (0.62)
Eastern larch beetle disturbance forest (9)	15.6 (1.3)	4.0 (0.7)	2.41 (0.12)	9.50 (1.10)
Northern white cedar (5)	12.8 (1.6)	2.8 (0.7)	2.26 (0.13)	7.81 (1.07)
Stagnant black spruce-tamarack bog (10)	11.8 (1.1)	6.6 (0.8)	2.12 (0.07)	6.62 (0.63)
Semi-productive black spruce-tamarack bog (12)	12.1 (1.0)	7.7 (0.8)	2.21 (0.06)	7.69 (0.45)
Mixed tamarack swamp conifer (15)	14.3 (1.0)	5.1 (0.6)	2.32 (0.09)	8.28 (0.85)
Mixed lowland conifer-(landscape) (19)	14.8 (0.9)	5.9 (0.6)	2.41 (0.04)	8.54 (0.33)
Productive (mature) black spruce-tamarack bog (12)	10.9 (1.0)	8.3 (0.8)	2.18 (0.07)	7.80 (0.61)
Mixed lowland conifer (25)	13.0 (0.7)	7.5 (0.5)	2.23 (0.05)	7.26 (0.43)
Recently harvested lowland conifers (6)	11.3 (1.4)	1.5 (0.5)	2.17 (0.08)	7.52 (0.74)

Community assemblages - Cover types

Results for each of these ten cover types are described by their 1) general vegetation characteristics, 2) bird community composition, 3) bird species most distinctive of the cover type based on PPI values, and 4) the bird species most abundant within the cover type. Species that were most distinctive (e.g., primarily found only within the cover type) may not be the most abundant species. The latter were often generalist species such as the Nashville Warbler or Yellow-rumped Warbler, which were commonly found throughout many cover types in the ALS.

Mixed lowland white cedar.- The cover type of points that contributed to this bird community were predominantly white cedar; however, black spruce, tamarack, balsam fir and deciduous cover were also commonly present. Points within this type have relatively high site indices (mean of 30 and range of 16-49) and were relatively old (mean of 130 years and a range of 66-179 years) (Appendices A, B). Mean DBH was 18 cm (range 10-30 cm), while mean height was 10 m (range 8-15 m) (Appendices A, B). Average species richness for this cluster was 15.8 species per point (Table 2). Species diversity was also high for both the Shannon's and Simpson's diversity index (Table 2). Distinctive species of this cover type were Swainson's Thrush (PPI=12, $p<0.01$) and Blackburnian Warbler (*Setophaga fusca*) (PPI=8, $p<0.05$) (Table 3). Additional species commonly found within this forest cover type were the Nashville Warbler, Black-throated Green Warbler (*Setophaga virens*), and Yellow-bellied Flycatcher (Appendix C).

Eastern larch beetle disturbance forests.- This cover type comprises trees in various stages from live to dead because of invasion by the ELB; however, tamarack predominates. Site indices were high with a mean of 41 (range 31-65), while stand ages were highly variable. Most points within this cover type were older (mean age=84 years and range from 15-135 years) (Appendices A, B). Bird points sampled typically had live understories and sub-canopies, with dead or relatively open canopies. Average species richness was second highest at 15.6 species (Table 2). Species distinctive of this cover type were Mourning Warbler (*Geothlypis philadelphia*) (PPI=11, $p<0.01$) and Ruffed Grouse (PPI=9, $p<0.01$). Species with high affinities for this cover type were White-throated Sparrow (PPI=15, $p<0.01$) and Black-and-White Warbler (*Mniotilta varia*)

(PPI=12, $p<0.01$), (Table 3). Nashville Warbler and Common Yellowthroat (*Geothlypis trichas*) were also abundant in this cover type (Appendix C).

Northern white cedar.- This forest cover type was dominated by large white cedar trees with open understories. Survey points were in areas of greater elevation and settings with adequate drainage. White cedar trees in this cover type averaged 28 cm in DBH and were about 12 m high (Appendix A). Site indices ranged from 27-39 and stands were about 130-135 years old (Appendix B). Average species richness for points in this cover type was 12.8 (Table 2). Bird species distinctive of this cover type were Black-throated Green Warbler (PPI=49, $p<0.01$), Ovenbird (*Seiurus aurocapilla*) (PPI=25, $p<0.01$), Red-eyed Vireo (*Vireo olivaceus*) (PPI=17, $p<0.01$), Black-capped Chickadee (*Poecile atricapillus*) (PPI=8, $p<0.01$), Yellow-bellied Sapsucker (*Sphyrapicus varius*) (PPI=8, $p<0.01$), and Northern Flicker (*Colaptes auratus*) (PPI=7, $p<0.01$) (Table 3). The Nashville Warbler was most common in this cover type (Appendix C).

Stagnant black spruce-tamarack bog.- Trees within this cover type are generally low in productivity and are short with small DBH. This habitat is often referred to as muskeg (Wright et al. 1992). Site indices averaged 21.5 (range 14-35) while average age of these stands was about 65 years (range 24-159 years) (Appendices A, B). Mean DBH of trees was 8 cm, while average height was 5-6 m (Appendices A, B). Average species richness was 11.8 species per point (Table 2). The Palm Warbler (*Setophaga palmarum*) (PPI=68, $p<0.01$) was highly distinctive of this cover, while Magnolia Warbler (*Setophaga magnolia*) (PPI=7, $p<0.05$) was also primarily found here, though in relatively low

abundance (Table 3). Species also common in this cover type were Nashville Warbler, Palm Warbler, Yellow-bellied Flycatcher, Yellow-rumped Warbler, White-throated Sparrow and Connecticut Warbler (Appendix C).

Semi-productive black spruce-tamarack bog.- Trees within this cover type are of intermediate height with moderate stem densities. Site indices averaged 27 (range 18-45) while average age was 97 years (range 53-163 years) (Appendices A, B). Mean DBH was 11 cm (range 8-18 cm) while trees averaged 10 m (range 6-14 m) tall (Appendices A, B). This cover type is typically not merchantable for harvesting; however, points within the productive end of this group could be considered for harvest or eventually will mature into harvestable forests. Average species richness was 12.1 species per point while species richness (20) was 7.7 (Table 2). The Connecticut Warbler (PPI=40, $p<0.01$) was most distinctive of this cover type, while the Yellow-rumped Warbler (PPI=12, $p<0.01$) and Chipping Sparrow (PPI=8, $p<0.05$) also had high affinities (Table 3). Species that were most abundant were Nashville Warbler, Connecticut Warbler, Yellow-rumped Warbler and Yellow-bellied Flycatcher (Appendix C).

Mixed tamarack swamp conifer.- Points within this cluster tended to have proportionally more tamarack than other mixed lowland conifer cover types or are naturally less productive. Tree species composition was approximately 48% tamarack, 20% black spruce, 18% white cedar, 9% deciduous and 5% other (Appendix A). Mixed tamarack swamp conifer stands tended to have high heterogeneity among points within this cluster due to a deciduous component. Average species richness was 14.3 species per point

within this cover type (Table 2). Northern Waterthrush (*Parkesia noveboracensis*) (PPI=11, $p<0.01$) was the only distinctive species, and the Winter Wren (PPI=7, $p<0.05$) (Table 3) also showed a weak affinity for this cover type. Most abundant species in this cover type were Nashville Warbler, White-throated Sparrow and Yellow-rumped Warbler (Appendix C).

Mixed lowland conifer (landscape).- This cover type had many similarities in vegetation attributes with the other *mixed lowland conifer* cover type, but differed primarily with landscape context. Mean site index was 34 (range 16-58), while mean age was 98 years (42-195 years) (Appendices A, B). Points in this cover type had a high proportion of non-lowland conifer cover types at the 1000 m scale (Appendices A, B). Blue Jay (PPI=10, $p<0.01$) was the only distinctive species that showed significant selection for this cover type (Table 3). Species abundant in this cover type were Nashville Warbler, Yellow-rumped Warbler and White-throated Sparrow (Appendix C).

Productive (mature) black spruce-tamarack bog.- Points in this forest cover type had relatively tall trees with large DBH's and basal areas (Appendices A, B). This cover type included areas with commercially-harvestable timber. Mean age was 127 years (range 97-159 years), while site index averaged 30 (21-39) (Appendices A, B). Average DBH was 15 cm (range 13-23 cm) while mean height was 13 m range (11-16 m) (Appendices A, B). This cover type had one of the lowest average species richness of 10.9 species per census point when compared with the other cover types. Species richness (20) was among the highest for this cover type (Table 2). Species most distinctive of this cover type were

Dark-eyed Junco (PPI=20, p<0.01), Golden-crowned Kinglet (*Regulus satrapa*) (PPI=10, p<0.01), and Boreal Chickadee (PPI=9, p<0.01) (Table 3). Species most abundant were Nashville Warbler, Yellow-rumped Warbler, Dark-eyed Junco, Golden-crowned Kinglet and Connecticut Warbler (Appendix C).

Mixed lowland conifer.- Points in this cover type were characterized by a mix of older tree species including black spruce, tamarack and white cedar (Appendix A). Many of the trees were of merchantable size. Mean age was 104 years (range 42-195 years), while mean site index was 27 (range 18-42). Average DBH was 15 cm (range 8-25 cm) while height was 11 m (range 4-16 m). Average bird species richness was 13 species per point (Table 2). The Yellow-bellied Flycatcher (PPI=15, p<0.01) and Ruby-crowned Kinglet (PPI=6, p<0.05) (Table 3) had high affinities for this cover type. Species abundant in this cover type were Nashville Warbler, Yellow-rumped Warbler, Yellow-bellied Flycatcher and Ruby-crowned Kinglet (Appendix C).

Recently harvested lowland conifers.- This cover type was characterized by points within recently harvested lowland conifer stands and in early stages of forest succession. Points typically had regenerating lowland conifers, but tended to be dominated by cattails, sedges, and a shrub component. Average age was 14 years, while site index was 44 (Appendix A). Average species richness per point was generally lower for all species richness calculations (Table 2). Species distinctive of this cover type were Swamp Sparrow (PPI=68, p<0.01), Sedge Wren (PPI=33, p<0.01), Alder Flycatcher (*Empidonax alnorum*) (PPI=24, p<0.01), Chestnut-sided Warbler (*Setophaga pensylvanica*) (PPI=14,

p<0.01), and Wilson's Snipe (*Gallinago delicate*) (PPI=12, p<0.01), (Table 3), while the Common Yellowthroat (PPI=34, p<0.01), Lincoln's Sparrow (PPI=9, p<0.01) and Veery (*Catharus fuscescens*) (PPI=6, p<0.05) also had high affinities. Species abundant in this cover type were Swamp Sparrow, Common Yellowthroat, Nashville Warbler, Sedge Wren and Alder Flycatcher (Appendix C).

Table 3. Percent perfect indication (PPI) values from an indicator species analysis (Dufrene and Legendre 1997) for 48 species within forest cover types in the Agassiz Lowland Subsection, Minnesota. PPI values represent a species affinity for a cover type. PPI takes into account a species relative abundance among each cover type and multiplies the relative abundance by frequency of sites within each cover type. PPI values range from 0-100 where a PPI value of 100 represents a species that is abundant in one cover type and present at all sites within the cover type. Species with significant PPI values for a cover type are italicized and if highly significant ($p<0.01$) an asterisk is included. Distinctive species (bold) have PPI values that are double of all other PPI values for all cover types. Distinctive species requires a minimum PPI value of five. Numbers of points (n) within each cover type are listed in parenthesis. Species are listed in taxonomical order.

Common and Scientific Name	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer-(landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)
Ruffed Grouse (Bonasa umbellus)*	0	9	0	0	0	0	1	0	0	0
Wilson's Snipe (Gallinago delicata)*	0	3	0	0	0	0	0	0	0	12
Mourning Dove (*Zenaida macroura*)	0	1	1	0	0	0	2	0	0	0
Yellow-bellied Sapsucker (Sphyrapicus varius)*	0	0	8	0	0	0	2	0	0	0
Hairy Woodpecker (*Picoides villosus*)	1	0	0	0	0	3	2	0	1	0
Northern Flicker (Colaptes auratus)*	0	0	7	0	0	0	0	0	0	1
Olive-sided Flycatcher (*Contopus cooperi*)	0	2	0	0	0	1	0	3	0	0
*Yellow-bellied Flycatcher (Empidonax flaviventris)**	12	1	0	9	11	3	0	1	15	0

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Common and Scientific Name	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer-(landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)
Alder Flycatcher (Empidonax alnorum)*	0	8	0	2	0	1	0	0	0	24
Blue-headed Vireo (*Vireo solitaries*)	1	0	1	0	4	2	1	1	4	0
Red-eyed Vireo (Vireo olivaceus)*	3	7	17	0	0	6	0	0	0	5
Gray Jay (*Perisoreus canadensis*)	1	0	0	0	0	0	1	3	2	0
Blue Jay (Cyanocitta cristata)*	2	0	1	0	0	3	10	0	2	0
Common Raven (*Corvus corax*)	1	0	1	0	1	0	0	0	0	0
Black-capped Chickadee (Poecile atricapillus)*	1	1	8	0	0	1	1	0	0	0
Boreal Chickadee (Poecile hudsonicus)*	2	0	0	1	0	0	0	9	0	0
Red-breasted Nuthatch (Sitta Canadensis)*	3	3	6	1	0	1	2	0	1	0
Brown Creeper (*Certhia americana*)	3	0	1	0	1	1	2	1	2	0
Winter Wren (Troglodytes hiemalis)	5	4	0	0	0	7	4	1	2	0
Sedge Wren (Cistothorus platensis)*	0	0	0	0	0	0	0	0	0	33
Golden-crowned Kinglet (Regulus satrapa)*	3	0	0	0	4	0	4	10	5	0

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Common and Scientific Name	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer-(landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)
Ruby-crowned Kinglet (Regulus calendula)	2	0	0	4	5	0	2	1	6	0
Veery (Catharus fuscescens)	0	4	0	0	0	4	0	0	0	6
Swainson's Thrush (Catharus ustulatus)*	12	0	0	0	0	0	0	0	4	0
Hermit Thrush (*Catharus guttatus*)	4	0	1	1	5	0	2	1	1	0
American Robin (Turdus migratorius)	0	0	3	0	1	1	1	0	1	0
Cedar Waxwing (*Bombycilla cedrorum*)	1	3	0	0	0	0	0	0	0	0
Ovenbird (Seiurus aurocapilla)*	3	3	25	0	0	1	3	0	0	0
Northern Waterthrush (Parkesia noveboracensis)*	0	0	0	0	0	11	0	0	1	5
*Black-and-white Warbler (Mniotilta varia)**	8	12	1	1	1	5	2	0	1	4
Nashville Warbler (*Oreothlypis ruficapilla*)	8	9	4	12	8	9	9	3	11	3
Connecticut Warbler (Oporornis agilis)*	0	3	0	4	40	0	0	4	0	0
Mourning Warbler (Geothlypis philadelphia)*	0	11	0	0	2	0	0	0	0	0

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Common and Scientific Name	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer-(landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)
*Common Yellowthroat (Geothlypis trichas)**	0	26	0	1	0	0	1	0	0	34
Northern Parula (Setophaga americana)	1	0	5	0	0	2	0	0	1	0
Magnolia Warbler (Setophaga magnolia)	0	2	0	7	0	3	2	0	0	0
Blackburnian Warbler (Setophaga fusca)	8	2	0	0	0	0	3	0	1	0
Chestnut Sided Warbler (Setophaga pensylvanica)*	0	3	0	0	1	0	0	0	0	14
Palm Warbler (Setophaga palmarum)*	0	0	0	68	3	0	0	0	0	0
*Yellow-rumped Warbler (Setophaga coronata)**	3	2	0	5	12	4	6	7	10	0
Black-throated Green Warbler (Setophaga virens)*	18	0	49	0	0	0	1	0	1	0
Chipping Sparrow (Spizella passerina)	1	0	0	3	8	0	2	5	0	0
*Lincoln's Sparrow (Melospiza lincolnii)**	0	7	0	4	0	0	0	0	0	9
Swamp Sparrow (Melospiza Georgiana)*	0	1	0	0	0	0	0	0	0	68
White-throated Sparrow (Zonotrichia albicollis)	1	15	0	3	6	14	3	0	1	4

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Common and Scientific Name	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer-(landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)
Dark-eyed Junco (Junco hyemalis)*	0	0	0	6	2	0	0	20	0	1
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	1	2	0	0	0	2	0	0	0	1
Purple Finch (*Haemorhous purpureus*)	2	1	2	0	0	1	0	1	1	0

Relationship of bird species with vegetation characteristics

Results from the CCA showed a significant relationship between breeding birds and vegetation variables for the first canonical axis (eigenvalue=0.245, 9.5% variation explained, species-environment correlation=0.91, $p<0.01$). The second and third canonical axes indicated significant bird-vegetation relationships, with both eigenvalues (Axis 2, 0.130, 5.1% variation explained; Axis 3, 0.09, 3.5% of variation explained) and species environment correlations (Axis 2, 0.83; Axis 3, 0.78) being equal or greater than those of the maximum achieved in randomization tests (based on Monte Carlo permutations test, 999 runs).

Table 4. Summary of vegetative characteristics and results from Canonical Correspondence Analysis (CCA). Results include vegetation correlations to the first three canonical axes. Vegetation cover is defined as percent (%) coverage within 100 m radius count, while other variable units are listed in parenthesis.

Variable	Axis 1	Axis 2	Axis 3
Balsam fir (%)	0.45	-0.16	0.10
Black spruce (%)	-0.77	-0.35	0.04
Black spruce DBH (cm)	0.12	-0.49	-0.39
White cedar (%)	0.70	-0.26	0.16
Tamarack (%)	-0.06	0.56	-0.25
Tamarack DBH (cm)	0.20	0.19	-0.33
Black spruce-tamarack (%)	0.16	-0.21	-0.69
All conifer cover (%)	-0.60	-0.20	-0.18
All conifer DBH (cm)	0.67	-0.27	-0.17
Shrub (%)	-0.04	0.20	-0.36
Tree species richness	0.71	0.02	0.06
Canopy height (m)	0.42	-0.32	-0.44
Estimated tree density (stems/314 m^2)	-0.08	-0.43	0.08
High canopy cover (%)	0.49	-0.51	-0.13
Subcanopy cover (%)	0.31	-0.24	0.02
Understory cover (%)	0.11	0.23	-0.14
Understory deciduous cover (%)	0.35	0.52	-0.26
Ground cover (%)	-0.80	0.03	-0.14
Site index (productivity, FIM)	0.33	0.28	-0.24
DBH (cm, FIM)	0.77	-0.05	-0.44
Basal Area (m^2/ ha, FIM)	0.23	-0.50	-0.28

The first canonical axis expresses bird species on the basis of their relationship with broad forest cover types (e.g., white cedar and black spruce forests). Variables positively correlated with Axis 1 were tree DBH, the proportion of white cedar, tree species richness and the DBH of coniferous trees (Table 4). Variables negatively correlated with Axis 1 were ground cover, black spruce cover and all conifers cover (%). The variable "deciduous cover" was removed from the analysis due to the multicollinearity with other variables (All conifer cover %). White cedar forests also had the highest composition of deciduous cover and one of the highest correlations with Axis 1 (Appendix A, Table 4). Based on these correlations, Axis 1 can be interpreted as "increasing white cedar/tree species richness/diversity" (Figure 4). The second canonical axis separated species based on correlations with forest structure. Variables positively correlated with Axis 2 were tamarack cover and understory cover (Table 4). Variables negatively associated with Axis 2 were high canopy cover and basal area (Table 4). Based on these correlations, Axis 2 can be thought of as "decreasing forest structure or biomass/basal area" (Figure 4).

Bird species associated with increasing tree species diversity were the Red-eyed Vireo, Ovenbird, and Black-throated Green Warbler, all of which were positively associated with Axis 1. These species were prominently found in white cedar forests. In contrast, bird species associated with black spruce and tamarack forests such as Palm Warbler, Connecticut Warbler and Dark-Eyed Junco were negatively associated with Axis 1. Bird species associated with decreasing forest structure, such as those found in open, shrubby areas (e.g., Lincoln's Sparrow, Chestnut-sided Warbler, Veery, Common Yellowthroat and Alder Flycatcher) were positively associated with Axis 2. Bird species

associated with large trees and mature forests (e.g., Boreal Chickadee, Golden-crowned Kinglet and Gray Jay) were negatively associated with Axis 2.

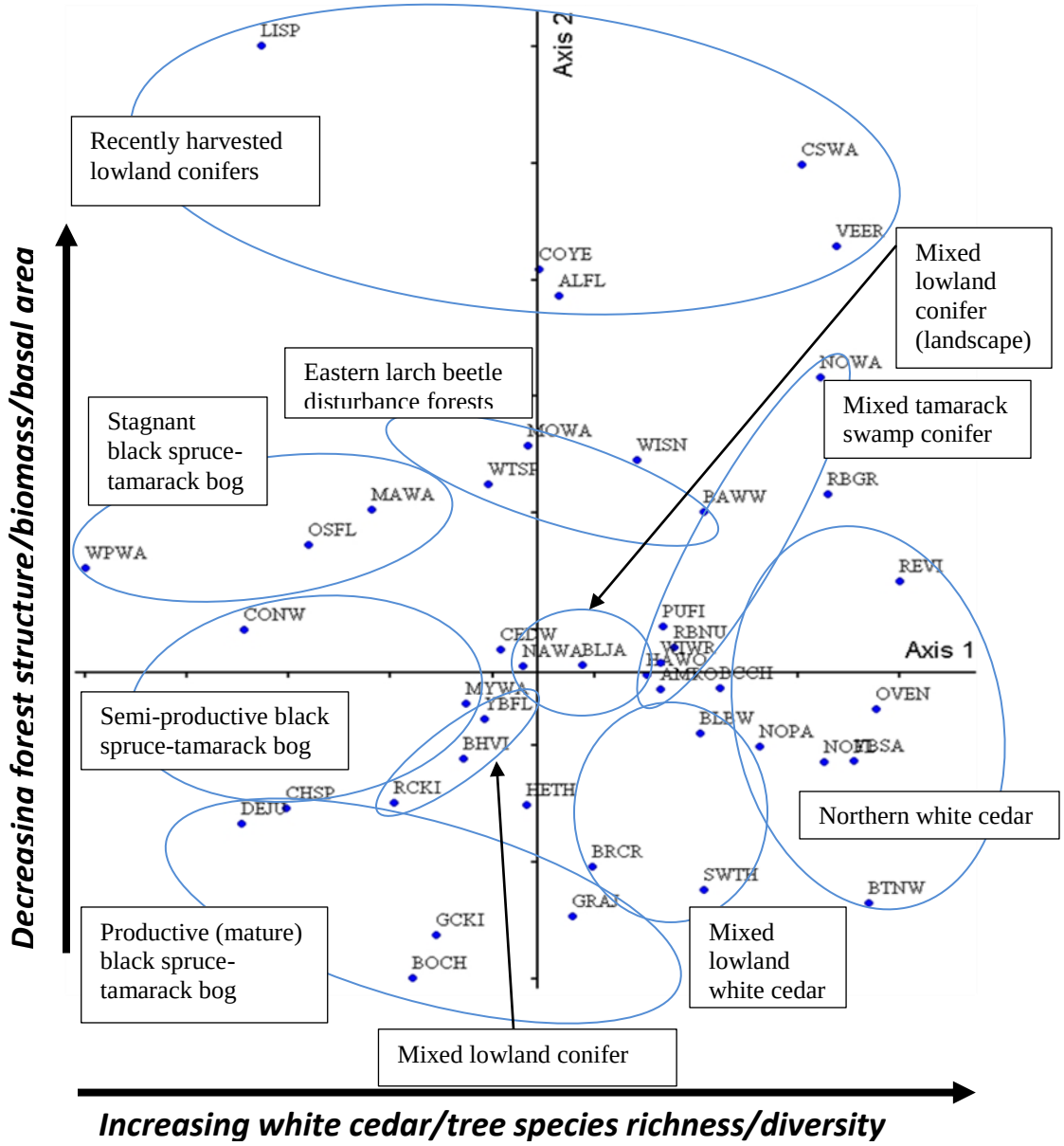

Figure 4. Canonical Correspondence Analysis (CCA) expressing the relationship among the vegetation variables (Table 2) and common bird species observed in the Agassiz Lowlands. Abundance of each species within 100m of point count locations were used in the analysis. DBH, tree species richness and white cedar coverage were positively associated with Axis 1 (Table 4). Variables associated with Axis 2 were tamarack cover, understory cover, basal area (-) and high canopy cover (-) (Table 4). Bird species distinctive of cover types from the PPI analysis, are circled on the ordination graph. Not all species circled are distinctive of the PPI cover types.

DISCUSSION

A total of 106 species were detected during all surveys for unlimited distances. Observations of these species reflected mostly territorial behaviors, primarily singing, calling, or drumming (with the exception of observed). This result is similar to the 115 species that Green (1995) listed in all forested habitats in the same region. Warner and Wells (1984) detected a total of 90 species in all lowland habitat types in the ALS, including non-forested habitats. Habitat types that did not have the potential to regenerate into lowland conifer forests were not sampled. When limiting the censuses to 100 m, the 77 species detected in lowland coniferous habitats is lower than both that of Green (1995) and Warner and Wells (1984), who included multiple cover types.

Nashville Warbler was the most abundant species counted, followed by Yellow-rumped Warbler and White-throated Sparrow. All three species were ubiquitous throughout the ALS. They were present in many of the forest cover types and often were the most abundant species within cover types where they occurred. These results were consistent with previous studies (Hanowski and Niemi 1983, Niemi and Hanowski 1984 and Warner and Wells 1984).

Bird community clusters/community metrics

Species Richness.- Highest species richness of all bird species was observed in those stands that had mixed associations of tree species. Cover types such as *Eastern larch beetle disturbance forest, mixed-lowland conifers*, and *mixed lowland white cedar* were more heterogeneous in composition and structure than the pure stands of black spruce-tamarack cover types. This heterogeneity created more variable habitat features within

the stands and allows for species not typical of lowland conifers (e.g., Ovenbird or Black-and-white Warbler) to satisfy their life history requirements. When species richness (20) was calculated only for those species associated with lowland conifer forests (Table 1), species richness was highest in the *black spruce-tamarack bog* cover types and *mixed lowland conifer* forest cover types (Table 3). The pattern of relationships for the community metrics when all species are included is evidence that heterogeneous habitats support a broader range of species (Warner and Wells 1984, Freemark and Merriam 1986, Hobson and Bayne 2000). Warner and Wells (1984) found that white cedar-spruce swamp and swamp thickets of mixed composition supported the highest number of species and diversity in the ALS, while muskeg and spruce island habitats had the lowest number of species.

Sixty-six of the 130 points sampled were consistently found in the same cluster as its replicate point count. Hence, 49% of the stands sampled had points that were classified into different clusters even though the points were within stands defined as homogenous for forest management purposes. It is likely that bird species at these points responded to subtle differences in the vegetation structure or other factors such as landscape context. There is broad overlap in the breeding bird communities within these clusters, especially for some of the common species such as Nashville Warbler or Yellow-rumped Warbler. However, many species such as the Connecticut Warbler, Palm Warbler, Swainson's Thrush, Sedge Wren and Winter Wren had very distinct associations with an individual cluster.

Clustering technique.- Decision-making with cluster analysis and the resulting dendrogram does not provide a clear choice on the number of clusters. I used the cut-off in the dendrogram that defined the 10 most distinctive groups (i.e., "bird communities"). The decision was based on bird species co-occurrences that were reasonable for forest management and represented realistic bird species associations based on my empirical experience in the field, plus support from the published literature (Warner and Wells 1984). Warner and Wells (1984) described nine forested peatland cover types that were developed previously based on floral composition, while the MNDNR currently identifies nine lowland conifer cover types for forest management purposes. Additional rationale that I considered in the selection of 10 clusters included the following: 1) more than 10 clusters resulted in some clusters having fewer than five points, and 2) fewer than 10 clusters resulted in cover types such as ELB infested stands being lumped with recently harvested lowland conifer forests. In both these situations I did not consider these as realistic representations of the bird communities or as ecologically distinct cover types. For example, as the number of points in a cluster decreases (e.g., two points in a cluster), the probability of an uncommon species having a high PPI value for that cluster increases (e.g., higher relative abundance/high frequency of sites). If ELB infested stands were lumped in with recently harvested stands, a new cover type called "*disturbed lowland conifers*" would have been identified. Here, Connecticut Warblers would have shown an affinity for stands that were disturbed, which may lead forestry or wildlife management to think that Connecticut Warblers are using recent clear cut forests. At this time there are no studies of which I am aware that has documented this species using recent clear cut forests. In addition, many sites were clustered in cover types of mixed composition (e.g.,

mixed lowland conifer, *mixed tamarack swamp conifer*, *mixed lowland conifer* (*landscape*)), where no single cover type was dominant. Grouping these three cover types/bird communities together would have resulted in the inability to identify features such as landscape influences to which the birds may respond.

For the cluster analysis, individual points were used as opposed to stands (130 points vs. 65 stands), due to variability among habitats within a stand. Sampling replicates were also important to gain confidence in the PPI values because the presence of a species at all five samples of a point leads to un-inflated PPI values. Combining them would lower our confidence to predict a species occurrence in a habitat type when calculated with the PPI analysis. For example, if a Palm Warbler is detected at only one of five replicates at the same point, collapsing these data would lead to inflated frequencies (presence/absence), which would result in inflated PPI values (frequency of 0.2 vs 1.0).

Community assemblages - Cover types

Mixed lowland white cedar.- These cover types had an average age of 130 years and had sites that were primarily composed of old, relatively productive white cedar, but black spruce and tamarack were often present, which separated this community from the northern white cedar community (Appendices A, B). It is likely this degree of mixing, occurring along a gradient of mineral soils to organic soils, influenced the high species richness of these points (Table 2). Many bird species ranging from upland species like Ovenbird to typical boreal species like Yellow-bellied Flycatcher found suitable breeding habitat within these forests.

Mixed lowland white cedar cover types encompassed a wide range of conditions; however, it was generally characterized as highly productive and was represented by older age classes. Bird species diversity was among the highest observed among the 10 bird community types and the Swainson's Thrush was most common in this cover type compared with other cover types. Swainson's Thrush has been associated with higher densities of shrubs and cover below two meters, with balsam fir understories (Rinaldi and Worland 2004). This is consistent with understories in *mixed lowland white cedar* forests in our study area. Old growth white cedar forests provided nesting habitats for the Swainson's Thrush, which requires shaded, dense understories for nesting (Jaakko Poyry Consulting, Inc. 1992, Evans Mack and Yong 2000). However, in Canada (Erskine 1977), forests of Minnesota and Wisconsin (Niemi et al. 2016, Wisconsin DNR 2005) Swainson's Thrush was present in a variety of coniferous habitat types (e.g., spruce, fir, hemlock and jack pine). The Minnesota Breeding Bird Atlas found Swainson's Thrush to be most prevalent in northeast Minnesota, primarily in the Superior National Forest (MNBBA).

Eastern larch beetle disturbance forests.- The continued expansion of ELB tamarack mortality will increase the prevalence of this bird community, which only includes points affected by ELB in the last 15 years. The bird community and forests that develop after infestation are transitional and characterized by an increase in species related to a continuum of early-successional stages (e.g., White-throated Sparrow, Common Yellowthroat and Mourning Warbler). However, several species more often found in lowland conifer cover types such as Connecticut Warbler and Lincoln's Sparrow were

also present. Because of the transitional nature of this forest cover type, these species will be less likely to persist as succession proceeds.

Few lowland conifer dependent species showed selection for this cover type. Interestingly, Connecticut Warbler counts in this cover type were similar to those of *stagnant black spruce-tamarack bog* and *productive (mature) black spruce-tamarack bog* cover types. I am unaware of previously published studies that document the use of ELB-disturbance forests by the Connecticut Warbler; no points in these stands were surveyed prior to the most recent outbreak of ELB in the early 2000s. The use of these areas by the Connecticut Warbler is unknown, but their use may be a fortuitous benefit to this species.

Northern white cedar.- This forest type was primarily composed of old and large-DBH white cedar trees. This type also often included a high proportion of deciduous canopy trees, an open understory, and drier ground conditions than other white cedar forests in the study area (Appendices A, B). When compared with other forest cover types, the bird species using these forests were most similar to those commonly found using upland deciduous forests (Niemi et al. 2016).

Bird species with high PPI values for this cover type included many crevice or cavity nesting species such as the Brown Creeper, Red-breasted Nuthatch, Hairy Woodpecker and Yellow-bellied Sapsucker. This emphasizes the importance of old, large diameter trees for these species; a forest type that is rare in this region. In addition, species such as the Black-throated Green Warbler and Ovenbird were among the most abundant species in this cover type and consistent with findings of Erskine (1977) and Warner and Wells (1984).

Stagnant black spruce-tamarack bog.- This cover type represented the black spruce and tamarack forests with low productivity and short-statured, stunted trees usually due to ombrotrophic conditions (Wright et al. 1992). The bird communities associated with this cover type have affinities to small diameter trees with open canopies and dense sphagnum moss (Appendices A, B). This forest type can also include stands in varying degrees of regeneration that shared the above structural attributes

The Palm Warbler had its highest affinity and was the second most abundant species within this cover type. These results were supported by Erskine (1977), Warner and Wells (1984), and Niemi and Hanowski (1992), who all found the Palm Warbler primarily in these muskeg cover types. In addition, many ground nesting species such as the Connecticut Warbler, Dark-eyed Junco, Yellow-bellied Flycatcher and Chipping Sparrow were shown to utilize this habitat type.

Semi-productive black spruce-tamarack bog.- Sites related to this bird community were primarily composed of black spruce and tamarack forests of intermediate structural attributes. Trees were generally intermediate in height, diameter, and canopy structure when compared to the *stagnant* and *productive (mature) black spruce-tamarack bog* cover types. Many combinations of age and site index can be found within this cover type. For example, a stand with a site index of 45 and 30 years old may be structurally similar to a stand that has a site index of 26 and an age of 100. The bird community in this cover type had a high species richness estimate for lowland conifer-dependent

species (Table 2). In addition, Connecticut Warbler, a SGCN, had high densities and affinity with this cover type (PPI value of 40; Appendix C).

Few studies have focused on lowland conifer forest types of intermediate productivity and their associated bird communities. Warner and Wells (1984) and Niemi and Hanowski (1984) provided limited quantitative habitat data for the sites they sampled. Niemi et al. (1983) provided detailed estimates of tree height and density in forested stands of the Red Lake Peatland, MN, USA, but did not include a forest cover type of intermediate tree density. Hence, comparisons were limited. Connecticut Warbler had the highest affinity for this cover type when compared with all other cover types. These results generally supported those of Niemi and Hanowski (1984, 1992) who found Connecticut Warblers in spruce forests, including those of intermediate tree densities with semi-open canopies. Erskine (1977) found Connecticut Warblers present in tamarack forests in Ontario; however, he did not report Connecticut Warblers in black spruce forests. Warner and Wells (1984) found this species in multiple cover types within their study area (e.g., in areas with both large and small trees). Additional research on the potential dependence of the Connecticut Warbler on this forest cover type is warranted in concert with its potential dependence on a landscape matrix dominated by lowland and upland coniferous forest (Lapin et al. 2013).

These stands have high importance for many boreal bird species, many of which are of conservation concern. The regeneration potential after harvest is unknown and likely to take a long time. Climate change models predict reductions in suitable habitat for black spruce in Minnesota by 2100 (Iverson et al. 2008); therefore, harvesting these stands must be evaluated along with their conservation or biodiversity value.

Mixed tamarack swamp conifers.- Tamarack forests were characterized by dense deciduous understories and white cedar, black spruce, balsam fir and paper birch trees were commonly interspersed with the tamarack. This cover type differs from the *mixed lowland conifer* cover types because it had on average more tamarack (~20%) at the 100 meter level, increased proportions of tamarack at the 200 meter level (~20%), and decreased amounts of evergreen trees at the 200 meter level (black spruce, white cedar ~20%). No general trend existed in migration strategy selection of this habitat type (e.g., long vs. short distance); however, it is possible there may be avoidance of tamarack habitat types by short-distance migrants and year round residents as cover within these habitat types is reduced upon arrival on breeding grounds. Few species dependent on lowland conifers were found in this cover type. This may be due to standing water and low ground cover which limited habitat for ground nesting species like Connecticut Warbler, Yellow-bellied Flycatcher and Palm Warbler. It is also possible that there may be landscape influences that have yet to be identified. This cover type was more similar to the *mixed lowland conifer* (*landscape*) cover type when compared with the *mixed lowland conifer* cover type (Figure 3).

Northern Waterthrush and Winter Wren (an SGCN) had their strongest affinities to this cover type. Both species may benefit from disturbances such as ELB that create downed trees and upturned tree roots or from the hummock-type conditions with standing water in the depressions (Jaakko Poyry Consulting, Inc. 1992). Both species likely find suitable habitat and microhabitats within this forest cover type. The late leaf-out of tamarack and the openness may also render this cover type less suitable for many species

such as permanent residents or short-distance migrants that require greater cover during the winter or early spring periods when they begin to nest.

Mixed lowland conifer (landscape).- This general forest cover type along with the other *mixed lowland conifer* cover type, had the least distinct bird communities relative to the other cover types. Blue Jay and Mourning Dove had their highest affinities for this cover type. The Mourning Dove is a relatively rare species in the ALS and likely occurs because of its association with agricultural and human settlements in the surrounding landscape. Most of the points sampled within these two cover types were in the western and northern areas of the ALS where upland forests and agricultural cover dominate. Many points in this cover type had large black spruce and tamarack trees.

Productive (mature) black spruce-tamarack bog.- This forest cover type was primarily found in mature, productive sites with tall, large diameter trees and closed canopies. These forests had among the highest bird species richness of the lowland conifer dependent species, as well as the most Species of Greatest Conservation Need (Table 2). Along with the previous two black spruce-tamarack cover types, these forests are among the most important habitats for many archetypal boreal bird species breeding in Minnesota. Five focal bird species were observed in this cover type, including three with their greatest affinity: Boreal Chickadee, Dark-eyed Junco and Golden-crowned Kinglet. Connecticut and Yellow-rumped Warbler were also found in this cover type.

Dark-eyed Junco prefers open understory forests with fewer stems and higher percentages of ground cover (Nolan et al. 2002). In this study, vegetation data within

points of this forest type concur with these results as the percent ground cover was among the highest (89%) and understory cover was among the lowest of any of the forest types sampled. These results contrast with those of Erskine (1977) and Warner and Wells (1984) who found Dark-eyed Junco to be most abundant in stunted muskeg habitats. Observations of Boreal Chickadee and Golden-crowned Kinglet in mature black spruce-tamarack forests have also been previously reported by Niemi and Hanowski (1984), Warner and Wells (1984), and in Canada by Erskine (1977).

Mixed lowland conifers.- Similar to the other *mixed lowland conifer (landscape)* cover type, points in this cover type had the least distinctive bird communities. In contrast to the other *mixed lowland conifer (landscape)* cover type, points in this cover type were generally embedded in a landscape of lowland conifer forests and comprised of common bird species of the ALS. Many of the points in these forest types were within fragmented landscapes and emphasize the need to protect large, contiguous landscapes of lowland coniferous habitats where they still exist.

Recently harvested lowland conifers.- Bird communities in this cluster were very distinctive and most closely resembled those found in open grass-sedge and shrubby wetland habitats. The bird community was characterized by Alder Flycatcher, Swamp Sparrow, Common Yellowthroat and Sedge Wren, all of which were rarely if ever found at sites in other clusters. These species dominate due to the "swamping" of these recently cut forests. These species were found to be abundant in these same habitat types surveyed by Warner and Wells (1984) and Niemi and Hanowski (1984).

Points in this cluster were all harvested 8-24 years prior to bird sampling. Few to no lowland conifer tree species had regenerated at four of the six sites, and only sparse coverage had occurred at the other two sites. Four additional sites that were harvested in the last 30 years had better regeneration. Because of the lack of regeneration or slow recovery of trees that have occurred following logging in the ALS, concerns remain on the extent that these areas can be sustainably harvested. It is prudent to invest in additional research on retrospective studies of existing logged sites and improve regeneration techniques prior to additional logging activity. In addition, the fragmentation of these extensive, contiguous lowland coniferous forests will likely have negative effects on many of the species of conservation concern such as the Connecticut Warbler (Lapin et al. 2013).

Multivariate analysis

The results from the CCA supported the distinction of the ten cover types identified by the cluster analysis. Distinctive species such as (Connecticut Warbler, Boreal Chickadee and Palm Warbler) segregated out in ordination space in groupings that were similar to the ten cover types identified, as shown in Figure 4. Many species found to the left of Axis 2 (Figure 4), were species of the pure black spruce-tamarack bog cover types. Moving up on Axis 2 indicates differences in bird species segregate out by age classes and tree density from more mature black spruce-tamarack stands (Boreal Chickadee) to immature black spruce-tamarack cover types (Palm Warbler). The Connecticut Warbler was found in cover types of black spruce and tamarack and of intermediate height and density.

Moving towards the right on Axis 1, represents a transition from pure black spruce-tamarack cover types, to mixed lowland conifer cover types with an increasing deciduous component of black ash and paper birch (Figure 4). This supports the results of the PPI analysis of white cedar stands (pure and mixed) having more distinctive species and higher overall species richness. The upper right portion of Figure 4 included species found in younger, deciduous forests such as Chestnut-sided Warbler and Veery.

Species of interest

Connecticut Warbler.- Connecticut Warblers had high specificity for *semi-productive black spruce-tamarack bog* cover types. Previous studies found Connecticut Warblers breeding in aspen forests in Western Canada (Kirk 1996), black spruce forests on organic soils in Ontario (Welsh and Lougheed 1996), intermediate or low tamarack habitat types in Ontario (Erskine 1977), and jack pine forests of Ontario (Erskine 1977) and Wisconsin (Wisconsin DNR 2005). Therefore, I expected to find them in a wide range of lowland conifer habitat types of varying forest structures.

Previously, Warner and Wells (1984) found this species to be distributed along a range of black-spruce tamarack habitats, while Nevers (1981), Nevers et al. (1981), Hanowski and Niemi (1983), and Niemi and Hanowski (1984, 1992), found Connecticut Warblers in closed canopy forests with intermediate/semi-productive structure. Niemi et al. (2016) described Connecticut Warblers as having high affinity for black spruce-tamarack lowland habitats out of 20 habitat types described in the National Forests of the Western Great Lakes. Models by Lapin et al. (2013) determined that Connecticut Warblers preferred larger contiguous tracts of lowland conifers throughout National

Forests of Minnesota. In a complimentary study, Zlonis et al. (2017) also showed that Connecticut Warbler's preferred large tracts of black spruce-tamarack at the landscape scale in the ALS. These findings could have conservation implications to the Connecticut Warbler because Iverson et al. (2008) predicted that lowland conifer species such as tamarack, black spruce, and white cedar may be the first to retreat northward in a warming climate.

Connecticut Warblers were also present in ELB disturbance forests. Five of the twelve points that were identified as having ELB mortality contained Connecticut Warblers. Two of those five points were classified into *semi-productive black-spruce tamarack bog* cover types, with the remaining points being grouped in the *ELB disturbance forest* cover types or *mixed tamarack swamp conifer* cover type. The structure of some ELB disturbance forests mimics that of semi-productive black spruce-tamarack forests. Generally, large diameter tamarack trees are killed by ELB, resulting in forest structure of small diameter trees of intermediate densities. I am unaware of previous studies that have found Connecticut Warblers using Eastern Larch Beetle disturbed forests. It is not known whether this species was present in stands prior to ELB infestations, and little is known about their natal philopatry.

Boreal Chickadee.- Boreal Chickadees showed significant selection for mature, productive black spruce-tamarack bog cover types. These findings were similar to those of Nevers (1981), Warner and Wells (1984) and Niemi and Hanowski (1984) who also found Boreal Chickadees in habitats with larger trees and in more productive forests. Hadley (2006) found Boreal Chickadees to use large mature boreal forest stands of

commercial value as their primary overwintering habitats and smaller diameter trees to a lesser extent. Zlonis et al. (2017), found Boreal Chickadees to be positively associated with large patches of evergreen forest and negatively associated with stunted forests at the landscape scale. Erskine (1977) found Boreal Chickadees throughout young and old boreal forests. The use of large, mature trees by this species is characteristic of many cavity nesters. Boreal Chickadees tend to breed in late spring (e.g., April/May) (Ficken et al. 1996) and it is possible that the spring and summer sampling did not fully capture all vocal or territorial males.

Yellow-bellied Flycatcher.- Yellow-bellied Flycatchers were present in 7 of the 10 cover types I described above. Similar distributions were seen by Warner and Wells (1984) where this species was found in most lowland conifer habitats in the study. Zlonis et al. (2017) did not identify covariates that were significant predictors of Yellow-bellied Flycatchers, primarily because the species was ubiquitous throughout the ALS. Yellow-bellied flycatchers showed no affinity for *northern white cedar, recently harvested lowland conifer* or *mixed lowland conifer (landscape)* cover types. This species is ubiquitous throughout most lowland conifer cover types, although in lower densities. For example, this species may require certain nest characteristics (e.g. sphagnum moss) that are not adequately quantified throughout the entire 100 m radius count.

Species such as the Golden-crowned Kinglet and Ruby-crowned Kinglet were more general in cover type selection when compared with Boreal Chickadee and Connecticut Warbler. Both species were found in over half of the cover types described. Golden-crowned Kinglets tended to be found in larger, mature forests, while Ruby-

crowned Kinglets were found with higher affinities in the intermediate cover types (stagnant, semi-productive cover types). Other species such as Winter Wrens, Purple Finches, Blue-headed Vireos and Red-breasted Nuthatches showed general ubiquity across multiple cover types.

SUMMARY

All lowland conifer cover types in the ALS are important to some species. Species found within lowland conifer forests of the ALS range from generalists to specialists in cover type preference. Species such as Nashville Warblers, Yellow-rumped Warblers and White-throated Sparrows occurred in a whole suite of lowland conifer cover types found within the ALS. Even species not regularly known to frequent lowland conifer forests, such as Sedge Wrens, were found abundantly in *recently harvested lowland conifer* cover types. Uncommon species such as the Connecticut Warbler had greatest affinities for *semi-productive black spruce-tamarack bog* cover types. Boreal Chickadees had high specificity for productive (mature) black spruce-tamarack bog cover types. Overall the variety of black spruce-tamarack bog cover types were important habitats for many lowland conifer associated species.

Anthropogenic disturbances pose some of the biggest threats to many species breeding in lowland conifers within the ALS. Global climate change could be the biggest threat to extirpating lowland conifers and their associated bird communities from Minnesota. These facilitations could lead to direct removal of tree species due to warmer climates, or assisted removal through insect infestations and other diseases. Direct disturbances such as logging may also pose a large threat to boreal bird species if

conducted in an unsustainable manner. It is one of the few disturbances (outside of fires) that can be controlled or manipulated to manage wildlife populations. In addition, regeneration of lowland conifers needs to be better understood. The pressure that will be placed on natural resource managers to manage future forests and wildlife populations will be unprecedented. Specifically, management of black spruce will be critical as ELB continues to eradicate old-growth tamarack from the ALS. Misguided natural resources management could be detrimental to many types of wildlife.

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Appendix A. Cover type variables estimated at each bird census point are averaged (standard error in parentheses) for each of the ten forest cover types defined from the hierarchical cluster analysis in the Agassiz Lowland Subsection (ALS), Minnesota. Variable types (spatial scales) were site, stand and landscape levels. Landscape variable spatial scales are listed in the variable description in the far left column (e.g., 200, 500, 1000 m radii). Landscape data and select site data (cover) are summarized as percent (%) while other variables are summarized by stem density (number of stems/314m^2), basal area (m2/ha), DBH (cm) and height (meters). Site level data was visually estimated by observers at each census point. Site level data summarized for combined data variables (e.g., Black spruce-tamarack DBH) was weighted according to proportion of cover within 100 meters of sample point. Stand level data was summarized from Minnesota Department of Natural Resources – Forestry Inventory Management database (MNDNR-FIM). Landscape data was summarized using Upper Midwest Gap Analysis Program (GAP) and data from MNDNR – data deli. The numbers of points summarized for each forest cover type are listed in parenthesis.

Variables	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer-(landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Variable type
All conifers % cover	94.4 (1.8)	90.5 (3.9)	74.3 (15.4)	100.0 (0.0)	100.0 (0.0)	90.8 (2.9)	93.0 (2.4)	100.0 (0.0)	97.8 (1.0)	85.0 (9.6)	Site
All conifers DBH	18.0 (1.0)	15.2 (2.8)	25.1 (3.8)	7.6 (0.5)	11.9 (1.0)	13.0 (1.0)	14.0 (0.8)	15.5 (0.8)	15.0 (1.0)	11.2 (3.0)	Site
All conifers height	11.1 (0.5)	10.9 (1.1)	12.1 (1.6)	5.6 (0.6)	9.6 (0.8)	9.6 (0.7)	10.3 (0.5)	12.8 (0.4)	10.7 (0.6)	7.8 (1.4)	Site
Balsam fir % cover	8.1 (2.1)	3.9 (3.0)	9.9 (4.1)	0.0 (0.0)	2.1 (2.1)	3.2 (1.9)	5.1 (1.7)	0.0 (0.0)	6.2 (2.3)	0.0 (0.0)	Site
Balsam fir DBH	12.4 (1.3)	12.2 (3.3)	19.1 (3.6)	0.0 (0.0)	7.6 (0.0)	8.9 (0.3)	11.2 (0.5)	0.0 (0.0)	12.4 (0.8)	0.0 (0.0)	Site
Balsam fir height	8.5 (0.8)	9.3 (2.9)	12.8 (1.9)	0.0 (0.0)	6.0 (0.0)	5.7 (0.4)	8.6 (0.5)	0.0 (0.0)	8.8 (0.6)	0.0 (0.0)	Site
Black spruce % cover	22.3 (3.4)	13.6 (7.2)	2.7 (1.8)	83.2 (6.7)	56.4 (8.1)	21.6 (8.1)	47.2 (8.1)	80.5 (7.5)	40.6 (5.5)	12.8 (8.6)	Site
Black spruce DBH	16.8 (1.3)	14.5 (1.8)	15.2 (0.0)	7.9 (0.5)	12.4 (1.0)	12.4 (1.3)	13.7 (0.5)	15.5 (1.0)	15.0 (1.0)	5.1 (1.5)	Site
Black spruce height	12.1 (0.9)	10.7 (1.1)	11.5 (1.6)	5.6 (0.7)	9.6 (0.9)	9.6 (0.9)	10.5 (0.5)	12.8 (0.4)	11.3 (0.6)	5.0 (1.7)	Site

Variables	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer-(landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Variable type
Black spruce-white cedar-balsam fir % cover	79.2 (4.8)	25.3 (8.7)	73.3 (15.1)	83.2 (6.7)	61.0 (8.5)	42.8 (8.8)	68.2 (6.1)	82.7 (5.9)	66.8 (5.4)	12.8 (8.6)	Site
Black spruce-white cedar-balsam fir DBH	17.8 (1.0)	18.3 (3.8)	25.1 (3.8)	7.9 (0.5)	12.2 (1.0)	13.0 (1.3)	13.5 (0.8)	15.5 (1.0)	14.7 (1.0)	5.1 (1.5)	Site
Black spruce-white cedar-balsam fir height	10.7 (0.5)	9.8 (1.6)	12.1 (1.6)	5.6 (0.7)	9.4 (0.9)	9.2 (0.8)	10.2 (0.5)	12.4 (0.5)	10.4 (0.6)	5.0 (1.7)	Site
Black spruce-tamarack % cover	37.6 (4.9)	76.8 (10.9)	3.6 (2.2)	100.0 (0.0)	95.5 (3.8)	69.6 (8.9)	71.6 (6.9)	97.8 (2.2)	71.5 (5.7)	85.0 (9.6)	Site
Black spruce-tamarack DBH	17.0 (1.0)	13.7 (1.8)	15.2 (0.0)	7.6 (0.5)	11.9 (1.0)	12.4 (1.0)	14.7 (1.0)	15.5 (0.8)	14.7 (1.0)	11.2 (3.0)	Site
Black spruce-tamarack height	12.5 (0.9)	11.1 (1.1)	11.5 (1.6)	5.6 (0.6)	9.7 (0.8)	9.7 (0.8)	10.6 (0.6)	13.0 (0.5)	11.5 (0.6)	7.8 (1.4)	Site
Canopy height (m)	13.6 (0.6)	12.2 (1.5)	16.8 (1.5)	8.5 (1.0)	11.8 (0.9)	12.2 (0.8)	13.4 (0.7)	15.3 (1.0)	13.6 (0.7)	4.5 (1.5)	Site
Deciduous % cover	5.6 (1.8)	9.5 (3.9)	25.7 (15.4)	0.0 (0.0)	0.0 (0.0)	9.2 (2.9)	7.0 (2.4)	0.0 (0.0)	2.2 (1.0)	15.0 (9.6)	Site
Deciduous DBH	13.5 (1.0)	12.7 (2.0)	18.8 (2.0)	0.0 (0.0)	0.0 (0.0)	12.2 (1.3)	14.7 (0.8)	0.0 (0.0)	11.4 (1.0)	15.2 (3.0)	Site
Deciduous height	9.8 (0.7)	10.1 (1.7)	12.8 (1.1)	0.0 (0.0)	0.0 (0.0)	8.6 (0.7)	10.3 (0.4)	0.0 (0.0)	9.1 (0.5)	9.5 (0.9)	Site
Ground cover	49.2 (6.2)	75.6 (8.2)	22.0 (3.7)	92.0 (2.9)	92.5 (2.2)	62.0 (6.6)	68.4 (5.5)	89.2 (2.9)	76.0 (4.0)	70.0 (6.3)	Site

Variables	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer-(landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Variable type
High canopy cover %	56.2 (5.2)	32.2 (8.5)	84.0 (4.0)	18.0 (3.9)	34.2 (5.6)	36.7 (5.2)	46.8 (3.5)	50.8 (4.5)	47.6 (3.3)	20.8 (13.4)	Site
High canopy cover % deciduous	5.9 (2.3)	20.0 (7.3)	34.0 (19.1)	0.0 (0.0)	0.0 (0.0)	10.0 (3.5)	11.6 (3.6)	0.0 (0.0)	2.8 (1.2)	3.3 (3.3)	Site
Lowland conifer % cover	86.4 (3.0)	84.5 (6.7)	64.4 (18.6)	100.0 (0.0)	97.9 (2.1)	87.6 (4.3)	87.5 (3.3)	100.0 (0.0)	91.6 (2.6)	85.0 (9.6)	Site
Lowland conifer DBH	18.8 (1.0)	16.0 (3.3)	25.9 (4.3)	7.6 (0.5)	11.9 (1.0)	13.5 (1.3)	14.5 (1.0)	15.7 (0.8)	15.5 (1.0)	11.2 (3.0)	Site
Lowland conifer height	11.3 (0.5)	10.9 (1.1)	11.8 (1.6)	5.6 (0.6)	9.6 (0.8)	9.7 (0.7)	10.4 (0.5)	12.8 (0.4)	10.8 (0.6)	7.8 (1.4)	Site
Shrub % cover	0.1 (0.1)	9.9 (6.4)	0.0 (0.0)	0.0 (0.0)	1.8 (1.4)	1.5 (0.8)	0.0 (0.0)	0.0 (0.0)	0.5 (0.5)	35.8 (11.0)	Site
Subcanopy % deciduous	13.5 (5.1)	13.3 (7.3)	28.0 (17.1)	0.0 (0.0)	4.2 (2.9)	16.0 (5.1)	11.6 (3.7)	0.0 (0.0)	6.4 (2.6)	0.0 (0.0)	Site
Subcanopy cover	32.4 (6.6)	13.3 (4.4)	20.0 (10.5)	18.0 (7.7)	11.7 (3.4)	19.3 (4.5)	31.1 (4.0)	25.0 (4.4)	28.8 (4.4)	0.0 (0.0)	Site
Tamarack % cover	15.3 (5.1)	63.1 (12.8)	1.0 (1.0)	16.8 (6.7)	39.0 (8.5)	48.0 (10.1)	24.3 (6.1)	17.3 (5.9)	30.9 (5.5)	72.2 (18.1)	Site
Tamarack DBH	16.8 (1.0)	13.0 (1.5)	15.2 (0.0)	6.9 (0.5)	11.9 (1.0)	13.5 (1.0)	16.5 (1.5)	15.5 (0.8)	14.0 (0.8)	12.2 (3.3)	Site
Tamarack height	11.6 (0.7)	10.7 (1.1)	9.0 (0.0)	5.4 (0.7)	9.4 (0.8)	10.4 (0.7)	10.6 (0.7)	13.5 (0.7)	11.2 (0.6)	7.9 (1.5)	Site
Tree density	49.6 (3.2)	24.8 (4.5)	37.8 (4.2)	46.9 (9.1)	39.1 (4.6)	33.3 (4.7)	51.7 (3.0)	49.3 (3.2)	46.4 (2.3)	10.7 (7.1)	Site
Tree species richness	3.7 (0.3)	2.7 (0.5)	3.2 (0.6)	1.7 (0.2)	2.1 (0.2)	2.9 (0.4)	3.2 (0.4)	1.7 (0.2)	2.8 (0.2)	1.5 (0.3)	Site
Understory % deciduous	16.5 (5.1)	50.0 (11.1)	40.0 (13.4)	1.0 (1.0)	22.5 (10.5)	46.7 (8.2)	17.9 (5.5)	15.0 (6.1)	10.0 (3.3)	93.3 (2.1)	Site

Variables	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer-(landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Variable type
Understory cover	29.7 (4.9)	47.8 (8.3)	24.0 (8.7)	35.0 (7.2)	29.2 (2.6)	36.7 (4.8)	46.3 (4.5)	26.7 (5.0)	38.8 (4.7)	56.7 (12.8)	Site
White cedar % cover	48.8 (3.5)	7.7 (5.0)	60.7 (17.4)	0.0 (0.0)	2.5 (1.8)	18.0 (6.0)	15.9 (5.1)	2.2 (2.2)	20.1 (4.2)	0.0 (0.0)	Site
White cedar DBH	18.8 (1.3)	33.8 (8.1)	26.4 (4.3)	0.0 (0.0)	12.7 (1.0)	14.7 (1.5)	14.0 (0.8)	12.7 (0.0)	17.8 (1.3)	0.0 (0.0)	Site
White cedar height	10.4 (0.5)	10.3 (1.9)	11.8 (1.6)	0.0 (0.0)	6.5 (1.0)	8.5 (0.6)	9.9 (0.5)	8.0 (0.0)	9.5 (0.6)	0.0 (0.0)	Site
White cedar-balsam fir % cover	56.8 (4.1)	11.6 (6.5)	70.6 (14.1)	0.0 (0.0)	4.5 (3.8)	21.2 (7.3)	21.0 (6.0)	2.2 (2.2)	26.3 (5.5)	0.0 (0.0)	Site
White cedar-balsam fir DBH	18.0 (1.0)	20.8 (4.6)	25.4 (3.8)	0.0 (0.0)	10.7 (0.3)	13.7 (1.3)	13.0 (0.8)	12.7 (0.0)	16.3 (1.0)	0.0 (0.0)	Site
White cedar-balsam fir height	10.2 (0.5)	8.5 (2.0)	12.1 (1.6)	0.0 (0.0)	5.7 (0.7)	8.2 (0.6)	9.8 (0.4)	8.0 (0.0)	9.4 (0.6)	0.0 (0.0)	Site
Age 2014	130.4 (8.5)	84.3 (16.3)	133.8 (0.4)	64.6 (12.3)	96.8 (10.8)	86.1 (6.6)	98.2 (8.6)	127.5 (7.4)	104.1 (7.9)	14.3 (4.0)	Stand
Basal area (m^2/ha)	30.7 (2.3)	15.6 (3.3)	26.9 (5.1)	10.9 (2.5)	18.8 (1.5)	16.3 (2.5)	22.5 (1.9)	27.3 (1.8)	20.7 (2.2)	0.8 (0.5)	Stand
DBH (cm)	20.6 (0.8)	15.0 (3.1)	23.9 (0.5)	3.8 (1.5)	13.0 (1.8)	17.5 (1.8)	16.3 (1.3)	15.8 (0.5)	15.2 (1.3)	1.8 (1.0)	Stand
Site index	29.8 (2.1)	40.9 (3.9)	30.8 (2.0)	21.5 (2.3)	27.7 (3.3)	35.3 (3.6)	34.1 (2.9)	30.0 (1.7)	27.2 (1.6)	44.7 (6.5)	Stand
Site index-age	3735.3 (242.1)	3314.3 (623.1)	4124.0 (281.2)	1293.5 (251.1)	2583.0 (311.8)	2970.9 (337.3)	3167.7 (306.4)	3731.8 (196.8)	2762.2 (246.2)	585.3 (130.9)	Stand
Black spruce 1000	11.1 (1.8)	8.8 (3.0)	5.5 (0.5)	35.4 (5.6)	29.1 (7.0)	12.2 (2.6)	16.2 (3.3)	49.0 (4.6)	17.8 (3.2)	7.9 (4.2)	Landscape
Black spruce 200	12.9 (3.1)	8.0 (4.5)	3.0 (1.9)	42.2 (10.5)	57.4 (10.6)	14.3 (4.7)	38.9 (9.1)	98.6 (2.4)	33.4 (7.0)	3.3 (2.1)	Landscape

Variables	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer-(landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Variable type
Black spruce 500	9.8 (1.8)	9.6 (3.4)	2.7 (0.9)	34.2 (8.4)	42.4 (8.6)	14.6 (3.2)	22.6 (4.9)	72.4 (3.7)	21.8 (4.3)	6.5 (3.9)	Landscape
Black spruce-white cedar 1000	40.9 (5.0)	22.6 (4.2)	25.1 (5.9)	37.8 (5.8)	37.0 (6.7)	26.2 (3.4)	27.3 (4.3)	56.6 (4.7)	35.5 (4.3)	15.3 (5.1)	Landscape
Black spruce-white cedar 200	72.5 (7.2)	15.1 (5.0)	51.7 (17.7)	44.4 (11.4)	68.4 (11.7)	32.6 (7.7)	50.7 (8.9)	99.5 (2.0)	62.9 (7.7)	5.2 (3.6)	Landscape
Black spruce-white cedar 500	53.4 (6.6)	21.4 (3.6)	34.2 (8.7)	36.4 (8.5)	52.8 (8.6)	28.2 (4.6)	35.4 (5.4)	77.7 (3.1)	44.3 (5.6)	10.0 (4.8)	Landscape
Black spruce-tamarack 1000	18.5 (2.6)	30.8 (5.8)	10.5 (0.6)	39.7 (5.4)	46.3 (5.7)	30.2 (4.7)	29.4 (4.2)	55.2 (4.2)	28.2 (3.2)	14.2 (5.4)	Landscape
Black spruce-tamarack 200	22.6 (4.8)	54.8 (8.9)	7.7 (2.2)	42.2 (10.5)	76.2 (7.3)	56.0 (7.8)	57.4 (7.8)	98.6 (2.4)	45.8 (6.9)	13.7 (6.1)	Landscape
Black spruce-tamarack 500	18.1 (2.7)	39.5 (6.5)	7.8 (2.0)	37.1 (7.7)	60.4 (7.1)	42.0 (5.7)	37.6 (5.1)	74.9 (3.8)	34.0 (4.4)	14.6 (5.9)	Landscape
ELB infestation 1000	13.9 (4.1)	22.4 (7.5)	6.1 (5.9)	0.0 (0.0)	25.3 (10.3)	24.5 (8.6)	14.0 (4.0)	2.8 (1.7)	8.5 (2.6)	13.9 (7.0)	Landscape
ELB infestation 200	7.9 (6.3)	37.5 (12.9)	6.1 (6.1)	0.0 (0.0)	35.6 (14.7)	23.2 (11.2)	18.7 (6.8)	3.8 (3.8)	9.0 (5.6)	33.9 (21.5)	Landscape
ELB infestation 500	14.1 (5.7)	32.2 (10.2)	6.6 (6.5)	0.0 (0.0)	30.3 (12.6)	24.9 (10.3)	17.0 (5.1)	3.7 (2.8)	8.9 (4.3)	23.5 (15.0)	Landscape
Forested 1000	73.9 (2.1)	67.8 (4.7)	77.5 (5.2)	62.9 (4.4)	77.9 (2.5)	66.0 (2.8)	64.4 (2.6)	70.4 (3.9)	72.0 (2.3)	38.6 (6.2)	Landscape
Forested 200	98.1 (2.5)	77.0 (9.8)	96.0 (3.7)	73.5 (11.3)	99.5 (2.0)	84.3 (5.8)	87.4 (4.1)	99.5 (1.7)	92.7 (4.3)	19.4 (7.4)	Landscape
Forested 500	86.0 (2.5)	68.2 (5.4)	88.4 (3.9)	67.3 (7.1)	89.1 (2.4)	70.9 (4.2)	75.6 (2.4)	85.6 (2.8)	81.1 (3.1)	31.2 (9.3)	Landscape
Lowland conifer 1000	48.3 (4.7)	44.6 (4.2)	30.1 (5.9)	42.1 (5.6)	54.2 (5.0)	44.2 (3.9)	40.5 (4.2)	62.8 (4.2)	45.8 (4.1)	21.5 (5.5)	Landscape

Variables	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer-(landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Variable type
Lowland conifer 200	82.1 (6.2)	61.9 (9.0)	56.4 (17.7)	44.4 (11.4)	87.2 (7.2)	74.3 (6.0)	69.2 (7.4)	99.5 (2.0)	75.2 (7.0)	15.6 (6.3)	Landscape
Lowland conifer 500	61.5 (6.2)	51.3 (5.1)	39.3 (9.4)	39.3 (7.9)	70.8 (6.4)	55.6 (4.1)	50.4 (4.7)	80.1 (3.3)	56.5 (5.4)	18.1 (6.3)	Landscape
Lowland deciduous 1000	0.3 (0.2)	0.7 (0.4)	0.7 (0.3)	0.1 (0.1)	0.5 (0.2)	1.0 (0.2)	0.7 (0.2)	0.2 (0.1)	0.5 (0.1)	0.2 (0.1)	Landscape
Lowland deciduous 200	0.3 (0.3)	0.0 (0.0)	3.4 (2.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.4 (0.9)	0.0 (0.0)	0.4 (0.3)	0.0 (0.0)	Landscape
Lowland deciduous 500	0.4 (0.3)	0.5 (0.4)	1.5 (0.7)	0.0 (0.0)	0.1 (0.1)	0.5 (0.2)	0.9 (0.3)	0.1 (0.1)	0.6 (0.2)	0.3 (0.1)	Landscape
Lowland shrub 1000	7.6 (1.3)	11.3 (2.7)	8.1 (3.2)	28.5 (5.1)	8.8 (1.5)	16.5 (2.2)	14.1 (1.8)	13.0 (1.9)	13.4 (1.9)	19.7 (3.3)	Landscape
Lowland shrub 200	4.0 (1.7)	11.3 (9.3)	6.6 (3.9)	30.1 (10.1)	0.0 (0.0)	11.6 (4.4)	10.5 (2.9)	2.6 (1.3)	9.3 (4.4)	32.7 (18.4)	Landscape
Lowland shrub 500	6.9 (1.5)	15.3 (5.6)	5.6 (1.9)	31.8 (6.4)	4.7 (1.1)	16.3 (3.4)	12.7 (1.5)	8.5 (2.3)	13.0 (2.7)	25.8 (8.9)	Landscape
Non-forested 1000	22.3 (1.9)	29.6 (4.7)	19.9 (5.2)	34.5 (4.4)	19.5 (2.5)	31.4 (2.8)	33.0 (2.6)	27.0 (3.9)	25.0 (2.3)	58.8 (6.2)	Landscape
Non-forested 200	8.3 (2.5)	29.4 (9.8)	10.4 (3.7)	32.9 (11.3)	4.5 (2.0)	22.1 (5.8)	19.1 (4.1)	5.0 (1.7)	13.7 (4.3)	87.0 (7.4)	Landscape
Non-forested 500	16.9 (2.5)	34.8 (5.4)	14.6 (3.9)	35.7 (7.1)	13.8 (2.4)	32.1 (4.2)	27.4 (2.4)	17.4 (2.8)	21.9 (3.1)	71.8 (9.3)	Landscape
Number of patches 1000	91.9 (6.3)	100.4 (8.4)	85.8 (7.4)	60.1 (5.6)	79.8 (9.2)	87.9 (7.2)	103.1 (6.7)	66.1 (6.6)	85.8 (4.8)	91.8 (3.6)	Landscape
Number of patches 200	6.2 (0.7)	7.1 (0.8)	6.4 (0.7)	4.6 (0.4)	4.7 (0.8)	6.1 (0.7)	6.5 (0.6)	2.4 (0.4)	5.8 (0.4)	6.2 (0.8)	Landscape

Variables	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer-(landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Variable type
Number of patches 500	25.6 (2.1)	35.2 (3.2)	25.6 (3.5)	19.9 (2.3)	23.9 (3.5)	25.1 (1.8)	28.5 (1.5)	15.7 (1.7)	25.4 (1.6)	32.3 (2.2)	Landscape
Open 1000	6.2 (1.1)	9.0 (3.8)	6.5 (2.7)	3.0 (0.9)	5.8 (1.4)	8.9 (2.4)	8.9 (1.2)	9.6 (2.5)	5.2 (0.9)	25.5 (6.7)	Landscape
Open 200	0.7 (0.3)	16.4 (6.8)	0.3 (0.2)	1.1 (0.8)	3.6 (2.0)	6.9 (3.4)	5.0 (2.4)	0.1 (0.1)	2.1 (1.1)	48.5 (15.4)	Landscape
Open 500	3.6 (1.2)	10.3 (4.0)	4.3 (2.1)	1.0 (0.4)	6.2 (1.8)	8.9 (2.7)	6.8 (1.7)	3.6 (1.5)	3.6 (0.9)	31.4 (9.2)	Landscape
Open water 1000	9.8 (1.4)	15.1 (3.6)	10.0 (3.1)	30.5 (5.2)	10.3 (1.7)	19.2 (2.4)	17.3 (2.0)	15.1 (2.1)	15.6 (2.0)	26.7 (6.1)	Landscape
Open water 200	4.9 (1.9)	11.7 (9.4)	7.6 (4.5)	31.1 (10.2)	0.5 (0.4)	15.0 (5.5)	10.9 (2.9)	3.1 (1.3)	10.0 (4.4)	36.2 (20.5)	Landscape
Open water 500	8.7 (2.0)	19.8 (6.9)	6.2 (2.0)	34.0 (6.8)	6.3 (1.7)	20.0 (4.1)	14.1 (1.6)	10.3 (2.5)	15.0 (2.9)	33.9 (13.3)	Landscape
Patch richness 1000	13.5 (0.5)	12.0 (0.6)	15.4 (0.7)	10.6 (0.7)	11.8 (0.9)	12.4 (0.8)	12.2 (0.6)	11.1 (0.5)	13.0 (0.5)	14.8 (1.1)	Landscape
Patch richness 200	4.2 (0.4)	4.3 (0.3)	4.8 (0.4)	3.3 (0.3)	2.8 (0.3)	3.9 (0.4)	4.3 (0.4)	2.3 (0.3)	4.2 (0.3)	4.0 (0.4)	Landscape
Patch richness 500	9.0 (0.5)	9.6 (0.4)	11.0 (0.3)	6.8 (0.5)	7.3 (0.8)	8.8 (0.2)	9.2 (0.5)	6.9 (0.5)	8.8 (0.4)	9.0 (1.0)	Landscape
Sedge meadow 1000	2.2 (0.3)	3.9 (1.1)	1.9 (0.5)	2.1 (0.5)	1.5 (0.3)	2.7 (0.4)	3.2 (0.6)	2.1 (0.4)	2.2 (0.3)	7.0 (3.7)	Landscape
Sedge meadow 200	0.9 (0.5)	0.3 (0.2)	1.0 (1.0)	1.0 (0.7)	0.5 (0.4)	3.4 (1.8)	0.5 (0.2)	0.5 (0.3)	0.7 (0.3)	3.5 (2.8)	Landscape
Sedge meadow 500	1.8 (0.8)	4.5 (1.5)	0.5 (0.2)	2.2 (0.9)	1.6 (0.7)	3.7 (0.9)	1.4 (0.3)	1.8 (0.4)	2.0 (0.4)	8.1 (4.8)	Landscape
Stagnant black spruce 1000	0.1 (0.1)	0.0 (0.0)	1.1 (0.7)	15.4 (2.0)	1.0 (0.6)	1.4 (1.1)	0.4 (0.2)	1.4 (0.8)	2.6 (1.3)	0.1 (0.1)	Landscape
Stagnant black spruce 200	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	28.4 (7.5)	1.0 (1.0)	2.9 (2.9)	2.6 (2.6)	0.1 (0.1)	2.3 (1.2)	0.0 (0.0)	Landscape
Stagnant black spruce 500	0.1 (0.0)	0.0 (0.0)	0.6 (0.5)	24.8 (2.2)	1.1 (0.8)	1.3 (1.3)	0.7 (0.5)	1.7 (1.1)	3.0 (1.6)	0.1 (0.1)	Landscape

Variables	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer-(landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Variable type
Stagnant black spruce-tamarack 1000	2.0 (1.3)	3.9 (1.5)	1.2 (0.7)	16.7 (2.5)	8.1 (4.4)	5.2 (2.0)	1.3 (0.7)	1.6 (0.8)	4.6 (1.4)	2.2 (1.4)	Landscape
Stagnant black spruce-tamarack 200	0.1 (0.1)	0.7 (0.5)	0.0 (0.0)	28.4 (7.5)	13.0 (7.3)	5.2 (3.6)	4.8 (3.3)	0.1 (0.1)	7.7 (4.1)	0.0 (0.0)	Landscape
Stagnant black spruce-tamarack 500	1.0 (0.8)	2.0 (0.9)	0.7 (0.4)	25.4 (2.2)	9.3 (5.0)	4.0 (2.1)	2.5 (1.7)	1.7 (1.1)	5.1 (2.2)	0.1 (0.1)	Landscape
Stagnant conifer 1000	2.0 (1.3)	3.9 (1.5)	1.2 (0.7)	16.7 (2.5)	8.1 (4.4)	5.2 (2.0)	1.3 (0.7)	1.6 (0.8)	4.7 (1.4)	2.2 (1.4)	Landscape
Stagnant conifer 200	0.2 (0.1)	0.7 (0.5)	0.0 (0.0)	28.4 (7.5)	13.0 (7.3)	5.2 (3.6)	4.8 (3.3)	0.1 (0.1)	7.8 (4.1)	0.0 (0.0)	Landscape
Stagnant conifer 500	1.1 (0.8)	2.0 (0.9)	0.7 (0.4)	25.4 (2.2)	9.3 (5.0)	4.0 (2.1)	2.5 (1.7)	1.7 (1.1)	5.2 (2.2)	0.1 (0.1)	Landscape
Stagnant tamarack 1000	1.9 (1.3)	3.9 (1.5)	0.0 (0.0)	1.3 (0.6)	7.0 (4.5)	3.8 (1.7)	0.9 (0.6)	0.2 (0.1)	2.0 (0.7)	2.1 (1.3)	Landscape
Stagnant tamarack 200	0.1 (0.1)	0.7 (0.5)	0.0 (0.0)	0.0 (0.0)	12.1 (7.4)	2.4 (2.4)	2.2 (2.1)	0.0 (0.0)	5.5 (3.8)	0.0 (0.0)	Landscape
Stagnant tamarack 500	0.9 (0.8)	2.0 (0.9)	0.1 (0.1)	0.6 (0.4)	8.1 (5.1)	2.7 (1.8)	1.8 (1.7)	0.0 (0.0)	2.2 (1.5)	0.0 (0.0)	Landscape
Tamarack 1000	7.4 (1.5)	22.0 (4.9)	5.0 (0.1)	4.3 (0.8)	17.2 (3.0)	18.0 (3.8)	13.2 (2.1)	6.2 (0.9)	10.4 (1.4)	6.2 (1.3)	Landscape
Tamarack 200	9.7 (3.3)	46.8 (8.6)	4.7 (2.6)	0.0 (0.0)	18.8 (7.5)	41.8 (8.4)	18.5 (3.7)	0.0 (0.0)	12.4 (3.2)	10.4 (6.0)	Landscape
Tamarack 500	8.3 (1.9)	29.9 (6.0)	5.1 (1.2)	2.9 (1.0)	18.0 (5.0)	27.5 (5.7)	15.0 (2.6)	2.4 (0.7)	12.2 (2.1)	8.2 (3.1)	Landscape
Upland conifer 1000	5.8 (2.8)	1.8 (1.2)	11.1 (6.0)	0.0 (0.0)	4.4 (2.6)	2.5 (1.7)	3.8 (1.4)	0.0 (0.0)	5.4 (2.3)	1.4 (1.1)	Landscape
Upland conifer 200	7.1 (5.8)	0.5 (0.3)	3.4 (3.1)	0.0 (0.0)	0.5 (0.5)	0.8 (0.8)	0.0 (0.0)	0.0 (0.0)	4.3 (4.0)	0.0 (0.0)	Landscape

Variables	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer-(landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Variable type
Upland conifer 500	5.7 (4.2)	1.1 (0.7)	7.6 (3.8)	0.0 (0.0)	3.7 (2.4)	1.7 (1.6)	1.7 (0.7)	0.0 (0.0)	5.2 (2.5)	0.0 (0.0)	Landscape
Upland deciduous 1000	17.5 (2.7)	16.8 (2.9)	34.4 (7.8)	4.0 (1.4)	10.8 (2.8)	13.2 (2.6)	18.1 (2.8)	5.8 (2.1)	15.5 (1.8)	13.3 (3.3)	Landscape
Upland deciduous 200	8.4 (2.4)	13.9 (6.5)	32.7 (13.4)	0.7 (0.6)	1.3 (0.9)	3.9 (1.7)	11.9 (4.4)	0.5 (0.3)	4.9 (1.1)	3.8 (2.3)	Landscape
Upland deciduous 500	17.3 (3.3)	13.3 (2.1)	39.2 (9.0)	2.5 (1.4)	5.2 (2.2)	9.0 (2.5)	20.0 (3.7)	3.7 (1.4)	13.6 (1.9)	12.7 (3.5)	Landscape
Upland forested 1000	23.6 (3.9)	19.3 (3.5)	46.2 (3.4)	4.1 (1.4)	15.6 (3.9)	16.6 (3.5)	22.6 (3.4)	6.0 (2.1)	21.4 (2.9)	14.9 (2.9)	Landscape
Upland forested 200	15.8 (5.9)	14.4 (6.8)	39.6 (14.6)	0.7 (0.6)	1.7 (0.9)	4.7 (2.3)	13.4 (4.6)	0.5 (0.3)	9.7 (4.2)	3.8 (2.3)	Landscape
Upland forested 500	23.4 (5.1)	14.9 (2.4)	48.3 (8.1)	2.5 (1.4)	9.0 (3.4)	11.3 (3.3)	22.6 (4.0)	3.8 (1.5)	19.4 (3.2)	13.0 (3.5)	Landscape
Upland open 1000	6.4 (1.3)	5.5 (1.8)	3.4 (1.1)	0.9 (0.3)	3.5 (1.1)	3.3 (0.7)	6.8 (1.5)	2.3 (1.0)	4.2 (0.9)	6.5 (0.4)	Landscape
Upland open 200	2.7 (1.5)	1.3 (1.0)	2.6 (1.6)	0.7 (0.7)	0.3 (0.3)	0.3 (0.3)	3.2 (1.7)	1.8 (1.3)	1.6 (1.0)	2.4 (1.1)	Landscape
Upland open 500	4.6 (1.3)	4.7 (2.9)	4.1 (1.5)	0.8 (0.4)	1.3 (0.5)	3.2 (1.3)	6.4 (1.6)	3.5 (2.0)	3.3 (1.0)	6.5 (2.7)	Landscape
White cedar 1000	29.8 (4.0)	13.7 (4.8)	19.6 (5.9)	2.5 (0.7)	7.9 (2.7)	14.0 (3.0)	11.1 (3.7)	7.7 (2.2)	17.8 (3.1)	7.4 (4.4)	Landscape
White cedar 200	59.7 (7.5)	7.1 (2.9)	48.7 (16.3)	2.1 (1.4)	11.0 (5.3)	18.3 (6.3)	11.8 (5.1)	2.3 (1.2)	29.5 (6.4)	1.9 (1.9)	Landscape
White cedar 500	43.5 (5.7)	11.8 (3.8)	31.6 (8.3)	2.3 (0.8)	10.4 (4.0)	13.6 (3.6)	12.8 (4.2)	5.2 (1.6)	22.5 (3.9)	3.5 (1.8)	Landscape

Appendix B. Ranges for all vegetation variables summarized for original survey points in clusters identified within lowland conifer forests of the Agassiz Lowland Subsection (ALS), MN. Number of points (n) per cover type is listed in parenthesis. Cover type variables were estimated at each bird census point for each of the ten forest cover types defined from the hierarchical cluster analysis in the ALS. Variable spatial scales were site, stand and landscape levels. Landscape variable spatial scales are listed in the variable description in the far left column (e.g., 200, 500, 1000 m radii). Landscape data and select site level data (cover) are summarized as percent while other variables are summarized by stem densities (number of stems/314m^2), DBH (cm) and height (meters). Site level data was visually estimated by observers at each census point. Site level data summarized for combined data variables (e.g., black spruce-tamarack DBH) was weighted according to proportion of cover within 100 meter limited distance sample point. Stand level data was summarized from Minnesota Department of Natural Resources – Forestry Inventory Management database (MNDNR-FIM). Landscape data was summarized using Upper Midwest Gap Analysis Program (GAP) and data from MNDNR – data deli. The numbers of points summarized for each forest cover type are listed in parenthesis.

Variables	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer (landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Variable type
All conifers % cover	(79-100)	(74-100)	(25-100)	(100-100)	(100-100)	(73-100)	(69-100)	(100-100)	(82-100)	(50-100)	Site
All conifers DBH	(13-25)	(5-33)	(13-36)	(5-10)	(8-18)	(5-20)	(8-20)	(13-23)	(8-25)	(5-25)	Site
All conifers height	(8-15)	(4-16)	(8-15)	(4-9)	(6-14)	(5-15)	(5-15)	(11-15)	(4-16)	(3-13)	Site
Balsam fir % cover	(0-25)	(0-26)	(0-18)	(0-0)	(0-25)	(0-25)	(0-23)	(0-0)	(0-40)	(0-0)	Site
Balsam fir DBH	(3-20)	(5-20)	(13-28)	(0-0)	(8-8)	(8-10)	(10-15)	(0-0)	(8-18)	(0-0)	Site
Balsam fir height	(3-15)	(3-16)	(8-16)	(0-0)	(6-6)	(4-7)	(6-13)	(0-0)	(5-14)	(0-0)	Site
Black spruce % cover	(0-50)	(0-53)	(0-9)	(44-100)	(23-100)	(0-92)	(0-100)	(13-100)	(0-100)	(0-50)	Site
Black spruce DBH	(8-25)	(8-20)	(15-15)	(5-10)	(8-18)	(5-20)	(8-20)	(13-23)	(5-23)	(3-8)	Site
Black spruce height	(7-21)	(6-14)	(9-14)	(3-10)	(5-14)	(4-15)	(6-15)	(11-15)	(4-19)	(2-8)	Site
Black spruce-tamarack % cover	(9-70)	(18-100)	(0-10)	(100-100)	(55-100)	(4-100)	(8-100)	(74-100)	(17-100)	(50-100)	Site

Variables	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer (landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Variable type
Black spruce-tamarack DBH	(8-25)	(5-23)	(15-15)	(5-10)	(8-18)	(5-20)	(8-23)	(13-23)	(5-23)	(5-25)	Site
Black spruce-tamarack height	(6-21)	(4-16)	(9-14)	(4-9)	(6-14)	(4-15)	(5-15)	(11-17)	(4-19)	(3-13)	Site
Black spruce-white cedar-balsam fir % cover	(33-100)	(0-61)	(25-100)	(44-100)	(23-100)	(0-92)	(0-100)	(39-100)	(0-100)	(0-50)	Site
Black spruce-white cedar-balsam fir DBH	(10-25)	(5-38)	(13-36)	(5-10)	(8-18)	(5-20)	(8-18)	(13-23)	(8-25)	(3-8)	Site
Black spruce-white cedar-balsam fir height	(8-15)	(3-16)	(8-15)	(3-10)	(5-14)	(5-15)	(6-15)	(10-15)	(4-16)	(2-8)	Site
Canopy Height (m)	(9-17)	(5-16)	(13-22)	(5-14)	(8-18)	(6-18)	(7-17)	(7-22)	(7-22)	(2-11)	Site
Deciduous % cover	(0-21)	(0-26)	(0-75)	(0-0)	(0-0)	(0-27)	(0-31)	(0-0)	(0-18)	(0-50)	Site
Deciduous DBH	(8-20)	(5-18)	(15-23)	(0-0)	(0-0)	(8-20)	(10-20)	(0-0)	(8-18)	(10-20)	Site
Deciduous height	(7-14)	(4-16)	(11-16)	(0-0)	(0-0)	(4-13)	(9-13)	(0-0)	(6-12)	(8-11)	Site
Ground cover	(17-90)	(30-100)	(10-30)	(80-100)	(80-100)	(30-100)	(10-100)	(70-100)	(30-100)	(50-90)	Site
High canopy cover %	(5-80)	(10-80)	(70-90)	(10-50)	(10-70)	(10-70)	(20-80)	(20-70)	(20-80)	(0-80)	Site

Variables	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer (landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Variable type
High canopy cover % deciduous	(0-30)	(0-50)	(0-90)	(0-0)	(0-0)	(0-40)	(0-50)	(0-0)	(0-20)	(0-20)	Site
Lowland conifer % cover	(64-100)	(48-100)	(9-100)	(100-100)	(75-100)	(53-100)	(57-100)	(100-100)	(60-100)	(50-100)	Site
Lowland conifer DBH	(13-28)	(5-38)	(13-38)	(5-10)	(8-18)	(5-20)	(8-20)	(13-23)	(8-28)	(5-25)	Site
Lowland conifer height	(8-15)	(4-16)	(7-15)	(4-9)	(6-14)	(5-15)	(5-15)	(11-15)	(4-16)	(3-13)	Site
Shrub % cover	(0-2)	(0-50)	(0-0)	(0-0)	(0-16)	(0-10)	(0-0)	(0-0)	(0-13)	(0-55)	Site
Subcanopy % deciduous	(0-60)	(0-50)	(0-90)	(0-0)	(0-30)	(0-50)	(0-50)	(0-0)	(0-50)	(0-0)	Site
Subcanopy cover	(0-80)	(0-40)	(0-50)	(0-70)	(0-30)	(0-60)	(0-60)	(10-50)	(0-70)	(0-0)	Site
Tamarack % cover	(0-67)	(0-100)	(0-5)	(0-56)	(0-77)	(0-100)	(0-100)	(0-61)	(0-100)	(0-100)	Site
Tamarack DBH	(13-23)	(5-23)	(15-15)	(5-10)	(10-18)	(10-25)	(8-28)	(13-20)	(8-20)	(5-25)	Site
Tamarack height	(6-15)	(4-16)	(9-9)	(4-9)	(6-13)	(7-15)	(5-15)	(10-17)	(4-18)	(3-13)	Site
Tree density	(30-74)	(4-41)	(30-52)	(24-120)	(2-50)	(9-88)	(33-84)	(36-74)	(24-67)	(2-46)	Site
Tree species richness	(2-5)	(1-5)	(1-4)	(1-2)	(1-4)	(1-5)	(1-6)	(1-3)	(1-5)	(1-3)	Site
Understory % deciduous	(0-80)	(0-90)	(10-80)	(0-10)	(0-90)	(0-100)	(0-80)	(0-60)	(0-60)	(90-100)	Site
Understory cover	(10-80)	(10-80)	(10-50)	(10-80)	(20-50)	(10-70)	(10-80)	(10-50)	(0-80)	(10-90)	Site
White cedar % cover	(29-75)	(0-43)	(9-100)	(0-0)	(0-20)	(0-81)	(0-62)	(0-26)	(0-57)	(0-0)	Site

Variables	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer (landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Variable type
White cedar DBH	(10-30)	(15-61)	(13-38)	(0-0)	(10-15)	(8-23)	(10-20)	(13-13)	(10-30)	(0-0)	Site
White cedar height	(8-14)	(4-16)	(7-15)	(0-0)	(4-9)	(4-13)	(7-13)	(8-8)	(5-15)	(0-0)	Site
White cedar-balsam fir % cover	(30-84)	(0-48)	(25-100)	(0-0)	(0-45)	(0-87)	(0-72)	(0-26)	(0-78)	(0-0)	Site
White cedar-balsam fir DBH	(10-28)	(5-38)	(13-36)	(0-0)	(10-10)	(8-20)	(10-20)	(13-13)	(10-25)	(0-0)	Site
White cedar-balsam fir height	(7-14)	(3-16)	(8-15)	(0-0)	(4-7)	(4-13)	(7-13)	(8-8)	(5-15)	(0-0)	Site
Age 2014	(66-179)	(15-135)	(133-135)	(24-159)	(53-163)	(41-133)	(42-195)	(97-159)	(42-195)	(8-27)	Stand
Basal area (m^2/ha)	(0-64)	(0-25)	(15-37)	(0-26)	(13-26)	(1-31)	(9-40)	(2-37)	(0-54)	(0-2)	Stand
DBH (cm)	(0-41)	(0-25)	(0-48)	(0-13)	(5-20)	(0-25)	(0-30)	(13-18)	(0-30)	(0-5)	Stand
Site index	(16-49)	(31-65)	(27-38)	(14-35)	(18-45)	(14-65)	(16-58)	(21-39)	(18-42)	(33-65)	Stand
Site index-age	(1980-5265)	(555-5936)	(359-5131)	(770-3339)	(954-4128)	(770-5936)	(1554-6825)	(3339-5168)	(954-6825)	(264-972)	Stand
Black spruce 1000	(1-26)	(3-25)	(4-7)	(8-66)	(6-75)	(0-32)	(0-58)	(28-82)	(0-55)	(0-21)	Landscape
Black spruce 200	(0-39)	(0-30)	(0-8)	(1-91)	(11-99)	(0-46)	(0-95)	(84-100)	(0-95)	(0-9)	Landscape
Black spruce 500	(0-21)	(0-28)	(0-5)	(6-76)	(7-94)	(0-40)	(0-64)	(51-95)	(0-66)	(0-19)	Landscape
Black spruce-tamarack 1000	(5-39)	(9-64)	(9-12)	(16-69)	(16-81)	(10-69)	(7-65)	(36-86)	(4-61)	(5-32)	Landscape

Variables	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer (landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Variable type
Black spruce-tamarack 200	(0-60)	(12-82)	(0-13)	(1-91)	(30-99)	(19-100)	(10-100)	(84-100)	(0-99)	(0-36)	Landscape
Black spruce-tamarack 500	(0-36)	(10-65)	(2-12)	(11-77)	(20-94)	(13-71)	(6-86)	(52-96)	(0-71)	(0-35)	Landscape
Black spruce-white cedar 1000	(3-75)	(3-39)	(13-42)	(8-69)	(10-78)	(6-51)	(1-67)	(36-88)	(2-86)	(0-29)	Landscape
Black spruce-white cedar 200	(0-100)	(0-41)	(9-88)	(1-100)	(11-100)	(0-72)	(0-95)	(87-100)	(0-100)	(0-20)	Landscape
Black spruce-white cedar 500	(0-96)	(5-36)	(15-60)	(11-81)	(12-100)	(1-54)	(0-71)	(62-95)	(0-97)	(0-24)	Landscape
ELB infestation 1000	(0-62)	(4-79)	(0-30)	(0-0)	(0-93)	(0-96)	(0-49)	(0-17)	(0-62)	(0-42)	Landscape
ELB infestation 200	(0-100)	(0-100)	(0-29)	(0-0)	(0-100)	(0-100)	(0-80)	(0-42)	(0-100)	(0-100)	Landscape
ELB infestation 500	(0-92)	(0-98)	(0-32)	(0-0)	(0-100)	(0-100)	(0-60)	(0-31)	(0-92)	(0-79)	Landscape
Forested 1000	(58-88)	(43-79)	(58-86)	(43-84)	(66-90)	(46-82)	(48-88)	(53-93)	(52-92)	(19-58)	Landscape
Forested 200	(79-100)	(16-100)	(86-100)	(8-100)	(84-100)	(31-100)	(35-100)	(91-100)	(21-100)	(0-38)	Landscape
Forested 500	(62-100)	(34-84)	(72-93)	(38-98)	(73-100)	(35-91)	(58-94)	(73-97)	(45-100)	(3-64)	Landscape
Lowland conifer 1000	(12-79)	(29-66)	(18-47)	(16-72)	(32-84)	(24-70)	(8-74)	(51-91)	(9-90)	(6-35)	Landscape
Lowland conifer 200	(3-100)	(13-83)	(11-89)	(1-100)	(30-100)	(31-100)	(15-100)	(87-100)	(0-100)	(0-36)	Landscape
Lowland conifer 500	(7-98)	(22-67)	(17-66)	(16-81)	(35-100)	(20-74)	(10-86)	(63-96)	(3-98)	(0-40)	Landscape

Variables	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer (landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Variable type
Lowland deciduous 1000	(0-3)	(0-3)	(0-1)	(0-0)	(0-2)	(0-3)	(0-3)	(0-1)	(0-3)	(0-0)	Landscape
Lowland deciduous 200	(0-5)	(0-0)	(0-9)	(0-0)	(0-0)	(0-0)	(0-15)	(0-0)	(0-5)	(0-0)	Landscape
Lowland deciduous 500	(0-5)	(0-3)	(0-4)	(0-0)	(0-1)	(0-3)	(0-4)	(0-1)	(0-3)	(0-1)	Landscape
Lowland shrub 1000	(2-21)	(1-27)	(1-18)	(7-54)	(0-17)	(1-28)	(2-31)	(3-24)	(0-34)	(10-29)	Landscape
Lowland shrub 200	(0-20)	(0-81)	(0-17)	(0-83)	(0-0)	(0-46)	(0-38)	(0-14)	(0-79)	(0-91)	Landscape
Lowland shrub 500	(0-18)	(2-52)	(1-11)	(1-50)	(0-11)	(1-53)	(3-24)	(2-23)	(0-50)	(1-52)	Landscape
Non-forested 1000	(9-40)	(18-54)	(11-40)	(14-55)	(7-32)	(16-52)	(9-49)	(5-44)	(5-46)	(40-78)	Landscape
Non-forested 200	(0-26)	(0-85)	(0-19)	(0-93)	(0-21)	(0-70)	(0-67)	(0-15)	(0-81)	(66-100)	Landscape
Non-forested 500	(0-38)	(16-66)	(7-28)	(2-62)	(0-27)	(9-65)	(6-42)	(3-27)	(0-55)	(36-97)	Landscape
Number of patches 1000	(57-149)	(74-160)	(65-101)	(34-86)	(32-134)	(53-163)	(44-145)	(19-93)	(43-122)	(85-108)	Landscape
Number of patches 200	(1-11)	(4-11)	(4-8)	(3-6)	(1-10)	(1-11)	(2-11)	(1-4)	(2-10)	(3-9)	Landscape
Number of patches 500	(11-38)	(26-59)	(17-34)	(11-29)	(3-43)	(18-48)	(18-42)	(6-26)	(9-43)	(26-41)	Landscape
Open 1000	(0-13)	(0-37)	(2-17)	(0-7)	(0-19)	(0-37)	(0-16)	(0-23)	(0-16)	(7-46)	Landscape
Open 200	(0-4)	(0-49)	(0-1)	(0-6)	(0-21)	(0-37)	(0-38)	(0-1)	(0-17)	(1-78)	Landscape

Variables	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer (landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Variable type
Open 500	(0-16)	(0-34)	(0-9)	(0-4)	(0-22)	(0-39)	(0-24)	(0-15)	(0-15)	(5-56)	Landscape
Open water 1000	(3-22)	(2-37)	(2-18)	(9-54)	(0-19)	(1-34)	(2-38)	(4-26)	(0-36)	(11-47)	Landscape
Open water 200	(0-20)	(0-81)	(0-18)	(0-83)	(0-4)	(0-70)	(0-38)	(0-14)	(0-81)	(0-95)	Landscape
Open water 500	(0-30)	(2-65)	(1-12)	(2-58)	(0-17)	(1-64)	(4-27)	(3-27)	(0-53)	(2-73)	Landscape
Patch richness 1000	(9-17)	(9-14)	(14-17)	(7-15)	(9-17)	(8-17)	(8-17)	(8-14)	(9-18)	(12-19)	Landscape
Patch richness 200	(1-6)	(3-5)	(4-6)	(2-5)	(1-6)	(1-7)	(2-8)	(1-4)	(2-7)	(3-5)	Landscape
Patch richness 500	(5-12)	(8-11)	(10-12)	(5-10)	(3-15)	(7-11)	(6-12)	(4-10)	(6-13)	(6-12)	Landscape
Sedge meadow 1000	(0-6)	(1-10)	(1-3)	(0-5)	(0-3)	(0-6)	(0-11)	(0-5)	(0-6)	(1-20)	Landscape
Sedge meadow 200	(0-7)	(0-2)	(0-5)	(0-7)	(0-4)	(0-24)	(0-3)	(0-3)	(0-7)	(0-16)	Landscape
Sedge meadow 500	(0-13)	(0-13)	(0-1)	(0-8)	(0-6)	(0-11)	(0-5)	(0-4)	(0-8)	(0-24)	Landscape
Stagnant black spruce 1000	(0-1)	(0-0)	(0-3)	(7-25)	(0-7)	(0-17)	(0-4)	(0-10)	(0-24)	(0-0)	Landscape
Stagnant black spruce 200	(0-1)	(0-0)	(0-0)	(0-66)	(0-11)	(0-40)	(0-47)	(0-1)	(0-21)	(0-0)	Landscape
Stagnant black spruce 500	(0-1)	(0-0)	(0-2)	(14-33)	(0-9)	(0-19)	(0-8)	(0-14)	(0-35)	(0-1)	Landscape
Stagnant black spruce-tamarack 1000	(0-22)	(0-9)	(0-3)	(7-28)	(0-41)	(0-20)	(0-12)	(0-10)	(0-25)	(0-7)	Landscape

Variables	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer (landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Variable type
Stagnant black spruce-tamarack 200	(0-1)	(0-3)	(0-0)	(0-66)	(0-68)	(0-40)	(0-47)	(0-1)	(0-89)	(0-0)	Landscape
Stagnant black spruce-tamarack 500	(0-13)	(0-6)	(0-2)	(14-33)	(0-45)	(0-24)	(0-32)	(0-14)	(0-37)	(0-1)	Landscape
Stagnant conifer 1000	(0-22)	(0-9)	(0-3)	(7-28)	(0-41)	(0-20)	(0-12)	(0-10)	(0-25)	(0-7)	Landscape
Stagnant conifer 200	(0-1)	(0-3)	(0-0)	(0-66)	(0-68)	(0-40)	(0-47)	(0-1)	(0-89)	(0-0)	Landscape
Stagnant conifer 500	(0-13)	(0-6)	(0-2)	(14-33)	(0-45)	(0-24)	(0-32)	(0-14)	(0-37)	(0-1)	Landscape
Stagnant tamarack 1000	(0-22)	(0-9)	(0-0)	(0-5)	(0-41)	(0-19)	(0-12)	(0-2)	(0-14)	(0-7)	Landscape
Stagnant tamarack 200	(0-1)	(0-3)	(0-0)	(0-0)	(0-68)	(0-34)	(0-38)	(0-0)	(0-89)	(0-0)	Landscape
Stagnant tamarack 500	(0-13)	(0-6)	(0-0)	(0-4)	(0-45)	(0-24)	(0-32)	(0-0)	(0-36)	(0-0)	Landscape
Tamarack 1000	(0-27)	(5-44)	(4-5)	(1-9)	(4-31)	(3-49)	(0-29)	(3-14)	(2-26)	(3-11)	Landscape
Tamarack 200	(0-44)	(11-82)	(0-13)	(0-0)	(0-70)	(0-100)	(0-47)	(0-0)	(0-52)	(0-36)	Landscape
Tamarack 500	(0-28)	(4-57)	(2-8)	(0-10)	(0-48)	(2-69)	(0-35)	(0-9)	(0-33)	(0-17)	Landscape
Upland conifer 1000	(0-46)	(0-9)	(0-29)	(0-0)	(0-31)	(0-25)	(0-16)	(0-0)	(0-45)	(0-7)	Landscape
Upland conifer 200	(0-93)	(0-3)	(0-15)	(0-0)	(0-5)	(0-11)	(0-1)	(0-0)	(0-94)	(0-0)	Landscape
Upland conifer 500	(0-71)	(0-5)	(0-21)	(0-0)	(0-28)	(0-23)	(0-10)	(0-0)	(0-57)	(0-0)	Landscape

Variables	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer (landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Variable type
Upland deciduous 1000	(1-40)	(6-36)	(15-53)	(0-12)	(0-29)	(0-33)	(2-43)	(0-21)	(1-35)	(3-22)	Landscape
Upland deciduous 200	(0-31)	(0-57)	(4-65)	(0-6)	(0-8)	(0-18)	(0-58)	(0-3)	(0-21)	(0-14)	Landscape
Upland deciduous 500	(1-45)	(5-24)	(17-63)	(0-10)	(0-23)	(0-31)	(1-55)	(0-15)	(0-30)	(3-24)	Landscape
Upland forested 1000	(1-60)	(8-44)	(39-57)	(0-12)	(0-38)	(0-48)	(2-48)	(0-21)	(1-57)	(4-23)	Landscape
Upland forested 200	(0-93)	(0-60)	(4-73)	(0-6)	(0-8)	(0-30)	(0-58)	(0-3)	(0-98)	(0-14)	Landscape
Upland forested 500	(1-80)	(6-28)	(26-72)	(0-10)	(0-31)	(0-39)	(1-57)	(0-16)	(1-71)	(3-25)	Landscape
Upland open 1000	(1-21)	(0-14)	(1-6)	(0-2)	(0-13)	(1-7)	(0-25)	(0-10)	(0-18)	(5-8)	Landscape
Upland open 200	(0-23)	(0-8)	(0-7)	(0-7)	(0-3)	(0-4)	(0-28)	(0-11)	(0-22)	(0-5)	Landscape
Upland open 500	(0-15)	(0-27)	(0-8)	(0-3)	(0-5)	(0-16)	(0-25)	(0-22)	(0-20)	(1-19)	Landscape
White cedar 1000	(2-54)	(0-36)	(9-36)	(0-5)	(0-30)	(1-43)	(0-57)	(1-24)	(0-47)	(0-27)	Landscape
White cedar 200	(0-100)	(0-21)	(9-82)	(0-11)	(0-56)	(0-67)	(0-85)	(0-12)	(0-91)	(0-11)	Landscape
White cedar 500	(0-82)	(0-29)	(15-55)	(0-5)	(0-45)	(0-48)	(0-63)	(0-14)	(0-54)	(0-10)	Landscape

Appendix C. Bird abundances calculated as mean detections per limited distance point count and standard error (in parenthesis) for each of the ten forest cover types within the Agassiz Lowland Subsection (ALS), Minnesota from the hierarchical cluster analysis. Abundances were summarized using only territorial behaviors (e.g., singing, calling). Sites were sampled three times in 2013 and twice in 2014. One sample each year was conducted in spring (May), while the other samples were conducted in summer (June/July). Abundances were calculated according to migration strategy. For example, short-distance migrants such as the Yellow-rumped Warbler had all 5 sampling rounds included in the analysis. Long-distance migrants such as the Connecticut Warbler were limited to the three summer sampling rounds. The numbers of points sampled for each forest cover type from the cluster analysis are listed in parenthesis.

Common and Scientific Name	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer (landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)
Ruffed Grouse (*Bonasa umbellus*)	0.0 (0.0)	0.2 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Wilson's Snipe (*Gallinago delicata*)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.0)
Mourning Dove (*Zenaida macroura*)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	0.0 (0.0)	0.0 (0.0)	0.2 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Hairy Woodpecker (*Picoides villosus*)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Northern Flicker (*Colaptes auratus*)	0.0 (0.0)	0.0 (0.0)	0.2 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)
Olive-sided Flycatcher (*Contopus cooperi*)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)
Yellow-bellied Flycatcher (*Empidonax flaviventris*)	0.7 (0.1)	0.2 (0.0)	0.1 (0.0)	0.6 (0.1)	0.7 (0.1)	0.4 (0.0)	0.1 (0.0)	0.2 (0.0)	0.8 (0.0)	0.1 (0.0)
Alder Flycatcher (*Empidonax alnorum*)	0.0 (0.0)	0.4 (0.1)	0.1 (0.0)	0.2 (0.0)	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.7 (0.1)
Great Crested Flycatcher (*Myiarchus crinitus*)	0.1 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)
Blue-headed Vireo (*Vireo solitarius*)	0.1 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.2 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0.2 (0.0)	0.0 (0.0)

Common and Scientific Name	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer (landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)
Red-eyed Vireo (*Vireo olivaceus*)	0.2 (0.0)	0.4 (0.1)	0.6 (0.1)	0.0 (0.0)	0.0 (0.0)	0.4 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.1)
Gray Jay (*Perisoreus canadensis*)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)	0.2 (0.0)	0.1 (0.0)	0.0 (0.0)
Blue Jay (*Cyanocitta cristata*)	0.2 (0.0)	0.1 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.0)	0.4 (0.0)	0.1 (0.0)	0.2 (0.0)	0.0 (0.0)
Black-capped Chickadee (*Poecile atricapillus*)	0.1 (0.0)	0.1 (0.0)	0.2 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0.0 (0.0)
Boreal Chickadee (*Poecile hudsonicus*)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.0)	0.0 (0.0)	0.0 (0.0)
Red-breasted Nuthatch (*Sitta canadensis*)	0.2 (0.0)	0.2 (0.0)	0.3 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0.2 (0.0)	0.1 (0.0)	0.1 (0.0)	0.0 (0.0)
Brown Creeper (*Certhia americana*)	0.2 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0.0 (0.0)
Winter Wren (*Troglodytes hiemalis*)	0.3 (0.0)	0.3 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.4 (0.0)	0.3 (0.0)	0.1 (0.0)	0.2 (0.0)	0.0 (0.0)
Sedge Wren (*Cistothorus platensis*)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.9 (0.2)
Golden-crowned Kinglet (*Regulus satrapa*)	0.2 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.0)	0.0 (0.0)	0.3 (0.0)	0.4 (0.0)	0.3 (0.0)	0.0 (0.0)
Ruby-crowned Kinglet (*Regulus calendula*)	0.2 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.0)	0.3 (0.0)	0.1 (0.0)	0.2 (0.0)	0.1 (0.0)	0.3 (0.0)	0.0 (0.0)
Veery (*Catharus fuscescens*)	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.1)
Swainson's Thrush (*Catharus ustulatus*)	0.2 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)

Common and Scientific Name	Mixed lowland white cedar (17)	Eastern larch beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer (landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)
Hermit Thrush (*Catharus guttatus*)	0.2 (0.0)	0.0 (0.0)	0.1 (0.1)	0.1 (0.0)	0.3 (0.0)	0.1 (0.0)	0.2 (0.0)	0.1 (0.0)	0.1 (0.0)	0.0 (0.0)
American Robin (*Turdus migratorius*)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)
Cedar Waxwing (*Bombycilla cedrorum*)	0.1 (0.0)	0.2 (0.1)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Ovenbird (*Seiurus aurocapilla*)	0.3 (0.0)	0.2 (0.1)	0.8 (0.1)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.3 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Northern Waterthrush (*Parkesia noveboracensis*)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.3 (0.1)
Black-and-white Warbler (*Mniotilta varia*)	0.4 (0.0)	0.6 (0.1)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0.4 (0.0)	0.2 (0.0)	0.0 (0.0)	0.1 (0.0)	0.3 (0.1)
Nashville Warbler (*Oreothlypis ruficapilla*)	1.5 (0.1)	1.7 (0.1)	1.0 (0.1)	2.1 (0.1)	1.6 (0.1)	1.9 (0.1)	1.8 (0.1)	0.9 (0.1)	2.0 (0.1)	1.0 (0.2)
Connecticut Warbler (*Oporornis agilis*)	0.0 (0.0)	0.3 (0.1)	0.0 (0.0)	0.4 (0.1)	1.3 (0.1)	0.1 (0.0)	0.1 (0.0)	0.3 (0.1)	0.1 (0.0)	0.0 (0.0)
Mourning Warbler (*Geothlypis philadelphia*)	0.0 (0.0)	0.3 (0.1)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Common Yellowthroat (*Geothlypis trichas*)	0.0 (0.0)	1.1 (0.1)	0.0 (0.0)	0.2 (0.0)	0.1 (0.0)	0.0 (0.0)	0.2 (0.0)	0.0 (0.0)	0.0 (0.0)	1.3 (0.1)
Northern Parula (*Setophaga americana*)	0.1 (0.0)	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)
Magnolia Warbler (*Setophaga magnolia*)	0.1 (0.0)	0.1 (0.0)	0.0 (0.0)	0.2 (0.1)	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Blackburnian Warbler (*Setophaga fusca*)	0.2 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)

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Chestnut-sided Warbler (*Setophaga pensylvanica*)	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.1)
Palm Warbler (*Setophaga palmarum*)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.3 (0.0)	0.2 (0.1)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)
Yellow-rumped Warbler (*Setophaga coronata*)	0.5 (0.0)	0.4 (0.0)	0.1 (0.0)	0.5 (0.0)	1.0 (0.1)	0.5 (0.0)	0.6 (0.0)	0.7 (0.0)	0.9 (0.0)	0.1 (0.0)
Black-throated Green Warbler (*Setophaga virens*)	0.7 (0.1)	0.1 (0.0)	1.5 (0.1)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.2 (0.0)	0.0 (0.0)	0.2 (0.0)	0.0 (0.0)
Chipping Sparrow (*Spizella passerina*)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.1)	0.4 (0.1)	0.0 (0.0)	0.2 (0.0)	0.3 (0.1)	0.1 (0.0)	0.1 (0.0)
Lincoln's Sparrow (*Melospiza lincolnii*)	0.0 (0.0)	0.3 (0.1)	0.0 (0.0)	0.2 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.1)
Swamp Sparrow (*Melospiza georgiana*)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.6 (0.1)
White-throated Sparrow (*Zonotrichia albicollis*)	0.2 (0.0)	1.2 (0.1)	0.0 (0.0)	0.4 (0.1)	0.7 (0.1)	1.1 (0.0)	0.4 (0.0)	0.1 (0.0)	0.3 (0.0)	0.6 (0.1)
Dark-eyed Junco (*Junco hyemalis*)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.0)	0.2 (0.0)	0.0 (0.0)	0.1 (0.0)	0.6 (0.0)	0.1 (0.0)	0.2 (0.1)
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)
Purple Finch (*Haemorhous purpureus*)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0.0 (0.0)