Development of Habitat Models and Habitat Maps for Breeding Bird Species In the Agassiz Lowlands Subsection, Minnesota, USA

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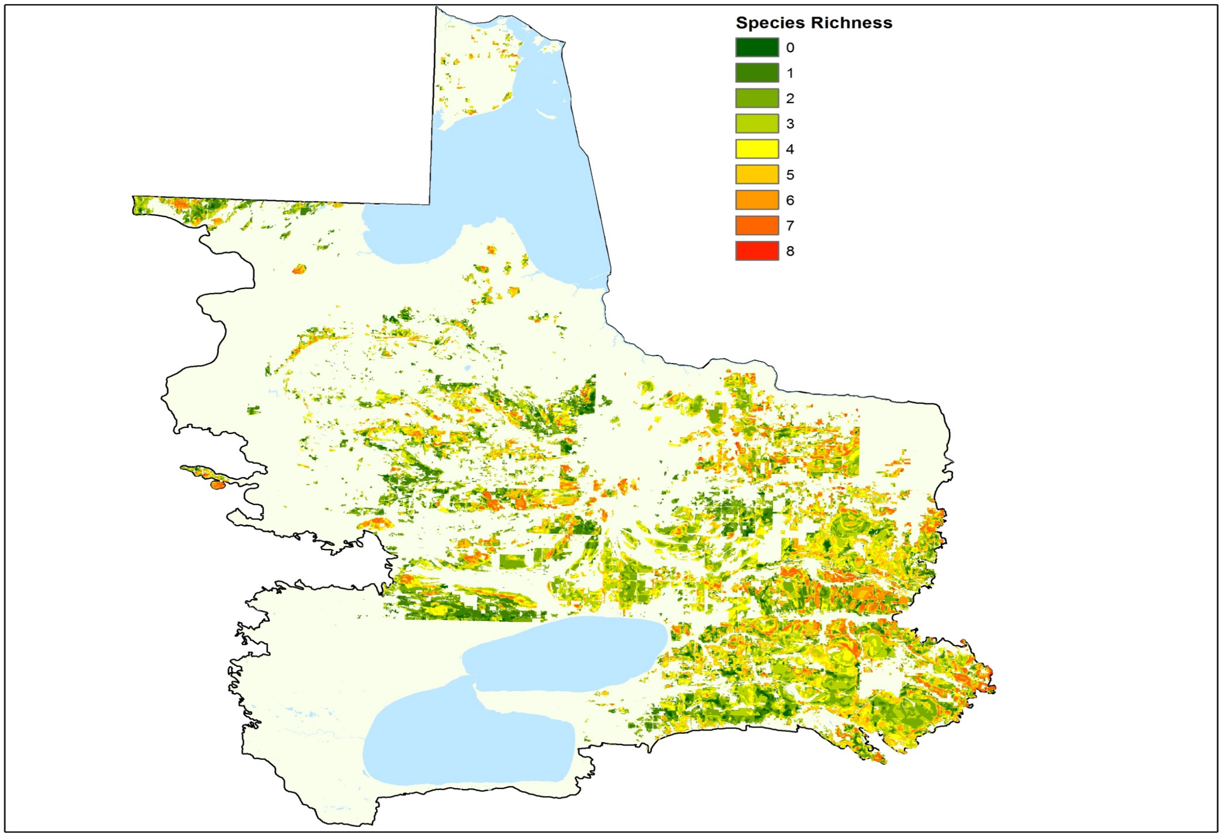

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Executive Summary

We report results of a two-year effort in 2013 and 2014 to sample breeding bird species in the extensive lowland coniferous forests in the Agassiz Lowland Ecological Subsection (ALS) of northwestern Minnesota. The effort is a part of the Minnesota Department of Natural Resources (MNDNR) forest planning process to identify forested areas of conservation concern to selected forest bird species potentially affected by logging activity. The general objectives were to: 1) identify lowland coniferous forest stands that encompassed a gradient of age classes, productivity as measured by site index, and forest patch sizes, 2) sample breeding bird populations within each of the selected stands in 2013 and 2014, 3) identify habitat and landscape characteristics associated with selected breeding bird species within these forest stand types, 4) develop habitat models for bird species of conservation concern and those potentially affected by logging activity, 5) apply the habitat models to state-owned land to map the potential distribution of individual species or combinations of species in the ALS, and 6) provide recommendations on forest management that could be beneficial for conservation of breeding birds within the ALS.

A total of 65 forest stands containing two points each were originally selected and sampled five times for breeding birds from May to early July in 2013 and 2014. A total of 109 bird species were counted in the ALS. We used the counts for the 48 most abundant bird species in each of the 130 points and a hierarchical cluster analysis to group the bird communities into 10 forest cover types. These 10 types capture the variation of the bird species assemblages found within the lowland conifer forests of the ALS. The 10 forest types were related to 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). We also used indicator species analysis to identify the affinity of the 48 bird species most representative of the 10 forest cover types.

Stand-level habitat and landscape data for all of the stands sampled were derived from a combination of field measurements, data gathered by the Minnesota Department of Natural Resources for forest stands, and land cover/landscape variables from remote sensing imagery. Vegetation characteristics associated with each of the 10 forest cover types were identified.

We modeled and mapped the habitat suitability for eight bird species that breed in the lowland conifer forests of the ALS using MaxEnt; a machine learning statistical tool that compares the presence of a bird species with a large number of random background locations to identify habitat and landscape characteristics potentially important for the species distribution and abundance. These species were *a priori* identified as among the species of conservation concern in the ALS: Yellow-bellied Flycatcher (*Empidonax flaviventris*), Boreal Chickadee (*Poecile hudsonicus*), Golden-crowned Kinglet (*Regulus satrapa*), Ruby-crowned Kinglet (*Regulus calendula*), Swainson's Thrush (*Catharus ustulatus*), Connecticut Warbler (*Oporornis agilis*), Palm Warbler (*Setophaga palmarum*) and Dark-eyed Junco (*Junco hyemalis*).

The indicator species analysis for the eight species of conservation concern and the focus of this study (focal species) had high affinities for the following forest cover types identified by the cluster analysis: Swainson's Thrush (*mixed lowland white cedar*); Palm Warbler (*stagnant black spruce-tamarack bogs*); Connecticut Warbler (*semi-productive black spruce-tamarack bogs)*; Golden-crowned Kinglet, Boreal Chickadee, and Dark-eyed Junco (*productive (mature) black spruce-tamarack bogs*); and Yellow-bellied Flycatcher and Ruby-crowned Kinglet (*mixed lowland conifers*). None of the focal species had high affinities for *Eastern Larch Beetle disturbance forests, northern white cedar, mixed tamarack swamp conifer, mixed lowland conifer-landscape,* or *recently harvested lowland conifers*.

Although the Yellow-bellied Flycatcher had a high affinity for *mixed lowland conifers* cover type, no individual or combinations of vegetation or landscape variables provided significant associations for this species in the modeling. The Yellow-bellied Flycatcher was ubiquitous across many lowland coniferous forests of the ALS. Habitat suitability maps were developed for individual species and all eight species combined. Subsequent testing of the individual species suitability models with an independent data set of 65 new points correctly predicted between 56 and 96% of the test data.

The overall results of these efforts are discussed and we present six overall recommendations for consideration in future planning and management of the ALS with respect to breeding birds. The report includes five figures, eight tables, six appendices, and a condensed file of all the raw data.

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Introduction

The Agassiz Lowlands Subsection (ALS), located in northwestern Minnesota, has been identified as encompassing key habitats for birds in the MN State Wildlife Action Plans (SWAP) because it includes breeding habitat for many Species of Greatest Conservation Need (SGCN) (MNDNR 2006). Forest planning in the subsection was initiated in 2013. As part of the planning process, needs were identified to understand how current forest management practices affect these SGCN and how forest management might maintain or improve lowland conifer habitats for these species.

Limited quantitative population data on birds and their habitats were available within the ALS. In the 1980's Hanowski and Niemi (1983), Niemi et al. (1983), Niemi and Hanowski (1984, 1992) and Wells and Warner (1984) gathered the most extensive data on birds in the Red Lake Peatland, an area that lies within the ALS. Hanowski and Niemi (1983) and Niemi and Hanowski (1984, 1992) were focused on examining the effects of a 500 kv transmission line through the peatland, while Niemi et al. (1983) and Wells and Warner (1984) focused on the potential to use peat such as for energy. Since the 1980's little avian research has been completed in the ALS; however, the Minnesota Breeding Bird Atlas (MNBBA) project gathered breeding bird data for most of the townships within the ALS (www.mnbba.org), and North et al. (2013a, b) summarized bird observations for the Beltrami State Forest and the Red Lake Wildlife Management areas of the ALS.

Bird communities within lowland coniferous forests of Canada have been studied by Erskine (1977), Calme and Desrochers (1996), Kirk et al. (1996), Welsh and Lougheed (1996), and Drapeau et al. (2000). In addition, there have been many studies on the effects of logging activity on breeding birds in Minnesota (e.g., Niemi and Hanowski 1984; Hanowski et al. 2003; Chizinski et al. 2011) and in Canada, including those within lowland coniferous forests (e.g., Imbeau et al. 1999, 2002; van Wilgenburg et al. 2008). Much of this information has recently been summarized by Niemi et al. (2016) for National Forests (NF's) in northern Minnesota and Wisconsin. At the individual species level, Lapin et al. (2013) gathered detailed data for the Connecticut Warbler a SGCN, though her data were from areas surrounding the ALS in the Chippewa and Superior NFs. These landscapes have a lower proportion of this species' preferred lowland conifer habitat.

Our objectives were to:

1. Identify 65 lowland coniferous forest-stands encompassing a gradient of age classes, site index, and forest patch sizes. These stands represent the variation in lowland coniferous forest types from young, recently harvested sites to old-growth stands.
2. Sample breeding bird populations within each of these stands in 2013 and 2014 from late spring to mid-summer.
3. Identify habitat and landscape characteristics associated with breeding bird species within these lowland coniferous forest types.
4. Develop habitat models for eight species of conservation concern and that are deemed most vulnerable to population decline with expected future forest conditions.

5. Construct maps that identify high priority habitats within the ALS that are potentially most important for breeding bird communities and for individual species classified as SGCN.
6. Provide recommendations for forest management in lowland conifer habitat that consider habitat associations of bird communities, specific habitat needs of forest bird species of conservation concern, and suggest possibilities for future monitoring needs.

Methods

Selection of survey stands.

We identified 65 forest stands (Figure 1) while considering the following: 1) MN state land, 2) stand age (0 to > 90 years), 3) site index, 4) minimum stand size of 20 acres (the minimum size to accommodate two replicate 100-m radius point counts), 5) spread across five forest districts to insure coverage across the ALS, and 6) within 500 m of a suitable access point. These stands provided a range of stand size conditions that naturally-occur within the ALS. The 65 forest stands were initially grouped into five categories of varying ages, species, site indices (productivity), and stand sizes. Age-classes selected were 0-30 years, 30-90 years, and greater than 90 years. Species of lowland conifers targeted were the predominant species within the ALS; black spruce (*Picea mariana*), tamarack (*Larix laricina)*, and white cedar (*Thuja occidentalis*). Site indices were chosen based on a preexisting classification scheme developed by the MNDNR and grouped into productive sites with an index greater 25 and unproductive sites less than 21. Stands with site indices less than 23, according to Minnesota's Department of Natural Resources - Forestry Division, are considered stagnant, while stands that are greater than 23 are considered productive. An emphasis was placed on distributing sites with a replication of 15 stands per group, except for regenerating stands, and sites in the older age categories. Previous sampling in recently logged areas within the ALS indicated low bird species richness in regenerating stands, primarily because of the sparse vegetation, so these stands were de-emphasized with lower replication.

Stands selected for sampling, were distributed across all five of the state forest districts within the ALS: Littlefork (24 stands), Deer River (3), Blackduck (8), Baudette (16) and Warroad (14) (Figure 1). Of the 65 stands, six stands contained Eastern Larch Beetle (ELB) (*Dendroctonus simplex*) infestations. ELB outbreaks have been massive, killing thousands of acres of trees each year in the region since 2000. Since then, ELB has killed approximately ~262,000 acres of tamarack or ~26% of the states one million acres of tamarack (Dana Carlson-MNDNR Forestry, *pers. comm*). At the time of stand selection during tamarack leaf-off, the extent of the presence of ELB was unknown.

In spring 2014, we selected an additional 65 new "test" stands (Figure 1). We used the same criteria as the original 65 stands. These were selected for three primary reasons: 1) gather additional breeding bird data, 2) provide additional data to test models developed from the original 65 stands, and 3) to insure representative coverage in new areas of the ALS that had not yet been previously sampled. The only difference between the characteristics of the new stands and the original stands were the range of site indices we sampled. We sampled across the entire range of site index values for lowland conifer species, including site index values 21-

25 that were omitted from the original stand selection. This was done to maintain a continuous gradient from stagnant habitat types to productive habitat types.

New stands selected for sampling were also distributed across the five state forest districts within the ALS. Stands selected were stratified among the following districts: Littlefork (27 stands), Deer River (11), Blackduck (9), Baudette (13) and Warroad (5). Of these 65 stands, six stands had ELB infestations. We did not sample areas immediately west and northwest of Upper and Lower Red Lakes (Figure 1) because they were either not on state owned land or were inaccessible.

Breeding Bird Sampling Design.

Each of the original stands was sampled a total of 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 June 2 to June 11, 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. For the original stands, we 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 we rotated observers so no point was sampled twice by the same observer. Within the second sampling periods of 2013 and 2014, we also randomized the sampling of forest stands so no stands were consistently sampled in early or late in the morning. For the third sampling period in 2013, we randomized the observer and the order the stands were sampled. One breeding bird survey was completed in each of the 65 test stands from 22 June to 8 July 2014.

We sampled each stand with two, ten-minute, unlimited distance point counts (Howe et al. 1998, Hanowski et al. 2005a, Etterson et al. 2009) during each survey period. We included estimates of distances from the sampling point, the minute interval when first detected, and behavior (e.g., singing, calling, fly-over, and any nesting activity observed). 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, and the presence of any precipitation as well as whether there was any noise present. 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).

We limited the bird detections to those within 100 m to insure the observations were within the forest stand of interest. Depending on migration strategy, we included a species in the summary for either three (June and July only) or all five sampling periods (May to July). For instance, for surveys in the original 65 stands and 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, *Zonotrichia albicollis*) we used all five surveys. We used three of our June to July counts for long-distance migrants when individuals of these species were on the breeding grounds within the ALS.

Forest Cover Types.

Forest Cover Type-Community Analyses. Initial attempts to relate breeding bird species and community metrics to the five predetermined habitat types based on FIM data were inconsistent and difficult to interpret due to the quality of variables used to categorize the sites.

Many traditional studies try to associate breeding bird species and community metrics to primary, predetermined habitat types. However, birds respond to different combinations of traditional habitat types, landscape features, (e.g., local clearcut), ground cover, local heterogeneity, and other site characteristics that are not adequately described by a single attribute such as dominant tree species or habitat type at the census point. Quantifying structural characteristics that species may respond to such as tree fall gaps in a forest is difficult and often overlooked.

An alternative approach to understanding patterns of species' ecological needs and habitat preferences is to evaluate community assemblages without initially linking the census sites to standard habitat categories. We applied a hierarchical cluster analysis (Sneath and Sokal 1973, McCune and Grace 2002) using mean log-transformed average bird species abundances from the 130 original sample points (65 forest stands) to identify relationships among points based on bird species community composition.

For the cluster analysis, we used individual points as opposed to stands (130 points vs 65 stands) because of the potential for natural variability within a stand. We only included those species that were counted at more than 7 sites (>5%) and had at least 10 observations. The cluster algorithm used Ward's method (hierarchical grouping) based on Euclidean distances (Wishart 1969) and was implemented in program R (R Core team 2012).

Bird habitat affinities.

To further test the strength of the breeding bird species within the defined clusters, we used DuFrene and Legendre's (1997) indicator species analysis to identify the most distinctive bird species for each cluster. The percent perfect indication (PPI) represents the degree of affinity to a category or cluster (hereafter a "cover type" when referring to vegetation characteristics) using a combination of abundance (e.g., total number of individuals per 10-minute point count) and frequency (e.g., number of sites a species was present within a cluster). PPI values theoretically range from 0-100, where 100 represents a situation where all individuals of a species were counted in just one cover type and the species was always present in samples of that cover type. PPI values and significance (p-value) were calculated in PCORD v6.08 (McCune and Mefford 2006). The p-value from the randomization test described by DuFrene and Legendre (1997) and McCune and Mefford (2006) represented 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. The cluster analysis represented an objective method to describe the bird communities in the ALS and the indicator species analysis was a means to describe the strength of the species relationship to a given cover type.

We also calculated community metrics such as species richness and species diversity; Shannon-Wiener and Simpson's indices. We calculated four different species richness metrics: 1) overall species richness for birds, 2) species richness for 20 lowland conifer associated species, 3) species richness for 10 lowland conifer focal species, and 4) species richness for all SGCN detected in our study (Table 1). We used generalized linear models (GLM's) with a Poisson error to model the differences in each species richness metric between cover types. From the GLM's, we obtained estimated species richness and standard errors for each cover type.

Habitat suitability modeling.

Environmental Covariates. Environmental covariates at different spatial scales were primarily derived from Minnesota's Forest-stand Inventory Monitoring database (FIM) and the Upper Midwest Gap Analysis Program (GAP) land cover database. FIM includes vector polygons of all state-owned forest lands with attributes related to forest structure and composition. 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 datasets used to derive predictor variables included MNDNR streams, rivers, and ditches (polyline) and MNDNR estimates of Eastern larch beetle induced tamarack mortality (polygon). All datasets were received through MNDNR personnel or downloaded via the MNDNR Data Deli (MNDNR 2012).

We developed two general categories of predictor variables: stand-level forest attributes and landscape variables (Table 2). Stand-level data were derived from forest stands where bird point-counts were conducted. These included nine continuous and categorical variables that characterized the stands and were potentially related with the selection of the stands by breeding birds (Tables 3, 4). Land cover and other landscape variables were derived at three spatial scales (200, 500, and 1000m) surrounding each count location. GAP level four land cover types were reclassified into eighteen land cover types of variable grain that were hypothesized to affect species breeding in lowland coniferous habitats (Tables 2, 4). A variety of metrics of landscape pattern used in previous modeling efforts were derived (Hawrot and Niemi 1996; Drolet et al. 1999; Crozier and Niemi 2003; Lapin et al. 2013), but were highly correlated and only patch richness and number of patches were retained for analysis. We processed environmental predictor variables in ArcGIS Version 10.2.2 (© esri.com), Geospatial Modelling Environment Version 0.7.3.0 (Beyer 2009-2012), and Fragstats Version 4 (McGarigal et al. 2012).

Modeling in MaxEnt. Correlations between species' presence locations and environmental predictor variables were modeled using the machine learning statistical tool, MaxEnt (Phillips et al. 2006; Elith et al. 2011). MaxEnt predicts a species' distributional pattern that is as close to uniform across the landscape as possible given the constraints environmental correlations impose on presence locations (Franklin 2009). For example, if no correlations exist between presence of a species and given environmental characteristics, then the model with 'maximum entropy' would be a uniform distribution.

MaxEnt compares environmental data at known presence locations to those of background environmental conditions, sampled from 10,000 random locations within the study area (Phillips 2005). A variety of transformations of raw predictor data are used to fit the model, including linear, quadratic, product, hinge, and threshold parameters (Elith et al. 2011). The model is then used to predict the distributional pattern of the species across the study area. Raw MaxEnt output is most readily defined as a relative rate of occurrence or relative habitat suitability (Merow and Silander 2014). However, given an *a priori* assumption of the species' prevalence within the study area, the raw output can be transformed to determine a probability of occurrence (*logistic output*; Phillips and Dudik 2008). Although criticized for this potentially arbitrary assumption (Royle et al. 2012), the logistic output can be useful if meaningful prevalence values are utilized (Merow et al. 2013). We primarily present raw

MaxEnt results, only making assumptions of prevalence to develop a standard occurrence scale for combining individual species models (see *Conservation mapping* below).

MaxEnt compares well with or outcompetes other modeling techniques (e.g., Elith et al. 2006, Phillips and Dudik 2008, Phillips et al. 2009) and has been shown to be similar to more conventional regression-based approaches used for modeling species environmental correlates (e.g., Renner and Warton 2013, Merow and Silander 2014), and can be applied to a variety of ecological questions depending on how models are calibrated and evaluated (Franklin 2009, Merow et al. 2013 *and references therein*). MaxEnt is increasingly being used in distributional analyses related to birds (e.g., Stralberg et al. 2009, Latif et al. 2014, Sohl 2014, Jackson et al. 2015, Maslo et al. 2015). We used MaxEnt to develop predictive models and maps of boreal bird distributions in the ALS for three specific reasons: 1) MaxEnt is robust to small sample sizes and has outperformed other methods when sample-sizes are small (Franklin 2009), 2) assumptions of absences are less relevant for several species such as the Boreal Chickadee, and 3) MaxEnt models are less sensitive to over-prediction than standard generalized linear model methods and have been shown to be more useful for prediction and extrapolation for conservation applications (Jackson et al. 2015).

Model parameterization. The transformations used by MaxEnt can create complex models (Merow et al. 2013); therefore, to maintain interpretability, we restricted analysis to only include linear and quadratic features of environmental predictor variables. In addition, any sampling biases were controlled by restricting the selection of random background environmental locations to areas within 500 m of bird sampling locations. This ensured that background locations were equally likely to contain any biases inherent in the sampling design, e.g., proximity to roadways. Five-fold cross-validation was used to validate model predictions. Five different partitions of 80% of the occurrence data were used to build submodels, while the remaining (and unique) partitions of 20% of occurrence were used to test each submodel. The predictions for these five test datasets were then averaged to create the overall model.

Data preparation and Variable reduction. First, bird observations were filtered by species, behavior, distance from observer, and sampling period. We included only observations of territorial male birds that were observed within 100 m and within the boundaries of the forest stand. Next, MaxEnt models run with each variable were evaluated using the area under the receiver operating curve (area under curve; AUC) as a test of the variables' capacity to separate species occurrence locations from random background locations (Phillips and Dudik 2008). All reported AUC values are averages of the test samples used in cross validation. Variables with AUC <0.55 (near random discrimination between background and presences) were removed from further analyses. The remaining subset of variables were tested for multicollinearity using ENMTools (Warren et al. 2008; Warren et al. 2010). If variables were highly correlated (r >0.68), the variable with higher AUC for the given species was retained for further analysis.

Model selection and evaluation. Starting with the reduced set of variables, we used backward elimination to develop a subset of potential models for each species (Parolo et al 2008; Bellamy et al. 2013). Depending on the species, between seven and 16 covariates were included in the preliminary model. After each model run, the variable that contributed the least to test AUC was removed until a single variable model remained. AICc values were calculated for each model using ENMTools. The model with the lowest value was selected as the 'best model' and used for interpretation and mapping. Significance was determined using a restricted-random model approach (Raes and ter Steege 2007, B. Wiestra *pers. comm.*). Random locations equivalent to the number of presence locations for a given species were selected and then modeled using the environmental predictor variables of the best model. The AUC from the data-driven model was compared with the distribution of AUC values determined by 999 iterations of random locations; if it fell within the top 5% of random AUC values, the model was deemed significant.

Model validation. Models were tested with the new stands sampled in 2014. Model predictions were assessed by first developing binary, suitable versus unsuitable, maps for each species using suitability scores for the top 90% of training data (lowest 10% of training data are considered unsuitable; Bellamy et al. 2013) and subsequently calculating the proportion of test samples that met or surpassed that threshold. Statistical significance was determined using chi-square tests.

Conservation mapping. We focused the modeling and mapping on eight species that were identified *a priori* as potentially most susceptible to logging activities in the ALS and that were likely species found in habitats for which forest management may have the greatest effects. These species included the following: Yellow-bellied Flycatcher, Boreal Chickadee, Golden-crowned Kinglet, Ruby-crowned Kinglet, Swainson's thrush, Palm Warbler, Connecticut Warbler, and Dark-eyed Junco. In addition to individual habitat suitability maps for these species, we developed three combined species maps that are potentially useful for conservation planning:

1. Binary suitability maps developed for all eight species were weighted equally and summed to create a map indicating the richness of these species and the potential conservation value of state-owned lowland conifer forests of the ALS.
2. Swainson's thrush and Palm Warbler, the two species least likely to be affected by current forest management practices, were excluded from map (1).
3. Probability of occurrence across the ALS (logistic output; see *Modelling in MaxEnt above*) was computed for the six species in map (3). Prevalence was estimated using the frequency of counts for which a given species was observed. Logistic outputs for each species were summed to create an index of conservation value for lowland conifer forests of the ALS. To ensure uncommon species were represented, each species was weighted by the inverse of its frequency in the forest stands sampled (Boreal Chickadee, 5.26; Dark-eyed Junco, 3.38; Connecticut Warbler, 3.13; Golden-crowned Kinglet, 2.37; Ruby-crowned Kinglet, 2.02; Yellow-bellied Flycatcher, 1.54).

RESULTS

Bird Species Observed on Study Plots.

We detected a total of 109 species with unlimited distance counts; 106 species in original stands and 76 species in new stands. For limited distance counts within 100 m, we detected a total of 77 species among the original stands and 55 species in the new stands selected in 2014 (Table 5). Forty-eight species had a large enough sample size in the original 65 stands and were considered in further in the hierarchical cluster analysis and calculation of PPI values (Appendix A).

Birds in Forest Cover Types.
Breeding Bird Community Clusters. We used a combination of observations of the bird species observed in the ALS, our field experience, and prior knowledge from the published literature on breeding birds to identify 10 clusters of breeding bird communities using the hierarchical cluster analysis (Appendix B). These 10 clusters were also supported by the subsequent calculation of PPI values for individual species described below. Additional rationale that we 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 Eastern Larch Beetle infested stands being lumped with recently harvested lowland conifer forests. In both these situations, we did not consider these as realistic representations of the bird communities or as ecologically distinct cover types.

Bird Community Clusters by Forest Cover Types.
The 10 clusters representing the bird communities were related to 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 are described by their dominant cover or structure; however, it is not uncommon for points within a cover type to be characterized by a non-dominant cover type or structure. For example, sites in the stagnant black spruce-tamarack cover types may vary between old, unproductive black spruce tamarack or young, productive black spruce tamarack, as both cover types may be structurally similar.

Breeding Bird Species within Forest Cover Types.
Mixed lowland white cedar.- The cover type of points that contributed to this bird community were predominantly white cedar, but black spruce, tamarack and balsam fir were also commonly present. Points within this type have relatively high site indices (mean of 30 and range of 16-49) and older (mean of 130 years and a range of 66-179 years) (Appendices C, D). Mean diameter at breast height (DBH) was 7 in (18 cm) [range 4-12 in], while mean height was 32 ft (10 m) with range [26-45 ft] (Appendices C, D). Average species richness for this cluster was highest at 15.8 species (Table 6). Species diversity was also the highest for both the Shannon-Wiener and Simpsons diversity index (Table 6). Bird species with high affinities for this cover type were Swainson's Thrush (PPI = 12, $p<0.01$) and Blackburnian Warbler (*Setophaga fusca*) (8, $p<0.05$) (Appendix E). Additional species commonly found within this forest cover type were the Nashville Warbler (*Oreothlypis ruficapilla*), Black-throated Green Warbler (*Setophaga virens*), and Yellow-bellied Flycatcher (Appendix A).

Eastern Larch Beetle disturbance forests. - This cover type comprises trees in various stages from live to dead because of invasion by the Eastern Larch Beetle; however, tamarack predominates. Site indices were high with a mean of 41 (range 31-65), while age was highly variable. Most points within this cover type were older (mean = 84 years and range from 15-135 years) (Appendices C, D). 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 6). Species with high affinities for this cover type were White-throated Sparrow (PPI= 15, p<0.01), Black and White Warbler (*Mniotilta varia*) (12, p<0.01), Mourning Warbler (*Geothlypis philadelphia*) (11, p<0.01), and Ruffed Grouse (*Bonasa umbellus*) (9, p<0.01) (Appendix E). Nashville Warbler and Common Yellowthroat (*Geothlypis trichas*) were also abundant in this cover type (Appendix A).

Northern white cedar. - This forest cover type was dominated by large white cedar trees with open under stories. Survey points were in areas of greater elevation and settings with adequate drainage. Cedar trees in this cover type averaged 11-12 in (28 cm) in DBH and were about 39 ft (12 m) high (Appendix C). Site indices ranged from 27-39 and were about 130-135 years old (Appendix D). Average species richness for points in this cover type was 12.8 (Table 6). Bird species with highest affinities for this cover type were Black-throated Green Warbler (PPI=49, p<0.01), Ovenbird (*Seiurus aurocapilla*) (25, p<0.01), Red-eyed Vireo (*Vireo olivaceus*) (17, p<0.01), Black-capped Chickadee (*Poecile atricapillus*) (8, p<0.01), Yellow-bellied Sapsucker (*Sphyrapicus varius*) (8, p<0.01), and Northern Flicker (*Colaptes auratus*) (7, p<0.01) (Appendix E). Species also common in this cover type was the Nashville Warbler (Appendix A).

Stagnant black spruce-tamarack bog. - Trees within this cover type were generally low in productivity and are short with small dbh. This habitat is often referred to as muskeg (Wright 1992). Site indices averaged 21.5 (range 14-35) while average age of these forests was about 65 years (range 24-159) (Appendices C, D). Mean dbh of trees in this cover type was 3 in (8 cm), while average height was 17 ft (5-6 m) (Appendix C). Average species richness was 11.8 species per point (Table 6). Species richness for the 10 focal species was highest at 5.5 species per point (Table 6). Only the Palm Warbler (PPI=68, p<0.01) and Magnolia Warbler (*Setophaga magnolia*) (7, p<0.05) had high affinities for this cover type (Appendix E). Species abundant in this cover type were Nashville Warbler, Palm Warbler, Yellow-bellied Flycatcher, Yellow-rumped Warbler (*Setophaga coronata*), White-throated Sparrow and Connecticut Warbler (Appendix A).

Semi-productive black spruce-tamarack bog. – Trees within this cover type were of intermediate height with moderate stem densities. Average site indices for this cover type were 27 (range 18-45) while average age was 97 (range 53-163) (Appendices C, D). Mean dbh was 4.5 in (11 cm) [range 3-7 inches] while trees were typically 32 ft (10 meters) [range 19-45 ft] tall (Appendices C, D). 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 (Table 6). Species richness (20) and focal (10) species richness was second highest, 7.7 and 5.3 respectively (Table 6). The Connecticut Warbler (PPI=40, p<0.01) was most distinctive of this cover type, while the Yellow-rumped Warbler (12, $p<0.01$) and Chipping Sparrow (*Spizella passerina*) (8, $p<0.05$) also had high affinities for this cover type (Appendix E). Species that were most abundant were Nashville Warbler, Connecticut Warbler, Yellow-rumped Warbler and Yellow-bellied Flycatcher (Appendix A).

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 C). Mixed swamp conifer stands tended to have high heterogeneity among points within this cluster due to the deciduous component. Average species richness was 14.3 species per point within this cover type (Table 6). Species with high affinities for this cover type were Northern Waterthrush (*Parkesia noveboracensis*) (PPI=11, $p<0.01$) and Winter Wren (*Troglodytes hiemalis*) (7, $p<0.05$) (Appendix E). Most abundant species in this cover type were Nashville Warbler, White-throated Sparrow, and Yellow-rumped Warbler (Appendix A).

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 the landscape context. Mean site index was 34, while mean age was 98 (Appendix C). Points in this cover type had a high proportion of non-lowland conifer cover types at the 1000m scale (Appendices C, D). Blue Jay (PPI=10, $p<0.01$) was the only species that showed significant selection for this cover type (Appendix E). Species abundant in this cover type were Nashville Warbler, Yellow-rumped Warbler and White-throated Sparrow (Appendix A).

Productive (mature) black spruce-tamarack bog. - Points in this forest cover type had relatively tall trees with large dbh and basal areas (Appendices C, D). This cover type included areas with commercially-harvestable timber. Mean age was 127 (range 97-159), while site index averaged 30 (21-39) (Appendices C, D). Average dbh was 6 in (15 cm) [range 5-9 inches] while mean height was 42 ft (13 m) [range 36-55 ft] (Appendices C, D). This cover type had the lowest average species richness of 10.9 species per census point when compared with the other cover types. Species richness was highest for the remaining species richness metrics, with the exception of focal species (10), which was second highest (Table 6). Species with high affinities in this cover type were Dark-eyed Junco (PPI=20, $p<0.01$), Golden-crowned Kinglet (10, $p<0.01$), and Boreal Chickadee (9, $p<0.01$) (Appendix E). Species most abundant in this cover type were Nashville Warbler, Yellow-rumped Warbler, Dark-eyed Junco, Golden-crowned Kinglet, and Connecticut Warbler (Appendix A).

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 C). Many of the trees were of merchantable size. Mean site index was (27) and average age was 104 for these cover types. Average bird species richness was 13 species per point (Table 6). The Yellow-bellied Flycatcher (PPI=15, $p<0.01$) and Ruby-crowned Kinglet (6, $p<0.05$) (Appendix E) 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 A).

Recently harvested lowland conifers. – This cover type was characterized by points within recently harvested lowland conifer stands were in an early stage of forest succession. Stands typically had regenerating lowland conifers, but tended to be dominated by cattails, sedges, and shrub component. Average age was 14 years, while site index was 44 (Appendix C). Average species richness per point was generally lower for all species richness calculations (Table 6). Species with high affinities for this cover type were Swamp Sparrow (*Melospiza georgiana*) (PPI=68, p<0.01), Common Yellowthroat (*Geothlypis trichas*) (34, p<0.01), Sedge Wren (*Cistothorus platensis*) (33, p<0.01), Alder Flycatcher (*Empidonax alnorum*) (24, p<0.01), and Chestnut-sided Warbler (*Setophaga pensylvanica*) (14, p<0.01), Wilson's Snipe (*Gallinago delicate*) (12, p<0.01), Lincoln's Sparrow (*Melospiza lincolnii*) (9, p<0.01) and Veery (*Catharus fuscescens*) (6, p<0.05) (Appendix E). Species abundant in this cover type were Swamp Sparrow, Common Yellowthroat, Nashville Warbler, Sedge Wren and Alder Flycatcher (Appendix A).

Breeding Bird Species of Interest.

Boreal Chickadee: This species was only found in three of the 10 bird community cover types. It was most abundant in *productive (mature) black spruce-tamarack bog* cover type (PPI=9, p<0.01), but also observed in the *mixed lowland white cedar* and *stagnant black spruce-tamarack bog* cover types (Appendix E).

Connecticut Warbler: This species had the highest affinity for the *semi-productive black spruce-tamarack bog* cover type with a very high PPI of 40 (p<0.01). The only other cover types where this species was observed was the *stagnant* and *productive (mature) black spruce-tamarack bog* cover types and points within the *Eastern Larch Beetle disturbance forests* (Appendix E).

Golden-crowned Kinglet: This species was most abundant in the *productive (mature) black spruce-tamarack bog* cover type (e.g., PPI=10). Additional cover types included *mixed lowland conifer, mixed lowland conifer (landscape), semi-productive black spruce-tamarack bog,* and *mixed lowland white cedar* (Appendix E).

Olive-sided flycatcher: This species was very rare within the ALS. We only commonly observed the species in the *productive (mature) black spruce-tamarack bog* cover type, but none of its PPI values were significant (Appendix E). The species was also recorded in points of the *Eastern Larch Beetle disturbance forests* and in *semi-productive black spruce-tamarack bog* cover types (Appendix E).

Ruby-crowned Kinglet: This species was most common in *mixed lowland conifer* cover types and also found with high affinities in *semi-productive* and *stagnant black spruce-tamarack bog* cover types (Appendix E).

Swainson's Thrush: This species was most common in *mixed lowland white cedar* cover types and only found in one other cover type; *mixed lowland conifer* (Appendix E)

Yellow-rumped Warbler: This species was found in all cover types except *northern white cedar* and *recently harvested lowland conifers* (Appendix E).

Yellow-bellied Flycatcher: This species was found in all cover types except *northern white cedar*, *mixed lowland conifer (landscape),* and *recently harvested lowland conifer* cover types (Appendix E).

Dark-eyed Junco: This species was most common in *productive (mature) black spruce-tamarack bog* cover types (PPI=20). They were also found in *stagnant* and *semi-productive black spruce-tamarack bog* cover types as well as *recently harvested lowland conifer* cover types (Appendix E).

Palm Warbler: This species was only found in *stagnant* and *semi-productive black spruce-tamarack bog* cover types. In stagnant black spruce-tamarack stands, it had a PPI value of 68 and a PPI value of three in semi-productive black spruce tamarack cover types (Appendix E).

Species of Greatest Conservation Need.

Twelve species were observed that have been designated as SGCN by the MNDNR. Original stands across all cover types had 12 SGCN, while new stands had five SGCN**.** Highest species richness for all SGCN was 2.5 species per point in the *productive (mature) black spruce-tamarack bog* cover type (Table 6).

Individual species modeling with MaxEnt.

Yellow-bellied Flycatcher was the most common species selected for analysis, with territorial males detected within 100m of the observer at 68% of points. Ruby-crowned Kinglet (52%), Golden-crowned Kinglet (44%), Connecticut Warbler (33%), Dark-eyed Junco (31%), Boreal Chickadee (20%), Palm Warbler (18%), and Swainson's Thrush (12%) were observed at intermediate levels. Presence locations ranged from a low of 15 for Swainson's Thrush to a high of 88 for Yellow-bellied Flycatcher (Table 7).

Habitat Suitability Models. Through variable reduction we calculated models using seven to 16 environmental variables per species (Table 7). Backward selection and subsequent comparison of AICc values produced best models ranging from one to nine variables. Based on comparisons with restricted random models, all species, except Yellow-bellied Flycatcher, were determined to have statistically significant models of habitat selection within the lowland coniferous forest of the ALS (Table 7). In conjunction with variable contributions, response curves (e.g.*,* Figure 2) demonstrate the effect and relative importance of environmental covariates on habitat suitability.

Land cover types in the local landscape (200m buffer) were highest contributors for six of eight species. Only two species had top contributions from stand-level variables; however, stand-level variables contributed to the best models for six species. Only the Dark-eyed Junco and Boreal Chickadee had no stand level variables included in the best model. Black spruce, individually or combined with one of the other tree species, appeared in the best models for most species (Table 7). No species appeared to be strictly associated with tamarack and only Swainson's Thrush exclusively selected cedar forests. In addition to tree species composition, general productivity of forest stands, as indicated by cover type 1 and site index (Table 3), contributed to best models for five species. Land cover types other than the lowland conifer tree cover (e.g., non-forest, sedge meadow) were included in the best models for five species, often at the 500m or 1000m landscape scales. Structural (e.g., basal area) or a variable related with structural characteristics (e.g., stand age) contributed to models for four species (Table 7).

Model validation. The usefulness of these models for prediction depended on species. Validation varied from a low of 56% of test samples correctly predicted for Golden-crowned Kinglet to a high of 96% correctly predicted for Palm Warbler (Table 8). Chi-square tests, comparing observed and correct predictions to those expected by chance, indicated significant predictive performance for six of eight species examined.

Conservation mapping.

Nearly 45% of state-owned, lowland conifer forests were predicted as suitable habitat for four or more of the eight species modeled, while only 5% of the area was suitable for seven species and a nominal percentage was predicted as suitable for all eight species (0.2%) (Figure 3). Approximately 47% of state-owned lowland conifer forests were predicted as suitable habitat for three or more of the six species potentially affected by timber harvest (Figure 4). Thirty-five percent of the area was predicted as suitable for four or more of these species, 12% for five or more and 5% for all six species. We did not develop a ranking scheme for conservation map 3; rather it portrays the relative conservation importance of lowland conifer forests in a continuous nature (Figure 5). Additional habitat suitability maps for individual species are included in Appendix F.

Discussion

A total of 109 species were detected during all of our surveys. Observations for the limited distance counts reflect territorial behaviors from species that sing, call, or drum as their primary vocalization while defending a territory. Warner and Wells (1984) detected a total of 90 species in all lowland habitat types in the ALS. Therefore, our total species number was slightly higher than those detected by Warner and Wells (1984), but the difference was largely due to the range of habitat types sampled.

Nashville Warbler was the most abundant species followed by Yellow-rumped Warbler and White-throated Sparrow within the original stands. 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 by Niemi and Hanowski (1984) and Warner and Wells (1984).

Bird Community Clusters and Forest Cover Types.

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 was likely that the bird species at these points responded to subtle differences in the vegetation structure or other factors such as landscape context. There was 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.

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 forests were more heterogeneous than the more pure stands of black spruce. This heterogeneity creates 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 was calculated only for those species associated with lowland conifer forests (Table 1), then species richness was highest in the black spruce-tamarack and mixed lowland coniferous forest cover types (Table 6).

Mixed lowland white cedar. - This forest types is currently not being considered for timber harvest in Minnesota. These cover types had an average age (130 yrs) greater than that of old-growth forests (>120 years) defined by the MNDNR. Sites were primarily composed of old, relatively productive cedar, but black spruce and tamarack were often present which separated this community from the northern white cedar community (Appendices C, D). 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 6). Many bird species ranging from more common upland species like Ovenbird to typical boreal species like Yellow-bellied Flycatcher found suitable breeding habitat within these forests. Increased harvest would likely not impact populations of the focal species listed in this report, with the possible exception of Swainson's Thrush. However, many of the bird points were in very old forest stands.

This forest cover type was characterized as highly productive and was represented by older age classes. Bird species diversity was the highest observed among the 10 bird community types and the Swainson's Thrush was most common in this cover type. Swainson's Thrush have been associated with higher densities of shrubs and cover below two meters with balsam fir understories (Rinaldi 2004). This is consistent with understories in *mixed lowland white cedar* forests in our study area. Old growth white cedar forests provide nesting habitats for the Swainson's Thrush, which requires shaded, dense understories for nesting (Jaakko Poyry Consulting Inc. 1992, Evans Mack 2000). Erskine (1977) in Canada and Niemi et al. (2016) in other forests of Minnesota and Wisconsin, however, found Swainson's Thrush 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.

ELB 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. Salvage logging of these sites is likely to cause a shift from the unique transitional bird community to the wetland-based community found in the *recently harvested lowland conifer* type. Forest researchers and managers should explore many possible management scenarios to maintain healthy tamarack stands, including salvage logging.

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* and *productive (mature) black spruce-tamarack* cover types. We are unaware of previously published studies that document the use of ELB-disturbance forests by the Connecticut Warbler. The most recent outbreak of ELB began in the early 2000's. Because no counts were counted in these stands prior to the infestation, the use of these areas by the Connecticut Warbler are 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 cedar trees. These cover types fit the age criteria of "old-growth" designation by the MNDNR as the average age of this cover type was 134 years. This type also often included a high proportion of deciduous canopy trees, an open understory, and drier ground conditions than other cedar forests in the study area (Appendices C, D). Though minimally harvested, these forests are more likely to be managed than sites in the *mixed lowland white cedar* cover type. When compared with other forest types, the bird species using these forests were most similar to those commonly found using upland deciduous forests (Niemi et al. 2016). Species richness for birds of SGCN and lowland conifer species was low (Table 6). If an economic incentive arises for use of these forests, then populations of the focal bird species would likely be unaffected. However, we would assume harvesting would be completed in a sustainable manner because of the old-growth nature of this forest cover type.

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 Sapsuckers. 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 some of 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 represents 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 mosses (Appendices C, D). This forest type can also include stands in varying degrees of regeneration that shared the above structural attributes. Harvesting is usually not considered in this forest type because of low biomass, but the tops of black spruce are often harvested for "Christmas trees." The effects of these harvests on the breeding bird community are unknown, but the sustainability of this harvest method should be evaluated because of the slow-growing trees found in this cover type.

Sites contributing to this bird community had the highest average richness of focal bird species (Table 6). The reason for high species richness of this group was because seven of the ten focal species were observed in this cover type (Table 1, Appendix A). The Palm Warbler had its highest affinity and was the second most abundant species within this cover type. These results are 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.

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. Site indices were usually near the low end of those recommended for harvesting, averaging about 28 (Appendix C). Trees were generally intermediate in height, diameter, and canopy structure when compared to the *stagnant* and *productive (mature) black spruce-tamarack* 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 with a stand that has a site index of 26 and an age of 100. The bird community in this cover type had high species richness estimates for both lowland conifer dependent species and focal species (Table 6). In addition, Connecticut Warbler, a SGCN, had high densities and affinity with this cover type (PPI value of 40; Appendix E). Harvesting of forest stands of this cover type would reduce available habitat for this species in the ALS.

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) provide limited quantitative habitat data for the sites they sampled. Niemi et al. (1983) provide 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 support 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 does 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 observed by Lapin et al. (2013).

We recommend forest managers re-evaluate the costs and benefits of harvesting black spruce-tamarack stands near the current low-end threshold of productivity (e.g., site indices 25-35). These stands have high importance for many boreal bird species; many of which have conservation concern. The regeneration potential after harvest is unknown and likely to take a long time period. Moreover, climate change models predict reductions in suitable habitat for black spruce in MN by 2100 (Iverson et al. 2008) and, hence, 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. None of the focal species were characteristic of this community (Table 6). 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. Though trees were occasionally large, low tree density probably make these forests poor candidates for timber harvest. Repeated disturbance from fluctuating water levels and possibly ELB may prevent this forest type from developing merchantable wood.

Northern Waterthrush and Winter Wren (a 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 of this forest type 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 cover types also fit the MNDNR designation of "old-growth" forests as trees within these cover types averaged 128 years. These forests had the highest bird species richness of the lowland conifer dependent species, as well as SGCN (Table 6). 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 of the 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 2002). Our 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).

This forest cover type is commonly harvested in the ALS. Reductions of this forest cover type in the ALS will directly affect population levels for each of the three species, Boreal Chickadee, Dark-eyed Junco, and Golden-crowned Kinglet, because of their strong associations with this cover type. The development of sustainable forest management strategies will be important to maintain their breeding populations within the ALS landscape.

Mixed lowland conifers. - Similarly 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 imbedded in a landscape of lowland conifer forests and comprised of the common bird species of the ALS. Many of the forest stands within these cover types would be better candidates for timber harvesting from the perspective of conservation of focal species, SGCN, and general protection of the boreal avifauna. Many of the points in these forest types were within fragmented landscapes and emphasize the need to protect large, contiguous landscape 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). Of the species found in this cover type, the Sedge Wren is a SGCN.

Points in this cluster were all harvested 8-24 years prior to bird sampling. Few to no lowland conifers had regenerated at four of the six sites and only sparse coverage had occurred at the remaining 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, there are landscape considerations as well. 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). To maintain populations of focal bird species considered here, it is imperative that forest management plans account for the probability of regeneration and the pace of regeneration when determining sustainable harvest levels.

Species of Greatest Conservation Need.

Within the original stands, Connecticut Warbler, Winter Wren, and Purple Finch were the most abundant SGCN in forested lowland conifer stands. Connecticut Warblers are ground nesters that use extensive ground cover (e.g., moss and Ericaceous species) for nesting (Pitocchelli 2012). In general, detections of Boreal Chickadee must be considered with some caution for several reasons: 1) we did not adequately sample during their prime breeding season, 2) territories can be greater than 5>ha in size (Ficken 1996) and, therefore, they are more difficult to detect over the course of a 10 minute census, and 3) territories are often defended with fewer vocalizations than other species (Ficken 1996) in which detection may be difficult and may require specialized sampling techniques. Regarding (1) above, both 2013 and

2014 were very late and cold spring seasons. In both years, cold and snow persisted in these habitats into early May which is unusual for the ALS. Because of the rarity of Boreal Chickadees in the ALS, it is unclear what affect this late spring had on the species. Further investigation of this species in the ALS is warranted.

Sedge Wren and Veery, two additional SGCN, had the highest affinities for *recently harvested* cover types. Sedge Wrens were only found in the *recently harvested lowland conifer* cover types. Sedge Wrens were typically found in tamarack stands that had been recently harvested in which patches of sedges were present within the stand.

Veery was identified in *recently harvested lowland conifers*, *ELB disturbance forests*, and *mixed tamarack swamp conifers* within the original sites. Observations of Veery were low among all habitat types (n<7). Based on life history, Veery are associated with young deciduous tree/shrub species found within these cover types. Stands with regenerating tamarack typically include taller deciduous shrub species that may mimic regenerating aspen in upland settings. Warner and Wells (1984) found similar results for Veery in which the species was present in shrub thickets in the ALS.

Of the SGCN that are found in lowland coniferous forests, we have a high level of confidence in habitats selected by Connecticut Warbler, Sedge Wren and Winter Wren. Confidence levels for the Boreal Chickadee, Black-backed Woodpecker, Purple Finch and Olive-sided Flycatcher are lower and need additional attention to assess habitat and landscape factors associated with their use of the ALS.

Habitat suitability modeling.

Model evaluation. The biological meaning of a model that discriminates background environmental locations from presence locations at rate of 0.61 (Yellow-bellied Flycatcher) is questionable. The literature varies, but a general recommendation is that 'useful' models have AUC around 0.70 or greater (Araújo et al. 2005). Models for boreal birds in the ALS generally met this criterion, with the exception of Yellow-bellied Flycatcher.

It is important to recognize that AUC and AICc are not directly related – AUC makes no penalty for model complexity. However, we found that AICc selected models were often the same or similar to models with the highest test AUC values. Both measures tended to select intermediate-complexity models, though for three species (Ruby-crowned Kinglet, Swainson's Thrush, and Palm Warbler) the AICc-selected model was more parsimonious. There is some evidence that intermediate-complexity models are better able to predict habitat selection and variable contributions (Warren and Seifert 2011).

Predictive ability of habitat models, especially those using remotely sensed geographic information related to land cover and other environmental variables, has been suggested to be moderate at best (Keller and Smith 2014). Yet, MaxEnt models developed here generally performed well, even though sample sizes were small for some species. Notable exception was for the Boreal Chickadee where few test data were available. Boreal Chickadee was among the earliest breeding species of those studied. Since our test data were gathered in late June, this species was not detected well. In contrast, models for two additional early-breeding species, Ruby-crowned Kinglet and Dark-eyed Junco, performed well with late-June test data (Table 8).

Swainson's Thrush and Palm Warbler, two species that had strong affinities for specific cover types in the ALS also agreed with the general understanding of their breeding habitat in lowland coniferous forests (Warner and Wells 1984; Niemi and Hanowski 1992, Wilson 1996). Palm Warbler was primarily found in stagnant black spruce and tamarack forests, while Swainson's Thrush were associated with cedar forests (Table 7). The high level of predictability of our modeling approach supports its use in determining species habitat requirements within lowland conifer forests of the ALS and provides substantial credibility for interpretation of these models built for the remaining species.

Individual species. Yellow-bellied Flycatcher was found in the majority of stands and count locations and are likely breeding in most lowland conifer forest types in the ALS. The best model indicated that this species preferentially selects stagnant stands surrounded by a variety of forest types (Table 7). However, the model was not significant when compared with random models. This suggests that this species is a generalist in the ALS and because of its ubiquity it is more difficult to predict its habitat use. At the current time, the ALS provides substantial forested habitat for the Yellow-bellied Flycatcher; however, this species did not occur in recent cut areas and would be negatively affected by extensive logging in the ALS. A summary of the species habitat distribution by Niemi and Hanowski (1992) and Niemi et al. (2016) indicates that the species is primarily found in mature lowland and some upland coniferous forest types.

The Ruby-crowned Kinglet and the Golden-crowned Kinglet in the genus, *Regulus*, also preferred black spruce or cedar forests with upland forests in the broader landscape. These species appear to generally segregate on a gradient of productivity with Ruby-crowned Kinglet preferring more stagnant stands and Golden-crowned Kinglet more productive stands (Table 7). However, these species were found in some of the same stands and might also segregate on smaller microhabitat scales or foraging techniques not studied here (Franzreb 1984).

Dark-eyed Junco was primarily associated with black spruce forests and, similar to Ruby-crowned Kinglet and Golden-crowned Kinglet, avoided tamarack forests and recent cut areas. These species are several of the most abundant and indicative species of the vast black spruce forests of boreal Canada (Erskine 1977). Future study should explore the ecological implications of tamarack avoidance. For example, it is possible that the late-spring emergence of needles, and potentially insect prey, in tamarack might limit use by these short-distance migrant species that select territories and breed prior to leaf-out. Mortality of nearly 26% of Minnesota's tamarack forest caused by Eastern larch beetle since 2000, probably is not negatively affecting these species and might even enhance their future habitat if forest regenerate into other lowland conifer types. The protection of a productivity gradient of spruce forests and continued lack of harvesting in cedar will likely support continued breeding populations of these species in the ALS.

Species of Greatest Conservation Need. Boreal Chickadee and Connecticut Warbler are designated as SGCN in Minnesota (SGCN; MNDNR 2006). Little is known about population trends of the Boreal Chickadee, but the Connecticut Warbler is of concern. Connecticut Warbler populations in Minnesota's National Forests have declined by as much as 8% per year over the past 20 years (Zlonis et al. 2014) and the species is listed as a conservation target by various groups (Rich et al. 2004; Rosenberg et al. 2014). Despite this, only one study has completed a detailed analysis of Connecticut Warbler breeding habitat in Minnesota. In the Superior and Chippewa National forests, Lapin et al. (2013) found the Connecticut Warbler was primarily found in forests with large contiguous patches of lowland conifer forests often surrounded by upland coniferous forest as opposed to upland deciduous forest. Models including local stand variables (e.g., those within 100 m buffer) such as tree and shrub density performed relatively poorly.

We found both the local (stand and 200 m buffer) and landscape (1000 m buffer) covariates to be important for the breeding habitat of Connecticut Warbler in the ALS (Table 7). Areas with highest predicted suitability were stagnant stands of intermediate basal area or productive stands of intermediate age (and thus basal area), surrounded by little or no productive cedar forest or sedge meadow (Figure 2). The latter negative associations imply selection for large areas of black-spruce or tamarack. Connecticut Warblers displayed a negative correlation with upland forests within 200 m (AUC = 0.59, single variable model). This species would benefit from forest management that avoids harvesting stagnant black spruce-tamarack forests with relatively high basal area, especially in landscapes surrounded by additional black spruce-tamarack forests. Many of these forest stand types are at the cusp of being considered economically viable for harvest by forest managers and may have been extensively harvested in the past.

Boreal Chickadee are permanent residents and had potentially completed breeding by the May bird sampling. It is possible that they were tending to nests at this time, making them more difficult to observe with aural surveys. For example, about half of Boreal Chickadee samples were from sites where they were not found on three previous visits, indicating the difficulty in detecting this species.

Similar to short-distance migrants, Boreal Chickadee utilized black spruce and avoided tamarack forests. Previous research in Minnesota suggests that lowland spruce forests are particularly important to this species (Warner and Wells 1984). Spruce forests provide food resources and cover not available throughout the year in tamarack. In addition to shedding needles annually, tamarack does not retain seeds for the majority of the year (Duncan 1954). The softer wood of spruce and cedar might also provide more naturally occurring and excavated nesting cavities for Boreal Chickadee. Protection of black spruce forests will likely allow the persistence of Boreal Chickadee and other archetypal boreal species in these hemi-boreal forests of Minnesota.

Conservation applications. Maps represent a broad interpretation of the relative habitat suitability across the ALS landscape (Appendix F; Merow et al. 2013). These habitat suitability maps can be used at an individual species level as well as combinations of species based on their potential for co-occurrence. To combine species' maps and provide managers with a useful conservation tool, we developed thresholds for suitable and unsuitable habitat for eight species breeding in the lowland-conifer forests of Minnesota (Appendix F). Managers can use these results to designate potential conservation areas or special management units that are particularly significant for bird species breeding within the ALS. The low proportion of the ALS predicted to be suitable for all species (Figures 3, 4) shows the importance of using multiple species or assemblages when determining those conservation priorities (Moilanen et al. 2005). Further testing and refinement of these models is encouraged for additional confidence in results.

Threats to birds are well documented and the most imperiled species have been identified (Rosenberg et al. 2014), but declines in populations are unlikely to be reversed unless local and regional conservation actions are taken. Our study indicated that a narrow geographical scope and habitat breadth can be used to identify specific habitat associations that can facilitate these conservation actions. Though, these results should be cautiously applied across other geographic areas in which they were not developed (Townsend Peterson et al. 2007). We recommend that future research and management collaborations utilize habitat data, often only available at local scales, to develop similar conservation targets.

Summary

Human induced disturbance pose some of the largest threats to many species breeding in lowland conifers within the ALS. Climate change looms as one of the most challenging issues in the ALS ecoregion of Minnesota because of its extreme northern distribution. Forest harvesting in this region in the past has been minimal, but has recently been increasing. The ability to have a sustainable harvest level; however, will be challenging because of the slow growth rates of many species of trees in the region, the variable hydrological conditions, and the lack of knowledge on forest succession or how to regenerate the forest. These issues are further exacerbated by insect problems like ELB and the demands for economic development. The pressure that will be placed on natural resource managers to manage these forests and wildlife populations is complex and daunting.

Management Recommendations. We identified site and landscape level habitat characteristics that are important to the eight species that were the primary focus of this overall sampling, modeling, and mapping effort. The ALS and its complex of wetland ecosystems represent the largest, remaining contiguous block of wetlands in the eastern United States (Wright et al. 1992). Areas within the ALS are being considered for RAMSAR designation (wetlands of international importance) and, therefore, a solid understanding on the impacts of forest harvesting and management are critical.

1. All Habitat Classes of the ALS are Important to Some Species.

Our sampling identified a diverse avifauna in the ALS. For most of the abundant species, including the focal species, it is possible to identify with a level of confidence the suite of forest cover types and landscapes of the ALS where the species was observed. Using an *a priori* list of eight species, we identified many areas of the ALS that will likely benefit at least six of the eight species simultaneously because they overlap in their habitat preferences (Figure 4). However, if we had selected a species such as the Sedge Wren, a Minnesota designated SGCN, then *recently harvested lowland conifer* cover types would be the most important forest type for this species. Even though a balance of forest cover types, age classes, and patch sizes are required to maintain a diverse avifauna of the ALS, we recommend managing the lowland coniferous forests of the ALS for a subset of species that require large blocks of lowland coniferous forest that were historically present. Species like the Sedge Wren occur abundantly in other parts of the ALS such as in large blocks of open shrub and sedge fens (Niemi and Hanowski 1992). Importantly, the ALS still retains many large, contiguous blocks of both open and forested cover types not found in many parts of the eastern United States, especially wetland ecosystems. Conservation of these large, contiguous areas of habitat should be a high priority.

2. Importance of the *Semi-productive and Productive (mature) Black Spruce-Tamarack Forest Type*.

Many species, especially focal species, were found to utilize *semi-productive and productive (mature) black spruce and tamarack bog* cover types. From the perspective of forestry, these were forest cover types of primary concern to forest management and planning in the ALS because they were commonly harvested and they were of importance to the focal species. These forest types typically have site indices in the range of 18 to 45. We suggest that forest harvest and management should focus on harvesting stands that have higher site indices. This does not necessarily mean strictly harvesting high site index forest types, but assumes harvesting productive stands allows for faster forest succession in subsequent years. In addition, landscape management will be extremely important for many species. Lapin et al. (2013) found that Connecticut Warblers required large habitat patches in the national forests of northern Minnesota. The importance of large landscapes of black-spruce and tamarack were confirmed in this study.

Management of black spruce cover types will require planning to maintain large patches in the ALS to protect adequate habitat for the Connecticut Warbler, many species of conifer dependent species, other focal species (e.g., Golden-crowned Kinglet, and Boreal Chickadee), and SGCN. This is critical information as these stands are desirable to harvest because they are productive and homogenous with the most cords per acre. This may have other implications because if tamarack is lost from the landscape, more demand may be placed on black spruce.

3. Benefits of Eastern Larch Beetle to Breeding Birds of the ALS?

Whether there are any benefits of ELB to breeding birds in the ALS is unclear, but they are likely to be temporary. Connecticut Warblers utilized these cover types to some extent. To our knowledge, there are no studies to analyze the effect of ELB on bird habitat use in this region. We observed some regeneration of white cedar in several ELB-affected stands. If white cedar becomes more prevalent in the ALS by replacing existing tamarack stands, this could favor species such as the Swainson's Thrush. However, Connecticut Warbler use of ELB infested stands will be temporary because we did not observe this species using white cedar forests. Black-backed Woodpecker, Hairy Woodpecker, and Northern Flicker were all species that potentially would benefit from these infestations, but again they would be temporary. Boreal Chickadee or Winter Wren may benefit from the excavated cavities made by woodpeckers or from uprooted trees, respectively. Further information on bird communities in ELB-affected stands is needed.

The impacts and longevity of the ELB in Minnesota are not fully understood. It is not known whether this beetle will persist and greatly reduce the area of tamarack forests within the ALS in the future. Friedman and Reich (2005) suggest that tamarack will continue to decline because of logging, insect outbreaks, and fire suppression. How tamarack forests will regenerate after an ELB infestation is also not known. It is appropriate to have a sufficient balance of stagnant to productive and young to old forests across the ALS. If the Eastern larch beetle persists, forest structure and composition could shift to mimic regenerating forest types; a type that ELB points were most similar to in the bird community cluster analysis.

4. Importance of Older, Mature Black Spruce, Tamarack and Cedar in the ALS.

Older lowland conifers, whether productive or stagnant, are important, not only for SGCN's, but also for species that depend on or have preference for these cover types. Species, such as the Golden-crowned Kinglet, Ruby-crowned Kinglet, Yellow-rumped Warbler, Connecticut Warbler, Dark-eyed Junco, Yellow-bellied Flycatcher, Boreal Chickadee and Swainson's Thrush, used older forests. These older forests found in the ALS, spanned a gradient of stagnant to productive forest types. *Mixed lowland white cedar, northern white cedar* and *productive black-spruce tamarack bog* cover types fit the age criteria of old-growth forests defined by the MNDNR. In addition, only 2 cover types had average ages of less than 80 years (*recently harvested lowland conifers* and *stagnant black spruce-tamarack bog cover types.* Appendix C). We did not complete a comparative study of population levels for SGCN relative to other areas of northern Minnesota, Wisconsin, or adjacent Canadian provinces. However, the population levels we observed in the ALS for the Yellow-bellied Flycatcher and Connecticut Warbler are among the highest we have observed in our 20 plus years of monitoring breeding birds in the national forests of Minnesota and Wisconsin (Niemi et al. 2016, Zlonis et al. 2015). Both species have been declining in northern Minnesota forests over the past 21 years (Zlonis et al. 2015) and deserve special attention in the ALS because they both appear to have healthy population levels. Yet their nesting productivity are unknown. In addition, there are many other species (e.g., orchids) that may require the old-growth forests of the ALS.

5. Microhabitat Characteristics of Concern.

Micro-characteristics within the forest stands are very difficult to study for small animal species like songbirds. Telemetry studies can improve this knowledge. Therefore, more detailed studies to identify specific microhabitats used by the focal species is recommended. Additional avenues of research include the investigation on use of small patch sizes within the ALS. For example, we only sampled stands that were larger than 20 acres. The likelihood of small patches comprising a large portion of area in the ALS, given the relative homogenous landscape, may be small. However, if logging activity or management increases in the ALS, then a better understanding of how or if bird species use these smaller patches may be helpful for forest management. For instance, can potential effects of fragmentation be mitigated by including corridors between patches for Connecticut Warbler or can large residual trees with available cavities aid nesting Boreal Chickadees?

6. Developing a Long-term Bird-monitoring Strategy.

The analyses and recommendations presented in this report would benefit from further bird monitoring in the ALS. In addition to accounting for annual variation not present in this dataset (spring 2013 and 2014 were both particularly cold and "phenologically" late), long-term monitoring would allow managers and researchers to better understand potential trends (and drivers) in bird populations in this unique portion of Minnesota. Unfortunately, current long-term sampling of four Breeding Bird Survey routes in the ALS likely will not provide sufficient detail about local bird populations (Niemi et al. 2016). Not only are lowland coniferous forests projected to be most severely affected by climate change, but forest types such as tamarack are facing immediate threats that will only be compounded with a warming climate. It is important that we understand how natural resources and wildlife populations might be affected by these threats in both the short and long-term and at local and regional scales. As the gateway to northern boreal forests and peatlands, bird-monitoring in the ALS could serve as an early-warning sign for these habitats across the continent and globe. Adaptive forest management strategies stemming from this work could form the foundation for protecting boreal biodiversity in Minnesota and beyond. We recommend developing an approach to continue bird monitoring in the ALS that includes continued sampling of at least some of the stands discussed in this report.

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Table 1: Lowland conifer species (20) are species 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). Focal species (10) were species selected as target species by the Minnesota Department of Natural Resources (MNDNR) and the Natural Resources Research Institute. Species of Greatest Conservation Need (SGCN) are species identified as species of conservation interest (MNDNR 2015). SGCN are species that were only detected on the project. Species are listed in alphabetical order.

Lowland conifer species (20)	Focal species (10)	Species of Greatest Conservation Need (SGCN)
American Three-toed Woodpecker	Boreal Chickadee	Black-backed Woodpecker
Black-backed Woodpecker	Connecticut Warbler	Boreal Chickadee
Blue-headed Vireo	Dark-eyed Junco	Cape May Warbler
Boreal Chickadee	Golden-crowned Kinglet	Connecticut Warbler
Brown Creeper	Olive-sided Flycatcher	Olive-sided Flycatcher
Chipping Sparrow	Palm Warbler	Purple Finch
Connecticut Warbler	Ruby-crowned Kinglet	Sedge Wren
Dark-eyed Junco	Swainson's Thrush	Spruce Grouse
Golden-crowned Kinglet	Yellow-bellied Flycatcher	Veery
Gray Jay	Yellow-rumped Warbler	Winter Wren
Hermit Thrush		
Olive-sided Flycatcher		
Palm Warbler		
Purple Finch		
Ruby-crowned Kinglet		
Spruce Grouse		
Swainson's Thrush		
Winter Wren		
Yellow-bellied Flycatcher		
Yellow-rumped Warbler		

Table 2: Landscape and forest stand variables included in habitat modeling. Landscape variables were summarized in 200, 500, and 1000 m buffers surrounding all 30 m grid cells in the Agassiz Lowlands Subsection. Foreste stand variables were derived from the stand where point counts were conducted (*c*, categorical). Forest stand cover types are described in Table 3. Landcover data come from the Upper Midwest Gap Analysis Program (1991e 1993); lands converted from forest to other types were updated using remotely sensed changee data (Hansen et al. 2013).

Landscape		**Forest stand**
Black spruce	Open-wet (lowland shrub, sedge meadow)	Age (2014)
Black spruce/tamarack	Open, non-habitat	Area
Cedar	Richness of patch types	Average DBH
Density of streams	Stagnant black spruce	Basal area
Evergreen (spruce, cedar)	Stagnant lowland conifer	Cover type 1 ***c***
Forest (all forest types)	Sedge Meadow	Cover type 2 ***c***
Larch beetle mortality	Stagnant tamarack	Cover type 3 ***c***
Lowland conifer (spruce, cedar, tamarack)	Tamarack	Site index
Lowland Shrub	Upland conifer	Trees per acre
Non-forest (all non-forest types)	Upland deciduous	
Number of patches	Upland forest (deciduous, coniferous)	

Table 3: Proportion of lowland conifer types within state-owned lowland conifer of the Agassiz Lowland Subsection. Cover types were combined in three separate variables for analyses of habitat associations, segregated by tree species and productivity (cover type 1), tree species only (cover type 2), and productivity only (cover type 3).

Type	%	Cover type 1	Cover type 2	Cover type 3
Black spruce	22	1	1	1
Stagnant black spruce	24	2	1	2
Tamarack	25	3	2	1
Stagnant tamarack	13	4	2	2
Cedar	7	5	3	1
Stagnant cedar	9	6	3	2

Table 4: Reclassifications of Upper Midwest GAP Analysis Program level-four land cover data in the Agassiz Lowland Subsection (ALS). All reclassifications were summarized in 200, 500, and 1000 m buffers surrounding each 30 m grid cell within lowland conifer forests of the ALS. Due to high correlations amongst reclassifications and buffer sizes, only one GAP variable and buffer scale containing any of the 'Reclass 3' variables were included in habitat suitability models.

Reclass 1	Reclass 2	Reclass 3	Reclass 4	%
Forest	Lowland conifer	Evergreen, black spruce-tamarack	Black spruce	%
Forest	Lowland conifer	Evergreen	Cedar	%
Non-forest	Open wet		Lowland shrub	%
Non-forest	Open, non-habitat		Open, non-habitat	%
Forest	Lowland conifer	Stagnant conifer	Stagnant black spruce	%
Non-forest	Open wet		Sedge meadow	%
Forest	Lowland conifer	Stagnant conifer	Stagnant tamarack	%
Forest	Lowland conifer	Black spruce-tamarack	Tamarack	%
Forest	Upland forest		Upland conifer	%
Forest	Upland forest		Upland deciduous	%

Table 5: Total number of species for both the original and new stands along with project totals for unlimited and limited-distance counts. Unlimited counts include all observations and unlimited distance detections. Limited distance counts were restricted to observations within 100 meters and territorial males.

Species Summaries	**Original Stands**	**New Stands**
Unlimited Counts	106	76
Limited Distance Counts	77	55

Table 6: Species richness metrics and species diversity indices for 10 cover types within the Agassiz Lowland Subsection (ALS), MN. Predicted species richness was calculated using generalized linear models (GLM's) 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 (20) and Focal (10) were calculated using 20 and 10 lowland conifer associated species, respectively (Table 1). Species Richness SGCN is calculated using only Species of Greatest Conservation Need. 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 parenthesis). The number of sample points for each cover type are listed in parenthesis.

Habitat Type	Species Richness	Species Richness (20)	Species Richness Focal (10)	Species Richness SGCN	Shannon's H Diversity Index	Simpsons Diversity Index
Mixed lowland white cedar (17)	15.8 (1.0)	6.9 (0.6)	3.8 (0.5)	1.5 (0.3)	2.51 (0.05)	10.16 (0.62)
Eastern Larch Beetle disturbance forest (9)	15.6 (1.3)	4.0 (0.7)	2.6 (0.5)	1.8 (0.4)	2.41 (0.12)	9.50 (1.10)
Northern white cedar (5)	12.8 (1.6)	2.8 (0.7)	1.0 (0.4)	0.6 (0.3)	2.26 (0.13)	7.81 (1.07)
Stagnant black spruce-tamarack bog (10)	11.8 (1.1)	6.6 (0.8)	5.5 (0.7)	1.0 (0.3)	2.12 (0.07)	6.62 (0.63)
Semi-productive black spruce-tamarack bog (12)	12.1 (1.0)	7.7 (0.8)	5.3 (0.7)	1.6 (0.4)	2.21 (0.06)	7.69 (0.45)
Mixed tamarack swamp conifer (15)	14.3 (1.0)	5.1 (0.6)	2.7 (0.4)	1.9 (0.4)	2.32 (0.09)	8.28 (0.85)
Mixed lowland conifer-(landscape) (19)	14.8 (0.9)	5.9 (0.6)	2.8 (0.4)	1.5 (0.3)	2.41 (0.04)	8.54 (0.33)
Productive (mature) black spruce-tamarack bog (12)	10.9 (1.0)	8.3 (0.8)	5.3 (0.7)	2.5 (0.5)	2.18 (0.07)	7.80 (0.61)
Mixed lowland conifer (25)	13.0 (0.7)	7.5 (0.5)	4.7 (0.4)	1.3 (0.2)	2.23 (0.05)	7.26 (0.43)
Recently harvested lowland conifers (6)	11.3 (1.4)	1.5 (0.5)	1.2 (0.4)	0.8 (0.4)	2.17 (0.08)	7.52 (0.74)

Table 7: Best Maxent models for each of seven species in the Agassiz Lowland Subsection as determined by lowest AICc value averaged amongst five cross-validated model runs. Effects of environmental variables were positive (+), negative (-), categorical (top categories indicated), or quadratic (q). Area under the receiver operator curve (AUC) was used as a metric of model fit and was determined by averaging cross-validated model runs of test samples. Significance was determined by comparing AUC to the distribution of replicated (999) restrictede random Maxent models.

Species	**Variables (effect, %contribution)**	**Samples**	**Models compared**	**AUC value**	***p* value**
Yellow-bellied flycatcher	Cover type 1 (stagnant types, 45%), Patch richness 500 m (q , 28%), Stand age (+, 14%), Stand area (q, 11%), Site Index (q, 3%)	88	7	0.61	0.24
Boreal chickadee	Evergreen 200 m (+ , 86%), Density of streams (+, 11%), Stagnant tamarack 500m (-, 3%)	26	14	0.83	<0.01
Golden-crowned kinglet	Evergreen 200 m (+ , 49%), Upland deciduous 1000m (+, 12%), Non-forest 200m (-, 9%), Upland coniferous 500m (+, 8%), Basal area (q, 7%), Cover type 2 (black spruce and cedar, 6%), Stand Area (q, 5%), Tamarack 200m (-, 2%), Number of patches 200m (-, 1%), Stand age (q, 1%)	57	12	0.75	<0.01
Ruby-crowned Kinglet	Evergreen 200m (+, 32%), Cover type 1 (stagnant types, 30%), Upland forest 500m (+, 22%), Non-forest 200m (-, 16%)	66	13	0.71	<0.01
Swainson’s Thrush	Black spruce/tamarack 200m (-, 30%), Stagnant black spruce/tamarack 1000m (-, 28%), Site index (-, 27%), Sedge meadow 500m (-, 14%)	15	15	0.87	<0.01
Connecticut Warbler	Black spruce/tamarack 200 m (+ , 35%), Cover type 1 (stagnant black spruce/tamarack , 20%), Cedar 1000 m (- , 20%), Sedge meadow 1000 m (- , 12%), Basal area (q , 11%), Stand age (q , 3%)	43	12	0.73	<0.01
Palm Warbler	Cover type 1 (stagnant black spruce/tamarack, 100%)	23	15	0.78	<0.01
Dark-eyed Junco	Black spruce 200m (+, 70%), Non-forest 1000m (+, 16%), Larch beetle mortality 500m (-, 9%), Density of streams 200m (+, 5%)	40	16	0.75	<0.01

Table 8: Test results of predictive ability of Maxent models for bird species in the Agassiz Lowlands of Minnesota. Suitability predictions for each species were transformed into binary maps using the top 90% of model training data and then tested against independently collected dataset. Significance values are results of chie square tests taking into account the observed and expected number of correct predictions based on the proportion of the study area predicted to be suitable.

Yellow-bellied flycatcher	43	88%	69%	<0.01
Boreal chickadee	10	60%	37%	0.12
Golden-crowned kinglet	18	56%	42%	0.24
Ruby-crowned Kinglet	14	93%	63%	0.02
Swainson's Thrush	10	60%	24%	<0.01
Connecticut Warbler	14	71%	45%	<0.05
Palm Warbler	25	96%	78%	0.03
Dark-eyed Junco	20	80%	53%	0.02

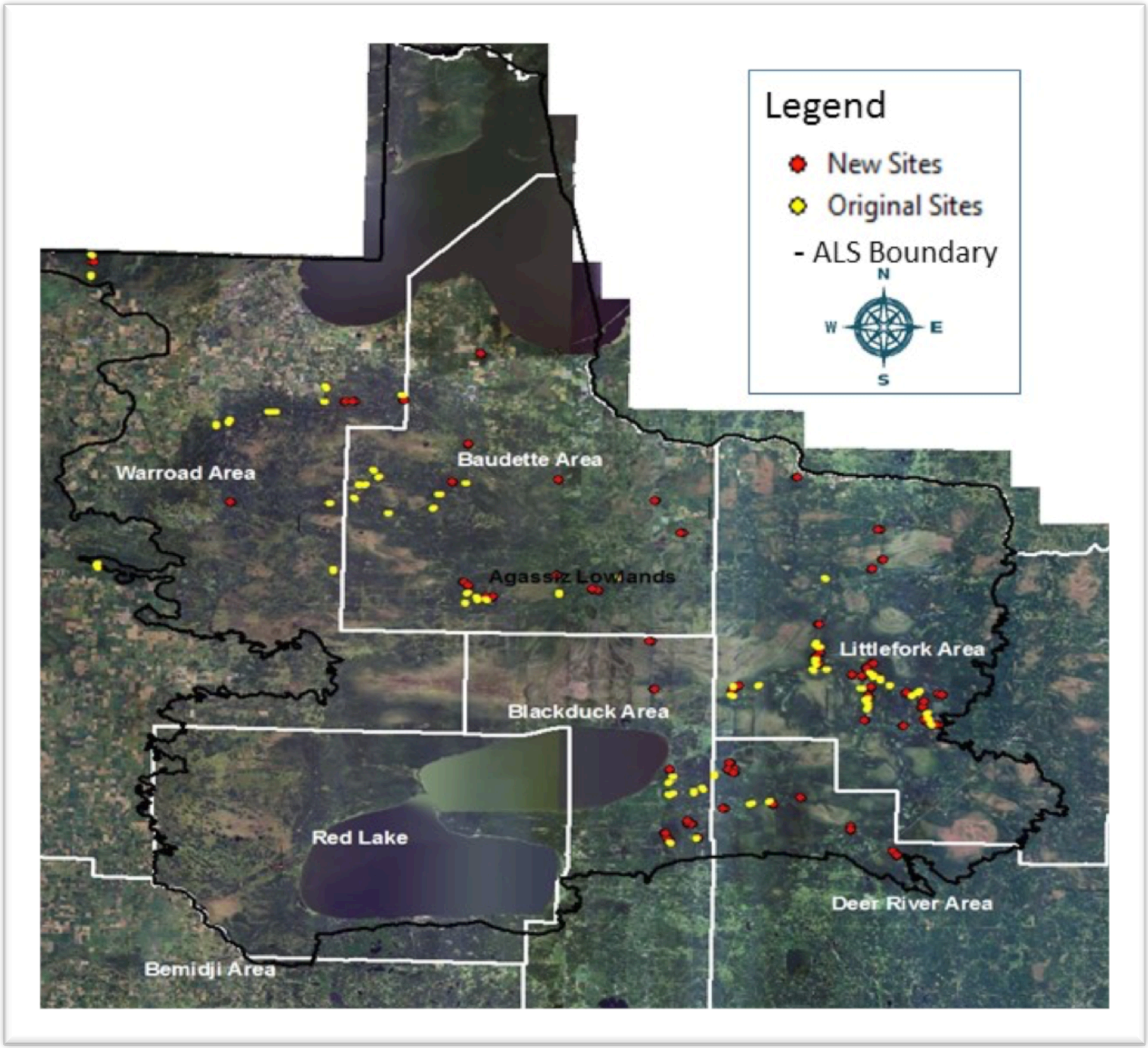


Figure 1. The distribution of bird points sampled in 2013-2014 in the Agassiz Lowland Ecological Subsection (ALS) of Minnesota. Figure includes both 65 original (yellow) and 65 new stands (red) that were sampled. Areas directly north and west of Upper and Lower Red Lakes were not sampled due to inaccessibility. Forestry districts are labeled in white, while the ALS boundary is outlined in black. Original stands were sampled 5 times each throughout 2013 and 2014 and new stands were sampled once in 2014.

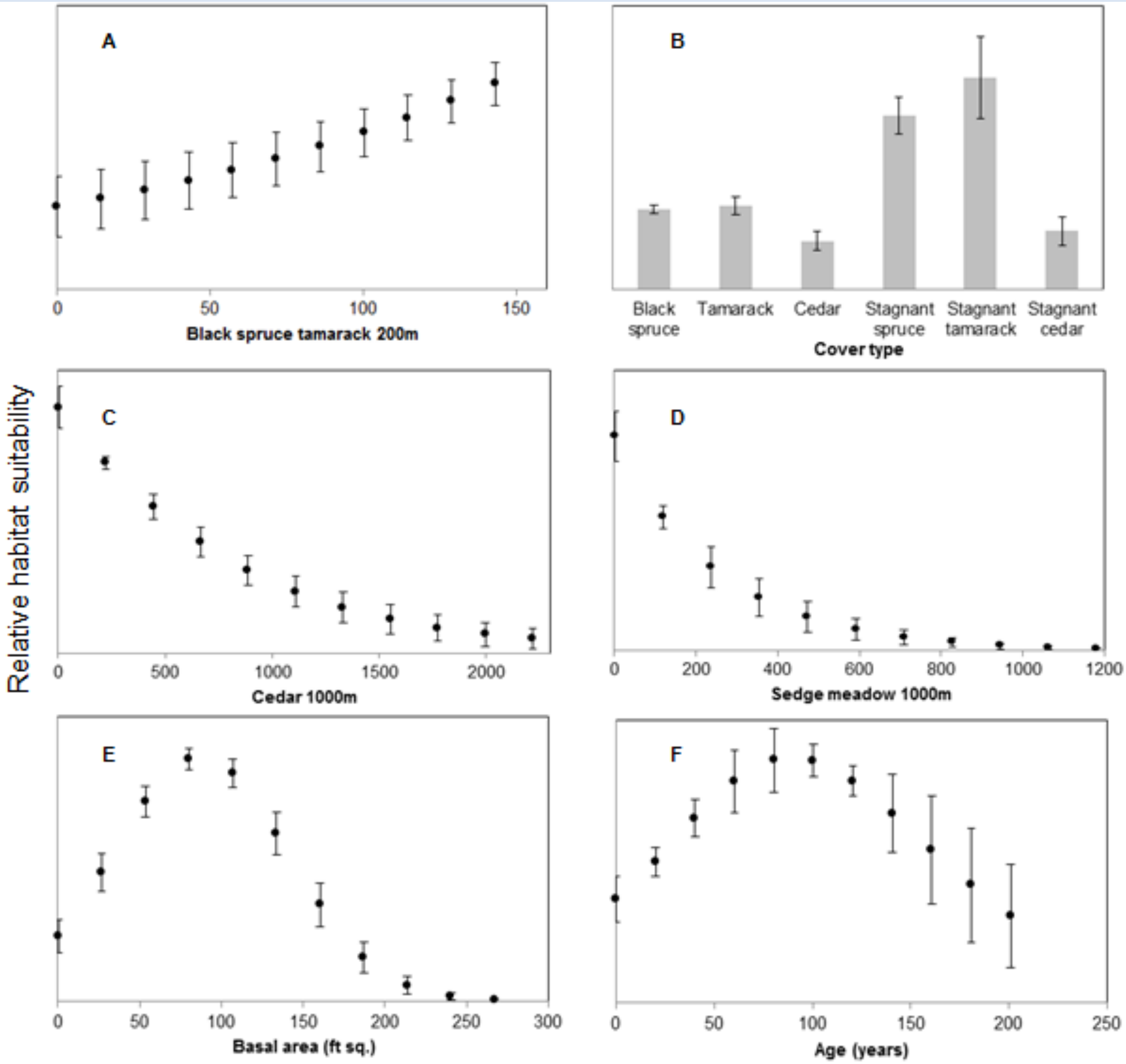


Figure 2: Connecticut Warbler response to environmental predictors used to model breeding habitat in the Agassiz Lowlands Subsection. Data points represent averages of five-fold cross-validation, error bars are one standard deviation. X-axes for landcover variables (panes A, C, D) are scaled according to the number of 30 m grid cells of the given landcover type within the given buffer size e.g. 200m buffer has a maximum of 149 grid cells.

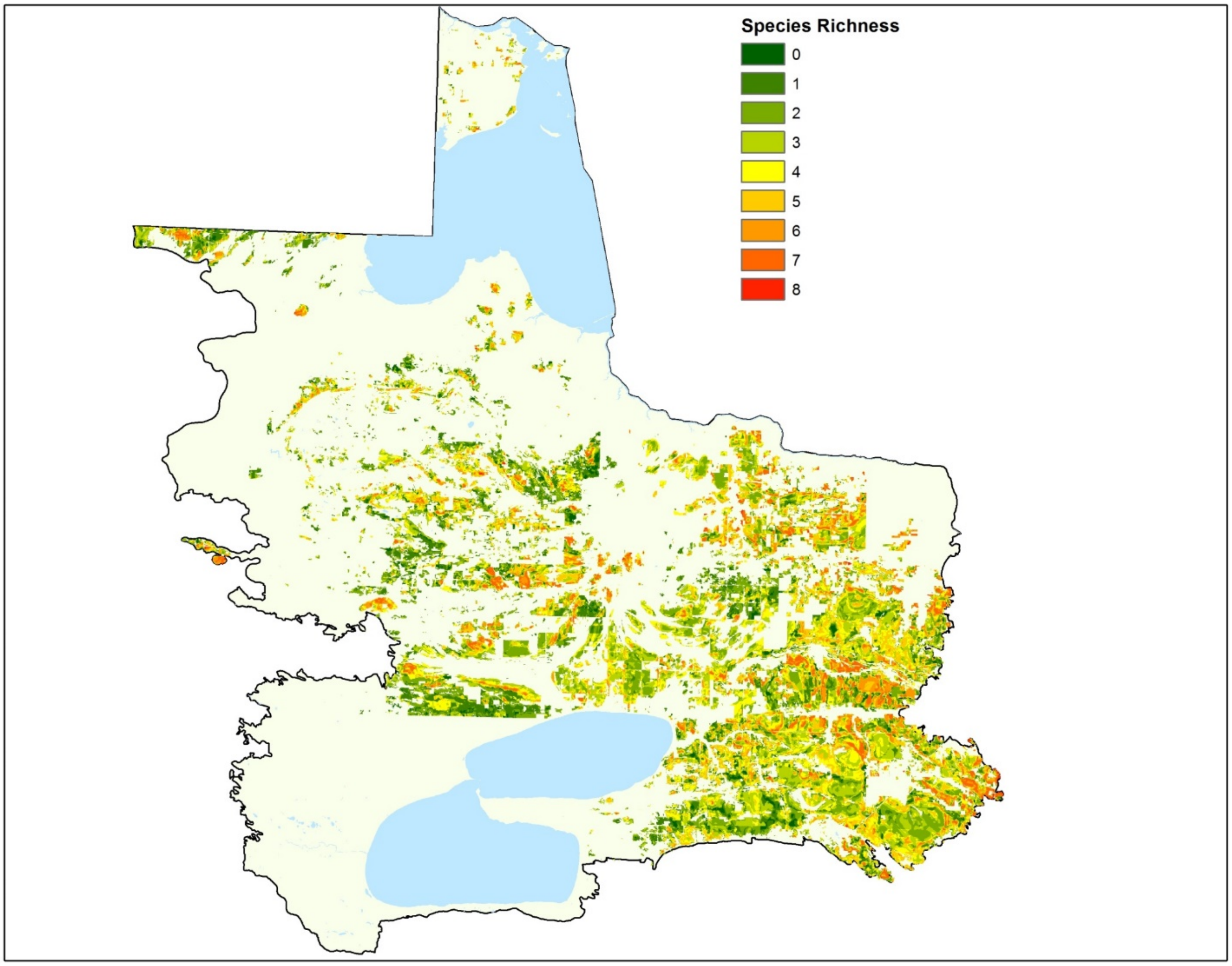


Figure 3: Predicted species richness of selected boreal birds breeding in the Agassiz Lowland Subsection of Minnesota state-owned land. Binary suitability maps (Appendix F) for six species were overlain to estimate the number of species potentially breeding in a given area. All species modelled were included; Yellow-bellied Flycatcher, Boreal Chickadee, Ruby-crowned Kinglet, Golden-crowned Kinglet, Swainson's Thrush, Connecticut Warbler, Palm Warbler, and Dark-eyed Junco.

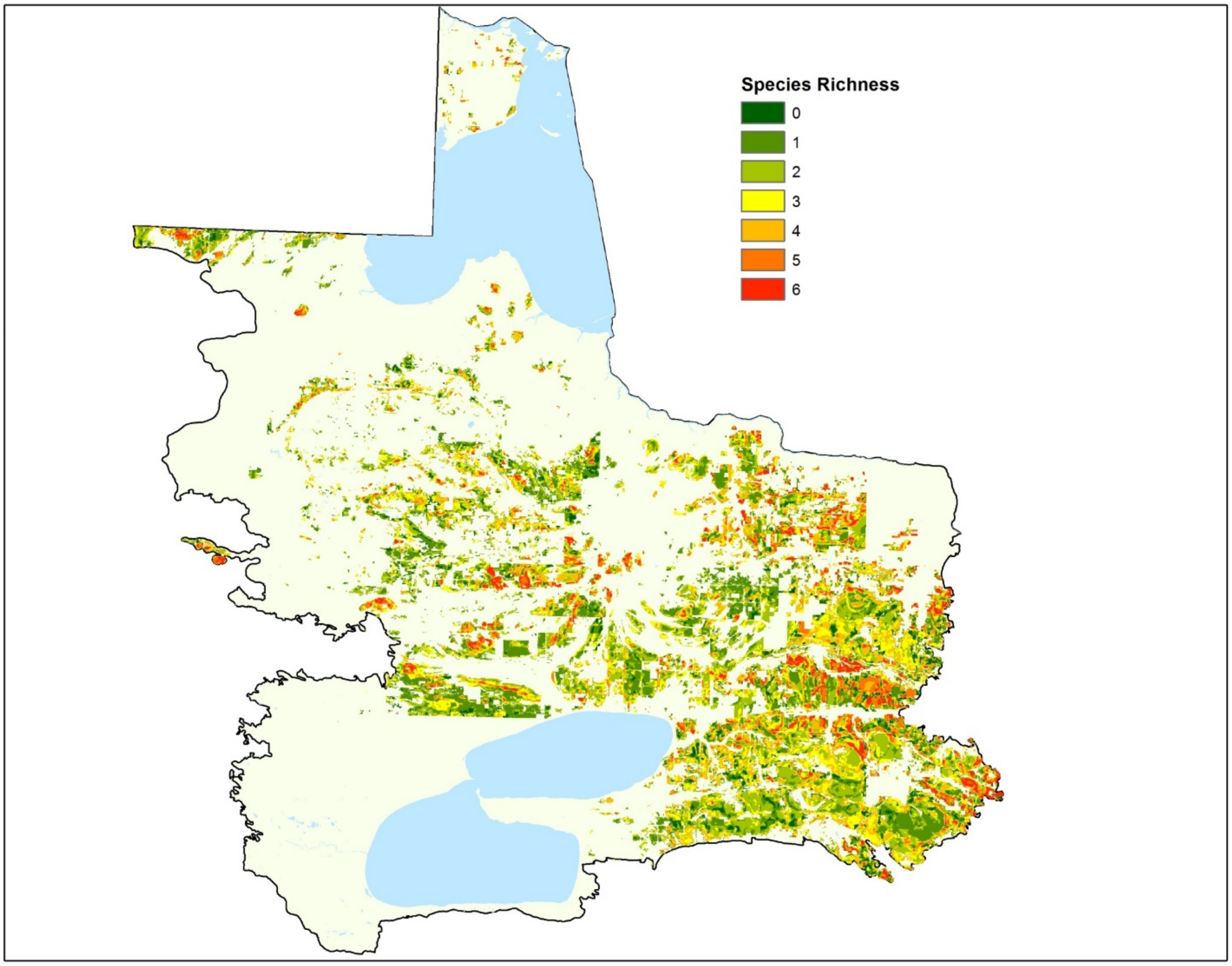


Figure 4: Predicted species richness of selected boreal birds breeding in the Agassiz Lowland Subsection of MN state-owned land. Binary suitability maps (Appendix F) for six species were overlain to estimate the number of species potentially breeding in a given area. Only species potentially affected by lowland conifer harvest were included; Yellow-bellied Flycatcher, Boreal Chickadee, Ruby-crowned Kinglet, Golden-crowned Kinglet, Connecticut Warbler, Dark-eyed Junco.

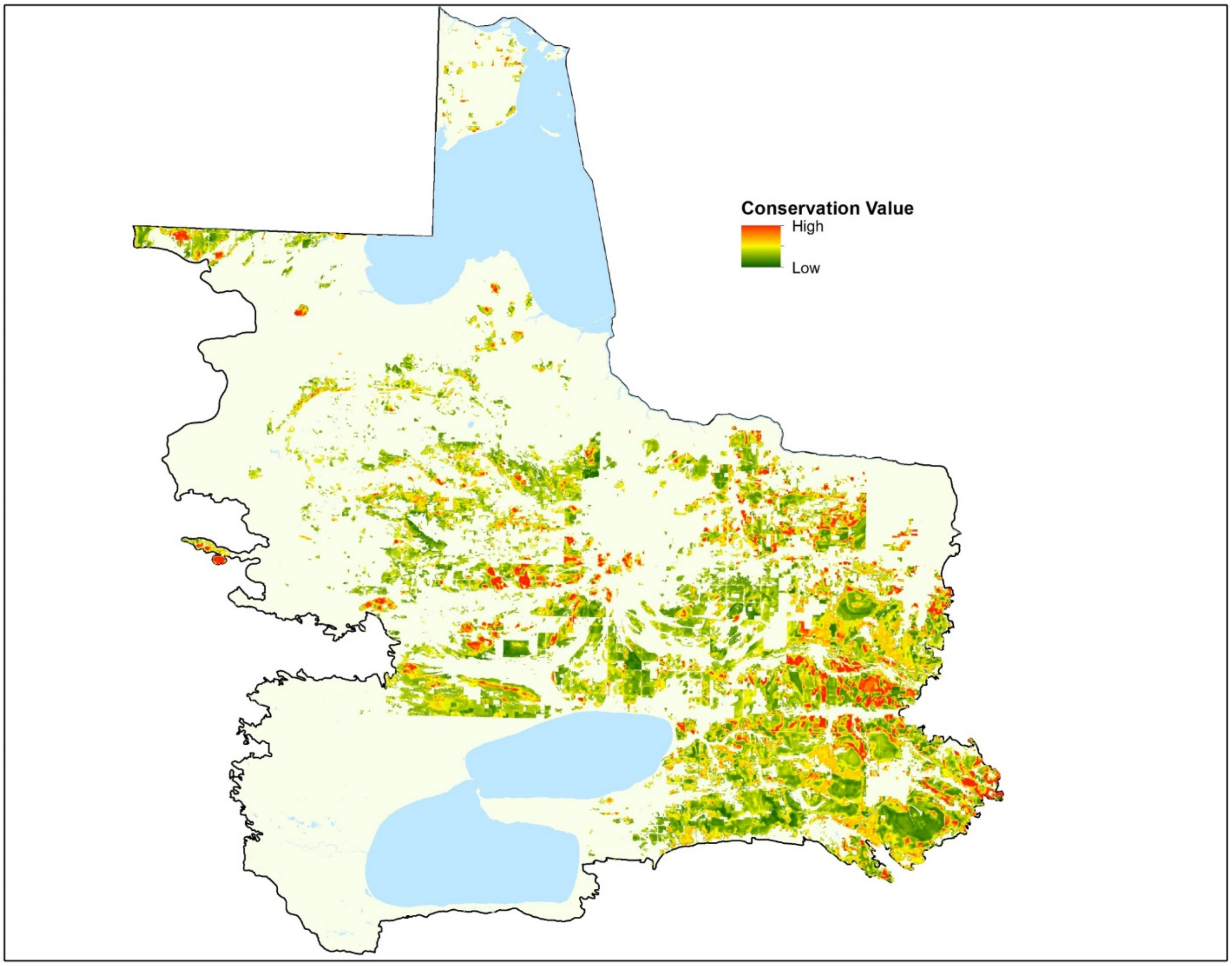


Figure 5: Conservation value of lowland conifer forests in the Agassiz Lowland Subsection of MN state-owned land as determined by distributions of selected boreal bird species. Probability of occurrence was calculated for each individual species map (Appendix F), then each map was weighted and summed between the six species potentially affected current lowland conifer harvest. To ensure that uncommon species were influential, the inverse of each species' frequency of observation at sample points was used as the weighting factor.

Appendix A. Bird abundances 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 (singing, calling, etc). 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)
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)
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)
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)
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)
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)

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)
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)
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)
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)
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)
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)
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)
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)
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)

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*)	0.0 (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)
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)
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)
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)
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)
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)
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)

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)
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)
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)
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)
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)
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)
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)
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)

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)
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)
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)
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)
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)
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)
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)
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)
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)

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*)	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)
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)
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)
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)
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)
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)
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)
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)
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)

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)
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)
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)
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)

Appendix B. 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 found at the bottom of the dendrogram (red boxes), represent forest cover types found within the ALS. Interpretations of cover types are provided in text boxes in the dendrogram.

Appendix C. 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 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), DBH (inches) and height (meters). Site level data were visually estimated by observers at each census point. Site level data summarized for combined data variables (e.g. Black Sprucel Tamarack DBH) were weighted according to proportion of cover within 100 meter limited distance sample point. Stand level data were summarized from Minnesota Department of Natural Resources – Forestry Inventory Management database (MNDNRl FIM). Landscape data were 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	7.1 (0.4)	6.0 (1.1)	9.9 (1.5)	3.0 (0.2)	4.7 (0.4)	5.1 (0.4)	5.5 (0.3)	6.1 (0.3)	5.9 (0.4)	4.4 (1.2)	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	4.9 (0.5)	4.8 (1.3)	7.5 (1.4)	0.0 (0.0)	3.0 (0.0)	3.5 (0.1)	4.4 (0.2)	0.0 (0.0)	4.9 (0.3)	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	6.6 (0.5)	5.7 (0.7)	6.0 (0.0)	3.1 (0.2)	4.9 (0.4)	4.9 (0.5)	5.4 (0.2)	6.1 (0.4)	5.9 (0.4)	2.0 (0.6)	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 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
Black Spruce-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-Cedar-Balsam Fir DBH	7.0 (0.4)	7.2 (1.5)	9.9 (1.5)	3.1 (0.2)	4.8 (0.4)	5.1 (0.5)	5.3 (0.3)	6.1 (0.4)	5.8 (0.4)	2.0 (0.6)	Site
Black Spruce-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	6.7 (0.4)	5.4 (0.7)	6.0 (0.0)	3.0 (0.2)	4.7 (0.4)	4.9 (0.4)	5.8 (0.4)	6.1 (0.3)	5.8 (0.4)	4.4 (1.2)	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
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
Cedar DBH	7.4 (0.5)	13.3 (3.2)	10.4 (1.7)	0.0 (0.0)	5.0 (0.4)	5.8 (0.6)	5.5 (0.3)	5.0 (0.0)	7.0 (0.5)	0.0 (0.0)	Site
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

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
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
Cedar-Balsam Fir DBH	7.1 (0.4)	8.2 (1.8)	10.0 (1.5)	0.0 (0.0)	4.2 (0.1)	5.4 (0.5)	5.1 (0.3)	5.0 (0.0)	6.4 (0.4)	0.0 (0.0)	Site
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
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	5.3 (0.4)	5.0 (0.8)	7.4 (0.8)	0.0 (0.0)	0.0 (0.0)	4.8 (0.5)	5.8 (0.3)	0.0 (0.0)	4.5 (0.4)	6.0 (1.2)	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
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	7.4 (0.4)	6.3 (1.3)	10.2 (1.7)	3.0 (0.2)	4.7 (0.4)	5.3 (0.5)	5.7 (0.4)	6.2 (0.3)	6.1 (0.4)	4.4 (1.2)	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

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
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	6.6 (0.4)	5.1 (0.6)	6.0 (0.0)	2.7 (0.2)	4.7 (0.4)	5.3 (0.4)	6.5 (0.6)	6.1 (0.3)	5.5 (0.3)	4.8 (1.3)	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
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
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
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

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 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
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-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-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-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
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
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
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

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
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
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

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 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
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

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 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

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
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
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

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 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

Appendix D. 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 per cover type are 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 (inches) and height (meters). Site level data were visually estimated by observers at each census point. Site level data summarized for combined data variables (e.g. black sprucev tamarack DBH) were weighted according to proportion of cover within 100 meter limited distance sample point. Stand level data were summarized from Minnesota Department of Natural Resources – Forestry Inventory Management database (MNDNRv 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 black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Data
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	(5-10)	(2-13)	(5-14)	(2-4)	(3-7)	(2-8)	(3-8)	(5-9)	(3-10)	(2-10)	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	(1-8)	(2-8)	(5-11)	(0-0)	(3-3)	(3-4)	(4-6)	(0-0)	(3-7)	(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

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 black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Data
Black Spruce DBH	(3-10)	(3-8)	(6-6)	(2-4)	(3-7)	(2-8)	(3-8)	(5-9)	(2-9)	(1-3)	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-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-Cedar-Balsam Fir DBH	(4-10)	(2-15)	(5-14)	(2-4)	(3-7)	(2-8)	(3-7)	(5-9)	(3-10)	(1-3)	Site
Black Spruce-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
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
Black Spruce-Tamarack DBH	(3-10)	(2-9)	(6-6)	(2-4)	(3-7)	(2-8)	(3-9)	(5-9)	(2-9)	(2-10)	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
Canopy Height (m)	(9-17)	(5-16)	(13-22)	(5-14)	(8-18)	(6-18)	(7-17)	(7-22)	(7-22)	(2-11)	Site
Cedar % Cover	(29-75)	(0-43)	(9-100)	(0-0)	(0-20)	(0-81)	(0-62)	(0-26)	(0-57)	(0-0)	Site
Cedar DBH	(4-12)	(6-24)	(5-15)	(0-0)	(4-6)	(3-9)	(4-8)	(5-5)	(4-12)	(0-0)	Site
Cedar Height	(8-14)	(4-16)	(7-15)	(0-0)	(4-9)	(4-13)	(7-13)	(8-8)	(5-15)	(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 black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Data
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
Cedar-Balsam Fir DBH	(4-11)	(2-15)	(5-14)	(0-0)	(4-4)	(3-8)	(4-8)	(5-5)	(4-10)	(0-0)	Site
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
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	(3-8)	(2-7)	(6-9)	(0-0)	(0-0)	(3-8)	(4-8)	(0-0)	(3-7)	(4-8)	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
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	(5-11)	(2-15)	(5-15)	(2-4)	(3-7)	(2-8)	(3-8)	(5-9)	(3-11)	(2-10)	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

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 black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Data
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	(5-9)	(2-9)	(6-6)	(2-4)	(4-7)	(4-10)	(3-11)	(5-8)	(3-8)	(2-10)	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
Age 2014	(66-179)	(15-135)	(133-135)	(24-159)	(53-163)	(41-133)	(42-195)	(97-159)	(42-195)	(8-27)	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

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 black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Data
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-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-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-Cedar 500	(0-96)	(5-36)	(15-60)	(11-81)	(12-100)	(1-54)	(0-71)	(62-95)	(0-97)	(0-24)	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
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
Cedar 1000	(2-54)	(0-36)	(9-36)	(0-5)	(0-30)	(1-43)	(0-57)	(1-24)	(0-47)	(0-27)	Landscape
Cedar 200	(0-100)	(0-21)	(9-82)	(0-11)	(0-56)	(0-67)	(0-85)	(0-12)	(0-91)	(0-11)	Landscape
Cedar 500	(0-82)	(0-29)	(15-55)	(0-5)	(0-45)	(0-48)	(0-63)	(0-14)	(0-54)	(0-10)	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

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 black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Data
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
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	(57.0-149.0)	(74.0-160.0)	(65.0-101.0)	(34.0-86.0)	(32.0-134.0)	(53.0-163.0)	(44.0-145.0)	(19.0-93.0)	(43.0-122.0)	(85.0-108.0)	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 black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Data
Number of Patches 200	(1.0-11.0)	(4.0-11.0)	(4.0-8.0)	(3.0-6.0)	(1.0-10.0)	(1.0-11.0)	(2.0-11.0)	(1.0-4.0)	(2.0-10.0)	(3.0-9.0)	Landscape
Number of Patches 500	(11.0-38.0)	(26.0-59.0)	(17.0-34.0)	(11.0-29.0)	(3.0-43.0)	(18.0-48.0)	(18.0-42.0)	(6.0-26.0)	(9.0-43.0)	(26.0-41.0)	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
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	(9.0-17.0)	(9.0-14.0)	(14.0-17.0)	(7.0-15.0)	(9.0-17.0)	(8.0-17.0)	(8.0-17.0)	(8.0-14.0)	(9.0-18.0)	(12.0-19.0)	Landscape
Patch Richness 200	(1.0-6.0)	(3.0-5.0)	(4.0-6.0)	(2.0-5.0)	(1.0-6.0)	(1.0-7.0)	(2.0-8.0)	(1.0-4.0)	(2.0-7.0)	(3.0-5.0)	Landscape
Patch Richness 500	(5.0-12.0)	(8.0-11.0)	(10.0-12.0)	(5.0-10.0)	(3.0-15.0)	(7.0-11.0)	(6.0-12.0)	(4.0-10.0)	(6.0-13.0)	(6.0-12.0)	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

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 black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Data
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
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

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 black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Data
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
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

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 black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)	Data
Upland Open 500	(0-15)	(0-27)	(0-8)	(0-3)	(0-5)	(0-16)	(0-25)	(0-22)	(0-20)	(1-19)	Landscape

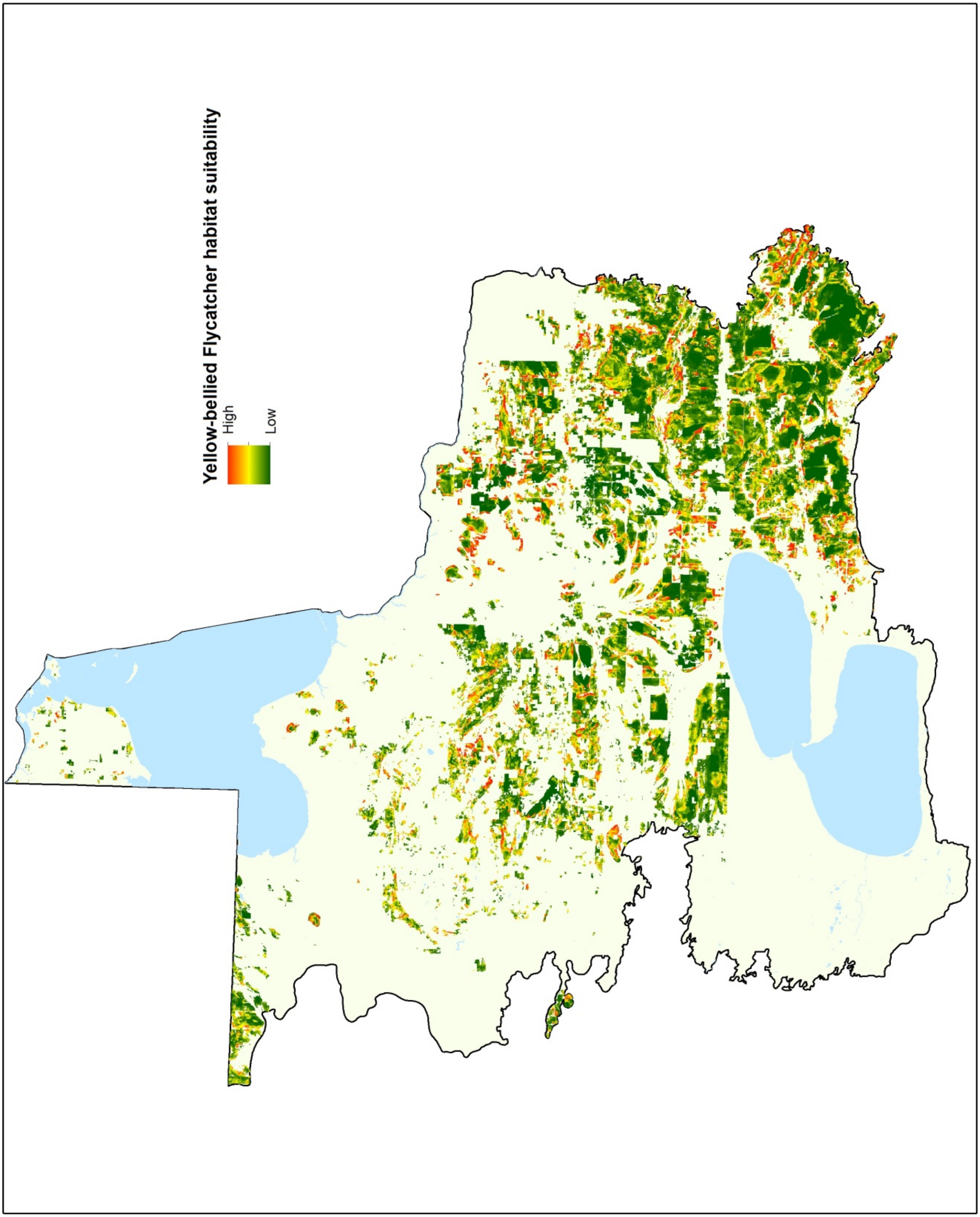
Appendix E. Percent perfect indication (PPI) values from an indicator species analysis (Dufrene and Legendre 1997) for 48 species within forest cover types in the Agassiz Lowland Subsection, Minnesota. PPI values represent a species affinity for a cover type. PPI takes into account a species relative 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. Numbers of points within each cover type are listed in parenthesis. Significant PPI values for a cover type are in bold numbers and if highly significant (p<0.01) an asterisk is included.

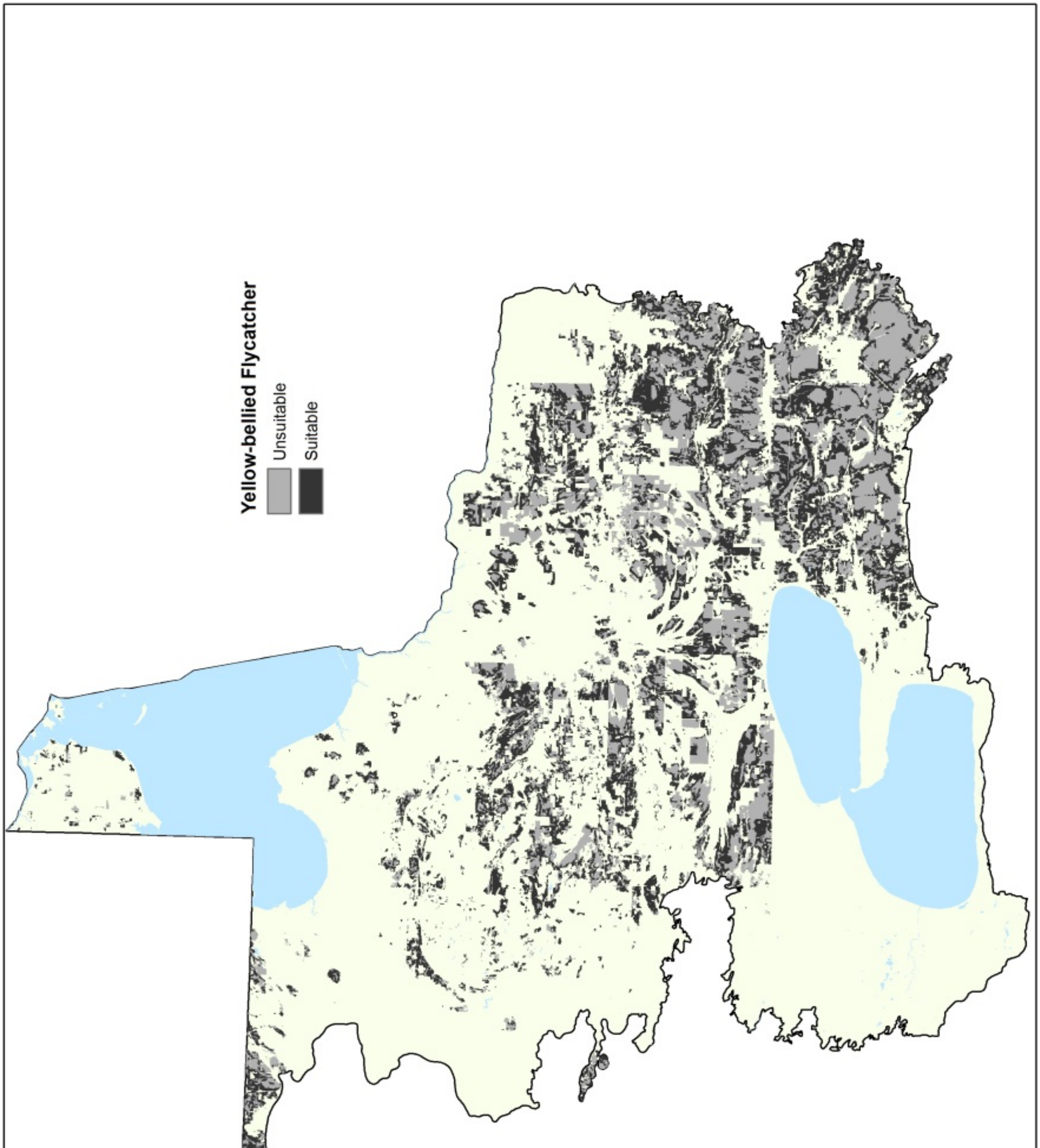
Common and Scientific Name	Mixed lowland white cedar (17)	Eastern Larch Beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer-(landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)
Alder Flycatcher *	0	8	0	2	0	1	0	0	0	**24**
American Robin	0	0	3	0	1	1	1	0	1	0
Black-and-white Warbler *	8	**12**	1	1	1	5	2	0	1	4
Blackburnian Warbler	**8**	2	0	0	0	0	3	0	1	0
Black-capped Chickadee *	1	1	**8**	0	0	1	1	0	0	0
Black-throated Green Warbler *	18	0	**49**	0	0	0	1	0	1	0
Blue Jay *	2	0	1	0	0	3	**10**	0	2	0
Blue-headed Vireo	1	0	1	0	4	2	1	1	4	0
Boreal Chickadee *	2	0	0	1	0	0	0	**9**	0	0
Brown Creeper	3	0	1	0	1	1	2	1	2	0
Cedar Waxwing	1	3	0	0	0	0	0	0	0	0
Chestnut Sided Warbler *	0	3	0	0	1	0	0	0	0	**14**
Chipping Sparrow	1	0	0	3	**8**	0	2	5	0	0

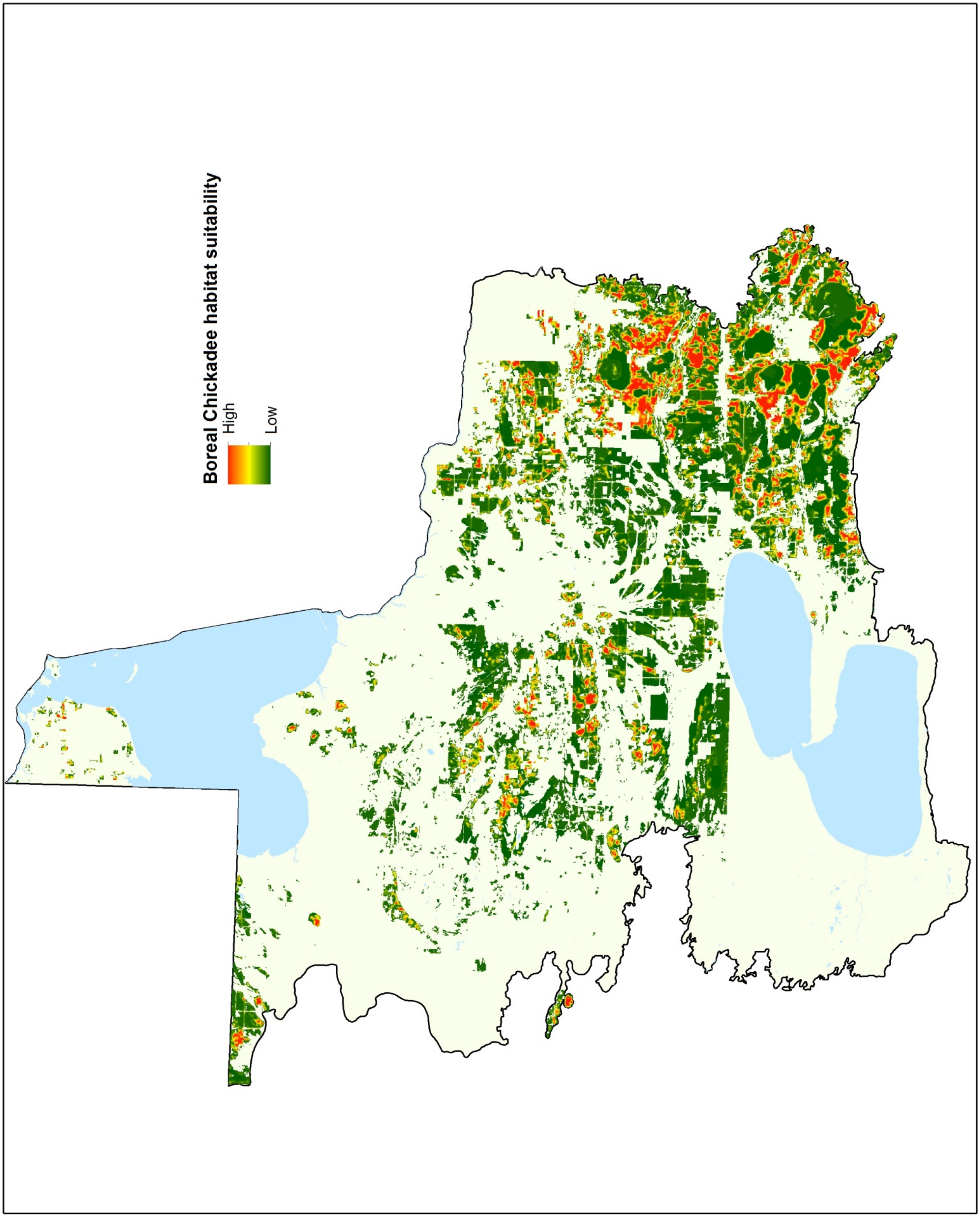
Common and Scientific Name	Mixed lowland white cedar (17)	Eastern Larch Beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer-(landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)
Common Raven	1	0	1	0	1	0	0	0	0	0
Common Yellowthroat *	0	26	0	1	0	0	1	0	0	**34**
Connecticut Warbler *	0	3	0	4	**40**	0	0	4	0	0
Dark-eyed Junco *	0	0	0	6	2	0	0	**20**	0	1
Golden-crowned Kinglet *	3	0	0	0	4	0	4	**10**	5	0
Gray Jay	1	0	0	0	0	0	1	3	2	0
Hairy Woodpecker	1	0	0	0	0	3	2	0	1	0
Hermit Thrush	4	0	1	1	5	0	2	1	1	0
Lincoln's Sparrow *	0	7	0	4	0	0	0	0	0	**9**
Magnolia Warbler	0	2	0	**7**	0	3	2	0	0	0
Mourning Dove	0	1	1	0	0	0	2	0	0	0
Mourning Warbler *	0	**11**	0	0	2	0	0	0	0	0
Nashville Warbler	8	9	4	12	8	9	9	3	11	3
Northern Flicker *	0	0	**7**	0	0	0	0	0	0	1
Northern Parula	1	0	5	0	0	2	0	0	1	0
Northern Waterthrush *	0	0	0	0	0	**11**	0	0	1	5
Olive-sided Flycatcher	0	2	0	0	0	1	0	3	0	0
Ovenbird *	3	3	**25**	0	0	1	3	0	0	0
Palm Warbler *	0	0	0	**68**	3	0	0	0	0	0

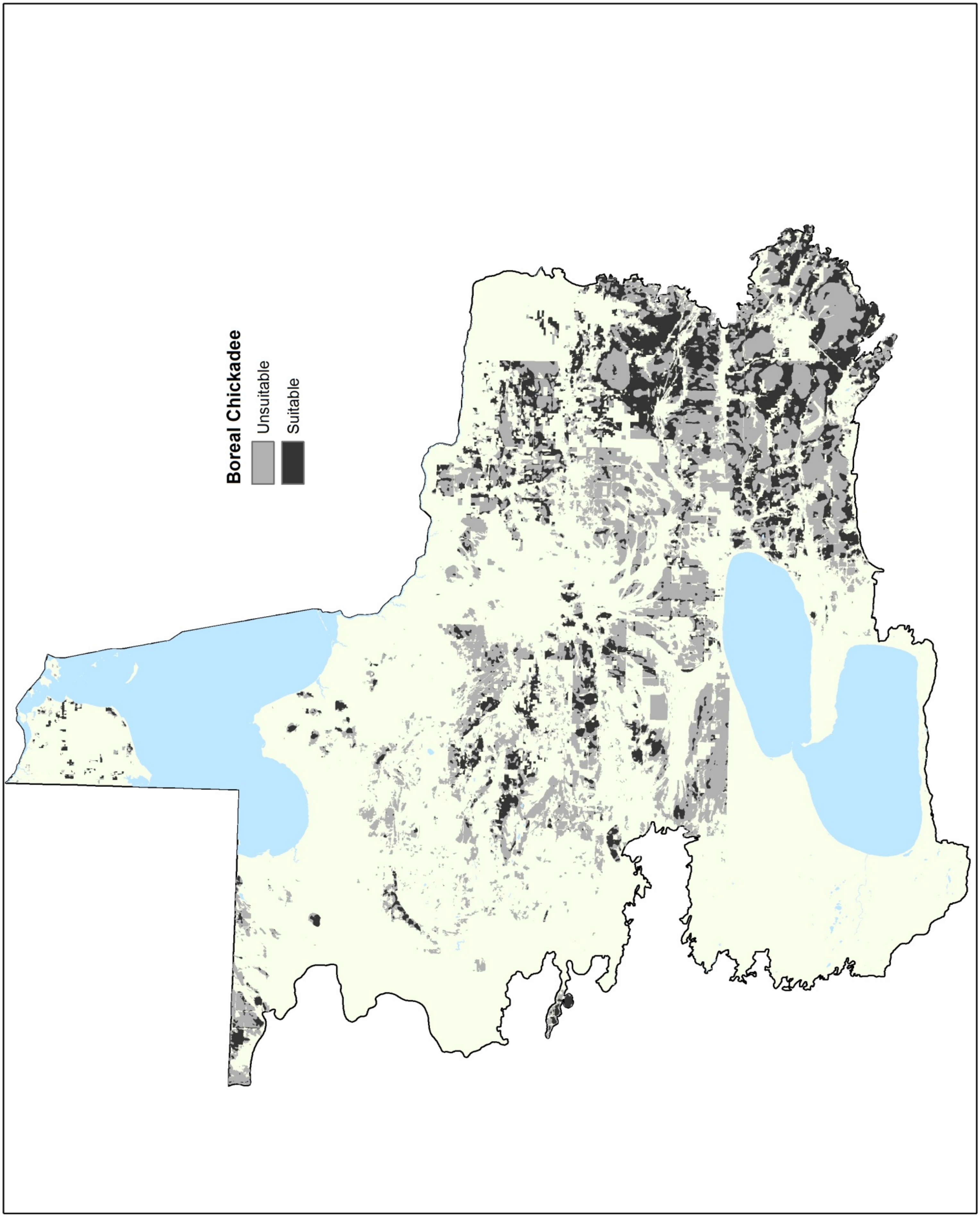
Common and Scientific Name	Mixed lowland white cedar (17)	Eastern Larch Beetle disturbance forests (9)	Northern white cedar (5)	Stagnant black spruce-tamarack bog (10)	Semi-productive black spruce-tamarack bog (12)	Mixed tamarack swamp conifer (15)	Mixed lowland conifer-(landscape) (19)	Productive (mature) black spruce-tamarack bog (12)	Mixed lowland conifer (25)	Recently harvested lowland conifers (6)
Purple Finch	2	1	2	0	0	1	0	1	1	0
Red-breasted Nuthatch	3	3	**6**	1	0	1	2	0	1	0
Red-eyed Vireo *	3	7	**17**	0	0	6	0	0	0	5
Rose-breasted Grosbeak	1	2	0	0	0	2	0	0	0	1
Ruby-crowned Kinglet	2	0	0	4	5	0	2	1	**6**	0
Ruffed Grouse *	0	**9**	0	0	0	0	1	0	0	0
Sedge Wren *	0	0	0	0	0	0	0	0	0	**33**
Swainson's Thrush *	**12**	0	0	0	0	0	0	0	4	0
Swamp Sparrow *	0	1	0	0	0	0	0	0	0	**68**
Veery	0	4	0	0	0	4	0	0	0	**6**
White-throated Sparrow *	1	**15**	0	3	6	14	3	0	1	4
Wilson's Snipe *	0	3	0	0	0	0	0	0	0	**12**
Winter Wren	5	4	0	0	0	**7**	4	1	2	0
Yellow-bellied Flycatcher *	12	1	0	9	11	3	0	1	15	0
Yellow-bellied Sapsucker *	0	0	**8**	0	0	0	2	0	0	0
Yellow-rumped Warbler *	3	2	0	5	**12**	4	6	7	10	0

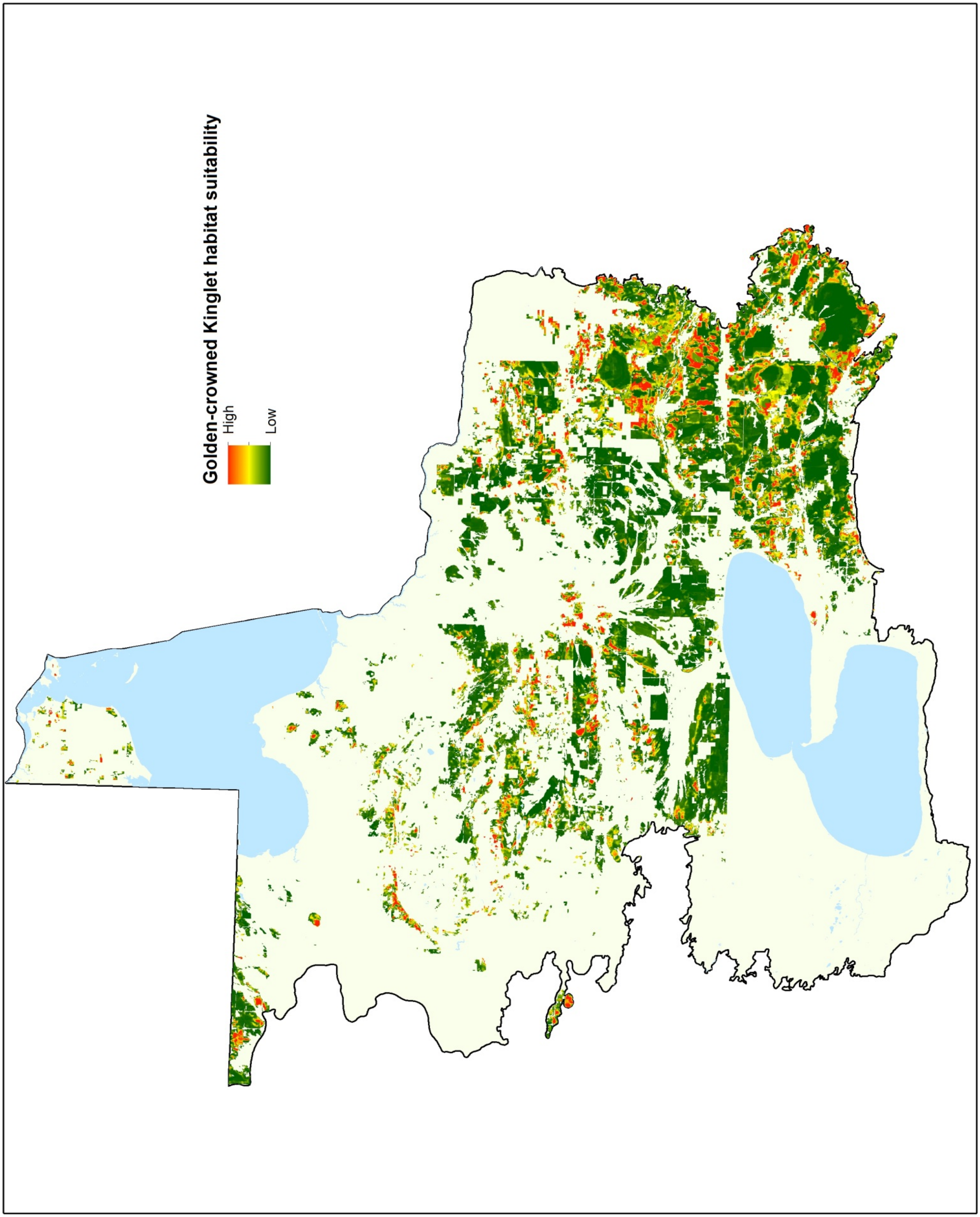
Appendix F: Relative habitat suitability index for boreal bird species breeding in the Agassiz Lowland Subsection of northern Minnesota. Raw Maxent output, rescaled to a cumulative index, is presented. Suitability scores should not be compared between species, rather, should be interpreted as a relative scale within each map. Thresholds were developed for each species' map (see methods), in order to create binary 'suitable' or 'unsuitable' maps.

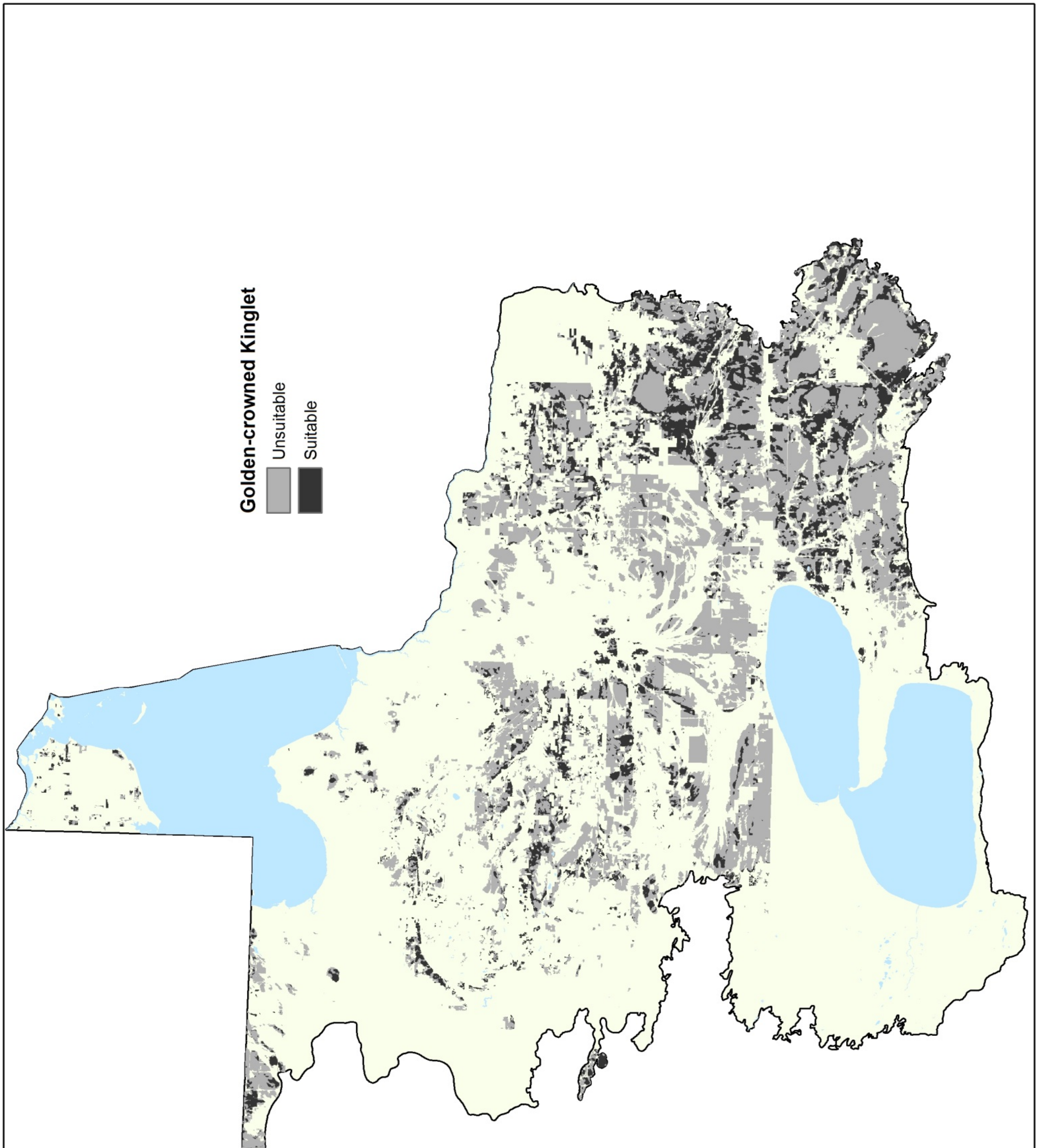

Yellow-bellied Flycatcher habitat suitability
High
Low

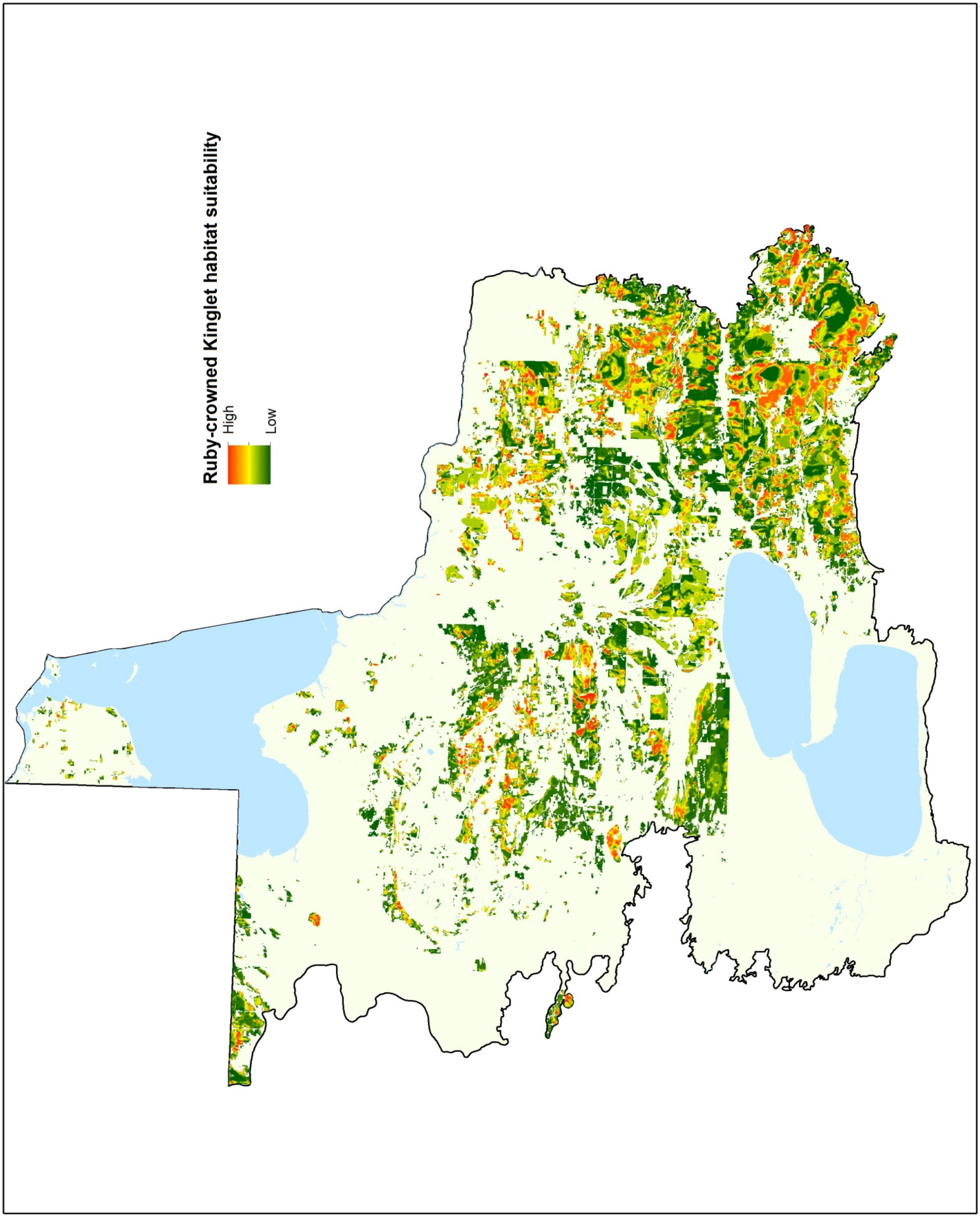

Yellow-bellied Flycatcher
Unsuitable
Suitable

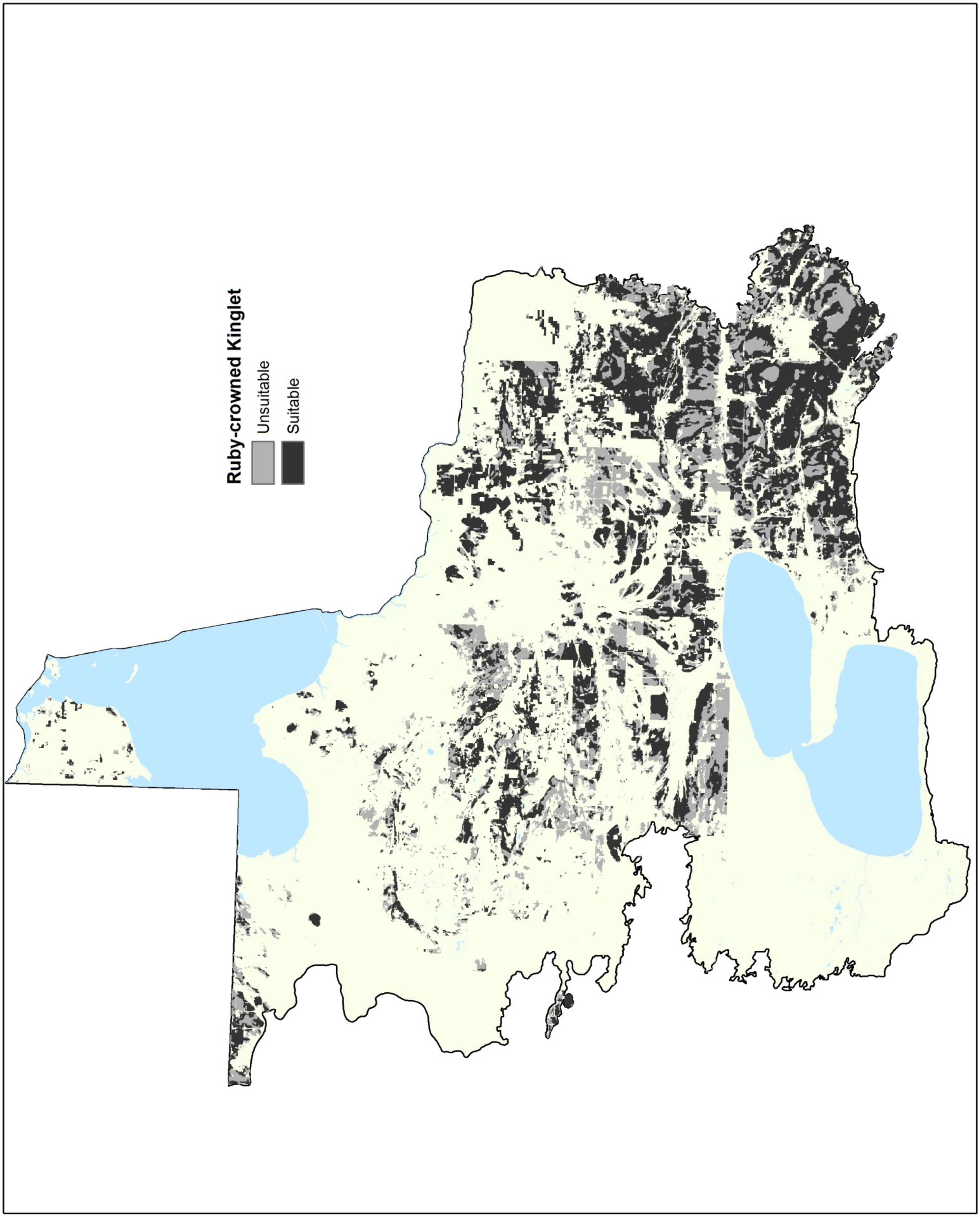

Boreal Chickadee habitat suitability
High
Low

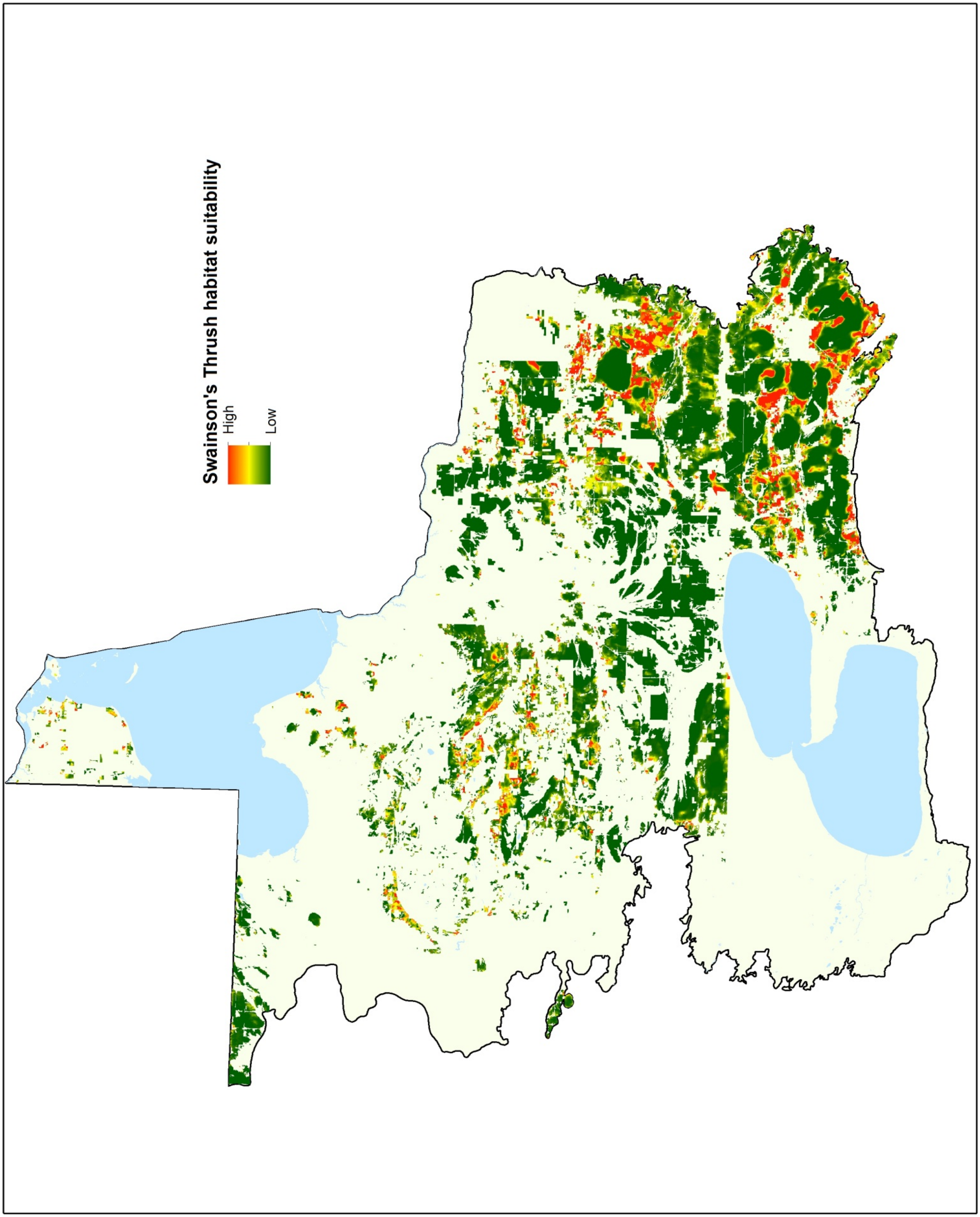

Boreal Chickadee
Unsuitable
Suitable

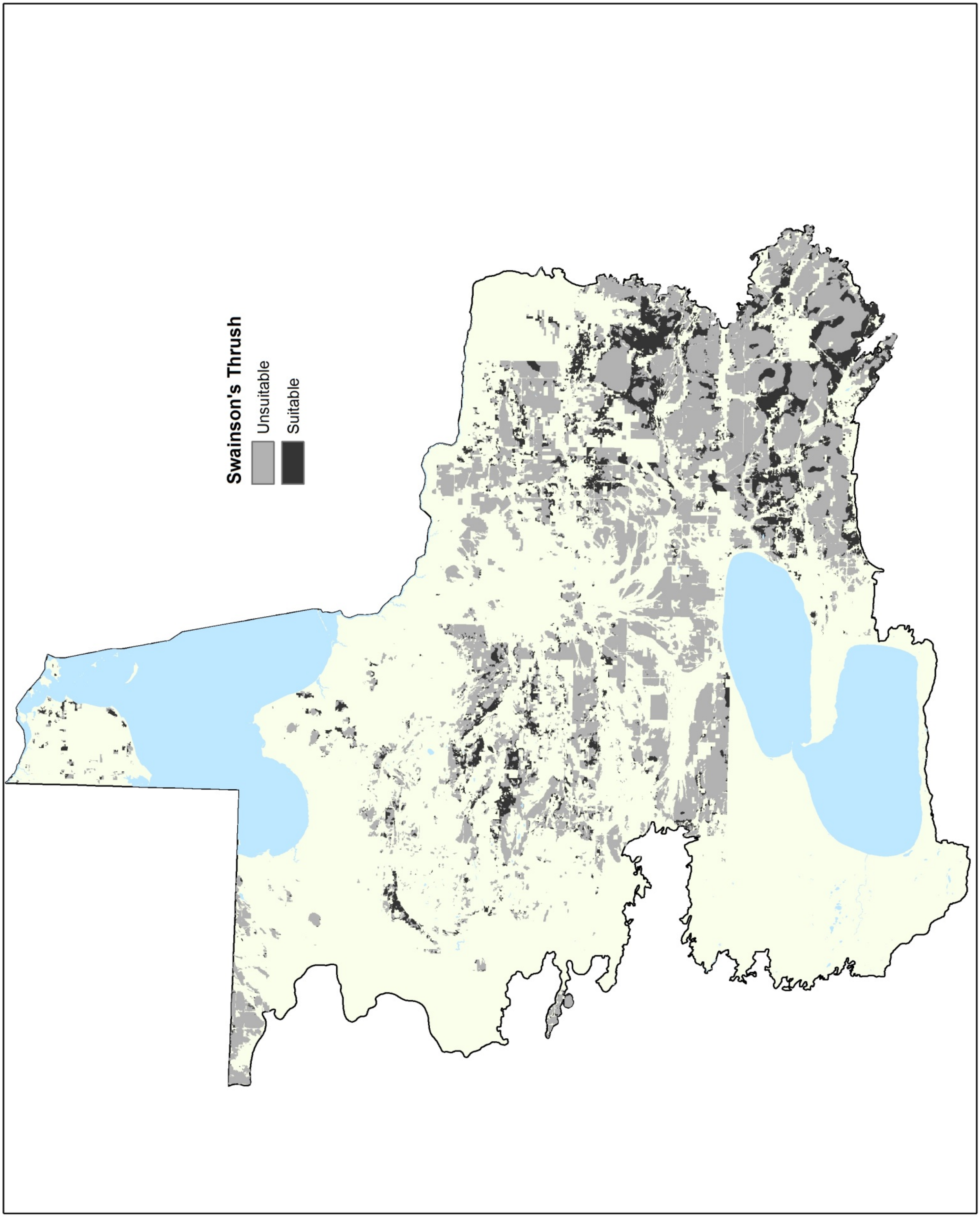

Golden-crowned Kinglet habitat suitability
High
Low

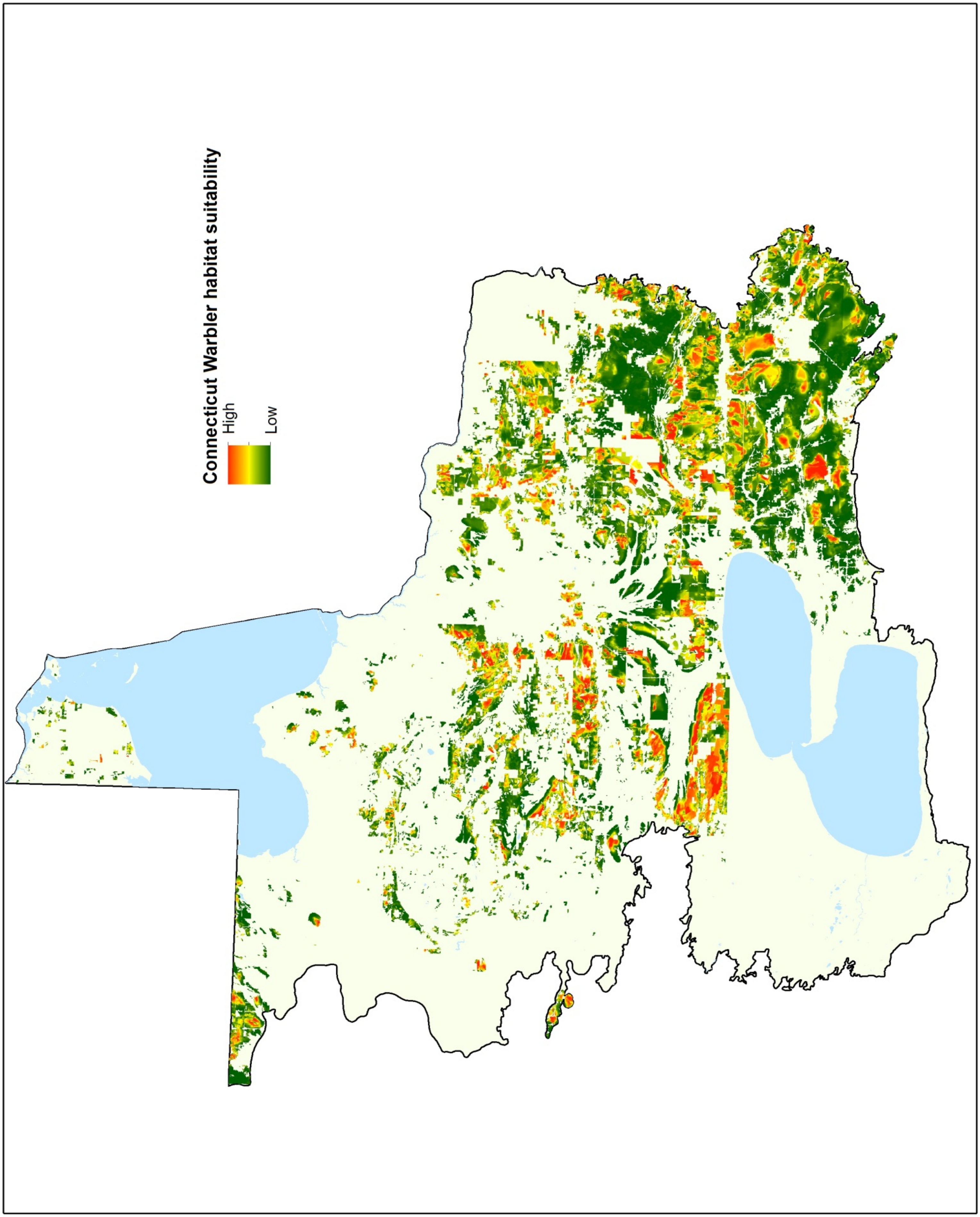

Golden-crowned Kinglet
Unsuitable
Suitable

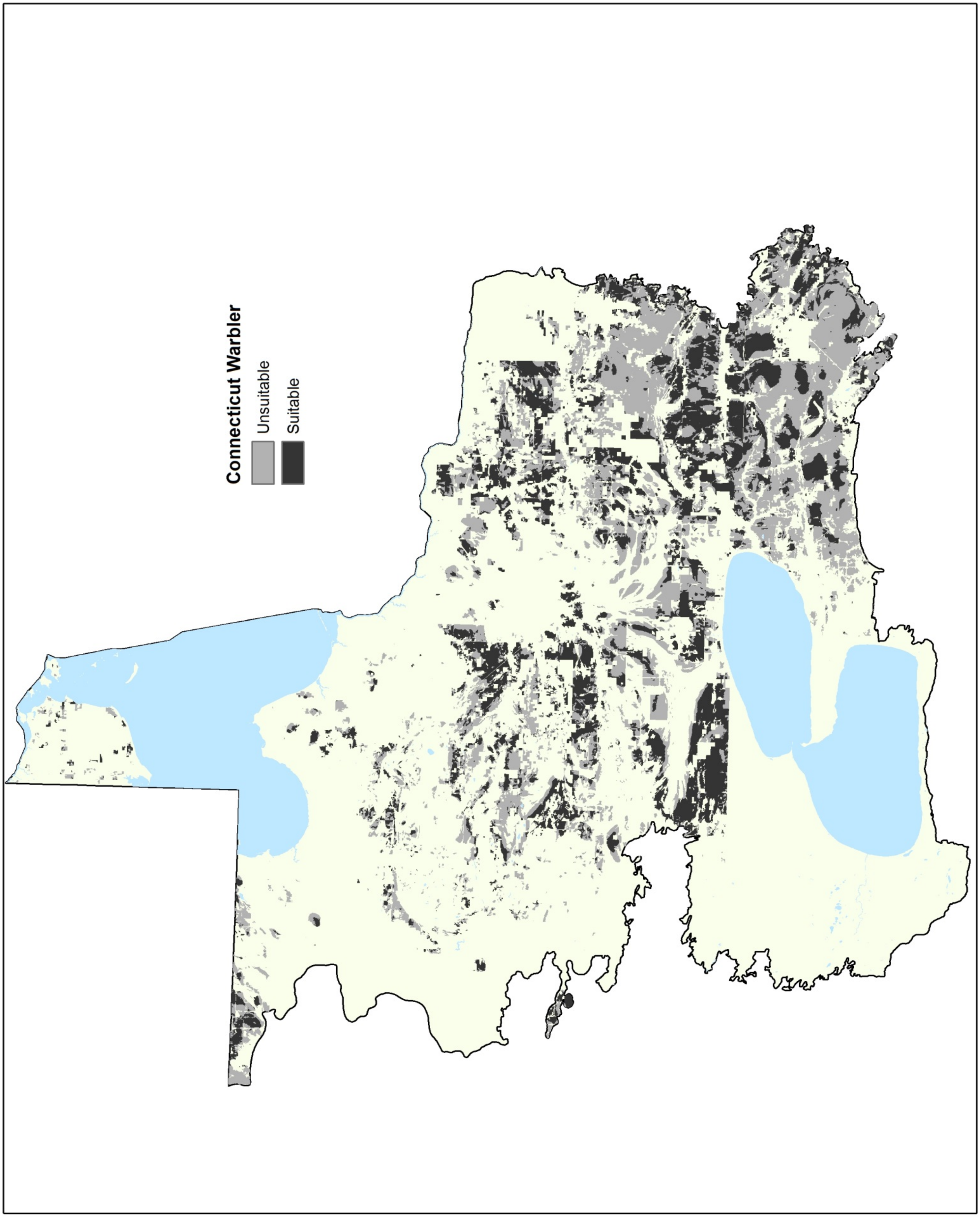

Ruby-crowned Kinglet habitat suitability
High
Low

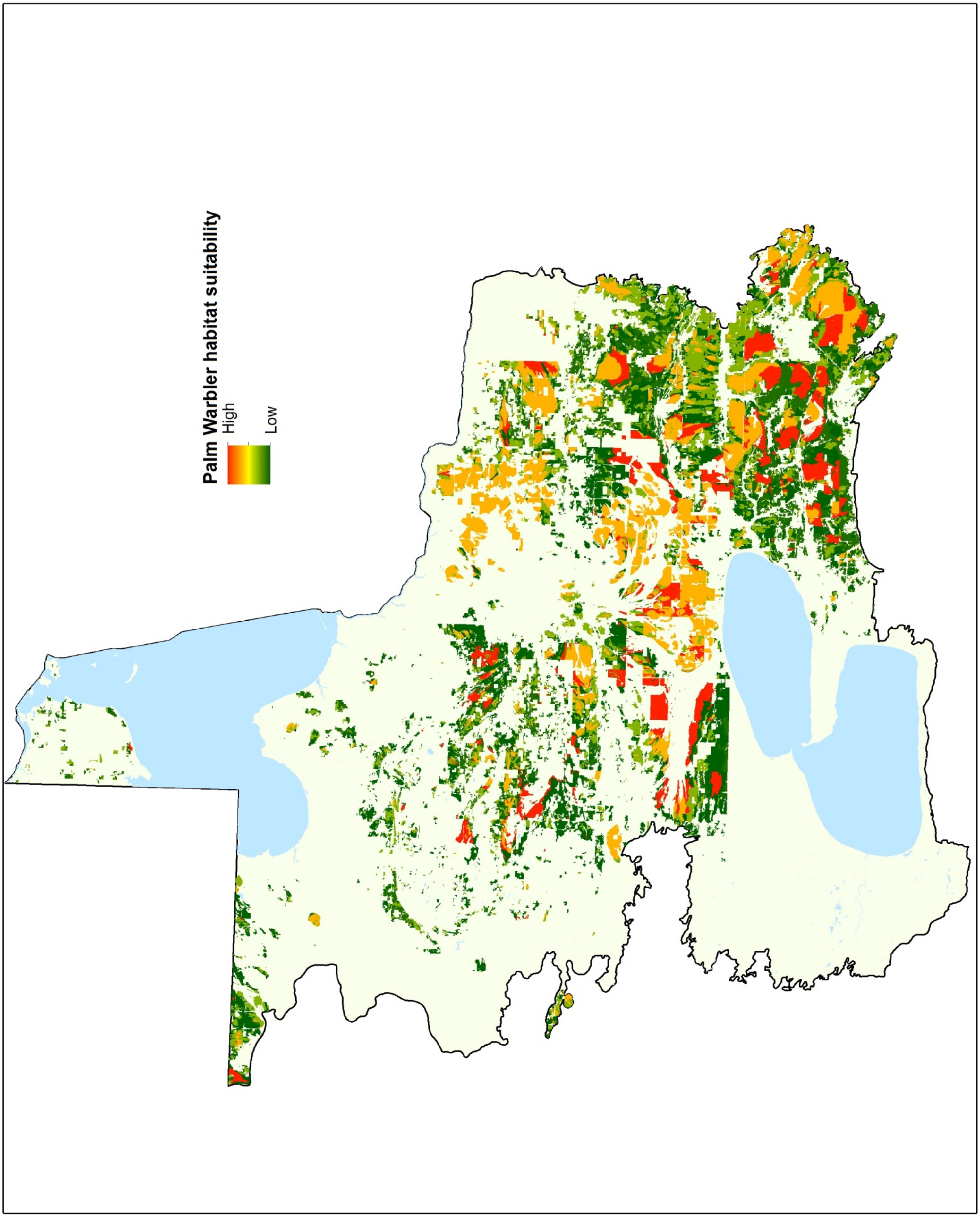

Ruby-crowned Kinglet
Unsuitable
Suitable

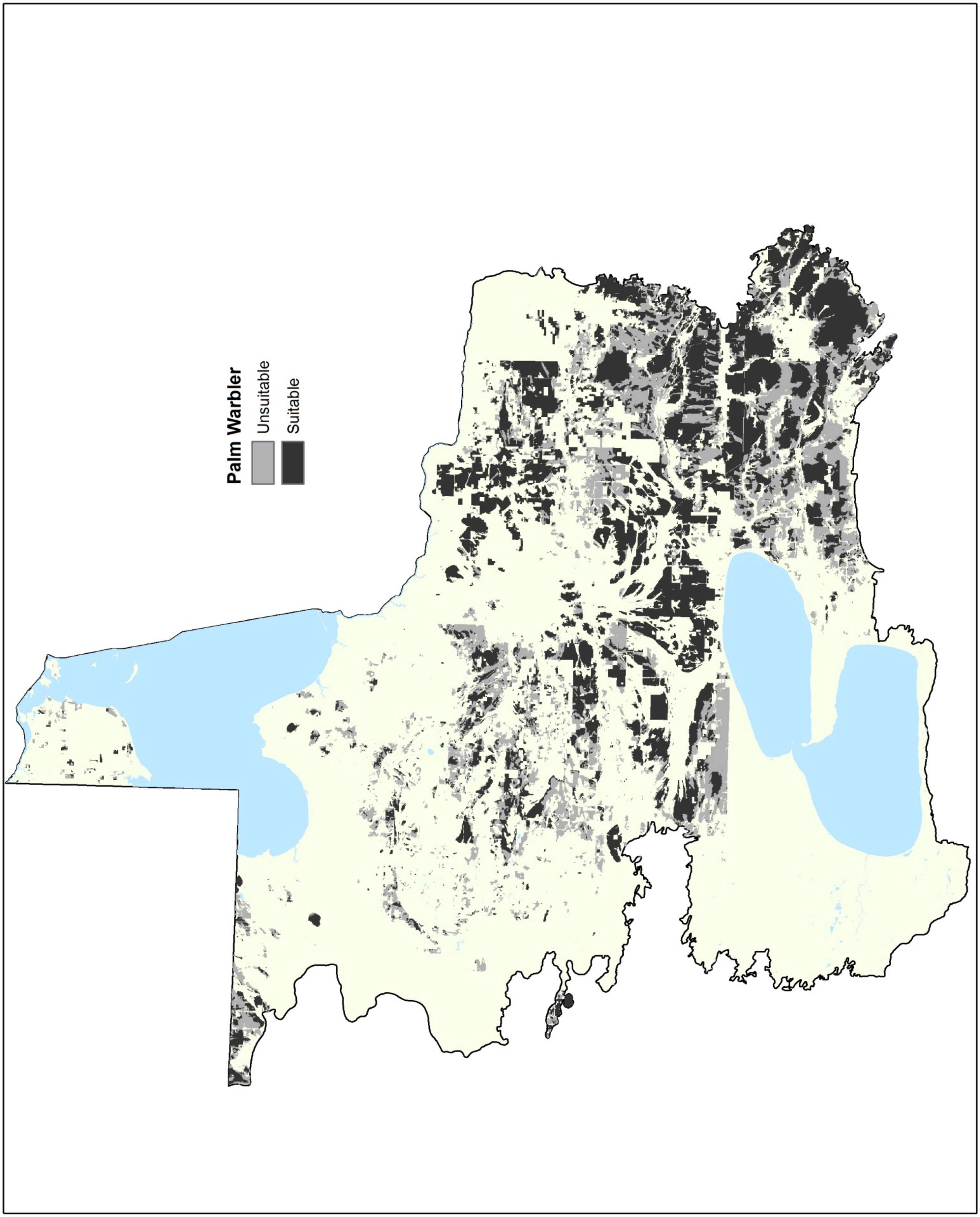

Swainson's Thrush habitat suitability
High
Low

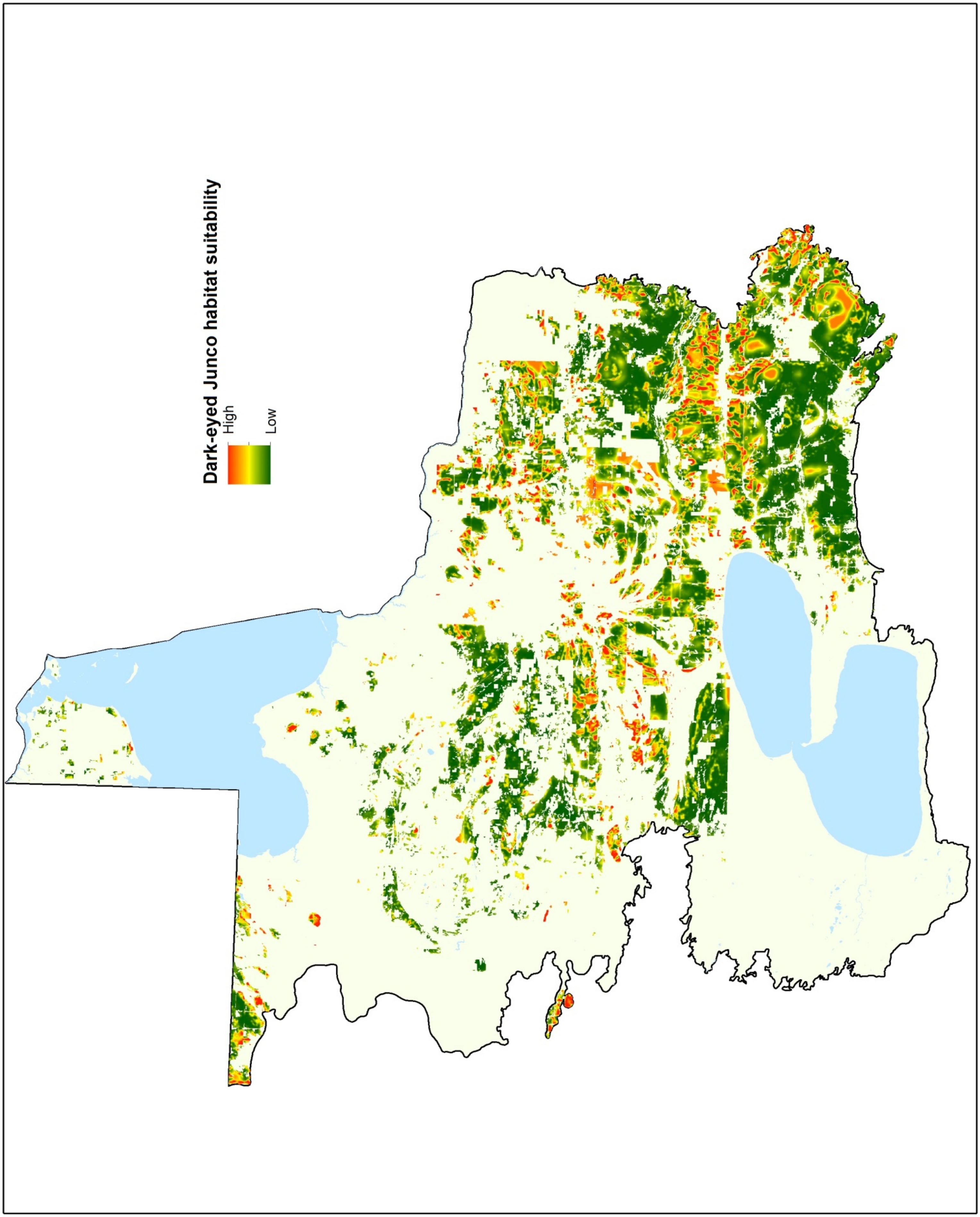

Swainson's Thrush
Unsuitable
Suitable


Connecticut Warbler habitat suitability
High
Low


Connecticut Warbler
Unsuitable
Suitable


Palm Warbler habitat suitability
High
Low


Palm Warbler
Unsuitable
Suitable


Dark-eyed Junco habitat suitability
High
Low


Dark-eyed Junco
Unsuitable
Suitable