Conservation planning for forests, tree species, and their genetic populations under climate change in Canada and the USA

by

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Abstract

Trailing edge tree populations at the warm or dry margins of a species' range often contain genetic traits that confer tolerance to environmental extremes. These traits may be valuable for supporting adaptation to future climates in other parts of the species' range, yet the populations that hold them are at heightened risk of loss under projected climate change if not actively conserved. This study presents a continental-scale analysis to identify trailing edge populations of the 100 most common North American tree species within the United States and Canada, systematically prioritize collection of at-risk populations, and to evaluate regions suitable for their long-term conservation through assisted migration.

Using a climate envelope modeling approach and 11 bioclimatic variables, we matched ecosystems historically occupied by a species (1960s baseline) with those projected to have similar climates under 2050s conditions (SSP2-4.5 scenario). Trailing edge populations were defined as those ecosystems where species lose suitable climate habitat by the 2050s. Conservation priorities were assessed using three criteria: (1) forest cover loss, indicating potential local extirpation due to fundamental niche limits; (2) climate velocity, estimating the geographic distance needed to track suitable conditions; and (3) the number of species with at-risk populations per ecosystem. These criteria were combined to identify jurisdictions where seed collections for assisted migration may have the greatest long-term value.

Our results show that trailing edge populations are concentrated in ecozones across the Appalachian region (in number of species with populations at risk), as well as the temperate mixed forests of Midwest and the southern boreal forest (proportional to local species richness). Summaries by jurisdiction with high predicted climate velocity and forest cover loss, such as states and provinces with forested areas bordering the central plains, are expected to have limited capacity for in situ persistence, highlighting a potential need for human intervention. Regions such as the Great Lakes basin and north-eastern Canada emerge as major prospective recipients of assisted migration due to high climate matching with trailing-edge populations and relatively stable forest potential under projected climates.

These findings are integrated in an online Protected Area Selection Tool for North America (http://tinyurl.com/PAST-NAm), which enables users to identify climatically suitable recipient protected areas or ecosystems for a source ecosystem and time period of interest. Limitations include the exclusive use of macroclimatic variables, ecosystem-level resolution, and the absence of projected uncertainty or non-analogue climate filters. The study provides a first assessment to support seed collection, in situ conservation, and climate-informed reforestation planning, with the understanding that species- and site-specific evaluations remain necessary for implementation.

Preface

This thesis is being prepared for submission as a journal article. Additional contributors to this publication are Andreas Hamann, Scott Nielsen, and Genevieve Dorrell. The study was conceived by AH, SN and NB. NB developed the natural land cover class prediction model, assessed population climate risk, and performed the conservation analysis with guidance from AH and SN. The study builds on ecozone-based species inventory and climate matching matrices developed by GD and AH. The web tool was programmed by AH, with input from NB and GD. Figures 1-3 were created by AH and GD based on the natural land cover class prediction model developed by NB. All other figures and tables were generated by NB. NB wrote a first draft of the thesis, reviewed and edited by AH.

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1 Introduction

Trailing edge tree populations, those occurring at the warmest or driest parts of a species' range, are focal points for conservation under climate change. Under shifting climates, these populations face range contractions or local extirpation, either because populations are outcompeted by species adapted to warmer environments or due to direct climate impacts when climates exceed physiological limits. Trailing edge populations are often genetically distinct, having evolved under frequent exposure to climatic extremes such as heat, drought, or otherwise marginal conditions. (Hampe & Petit, 2005; Lesica & Allendorf, 1995; Pelletier, Couture, & de Lafontaine, 2023). Under climate warming, such locally adapted populations with unique heat and drought tolerance traits are becoming increasingly valuable as parts of a species' current range begin to resemble the historical climate of its warm/dry edge. They may serve as important reservoirs of pre-adapted genotypes that can enhance resilience in other parts of the species' range, when used in assisted gene flow or assisted migration strategies (Aitken & Whitlock, 2013; O'Neill, Hamann, & Wang, 2008).

While trailing edge populations often exhibit lower genetic diversity within individual populations due to small population sizes and strong selective pressures, genetic differentiation between populations is typically high (Hampe & Petit, 2005). This can be especially pronounced in isolated populations where local adaptation can occur rapidly, leading to the emergence of distinct ecotypes. These isolated populations may harbor unique combinations of adaptive traits that are valuable for bolstering the climate resilience of other sites or populations (Macdonald, Llewelyn, Moritz, & Phillips, 2017). In other cases, trailing edge populations persist along elevation gradients where connectivity is maintained over time. Here, environmental heterogeneity and gene flow can sustain high within-population genetic diversity, providing strong evolutionary potential for future adaptation. Both types of trailing edge populations, isolated and rapidly evolving or connected and genetically diverse, may harbor value for conservation and adaptive management. For example, a recent study on jack pine (*Pinus banksiana*) found that trailing edge populations displayed lower and more variable serotiny than core populations, an adaptive trait that may enhance resilience in regions with infrequent fire regimes (Pelletier et al., 2023). Adaptive traits such as these, along with the observed genetic differentiation among trailing edge populations, make them important targets for genetic conservation even if the species as a whole is not currently threatened.

Alongside their evolutionary significance, trailing edge forests in North America face heightened threats due to the combined impacts of climate change, altered disturbance regimes, and human land use. In western regions, increased wildfire frequency and severity driven by prolonged drought and warming temperatures are major drivers of ongoing forest change (Parks, Dobrowski, Shaw, & Miller, 2019; Rodman, Crouse, Donager, Huffman, & Meador, 2022). Recent findings already show evidence of present-day climate warming pushing these already water-limited ecosystems beyond their historical thresholds, leading to regeneration failure and increased tree mortality (Rodman et al., 2022; Worrall et al., 2013). In the eastern and central parts of the continent, trailing edge tree populations often occupy low-elevation sites with productive soils and warmer climates (Parks et al., 2019), the same landscapes that have largely been converted to agriculture or have been subject to urban development. This habitat loss and fragmentation from land-use change further isolate and reduce the viability of warm-adapted tree populations (Rhoades et al., 2024).

Climate change over the past several decades has already led to measurable effects to populations of many North American tree species. Climate envelope modeling indicates that populations are already experiencing a lag between their historical climatic niches and current local climates, estimated at approximately 310 km in latitude or 140 m in elevation as of the 2020s (L. K. Gray & Hamann, 2013). While species as a whole may persist, populations at the trailing edge are among the first to encounter conditions that exceed their physiological limits. For example, trembling aspen (*Populus tremuloides*) has experienced widespread branch dieback and mortality in marginal habitats where climatic suitability has declined (Worrall et al., 2013). While climatic maladaptation may not immediately result in local extirpation and range contraction, it is expected to compromise forest resilience and increase the likelihood of abrupt transitions following disturbances such as fire, insect outbreaks, or drought. Such events have become more frequent and severe under climate change (Parks et al., 2019; Seidl et al., 2017), and as a consequence, trailing edge populations are already being impacted (Rodman et al., 2022).

Given these risk factors, it is unlikely that natural mechanisms such as gene flow, seed dispersal, and evolutionary processes will allow tree populations to cope with the rate of observed and projected climate change (Aitken, Yeaman, Holliday, Wang, & Curtis-McLane, 2008). Human assisted migration and assisted gene flow have therefore emerged as important conservation and management strategies to mitigate maladaptation and preserve genetic diversity in forest trees (Aitken & Whitlock, 2013; Aitken et al., 2008; Sáenz-Romero et al., 2016; M. I. Williams & Dumroese, 2013). Several authors have emphasized the importance of incorporating trailing edge populations into conservation planning, due to their unique adaptive traits and potential value for future forest resilience (Hampe & Petit, 2005; Aitken & Whitlock, 2013; Sáenz-Romero et al., 2016).

A number of agencies and organizations are already engaged in gene conservation efforts relevant to trailing edge populations. In Canada, the National Tree Seed Centre and the National Forest Genetic Resource Centre (Natural Resources Canada, 2023) coordinate both in situ and ex situ conservation of forest genetic resources, including climatically marginal populations. In western Canada, the provinces of British Columbia and Alberta implement climate-based seed transfer guidelines and maintain seed orchards and conservation collections (Government of Alberta, 2018; Government of British Columbia, 2024). In the United States, a variety government agencies and non-profit organizations maintain ex situ conservation collections and a network of in situ conservation areas that aim to preserve adaptive variation (USDA, 2017).

Here, we contribute a systematic and spatially explicit analysis identifying trailing edge populations for the 100 most frequent tree species across North America. As such, the study scope does not include rare species, but instead focuses on genetic conservation efforts of trailing edge populations for forest trees that are of broad ecological and commercial importance. The research is meant to support efforts of government agencies such as those noted above. The results presented here can inform conservation priorities for both in situ and ex situ efforts, help guide seed collection and deployment under changing climates, and support decision-making on where to invest resources for conserving adaptive genetic variation in forest trees. To make communication of our findings easily accessible in any jurisdiction, our analysis is based on widely used ecosystem delineations to identify source populations and potential in situ climate change refugia.

2 Materials & methods

2.1 Ecosystem delineations

To establish a consistent spatial framework for analysis, we integrated multiple ecological and climatic classification systems across North America, prioritizing delineations that are most widely recognized and used by local agencies and resource managers. We used the finest available level of hierarchical classification systems, typically including four levels with Level IV representing the most detailed ecological units. Where Level IV was not available, we used Level III. In British Columbia, we used Level 4 units from the Biogeoclimatic Ecosystem Classification (BEC) system, which provides a detailed and climatically grounded ecological framework (British Columbia Ministry of Forests, 2024). In Alberta, ecosystem units were based on the province's Natural Regions and Subregions classification (Natural Regions Committee, 2006), which similarly reflects variation in regional climate, vegetation, and soil. For the rest of Canada we used the Terrestrial Ecozones, Ecoregions, and Ecodistricts dataset developed by Agriculture and Agri-Food Canada, specifically selecting Level 4 Ecodistricts (Agriculture and Agri-Food Canada, 2013). For the United States, we used the U.S. Environmental Protection Agency's Level IV Ecoregions, which provide a widely adopted national standard for fine-scale ecological delineation (U.S. EPA, 2013). In Alaska, where Level IV delineations are not available, we used Level III EPA ecoregions.

The above classifications were merged into a single dataset consisting of 2,120 unique ecosystem units at Level 4 (or Level 3 for Alaska). Because many of these ecological units span substantial elevational gradients, we further stratified units based on mean annual temperature (MAT). Ecosystems with an internal MAT range exceeding 4°C were subdivided into 2°C bands, a resolution chosen to reflect potential genetic differentiation and potential changes in species composition along elevation gradients. To limit the number of subdivisions we only retained elevation bands that exceeded a minimum area of 100 km², while smaller areas, such as isolated mountain peaks or narrow ridges, were merged with adjacent elevation bands.

All input layers were reprojected to a common coordinate system (North America Lambert Conformal Conic) and merged using a hierarchical spatial overlay process. In cases where ecological units spanned multiple political jurisdictions, the unit was assigned to the jurisdiction with the greater proportion of area. The resulting spatial layer provided a high-resolution ecosystem framework suitable for continental-scale analyses and for all subsequent climate characterization, climate matching, trailing edge identification, and conservation prioritization in this study. With the additional elevation bands, 2270 ecosystem units in total provide a modeling framework with units that are reasonably homogenous in climate conditions and in tree species composition.

2.2 Climate data

To characterize past, present, and future climatic conditions across ecosystems, we used 11 biologically relevant bioclimatic variables derived from monthly temperature and precipitation data using the ClimateNA software (Wang, Hamann, Spittlehouse, & Carroll, 2016), which is based on PRISM (Parameter-elevation Regressions on Independent Slopes Model), an interpolation system developed by the PRISM Climate Group at Oregon State University. PRISM integrates data from weather stations with digital elevation models and uses climate-elevation regression to account for the effects of elevation, rain shadows, coastal proximity, and temperature inversions. This method produces gridded climate surfaces that are particularly accurate in mountainous regions and is widely used for ecological and hydrological modeling across North America. ClimateNA further applies downscaling based on local environmental lapse rates, resulting in high-resolution climate surfaces that reflect fine-scale climatic gradients in mountainous terrain.

The 11 bioclimatic variables selected for analysis include climatic factors known to influence plant distribution, productivity, and phenology: Mean Annual Temperature (MAT), Mean Warmest Month Temperature (MWMT), Mean Coldest Month Temperature (MCMT), and Temperature Difference (TD), calculated as MWMT – MCMT to represent continentality. We also included Extreme Minimum Temperature (EMT), defined as the coldest temperature expected over a 30-year period, a potential driver of cold hardiness adaptations. Precipitation variables included Mean Annual Precipitation (MAP), Growing Season Precipitation from May to September (MSP), Precipitation as Snow (PAS), and a Climate Moisture Index (CMI), which integrates heat and moisture availability. Thermal indices included Chilling Degree Days below 0°C (DD0) and the Number of Frost-Free Days (NFFD), which represent thresholds important for plant growth and dormancy.

Historical and projected climate data were obtained for five time periods. Two historical 30-year normal periods were used for reference: the 1960s baseline (1951–1980) and the 1990s climate normal period (1981–2010). Three future time periods were included: the 2020s (2011–2040) best representing current climatic conditions, the 2050s (2041–2070) for mid-century conditions, and the 2080s (2071–2100) for late-century projections. Future climate projections were based on an ensemble of eight CMIP6 Global Climate Models (GCMs) selected by criteria outlined in Mahony et al. (2022), including performance in simulating historical climate across North America, representation of key global circulation regimes, and independence to reduce inter-model redundancy (Mahony, Wang, Hamann, & Cannon, 2022). This ensemble provides a balanced sample of plausible future climates under the Shared Socioeconomic Pathway SSP2-4.5, which represents a moderate emissions scenario with intermediate assumptions about mitigation and socioeconomic development. Ensemble averaging was used to reduce the influence of individual model biases and provide a robust central estimate of future climate conditions for each time period.

Climate surfaces were generated at a spatial resolution of 1 km^2, allowing close alignment with the resolution of ecosystem delineations and capturing topographically driven variability. For each ecosystem unit, mean values of all 11 bioclimatic variables were computed by averaging the corresponding raster cells within the unit's boundaries. These aggregated climate values formed the basis for subsequent analyses, including climate analog comparisons among ecosystems from past (source) and future (target) climate conditions.

2.3 Climate change velocity

As an indicator of the pace of climate change and the potential need for human-assisted migration, we calculated climate velocity following the method originally developed by Loarie et al. (Loarie et al., 2009). Climate velocity is a spatial metric that quantifies the minimum distance a population would need to migrate each year to track a stable climate over time. It is derived by dividing the temporal rate of climate change (e.g., °C per year) by the spatial gradient of climate variability across the landscape (e.g., °C per kilometer), yielding a velocity expressed in kilometers per year. This measure captures exposure to climate change independent of species-specific biology and provides a general indicator of whether climate is changing faster than a species can disperse.

To improve realism at local scales we used a distance-based algorithm which identifies the closest future location that matches a given baseline climate, rather than relying on slope-based estimates of spatial climate gradients (Hamann, Roberts, Barber, Carroll, & Nielsen, 2015). This method reduces biases that can arise in flat terrain where slope-based velocities may be inflated, and in mountainous terrain where the improved algorithm accounts for the possibility of "climatic cul-de-sacs," such as mountaintop extirpations with no suitable upslope habitat. By incorporating source and destination information, the method allows for both forward velocity calculations (from present to future) and reverse velocity calculations (from future back to current climate analogues), each offering distinct insights into species vulnerability and the potential utility of assisted migration.

For this study, we calculated forward climate velocity based on projected changes in Mean Annual Temperature (MAT) between the 1960s baseline (1951–1980) and mid-century conditions (2041–2070). MAT was selected as a univariate proxy for broader climate change exposure due to its strong association with species distributions and physiological thresholds in trees. Calculations were performed at a spatial resolution of 1 km^2, consistent with the resolution of our ecosystem units and climate surfaces. For each grid cell in the 1960s climate surface, we identified the nearest cell in the 2050s projection that had a matching MAT value within a predefined threshold (±0.2°C), and computed the geographic distance between the two points. This distance was divided by the number of years between the two time periods (60 years) to yield an annual velocity in kilometers per year.

Finally, we summarized climate velocity within our study units by averaging velocity values within each delineated ecosystem unit. These values serve as an indicator of the scale of transfer distance required for populations within each ecosystem unit, and may inform whether the rate of change is likely to exceed natural dispersal rates of forest tree species. Areas with high velocity values are not only at high risk of climate disequilibrium, but also will require more substantial intervention in terms of population transfer distance, and therefore are potential candidates for assisted migration or gene conservation interventions.

2.4 Tree species data

Tree species composition was estimated using data from two major national forest monitoring programs: Canada's National Forest Inventory (NFI) (Beaudoin, Bernier, Guindon, Villemaire, & Guo, 2014) and the equivalent US forest inventory, using the same methodological approach (Wilson, Lister, & Riemann, 2012). Because Wilson et al. (2012), did not include Alaska, we used plot data from the U.S. Forest Inventory and Analysis (FIA) program (A. N. Gray, Brandeis, Shaw, McWilliams, & Miles, 2012) for this state.

For Alaska, species basal area was calculated for each plot by summing the basal area of all measured trees per species, averaged across all measurement years for that plot. Plot coordinates (latitude and longitude) were used to assign each plot to its corresponding ecosystem unit. For each ecosystem, species composition was then estimated by averaging species-level basal area across FIA plots. Although the FIA coordinates are spatially fuzzed to protect landowner privacy, the spatial resolution of our ecosystem units is sufficiently coarse to accommodate this uncertainty. For the 250-meter resolution raster maps covering Canada and the lower US states (Beaudoin et al., 2014; Wilson et al., 2012) we assigned each raster pixel to an ecosystem unit based on its centroid location and then averaged species composition across all pixels within each unit.

To ensure taxonomic consistency across datasets, we harmonized species names using Latin binomials and verified them against common names where unambiguous matches existed. Species codes from Little's Atlas of United States Trees (Little, 1971) were appended to all species records to facilitate integration with U.S. forestry databases, including the Silvics of North America reference (Burns & Honkala, 1990), which uses the same nomenclature system.

2.5 Climatic habitat for forest trees

To characterize available habitat for each tree species and enable meaningful comparisons across ecosystems, we estimated the proportion of land within each ecosystem that could support forest cover under natural conditions. This estimate serves two purposes: (1) the estimate served as the basis for scaling species frequencies derived from plot and inventory data, so that total species abundance, combined with non-forested areas, would sum to 100% of land area within each ecosystem; (2) the estimates were used to inform predictions for future forest cover as a potential risk factor, where predictions of forest cover loss are interpreted as climate shifts exceeding the fundamental niche space of all forest tree species.

The initial estimate of forest cover was derived from the MODIS Vegetation Continuous Fields (VCF) product, MOD44B Version 6 (DiMiceli, Townshend, Carroll, & Sohlberg, 2021), which provides a global fractional estimate of tree canopy cover at 250 m spatial resolution. The raster was reprojected to Lambert Conformal Conic (LCC) projection to match the spatial framework used for ecosystem delineations. Within each ecosystem unit, the proportion of forested land was calculated as the mean of all VCF pixels.

Because substantial portions of potential forest land have been converted to anthropogenic land uses, particularly agriculture and urban development, we generated an additional estimate of potential natural forest cover to more accurately reflect the area suitable for tree species occupancy in the absence of human disturbance. For this purpose we used a MODIS land cover classification product from the North American Land Change Monitoring System (Commission for Environmental Cooperation, 2005), which explicitly maps agriculture and urban classes. A deep neural network classifier was then trained to replace the agriculture and urban classes with the most probable natural land cover class based on the pixel's annual climate and topography. Pixels identified as water were excluded from both training and prediction. This process yielded a climate-informed spatial reconstruction of potential natural land cover, allowing estimation of backfilled forest cover by summing the proportion of pixels predicted to be forest within each ecosystem.

The neural network employed for land cover classification was a feed-forward deep learning model designed to predict 17 natural land cover classes, excluding agriculture and urban classes from the training data set but included as prediction targets to be classified. The model was trained on 11 bioclimatic variables (as described above) and 16 topographic predictors, including terrain indices such as topographic position and convergence, aspect components (northness, southness), exposure, and proximity to water bodies (lakes, rivers, and oceans), following the methodology of (Namiiro, Hamann, Wang, Castellanos-Acuña, & Mahony, 2025).

The model architecture was a feed forward model consisting of seven dense hidden layers with progressively fewer neurons: 2048, 1024, 512, 256, 128, 64, and 32 nodes, respectively. The initial wide layers were used to capture complex, regionally variable interactions among climate and terrain predictors across the continent. All hidden layers used ReLU activation functions, while the output layer included 17 neurons with a softmax activation function for multi-class classification. The model was trained using categorical cross-entropy loss, the Adam optimizer, and a batch size of 64. We implemented the model using the Keras package for R, with Google's TensorFlow v2.10.1 machine learning platform for Python 3.9 as the computational backend. Model development and training were conducted on a an Nvidia RTX 3060 GPU, using a software stack compatible with Nvidia's cuDNN v.8.1.0 and CUDA 11.2 libraries. The architecture and hyperparameters were empirically optimized by varying the number of hidden layers (1–8 tested) and neurons per layer (ranging from 32 to 2048). The model was trained using an 80:20 training-to-validation split, and final architecture selection was based on validation accuracy and training stability. The final model produced spatial predictions of potential natural land cover at 250 m resolution, which were subsequently aggregated to estimate backfilled forest cover at the ecosystem level. The predicted land cover was combined with observed land cover values to create a composite land cover model that uses observed natural classes where available.

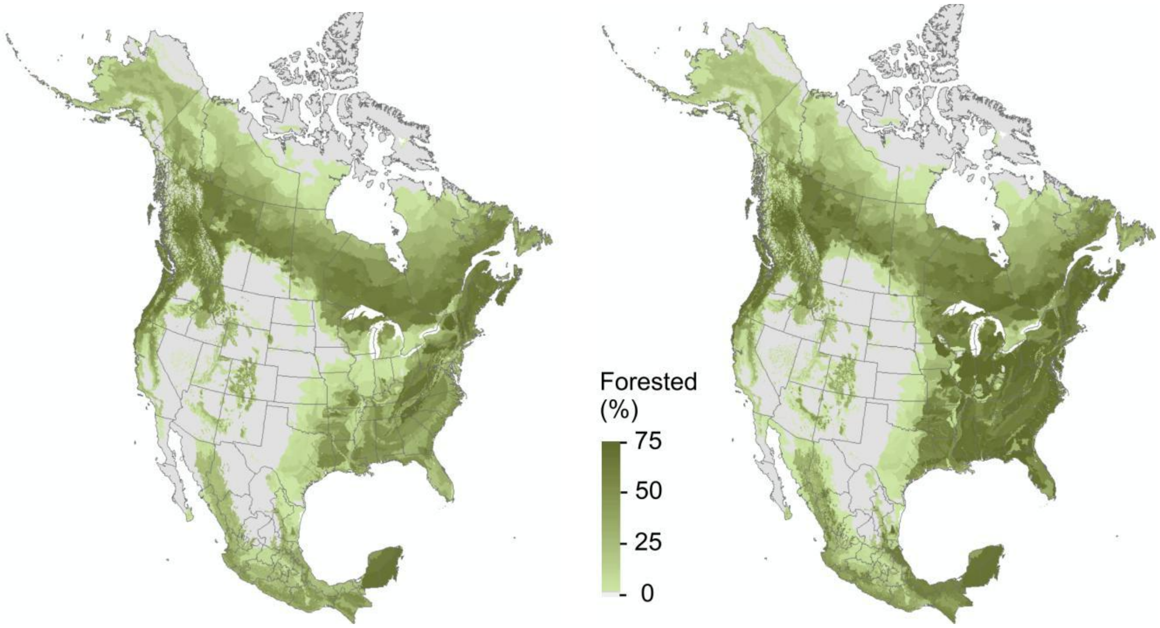

Figure 1. Ecosystem averages of forest coverage based on MODIS vegetation continuous field data (left), and with agricultural and urban areas backfilled according to the most probable land cover class (right).

The resulting backfilled forest cover estimates (Fig. 1) were used to scale species frequencies derived from forest inventories. For each ecosystem, the relative abundance of all tree species was scaled to sum to the estimated proportion of forested area under potential natural conditions. This allowed for meaningful comparison of species potential climate habitat across ecosystems with varying degrees of forest cover, including those where human disturbance has significantly reduced present-day forest extent. Species frequencies for each ecosystem thus reflect the expected natural abundance of climatically suitable habitat.

2.6 Identifying at-risk trailing edge populations

To identify tree populations that may be at risk under near-future climate change, we applied a bioclimatic envelope matching approach using ecosystems as the spatial units. This method projects future climate conditions onto observed baseline distributions by matching each ecosystem's projected climate to ecosystems with similar climates from a historical reference period. The approach relies on the assumption that species currently inhabiting a given climate envelope will be most likely to persist or thrive in future areas with similar climatic conditions.

We used the 1960s climate (1951–1980) as the baseline reference and matched it to projected 2050s climate (2041–2070) using a standardized Euclidean distance matrix based on 11 selected bioclimatic variables (described above). Mid-century projected climates were chosen for prioritization in order to identify current and near-future climate risk and limit uncertainty in climate predictions. For each ecosystem under future climate conditions, we identified the five most climatically similar ecosystems from the 1960s baseline and inferred future species composition by averaging species frequencies across these analogs. The averaging approach was chosen to reduce the influence of outlier values that may arise from anomalies and errors. Some ecosystems, particularly smaller ones, may lack direct inventory observations, while others are delineated based on edaphic or physiographic features rather than climate per se. Averaging across multiple close analogs mitigates these sources of error and provides a more stable estimate of climate habitat for species assemblages.

The approach enables identification of trailing edge populations at risk, namely those that may lose climate habitat within their current range by the 2050s. If the future climate of an ecosystem currently occupied by a species is best matched to ecosystems outside that species' historical range, we infer a potential loss of suitable climate space for that population. Similarly, if future climates are matched to the historical climate of an at-risk population, it suggests a potential target ecosystem that could serve as climate change refugium for the population.

To quantify climate-associated risk, we applied threshold-based criteria relative to the distributions of each species. Trailing edge populations were defined as those falling below a species-specific threshold by the 2050s. The species-specific threshold was calculated as the frequency corresponding to the 15th percentile of level-4 ecosystem averages, across all ecosystems in which a species was present in the 1960s historical reference. This threshold typically corresponds to around 0.1% of the total potential species abundance, i.e., 0.1% of the area of climate habitat multiplied by the expected frequency, summed over all ecosystems where a species occurs. To further screen putative trailing edge populations, a climatic restriction was applied where only populations inhabiting the 90th percentile of temperature (MAT) or dryness (CMD) within the respective species' range were retained for analysis. Therefore, the trailing edge definition used here represents climatically marginal populations in ecosystems where those species tend to occur at low frequencies. The thresholds were chosen empirically by visual inspection of putative trailing edge populations to work consistently for high- and low-abundance species.

To ensure that trailing edge populations identified by the climate envelope model reflect real, present-day occurrences, we implemented a dual validation filter. First, we required that each species be recorded in forest inventory data within the ecosystem unit. Second, to address possible species misidentifications and the presence of introduced species in inventory datasets, we cross-referenced each ecosystem with buffered historical range maps from Little (1971).

Ecosystem units representing trailing edge populations at risk were only retained if they intersected a species' native range (with a buffer to account for spatial inaccuracies in the maps) and also contained confirmed inventory records. This filtering ensured that ecosystems flagged as climatically vulnerable indeed represent areas where the species currently exists and could be visited for conservation seed collections.

2.7 Prioritizing conservation action

To prioritize seed collections for assisted migration and long-term genetic conservation, we use three criteria that integrate complementary factors (1) the severity of climate-driven risk of local population extirpation in the short term, (2) the potential for natural dispersal or gene flow to maintain genetic diversity versus the need for human intervention, and (3) the overall conservation value of each ecosystem in terms of species richness and genetic diversity potentially at risk.

To represent the first criterion we use the projected forest cover loss between the 1960 baseline and the 2050s projection, based on modeled changes in potential forest habitat (as described in section 2.5). This metric serves as a proxy for fundamental climatic constraints on tree growth. A projected decline in forest cover indicates that climate conditions in an ecozone may exceed the physiological tolerances of most tree species, suggesting heightened risk of widespread regeneration failure, mortality, and local extirpation. In such cases, warm- or dry-adapted populations may be lost due to direct climatic stress. In contrast, ecosystems where forest cover is projected to remain stable may still experience gradual species turnover, but without the same immediacy of climate-driven collapse.

The second criterion is climate velocity, calculated as the spatial displacement (in kilometers) of a location's climate analogue between the 1960s and 2050s (as described in section 2.3). This metric quantifies the rate and distance at which species would need to migrate to track suitable climate conditions. Higher climate velocities suggest that natural dispersal for long-lived species with limited seed dispersal may be insufficient to keep pace with climate change. In these cases, assisted migration may be required to facilitate population persistence. Conversely, areas with low velocity values may allow species to persist through short-range dispersal, especially if upslope movement or pollen flow can enable gradual range shifts to suitable climate habitat over relatively short distances (Suggitt et al., 2018).

The third criterion is a measure of overall conservation value, expressed as the number and proportion of species with trailing edge populations identified within each ecozone (as described in section 2.6). This reflects the extent to which an ecosystem harbors a high concentration of climatically at-risk populations. By considering both the absolute number and the relative proportion of trailing edge populations, we capture ecosystems that are either rich in biodiversity or disproportionately important for conserving species at the margins of their climatic range. All else being equal, priority should be given to ecosystems where a larger number of species face climate-induced decline, signaling both greater urgency and higher return on conservation investment.

To synthesize these metrics, we aggregated values at the jurisdictional level (province or state), calculating the sum of trailing edge populations, the mean projected loss of forest cover, and the mean climate velocity across all ecozones within each jurisdiction. This allowed for a comparative assessment of seed collection priorities across North America, highlighting jurisdictions where both the need and opportunity for conservation intervention are greatest.

2.8 Assessment of assisted migration targets

To complement seed collection strategies, we evaluated the potential for in situ conservation and assisted migration by assessing future recipient sites across North America. While ex situ conservation through seed banking can safeguard genetic material, in situ strategies offer the added benefit of preserving evolutionary processes and allowing continued local adaptation. Warm-adapted tree populations identified as vulnerable under future climates may also provide valuable genetic material for reforestation or restoration programs where current populations face climate-related decline. For this reason, we examined the extent to which ecosystems across North America could serve as climate refugia, focusing particularly on areas with both suitable future climates and existing conservation infrastructure.

Two metrics were calculated to assess each ecosystem's suitability to support assisted migration. The first metric was demand, which quantified the number of trailing edge populations for which an ecosystem's projected 2050 climate was identified as a suitable analogue. This reflects the potential role of the ecosystem as a future host for populations from warmer or drier regions. The second metric was capacity, calculated as the area of protected land with climate habitat suitable for forest trees by the 2050 as a metric for sufficient protected climate habitat to accommodate incoming populations. Protected area data was sourced from the

World Database on Protected Areas (UNEP-WCMC, 2025) and restricted to those recognized by the International Union for Conservation of Nature (IUCN) for quality control. Finally, summaries of demand and capacity were aggregated by province and state to inform regional planning and highlight jurisdictions where investments, such as expanding protected areas or designating new restoration sites would be best placed.

To further support in situ conservation efforts, we developed an online tool, the Protected Area Selection Tool for North America (PAST-NAm), available at http://tinyurl.com/PAST-NAm. This tool identifies protected areas that provide suitable climate habitat for populations of concern under future climate conditions, using the analytical approach described in this study. The matching procedure is applied to climate envelopes defined by Level 4 ecosystem units, which represent genetically and ecologically coherent population segments. Reserve selection is further prioritized by IUCN management category, with preference given to Category IV reserves that support restoration and active management, followed by more strictly protected reserves and, subsequently, less formal or multi-use areas. The tool also requires that reserves contain at least 50 square kilometers of climatically suitable habitat for the selected population.

3 Results

3.1 General predictions of the climate envelope model

To illustrate the broad-scale climate habitat shifts from our modeling approach, we visualized predicted changes in ecosystem climate envelopes between the 1960s baseline (1951–1980) and projected mid-century conditions (2041–2070). These visualizations provide an initial high-level assessment of the spatial pattern and severity of shifts in climate habitat relevant to forest ecosystems.

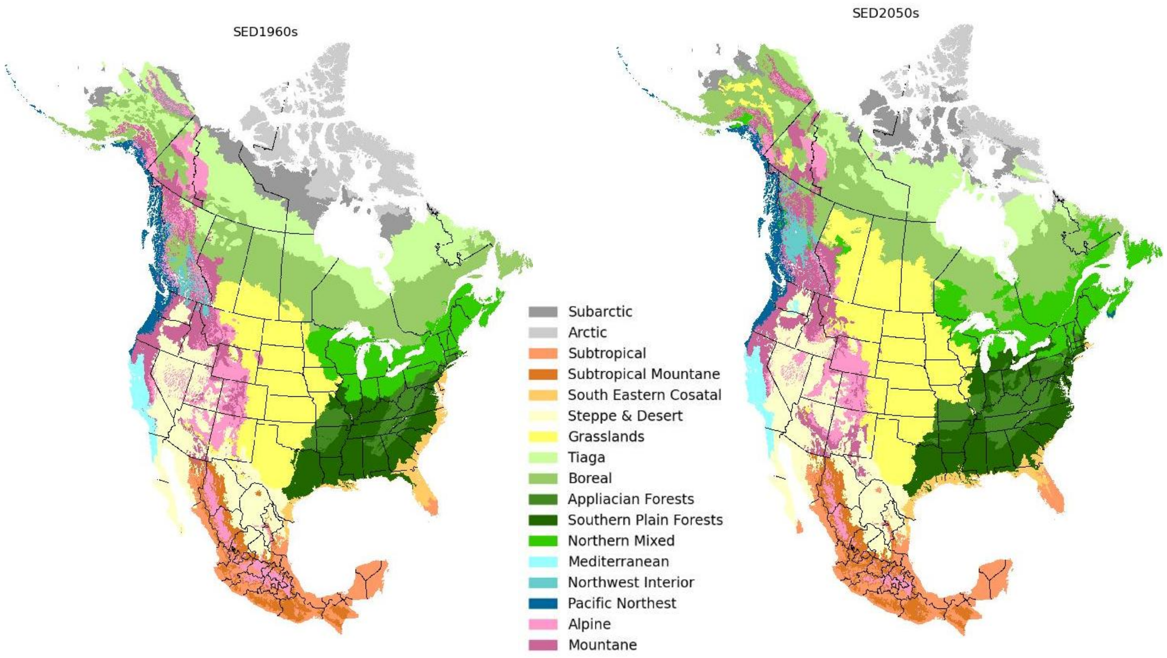

Figure 2. Climatic habitat supportive of different biomes for the 1960s baseline historic period (left) and projected 2050s climate (right). The predictions are based on a majority vote of biome types from the 5 best matching level-4 ecosystems.

The results show consistent northward shift of climate envelopes supportive of grassland and dry woodland biomes into areas currently classified as boreal forest, particularly in western

Canada and interior Alaska, as well as grassland expansions into the eastern temperate forests of the United States (Fig. 2).

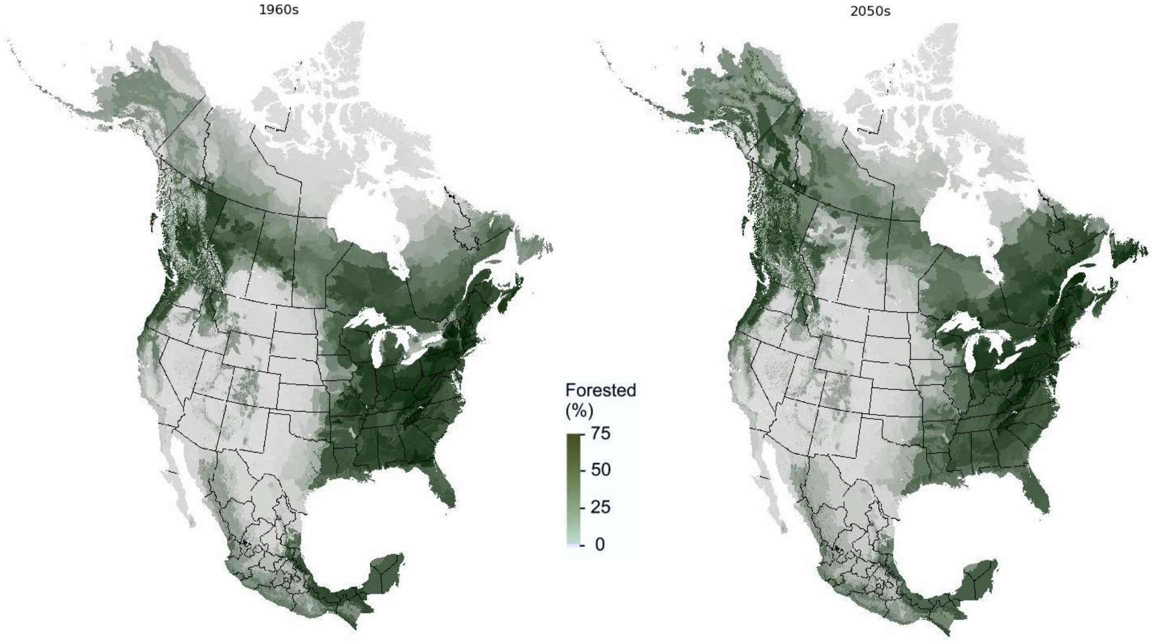

Figure 3. Climatic habitat supportive forest cover assuming no human development for the 1960s baseline historic period (left) and projected 2050s climate (right), used as a risk factor to evaluate the need for gene conservation in the short term due to high risk of population extirpation. The predictions are based on the average reconstructed natural forest cover from the 5 best matching level-4 ecosystems.

Figure 3 shows the corresponding change in predicted forest cover under climate change, excluding human development. Projected forest cover decreases along the southern fringe of the boreal forests of western Canada, especially in Alberta and Saskatchewan, but also in southern British Columbia. A contraction of montane forests in the western United States occurs as well, but is not clearly visible at this map scale. Another region of forest loss is visible at the western limit of the eastern temperate forests of the United States, consistent with modeled transitions to more grassland-like climates. These shifts in climate habitat highlighting regions where near-future climate change may exceed the physiological limits of many forest tree species.

Conversely, projected forest cover is largely maintained or even increases in higher elevation zones and northern ecozones, indicating regions that may gain climatic suitability for forest establishment and could potentially serve as recipients for assisted migration.

3.2 Identifying vulnerable trailing-edge populations

To identify trailing edge populations at risk of climate-induced habitat loss, we applied our climate envelope matching framework to 2050s projections (2041–2070). The period represents a medium-term planning horizon for conservation collections (i.e., ~ 25 years from now), with little uncertainty or difference in climate change projections by different models or different emission scenarios. For each tree species, we assessed where climate conditions supportive of their occurrence are expected to contract geographically, indicating populations that may experience increased physiological stress that could lead to medium-term dieback or mortality, as well as reduced competitiveness that could lead to poor regeneration and subsequent local extirpation in the longer term (Fig. 4, red areas).

Trailing edge populations were defined as those occurring in ecozones where the projected species frequency falls below the 15th percentile of the species' historic occurrence distribution, calculated across all ecozones within its current range. To ensure that inferred trailing edge populations represent genuinely at-risk native occurrences, we required that ecozones had non-zero species abundance in the 1960s baseline and overlapped with the species' historical range based on spatially buffered Little (1971) range maps. This dual criterion helped exclude spurious trailing edge population identifications resulting from either taxonomic misidentification or planted/introduced occurrences outside native distributions.

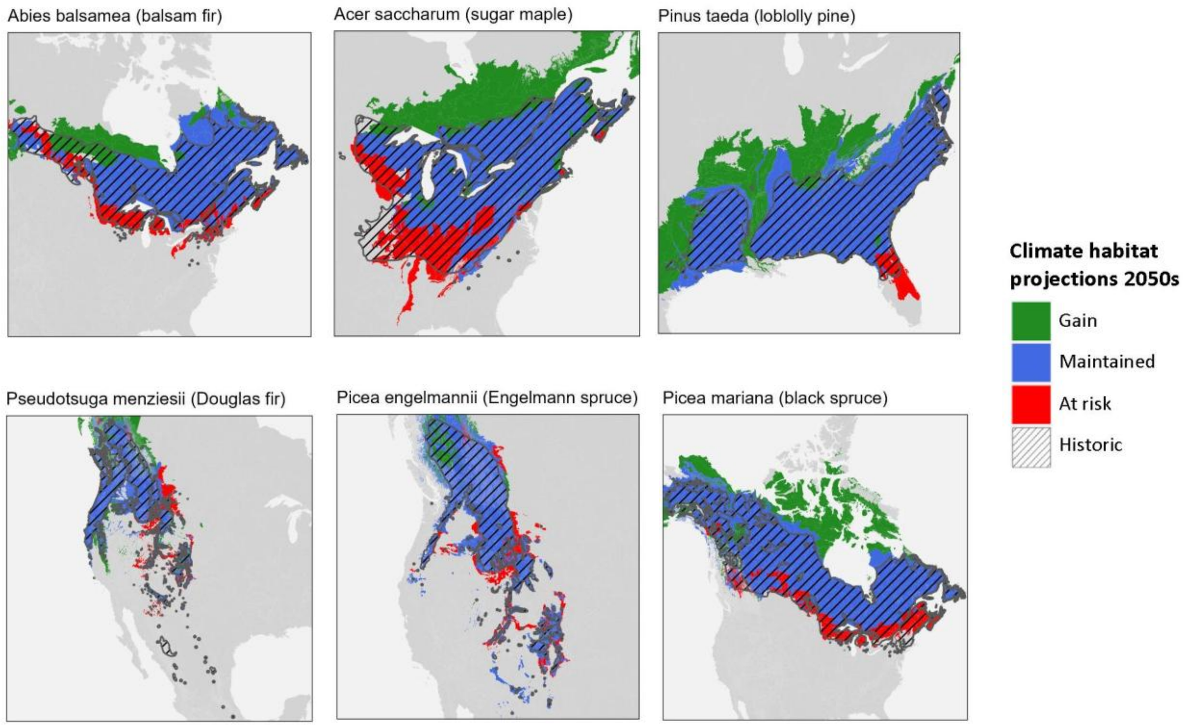

Figure 4. Examples of trailing edge tree populations at risk of climate habitat loss by the 2050s. Red areas indicate ecozones within the historical range of each species that are projected to fall below the 15th percentile of ecosystem frequencies, suggesting loss of suitable climate habitat. Green areas represent potential range expansion (rise above the 30th percentile outside the historic range), and blue areas indicate climate persistence within the current range. Black hatch shows historical species ranges based on Little (1971).

To provide a complete visual assessment of species' climate habitat dynamics, we also quantified projected range expansions and areas of climatic persistence. Range expansions were defined where ecozones that were historically outside the species' range had projected frequencies exceeding the 30th percentile of historic occurrence values. Areas of climatic persistence were defined as ecozones within the species' historical range where projected occurrence remained above the 15th percentile threshold, indicating continued suitability despite climate change. However, for conservation prioritization and seed collection analyses, we focused exclusively on trailing edge populations under projected climate risk.

Visual assessments of this classification approach for selected species with differing ecological characteristics and distributions: *Abies balsamifera* (balsam fir), *Acer saccharum* (sugar maple), *Pinus taedus* (loblolly pine), *Psuedotsuga menziesii* (douglas fir), *Picea engelmannii* (Engelmann spruce), and *Picea mariana* (black spruce) in Fig. 1 demonstrate that the percentile threshold method used performs consistently across species with differing distributions and relative abundances, producing ecologically plausible patterns of habitat loss (red), persistence (blue), and expansion (green).

To provide a broader perspective on the geographic distribution of climate-vulnerable trailing edge populations, we summarized the importance of potential losses across ecosystems based on the number and proportion of species with populations at risk. Figure 5 highlights ecosystems where trailing edge species populations are concentrated with projected loss of suitable climate habitat by the 2050s. The right panel displays the absolute tree species climate threat as the number of species identified as having trailing edge populations within each ecozone, revealing elevated concentrations of climate risk across the Appalachian Mountains and eastern US temperate forests in general. These regions are historically species-rich, and to also account for differences in regional species richness, we mapped relative tree species climate threat as the proportion of trailing edge populations to local species richness (Fig. 5, left panel). This complementary view identifies regions such as the boreal-temperate transition zones, mountain systems in the western United States, and the western margin of eastern temperate forests, where a large fraction of the historically present trailing edge populations at risk, despite lower absolute species counts. Together, these maps identify both species-rich climate risk hotspots and areas of concentrated relative risk to guide conservation planning. A summary table of all relevant ecozones and their climate risk factors is available in Appendix C.

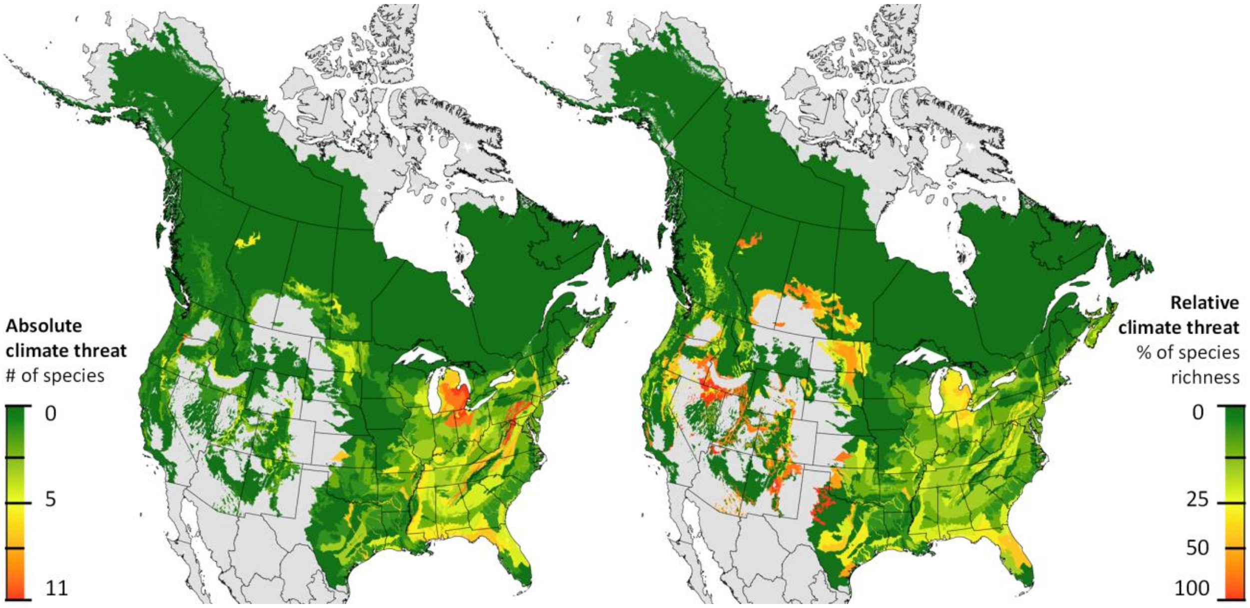

Figure 5. Trailing edge tree populations at warm or dry range margins that are at heightened risk due to climate change. The left panel shows the total count of at-risk populations as number of threatened species in each ecosystem, the right panel expresses climate threat as the proportion of at risk species to all study species in the ecosystem.

3.3 Prioritizing conservation collections

To prioritize seed collections for assisted migration and long-term genetic conservation, we used a multi-factor approach that integrates three complementary dimensions of risk and conservation value: (1) the severity of projected climate-driven forest habitat loss, representing the likelihood of population extirpation due to exceeding their fundamental niche limits; (2) climate change velocity, representing the geographic distance populations must travel to remain within suitable climate, and thereby indicating the need for human intervention; and (3) the overall conservation value of each ecosystem, measured as the number of tree species projected to experience trailing edge habitat loss within a given unit (Fig. 5). The approach captures both direct threats and strategic opportunities for in situ conservation and assisted migration planning.

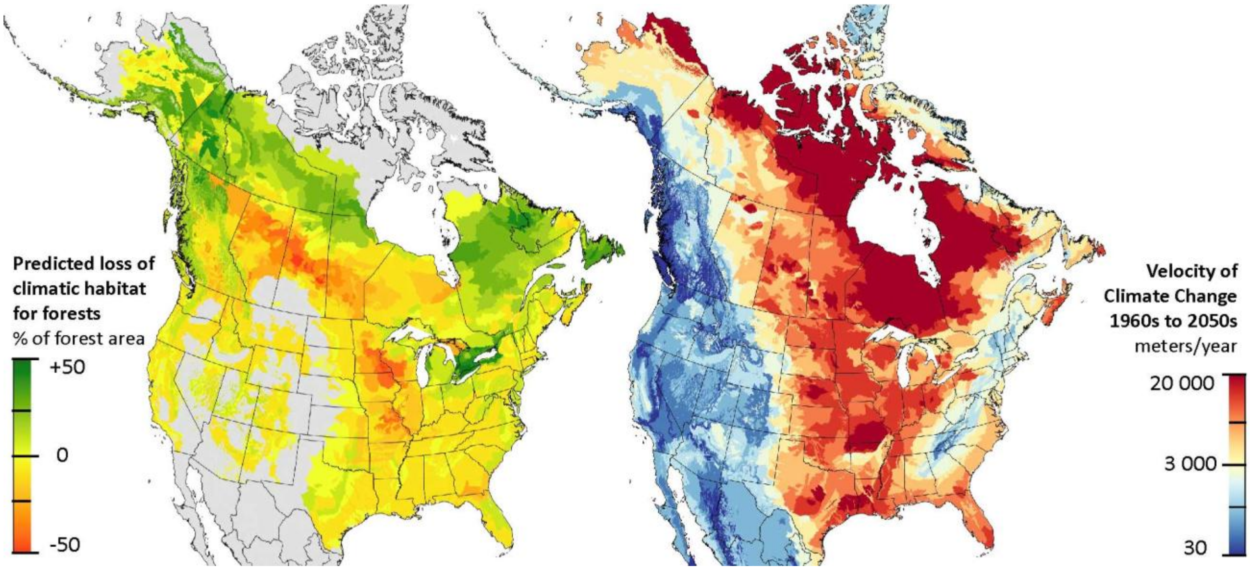

Figure 6. Climate-related risk factors for prioritizing gene conservation collections. Left panel shows projected forest cover loss between 1960s and 2050s, indicating regions where climatic conditions may exceed the physiological limits of forest tree species. Right panel shows climate velocity (m/year), representing the distance populations must shift annually to remain within their historical climate envelope, and highlighting areas where natural migration may be insufficient.

Figure 6 presents the two primary risk factors used in this prioritization framework. The left panel maps projected losses in forest potential between the 1960s and 2050s, identifying ecozones where climatic conditions may no longer support any forested vegetation types. These areas reflect changes to climate habitat within ecosystems that lead to partial or complete loss of the naturally expected forest cover, implying conditions outside the physiological tolerances of most tree species. The right panel shows climate change velocity, defined as the annual geographic distance that must be traversed to track an ecosystem's historic climate. Higher values imply limited capacity for natural dispersal or gene flow to keep pace with shifting climate envelopes, suggesting a need for human intervention. To identify spatially explicit priorities for the collection of trailing edge populations for assisted migration, we mapped ecozone 1960s - 2050s climate velocity against projected forest cover loss under 2050s projected climate (Figure 7).

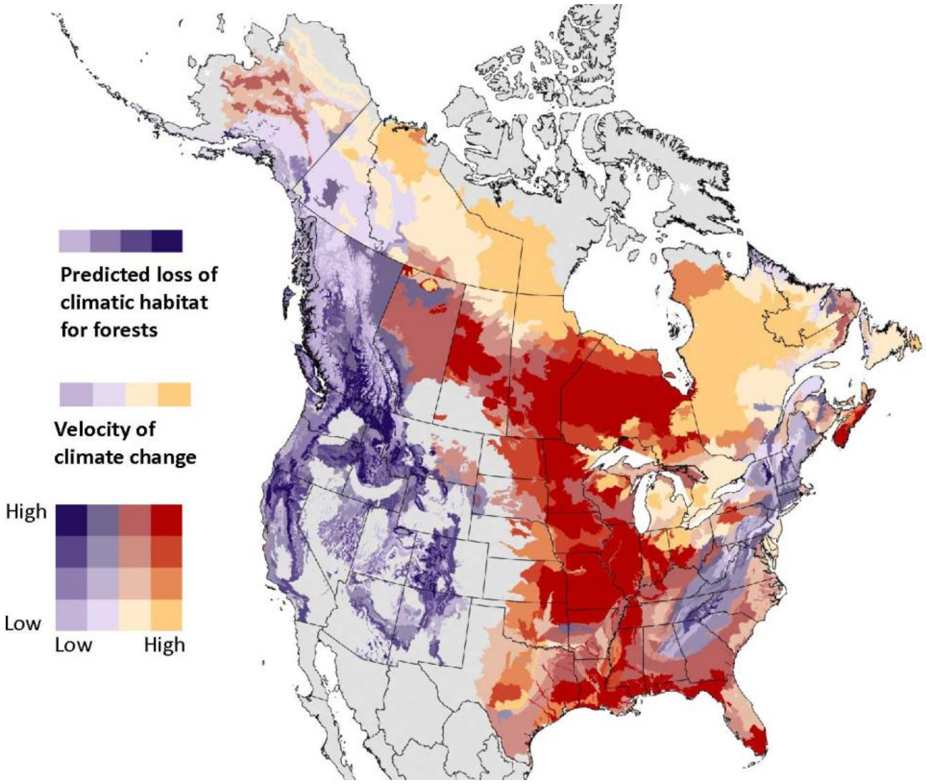

Figure 7. Bivariate prioritization of ecozones for gene conservation collections. Each ecozone is plotted by its projected forest cover loss and climate velocity between 1960s and 2050s. Ecozones in the upper-right quadrant (dark red) are at highest risk, with both elevated forest habitat loss and high climate displacement rates, indicating greater need for proactive collection and assisted migration of trailing edge populations.

To complement the ecozone-level prioritizations, we assessed climate-related conservation risk at the jurisdictional level by aggregating projections across provinces and states. This higher-level perspective provides a strategic overview for resource allocation and policy planning, identifying jurisdictions where near-future climate change may pose the most urgent and widespread threats to forest genetic resources. The combination of climate velocity and forest cover loss points to conservation priorities in the upper quadrant, with point size scaled by the number of species projected to experience trailing edge climate habitat loss, indicating conservation value (Fig. 8). This tri-variate summary integrates all three risk dimensions introduced in our framework: climate displacement rate, severity of local climate change, and overall species-level conservation value, offering a visual composite index of urgency and responsibility by jurisdictions.

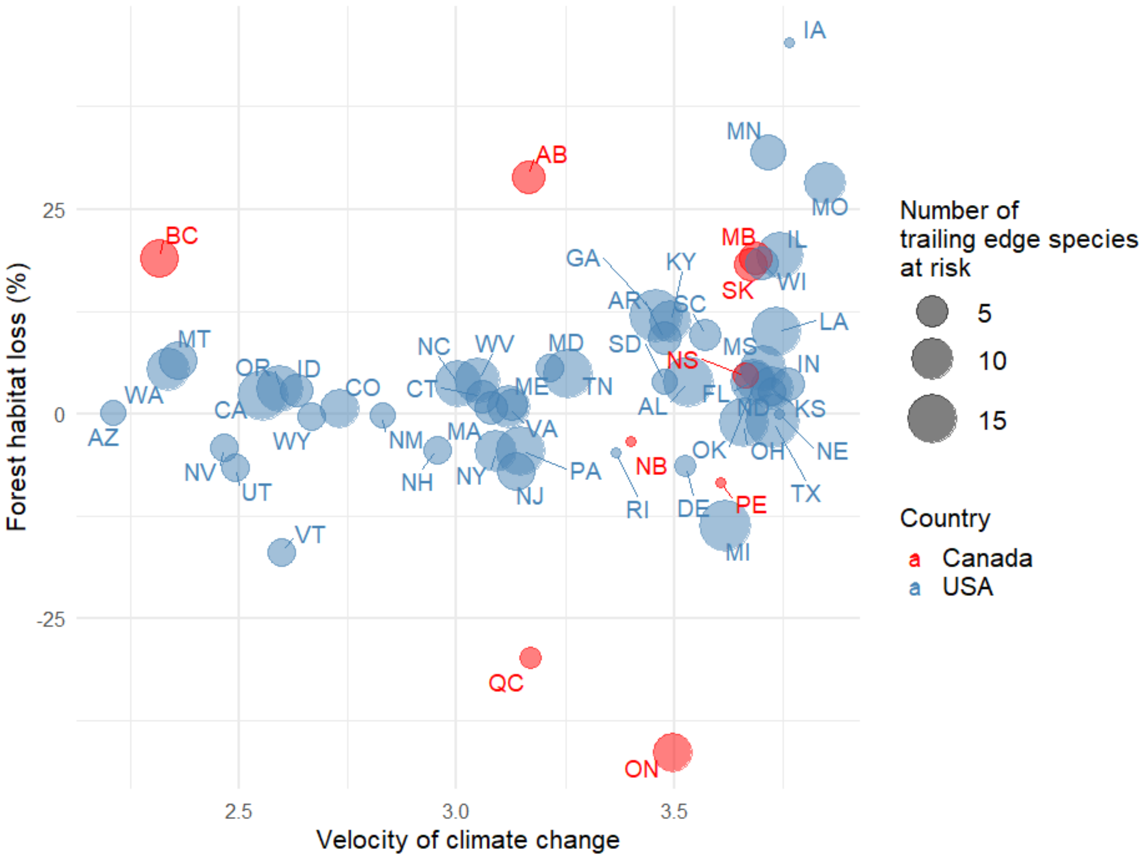

Figure 8. Near-future climate risks for genetic diversity, aggregated by jurisdictions. States and provinces in the upper right face the largest projected forest cover loss by the 2050s (indicating fundamental niche limits for all species are exceeded on a portion of their land base) and the highest climate change velocity values (indicating the need for human intervention). The responsibility of jurisdictions with regards to conservation values is represented by the size of circles.

To provide greater detail on potential targets for intervention, we identified the ecozone with the highest projected species loss within each jurisdiction and listed the species affected at that location (Table 1). These summaries allow jurisdictions to identify priority ecosystems for collection efforts and the specific trailing edge populations most in need of conservation. While each risk dimension provides useful insights individually, their integration reveals priority areas with the greatest need and return on investments in conservation collections. For example, the ecozone with the highest number of trailing edge populations in Louisiana, ID 2076 (Floodplains and low terraces), exhibits a high velocity (5023 m/year) and moderate forest cover loss (17%), and contains trailing edge populations for 7 species (Table 1). Due to its geographic area, ecosystem diversity, and relative positioning at the boundary of grasslands and southern pine, Texas ranks at the top when considering the total number of species with climate-threatened species within jurisdictions. Conservation planning using these jurisdictional summaries should consider both the overall jurisdictional values for high level prioritization schema and individual ecozone risk factors for within- and cross-jurisdictional planning. Risk factors for all ecozones can be found in Appendix C.

Table 1. Trailing edge assisted migration collections prioritized by province/state. For each jurisdiction, the ecozone with the highest projected species loss and the species' expected to be lost in that ecozone are provided. Jurisdictional and priority ecozone values of risk factors (number of species at risk, climate velocity, and forest potential loss) are also provided. The top 10 jurisdictions by total species loss are displayed here; a full table may be viewed in Appendix A. Ecozone information, including full ecozone names, may be found in Appendix C.

Jurisdiction	Species at-risk	Climate velocity	Forest loss	Priority Ecozone	Ecozone velocity	Ecozone forest loss	Ecozone species-at-risk	Ecozone species at-risk (list)
TX	19	5479	-1	2048	4165	-5	7	acersacc, carpcaro, nyssaqua, taxodist, quermich, caryovat, nysssylv
GA	18	3332	12	2101	3983	25	5	queralba, lirituli, pinuechi, betunigr, caryglab
MI	17	4246	-13	1580	3638	-12	10	pinubank, abiebals, betupapy, larilari, betualle, thujocci, popubals, tsugcana, fraxnigr, prunpens
AL	16	3620	3	2082	2951	6	5	tsugcana, querrubr, querprin, quercocc, pinuvirg
CA	16	458	2	1389	227	10	5	poputrem, pinucont, thujplic, tsughete, abieamab
LA	15	5495	10	2076	5023	17	7	fagugran, carycord, quermacr, juglnigr, lirituli, caryglab, caryovat
OH	15	4729	-1	1684	6131	-7	9	poputrem, betupapy, betualle, thujocci, popubals, pinustrb, popugran, fraxnigr, prunpens
PA	15	1607	-5	1673	720	-4	11	poputrem, betupapy, larilari, picerube, betualle, pinuresi, fraxnigr, acerspic, sorbamer, betupopu, acerpens
TN	15	2402	5	1878	497	2	6	betualle, pinustrb, tsugcana, popugran, acerpens, betulent
IL	14	5550	20	1732	5111	2	6	poputrem, pinubank, betupapy, thujocci, popubals, prunpens

3.4 Evaluating recipients for in situ conservation

To assess potential recipient sites for assisted migration and in situ conservation of trailing edge populations, we evaluated each ecozone's demand for acceptance of threatened populations and capacity for in situ conservation of forest species (herein referred to as 'demand' and 'capacity') under 2050s climate conditions. Demand was defined as the number of species with climate-threatened populations for which an ecozone is projected to provide suitable climatic habitat under 2050s climate projection. Capacity was estimated as the area of IUCN-categorized protected land within the ecozone, multiplied by its projected forest cover potential under 2050s climate.

Mapping projected demand across the study region revealed spatial patterns in future climate suitability for displaced populations (Fig. 9). High-demand ecozones include the Great Lakes region, particularly southern Ontario and northern Minnesota as well as the northern Appalachians, with areas of concentrations in Pennsylvania, West Virginia and Ohio. Smaller areas of concentration are found on the east coast in New Brunswick, providing plausible climate refugia with a strong buffer due to oceanic influences. These areas are predicted to offer climate conditions analogous to the historic habitat of many trailing edge populations and may play a key role in maintaining genetic diversity through conservation plantings or restoration efforts.

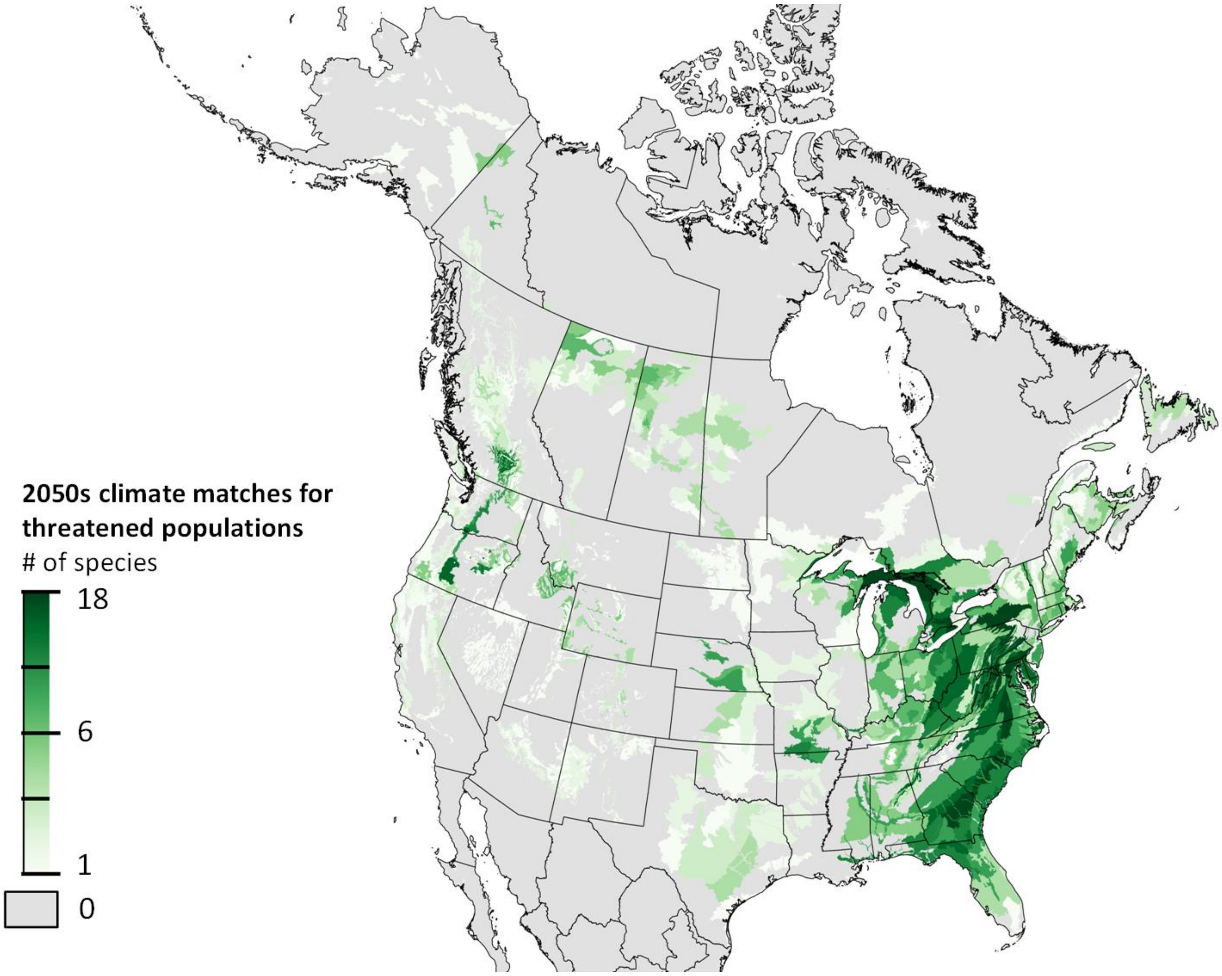

Figure 9. Projected demand for incoming assisted migration of trailing edge populations at risk by ecozone. Demand is quantified as the number of species with climate-threatened trailing edge populations for which the ecozone is projected to provide suitable climatic habitat under 2050s conditions.

We next compared demand and capacity at the ecozone level to identify potential mismatches (Fig. 10). In most regions, projected demand is well aligned with the amount of protected forest habitat, suggesting that translocated populations could be accommodated within the existing conservation network (blue and green shades). However, several ecozones, largely scattered throughout western Canada and the United States show high projected demand with comparatively limited capacity for in situ conservation within the current protected area network.

Targeted expansion of protected areas or the establishment in situ conservation plantations should focus on these areas. Of course, restoration and reforestation plantations outside formal reserves, with material from trailing edge populations may offer a valid alternative for the maintenance of valuable genotypes in situ.

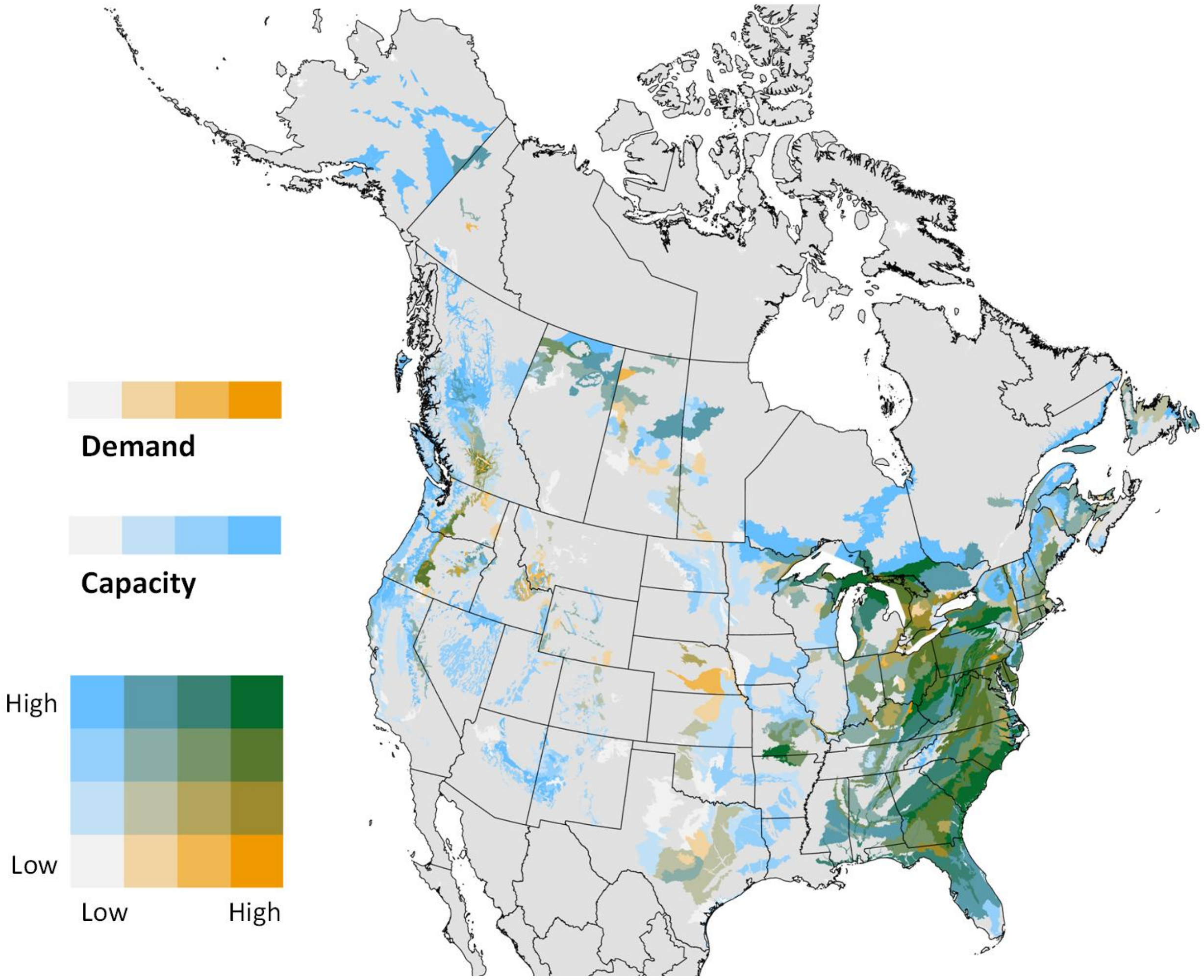

Figure 10. Demand versus capacity for accepting assisted migration across ecozones. Demand represents the number of species with trailing edge populations matched to each ecozone under 2050s climate. Capacity is measured as the projected area of protected forest (km²) under 2050s forest cover scenarios. Ecozones with high demand but low protected capacity are highlighted in orange, indicating potential conservation gaps. Ecozones with no demand have been excluded and are represented in grey.

To support jurisdictional planning, we again aggregated demand and capacity by province and state (Fig. 11). This summary helps identify jurisdictions with particularly strong potential to support future populations at risk and where policy or investment could maximize long-term conservation outcomes. Jurisdictions in the top right quadrant, such as Ontario, standout as prime receptors for conservation-focused assisted migration, having both high demand and plentiful capacity, while jurisdictions to the center/lower right may benefit from investment in more in situ conservation infrastructure to accommodate assisted migration demands. Table 2 lists the top 10 jurisdictions by total number of climate-threatened populations expected to find future climate analogs within their boundaries, along with key statistics on predicted forest potential change and protected forest cover.

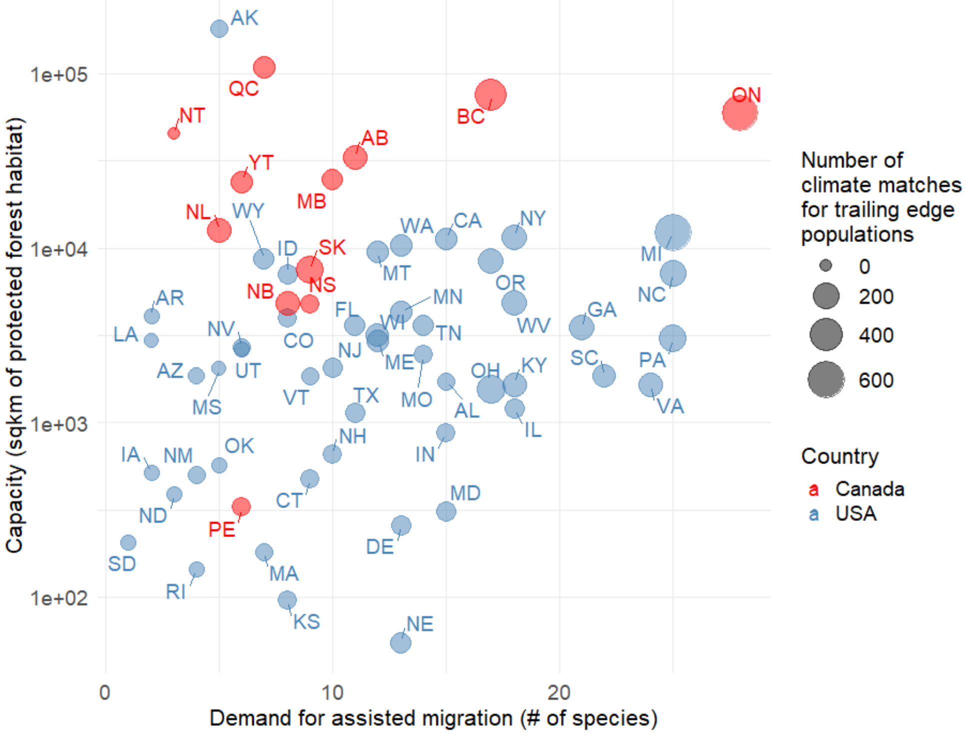

Figure 11. Jurisdictional summary of projected demand and capacity for assisted migration. Each province or state is plotted by the number of threatened species projected to find suitable climate habitat (demand) and the area of protected forest projected for 2050s (capacity, in $\log_{10}$ km^2). Point size reflects the number of trailing edge populations. Jurisdictions in the upper right combine high demand with high capacity, suggesting strong conservation opportunities.

Table 2. Leading jurisdictions for accepting assisted migration of climate-threatened populations. For each province or state, we report the number of species with climate-threatened populations, number of trailing edge populations, and total number of populations (both threatened and non-threatened) expected to find suitable habitat within the jurisdiction under 2050s projected climate conditions. Historic and projected forest cover potential (%), and total protected forest area ('Capacity'; km²) under 2050s climate are also summarized by jurisdiction. The top 10 jurisdictions by total matched species are shown here; the full dataset is provided in Appendix B.

Jurisdiction	**Threatened Species Demand**	**Threatened Population Demand**	**Total Population Demand**	**Forest Potential 1960 (%)**	**Forest Potential 2050 (%)**	**Capacity (km2)**
ON	28	556	5295	45	57	59199
MI	25	613	2917	57	67	12284
NC	25	182	839	71	69	7194
PA	25	216	633	73	76	3027
VA	24	141	610	71	70	1651
SC	22	115	258	65	58	1848
GA	21	159	485	70	58	3482
IL	18	46	177	69	49	1209
KY	18	125	467	75	64	1656
NY	18	152	958	71	74	11514

4 Discussion

4.1 Strategic conservation of trailing edge populations

Our analysis revealed that concentrations of trailing edge populations are located at approximately mid-latitude of the eastern temperate forests, covering the US states of North Carolina, Tennessee and Virginia. This represents a region of high species and genetic diversity where many important north-eastern forest tree species have their southern distribution limits (Currie & Paquin, 1987; Dexter, Segovia, & Griffiths, 2019; Hart, Oswalt, & Turberville, 2014). These areas, particularly the Appalachian Mountains, provide cooler microclimates at higher elevations that allow northern species to persist farther south than they otherwise could. This includes forest tree species of major economic and ecological importance, such as Red Spruce (*Picea rubens*), Sugar Maple (*Acer saccharum*), or American Beech (*Fagus grandifolia*).

Should gene conservation efforts focus on collections and translocation of trailing edge populations from this region? In some cases, the answer should be affirmative. The region harbors species that are federally or state-listed as rare, threatened, or endemic. Examples include Fraser Fir (*Abies fraseri*), listed as endangered by the IUCN Red List, which occurs in high-elevation spruce-fir forests in North Carolina, Tennessee, and Virginia and faces significant threat from an invasive insect pest, the Balsam Woolly Adelgid (*Adelges piceae*) (Farjon, 2013a). Another example is Eastern Hemlock (*Tsuga canadensis*), which extends the southern edge of its range into the Appalachian mountains, also threatened by climate warming trends and insect pests (Farjon, 2013b).

However, in a broader context, trailing edge populations of widespread forest species are not necessarily at imminent risk of extirpation. In the absence of major disturbance, maladaptation to climate alone is unlikely to drive large-scale mortality or contraction over the next few decades (Parks et al., 2019). In mountainous regions such as the Appalachians and Pacific Northwest, elevational gradients offer microrefugia, allowing populations to persist or migrate over short distances to remain within suitable climates (Suggitt et al., 2018). Closer inspection of the hotspots of trailing edge populations our study identified within the Appalachian range reveals that they are primarily concentrated in lower elevations such as the northern shale valleys, while nearby elevational maximums exhibit low levels of species threat, suggesting that: A) the climate threatened populations in the region can travel smaller distances to find suitable climatic habitat by migrating upslope, and B) the high-elevation populations of the region are not at immediate risk of climate-related extirpation. However, other findings in medium-term timescales predict the loss of spruce-fir forest climate refugia in the region by the end of the century (Wason, Bevilacqua, & Dovciak, 2017). While our study focuses on immediate climate risk to tree populations, effective conservation planning should integrate a variety of timescales for proactive management.

In contrast, the flatter landscapes of the Midwest and lower boreal forest where our analysis identified high climate velocity and high relative forest cover loss generally have fewer tree species overall, making them less attractive targets for biodiversity-focused conservation efforts. The combination of maladaptation and increasing frequency of climate-driven disturbances, such as drought, fire, and pests, elevates the risk of population loss. Stochastic disturbance events can act as tipping points, eliminating already stressed populations before conservation interventions are in place (Seidl et al., 2017). While our analysis quantifies risk based on projected climate suitability alone, future efforts could integrate disturbance likelihood to refine collection priorities.

For forest managers, the results offer direct guidance. Figure 5 and Appendix A identify priority jurisdictions and ecozones, along with the species most at risk in each. Focusing on areas with high risk and high species richness improves the efficiency of seed collection programs, allowing multiple vulnerable populations to be addressed with fewer resources. To avoid conservation gaps, collection efforts should aim for complementarity across zones ensuring representation of diverse species and regions beyond top-priority sites.

4.2 Connecting threatened populations to suitable recipient sites

Identifying recipient sites for assisted migration can be viewed as a logistical conservation challenge. However, when implemented through regular reforestation and ecosystem restoration activities, it is also a strategic opportunity to harness warm-adapted genetic diversity to sustain forest health and productivity in a changing climate. Rather than viewing assisted migration as a last-resort intervention, we propose reframing it as a forward-looking strategy to re-establish adaptive potential where it is most needed. The target regions trailing edge populations, identified in this study, are not just passive recipients of displaced populations. They are staging grounds where the potentially valuable genetic legacies of trailing edge populations can persist, evolve, and contribute to resilient future forests.

While many jurisdictions appear well-positioned to receive incoming populations, macro-climatic habitat suitability alone is no guarantee of success. Ecological compatibility, site-specific microclimates, and land-use histories must also align to ensure survival and integration of translocated genotypes. For example, some areas may offer climatically suitable habitat but lack appropriate soil substrates, disturbance regimes, or successional stages needed for successful establishment (Halofsky, Peterson, & Harvey, 2020; Ni & Vellend, 2024). Others may support forest ecosystems in principle but are so fragmented by agriculture or development (USDA Forest Service, 2021) that landscape-level connectivity becomes a limiting factor to future maintenance and evolution of genetic diversity (Parks, Holsinger, Abatzoglou, Littlefield, & Zeller, 2023). In this context, protected areas are invaluable not just for their permanence but also for their capacity to offer relatively intact ecological templates where species interactions, nutrient cycles, and disturbance dynamics can proceed relatively unimpeded (Parks, Holsinger, Blankenship, et al., 2023). Assisted migration within such environments may be more likely to maintain the evolutionary and ecological integrity of species, allowing trailing edge populations to not only survive but adapt and evolve.

We should also not ignore potential ecological risks when receiving translocated populations. Introducing genotypes outside their native context can potentially disrupt local ecosystem functions, facilitate hybridization, or unintentionally spread pests and pathogens (Winder, Nelson, & Beardmore, 2011). While these concerns are often raised in the context of non-native species introductions, they also apply, albeit to a lesser extent, to assisted migration of native species or genotypes, alongside other risks such as outbreeding depression (Aitken & Whitlock, 2013; M. I. Williams & Dumroese, 2013). To mitigate these risks, seed transfers should prioritize genetic affinity and ecological fit: matching not only the climate envelope but also shared biotic communities, soil types, and disturbance histories. Incorporating genetic screening and common garden trials as already practiced in many forestry programs (M.

Johnston, S. Webber, G. O'Neill, T. Williamson, & Hirsch, 2009; USDA Forest Service, 2024) can help ensure that conservation translocations are ecologically sensitive, evolutionarily informed, and practically effective.

While the ecological rationale for assisted migration is gaining clarity as climate continues to change, the success of such programs also hinge on social acceptance, institutional coordination, and policy frameworks. As previous studies have emphasized (Pedlar et al., 2012; Schwartz et al., 2012), public concerns over “tampering with nature,” uncertainties about long-term impacts, or conflicting land-use priorities can pose barriers to implementation. Our jurisdiction-level results reveal that some of the most promising recipient areas, such as southern Ontario, Pennsylvania, or Ohio, are dominated by private landownership or heavily modified landscapes, where regulatory authority is diffused and competing interests can be expected (Ontario Ministry of Natural Resources, 2021; USDA Forest Service, 2021). In these contexts, partnerships with private landowners, conservation NGOs, and Indigenous communities will be critical. Incentive programs that align conservation with economic or cultural values, such as carbon offset credits, agroforestry schemes, or community seed banks, may be needed to move beyond the confines of public land and integrate assisted migration into broader land-use systems.

Lastly, while our study provides a spatially explicit foundation for identifying where conservation resources could have the greatest immediate impact for trailing edge populations, prioritization is only the first step. Operationalizing assisted migration at meaningful scales requires sustained investments in seed collection, storage, propagation, and monitoring, each of which brings logistical challenges and knowledge gaps. For instance, the future suitability of recipient sites will depend not only on temperature and precipitation, but also on future fire regimes, pest pressures, and land-use change, which are more difficult to predict. Moreover, some of the trailing edge populations identified in this study may or may not represent unique ecotypes or harbor genetic traits of value. Investing in short- and long-term common garden testing, and/or genomic analysis could help to reduce these uncertainties. In this sense, our spatial analysis is best viewed as a dynamic decision-support tool, one that invites refinement as new ecological, genetic, and socio-political information becomes available.

4.3 Interpreting climate matches and using the PAST-NAm tool

While the spatial framework developed in this study offers high-level conservation guidance, translating these insights into practice requires a careful reading of both projections and their limitations. To support the process of finding target conservation sites for populations of concern, we developed a companion online tool: the Protected Area Selection Tool for North America (http://tinyurl.com/PAST-NAm), which was developed as a decision-support platform to implement the insights of this study. It enables users to identify climatically suitable protected areas for any population of concern, including the trailing-edge populations subject to this study, guided by multivariate climate matching at the ecosystem level as described in this study. While the tool is designed to be intuitive and actionable, linking species and ecosystems to specific protected areas, it should be used with an understanding of its core assumptions and limitations.

A key assumption in this framework is that ecosystem delineations track both climate and species communities closely. In many areas this assumption holds well, especially in plains and lowland forests. However, in mountainous terrain, ecosystems often span steep elevation gradients or patchy microclimates. While PAST-NAm introduces elevation bands to improve resolution, these do not yet align with species turnover thresholds, which may lead to erratic migration recommendations in topographically complex regions. In such cases, managers are advised to treat PAST-NAm outputs as coarse indicators and refine selections with local knowledge.

Another caveat relates to the matching of future and historical climates. The tool uses 30-year climate normals for both past (1960s, 1990s) and future projections (2020s, 2050 and 2080s), as these provide a more stable signal than decadal averages. However, observed historical climate trajectories sometimes diverge from ensemble-based future projections in either magnitude or direction. For example, a location may have warmed faster than models anticipated, or become drier instead of wetter. Users should consider this divergence when interpreting results: if observed change exceeds projected trends, it may be appropriate to advance the time horizon (e.g., use 2080s projections instead of 2050s). In contrast, if observed change has lagged behind projections, a more conservative migration strategy may be warranted. Ultimately, adaptation efforts must align with observed climate trajectories, not with projections.

While PAST-NAm helps guide species transfers based on climatic suitability, it does not account for non-climatic ecological factors that are often critical to establishment. Rare or low-frequency species may be habitat specialists, restricted to riparian zones, particular soil types, or unique disturbance regimes. For these, climate matching must be supplemented with habitat-specific silvics knowledge or local field assessments. The tool also does not yet identify non-analog climates, those with no historical counterpart, which are increasingly expected under high-emissions scenarios (J. W. Williams, Jackson, & Kutzbacht, 2007). Users may infer the degree of novelty using the climate distance metrics, with values <0.5 indicating good matches, and values >1 suggesting novel, potentially high-risk conditions.

Future versions of PAST-NAm aim to address several of these issues, including the incorporation of multiple individual AOGCMs for uncertainty estimates, species-specific probabilities of habitat suitability, and improved elevation-based stratification of ecosystems. Until then, we recommend that the tool be used to suggest plausible management actions that should be checked against local ecological and species specific knowledge, not incorporated in this research. Results are most useful as a starting point for planning seed collections and pilot translocations, not as a replacement for common garden trials, genetic screening, or ecological impact assessments.

In summary, we aim to offer a practical and scalable approach to identifying suitable recipient sites for assisted migration, but like any model-based tool, it is only as good as its assumptions and inputs. We encourage users to treat outputs as guidance rather than prescriptions, and to adapt recommendations using ground-level ecological, genetic, and land-use information. In doing so, conservation practitioners can turn a model-informed map into a living, evolving conservation strategy.

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Appendix A: Jurisdictional threat and collection priorities

The following table provides jurisdictional summaries for tree species climate risk and collection priority. The following information is summarized for each entry:

- **Jurisdiction**: province (Canada) or state (USA); abbreviated.
- **Species at-risk**: the number of species in the jurisdiction with trailing edge populations identified as at-risk under 2050's climate.
- **Climate velocity:** the mean climate velocity of the jurisdiction in m/year. Describes the geographic distance that must be traveled per year in order to remain at the same mean annual temperature.
- **Forest Loss:** the jurisdictional mean forest potential loss between 1960 and 2050s climate projections. Negative values denote increases in forest potential.
- **Priority ecozone:** denotes the ecozone ID within the jurisdiction that contains the most trailing edge populations. See Appendix C for a complete list of ecozone names and ecozone risk assessment.
- **Ecozone velocity:** the mean climate velocity (m/year) of the priority ecozone.
- **Ecozone forest loss:** the predicted forest potential loss between 1960 and 2050s climate projections of the priority ecozone.
- **Ecozone species at-risk**: the number of species identified as at risk within the priority ecozone. The following column lists the codes of these species. See Appendix D for a complete list of species within the study and species risk assessment.

Jurisdiction	Species at-risk	Climate velocity	Forest loss	Priority Ecozone	Ecozone velocity	Ecozone forest loss	Ecozone species-at-risk	Ecozone species at-risk (list)
TX	19	5479	-1	2048	4165	-5	7	acersacc, carpcaro, nyssaqua, taxodist, quermich, caryovat, nysssylv
GA	18	3332	12	2101	3983	25	5	queralba, lirituli, pinuechi, betunigr, caryglab
MI	17	4246	-13	1580	3638	-12	10	pinubank, abiebals, betupapy, larilari, betualle, thujocci, popubals, tsugcana, fraxnigr, prunpens
AL	16	3620	3	2082	2951	6	5	tsugcana, querrubr, querprin, quercocc, pinuvirg
CA	16	458	2	1389	227	10	5	poputrem, pinucont, thujplic, tsughete, abieamab
LA	15	5495	10	2076	5023	17	7	fagugran, carycord, quermacr, juglnigr, lirituli, caryglab, caryovat
OH	15	4729	-1	1684	6131	-7	9	poputrem, betupapy, betualle, thujocci, popubals, pinustrb, popugran, fraxnigr, prunpens
PA	15	1607	-5	1673	720	-4	11	poputrem, betupapy, larilari, picerube, betualle, pinuresi, fraxnigr, acerspic, sorbamer, betupopu, acerpens
TN	15	2402	5	1878	497	2	6	betualle, pinustrb, tsugcana, popugran, acerpens, betulent
IL	14	5550	20	1732	5111	2	6	poputrem, pinubank, betupapy, thujocci, popubals, prunpens
NC	14	1688	4	1871	665	4	9	acersacr, pinustrb, tsugcana, acerspic, acerpens, juglcine, pinurigi, querbico, betulent
OR	14	451	3	1281	229	-3	9	poputrem, pinucont, abielasi, tsughete, piceenge, abieamab, lariocci, tsugmert, pinualbi
FL	13	4798	4	2116	5007	23	6	fagugran, queralba, lirituli, pinuechi, betunigr, caryglab
MS	13	5141	5	1984	5048	9	8	acersacr, querrubr, tiliamer, juglcine, querprin, lirituli, quercocc, querpalu
WV	13	1296	4	1678	619	7	11	poputrem, picerube, betualle, tsugcana, pinuresi, popugran, fraxnigr, acerspic, sorbamer, betupopu, acerpens
KS	11	5335	3	1908	5519	-2	6	fraxpenn, quermacr, junivirg, juglnigr, popudelt, gledtria
VA	11	1720	1	1807	778	4	7	pinustrb, tsugcana, popugran, acerspic, acerpens, pinurigi, betulent

Jurisdiction	Species at-risk	Climate velocity	Forest loss	Priority Ecozone	Ecozone velocity	Ecozone forest loss	Ecozone species-at-risk	Ecozone species at-risk (list)
WA	11	251	5	1211	127	15	3	chamnoot, abieamab, pinualbi
KY	10	3510	11	1889	4785	9	5	acersacr, fagugran, popugran, tiliamer, pinurigi
MO	10	7140	28	1968	7323	31	5	acersacr, tiliamer, juglcine, quercocc, caryglab
NY	10	1511	-5	1498	602	-5	6	abiebals, betupapy, larilari, picerube, popubals, sorbamer
CO	9	816	0	1658	300	3	4	poputrem, pinucont, abielasi, piceenge
OK	9	4934	4	1992	5528	0	2	junivirg, quermueh
ON	9	3354	-41	811	2287	-43	3	piceglau, abiebals, larilari
BC	8	317	19	970	270	13	2	picemari, piceglau
MT	8	244	6	1277	214	5	4	pinucont, betupapy, thujplic, lariocci
NJ	8	1483	-7	1641	926	-19	5	poputrem, betupapy, fraxnigr, prunpens, betupopu
MN	7	5327	32	1316	5963	8	3	abiebals, popubals, prunpens
AB	6	2261	29	1124	2560	44	5	picemari, pinubank, piceglau, abiebals, larilari
AR	6	3391	9	1974	4039	9	3	querrubr, juglcine, querpalu
CT	6	1204	2	1583	1363	-14	4	poputrem, betupapy, sorbamer, betupopu
ID	6	458	2	1460	270	0	5	poputrem, pinucont, abielasi, piceenge, pinualbi
IN	6	5832	3	1795	6815	12	3	poputrem, popugran, fraxnigr
MA	6	1347	1	1513	1358	-1	3	poputrem, betupapy, sorbamer
MB	6	5038	19	582	1966	27	5	picemari, pinubank, piceglau, abiebals, larilari
SK	6	4847	18	528	3742	43	5	picemari, pinubank, piceglau, abiebals, larilari
WI	6	5091	18	1600	4087	22	4	pinubank, betupapy, larilari, popubals
ME	5	1404	1	1354	1670	2	3	picemari, piceglau, abiebals
SC	5	3772	10	2051	4242	22	3	fraxamer, pinuechi, caryglab
MD	4	1721	5	1722	1187	7	4	pinustrb, popugran, fraxnigr, acerpens
ND	4	5331	2	1304	5354	2	4	betupapy, popubals, tiliamer, prunpens
NH	4	963	-4	1428	1243	4	3	abiebals, betupapy, larilari
NV	4	325	-4	1607	146	-2	2	poputrem, poputric
UT	4	320	-6	1413	243	-5	4	poputrem, pinucont, abielasi, piceenge
VT	4	400	-17	1392	445	-31	3	abiebals, popubals, sorbamer
WY	4	485	0	1539	648	1	2	betupapy, ostrvirg

Jurisdiction	Species at-risk	Climate velocity	Forest loss	Priority Ecozone	Ecozone velocity	Ecozone forest loss	Ecozone species-at-risk	Ecozone species at-risk (list)
AZ	3	187	0	1906	82	0	2	pseumenz, acernegu
NM	3	713	-1	1865	665	-1	2	acernegu, popudelt
NS	3	4743	5	743	4172	1	3	picemari, pinubank, piceglau
SD	3	3736	3	1558	4930	0	1	tiliamer
DE	2	3424	-6	1757	2783	-12	2	popugran, fraxnigr
QC	2	1500	-30	807	1741	-28	2	picemari, piceglau
IA	1	5812	46	1608	5812	45	1	betupapy
NB	1	2548	-4	711	2827	-5	1	piceglau
NE	1	5518	0	1686	5679	0	1	ostrvirg
PE	1	4067	-9	627	3816	-5	1	piceglau
RI	1	2327	-4	1528	2327	-5	1	betupapy

Appendix B: Jurisdictional demand and capacity summary table

The following table summarizes the demand and capacity for the acceptance of climate-rescue assisted migration for the purposes of in situ genetic conservation. It includes the following parameters:

- **Jurisdiction**: province (Canada) or state (USA); abbreviated.
- **Threatened species demand**: the number of species with trailing edge populations that find suitable climate habitat within the jurisdiction under 2050's climate projections.
- **Threatened population demand**: the number of trailing edge populations that find suitable climate habitat within the jurisdiction under 2050's climate projections.
- **Total population demand**: the total number of populations (threatened and non-threatened) that find suitable climate habitat within the jurisdiction under 2050's climate projections.
- **Forest potential 1960**: the mean percentage of ecozone forest potential among ecozones within the jurisdiction according to historic plot data, adjusted to predict potential forest habitat based on climate data in agriculture and urban zones.
- **Forest potential 2050**: the mean percentage of ecozone forest potential among ecozones within the jurisdiction according to 2050's climate projections, adjusted to predict potential forest habitat based on climate data in agriculture and urban zones.
- **Capacity**: the sum of IUCN-recognized protected forest area under 2050's projections within ecozones climate-matched to threatened populations in the jurisdiction. Protected forest area (square kilometers) is estimated by the product of total protected area within the ecozone and the 2050's predicted forest potential of the ecosystem.

Jurisdiction	Threatened Species Demand	Threatened Population Demand	Total Population Demand	Forest Potential 1960 (%)	Forest Potential 2050 (%)	Capacity (km2)
ON	28	556	5295	45	57	59199
MI	25	613	2917	57	67	12284
NC	25	182	839	71	69	7194
PA	25	216	633	73	76	3027
VA	24	141	610	71	70	1651
SC	22	115	258	65	58	1848
GA	21	159	485	70	58	3482
IL	18	46	177	69	49	1209
KY	18	125	467	75	64	1656
NY	18	152	958	71	74	11514
WV	18	174	284	77	73	4804
BC	17	372	3059	48	49	75601
OH	17	238	720	71	72	1552
OR	17	165	233	31	28	8421
AL	15	25	99	63	60	1725
CA	15	98	253	17	16	11252
IN	15	44	150	71	68	874
MD	15	52	228	68	63	310
MO	14	35	229	63	39	2435
TN	14	63	139	69	65	3584
DE	13	55	366	58	64	258
MN	13	80	940	45	28	4343
NE	13	71	131	4	4	55
WA	13	98	289	40	37	10385
ME	12	82	885	69	71	2941
MT	12	88	301	22	18	9559
WI	12	111	883	64	52	3139
AB	11	127	511	46	31	33234
FL	11	64	125	59	55	3610
TX	11	53	125	12	12	1138
MB	10	63	444	31	17	24584
NH	10	39	271	72	73	655
NJ	10	49	644	64	71	2078
CT	9	42	245	69	67	476
NS	9	37	1277	67	66	4735
SK	9	230	913	26	8	7485
VT	9	23	233	72	78	1851
CO	8	39	26	11	11	3954
ID	8	50	138	25	21	7104

Jurisdiction	Threatened Species Demand	Threatened Population Demand	Total Population Demand	Forest Potential 1960 (%)	Forest Potential 2050 (%)	Capacity (km2)
KS	8	36	57	11	6	96
NB	8	123	1798	68	70	4835
MA	7	26	274	70	67	182
QC	7	91	2189	42	56	109112
WY	7	74	65	13	12	8627
NV	6	22	38	5	8	2707
PE	6	37	597	48	65	326
UT	6	7	19	8	10	2638
YT	6	80	355	23	44	24055
AK	5	22	293	22	37	179906
MS	5	5	60	66	61	2043
NL	5	143	1428	32	55	12593
OK	5	9	98	20	18	573
AZ	4	13	6	6	6	1845
NM	4	23	11	5	6	502
RI	4	7	150	53	57	144
ND	3	11	94	6	4	391
NT	3	0	151	17	31	45206
AR	2	6	140	61	53	4083
IA	2	6	36	25	14	515
LA	2	2	78	59	51	2929
SD	1	9	97	6	4	206

Appendix C: Ecozone summary table

The following table includes basic information about the ecozones included in this study, including the ecozone ID, name, biome, jurisdiction, latitude and longitude of ecozone centroid, and the following metrics:

- **Climate velocity**: the ecozone's mean climate velocity in meters per year. Describes the geographic distance that must be traveled per year in order to remain at the same mean annual temperature.
- **Richness 1960**: the number of species identified as historically present in the ecozone according to cross-validated species plot data and Little range. Note that this estimate only includes the 100 study species, so actual species richness may be higher.
- **At-risk 2050s**: the number of species identified as at-risk under 2050s climate projections in this ecozone (present in 1960s, predicted to decline to below 0.1% ecozone occurrence in 2050s).
- **Gain 2050s**: the number of species predicted to gain suitable habitat in the ecozone under 2050s climate projections (absent in 1960s, predicted to rise above 1% ecozone occurrence in 2050s).

The table is sorted in descending order by number of species identified as at-risk in the 2050s. Ecozones with no trailing edge populations have been excluded from the table.

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
1497	McGrath Till Plain and Drumlins	Temperate Mixed	MN	45.66	-93.95	4417	47	20
1871	Southern Shale Valleys	Temperate Mixed	NC	35.19	-84.26	665	4	20
1444	Wadena/Todd Drumlins and Osakis Till Plain	Temperate Mixed	MN	46.22	-95.05	6607	35	17
1678	Northern Limestone/Dolomite Valleys	Temperate Mixed	WV	39.55	-77.96	619	7	17
1391	Alexandria Moraines and Detroit Lakes Outwash Plain	Temperate Mixed	MN	46.33	-95.67	6751	19	16
1392	Champlain Lowlands	Temperate Mixed	VT	44.39	-73.32	445	-31	16
1494	Anoka Sand Plain and Mississippi Valley Outwash	Temperate Mixed	MN	45.48	-93.6	3580	44	16
1515	St. Croix Stagnation Moraines	Temperate Mixed	WI	45.32	-92.6	3540	44	16
1579	Central Sand Ridges	Temperate Mixed	WI	44.1	-89.33	4685	42	16
1807	Northern Inner Piedmont	Southern Pine	VA	36.89	-79.63	778	4	16
1932	Plateau Escarpment	Temperate Mixed	TN	35.86	-85.31	1844	8	16
1469	Taconic Foothills	Temperate Mixed	NY	42.67	-73.5	549	-2	15
1673	Northern Shale Valleys	Temperate Mixed	PA	40	-77.58	720	-4	15
1936	Eastern Highland Rim	Southern Pine	TN	36.07	-85.94	2490	3	15
1414	St. Lawrence Lowlands	Temperate Mixed	NY	44.6	-75.28	1461	-29	14
1782	Permian Hills	Temperate Mixed	WV	39.45	-81.05	2221	8	14
1542	Green Bay Till and Lacustrine Plain	Temperate Mixed	WI	44.69	-88.46	5643	-9	13
1543	Big Woods	Temperate Mixed	MN	44.76	-93.76	4239	38	13
1565	Blufflands and Coulees	Temperate Mixed	WI	43.68	-91.15	4354	49	13

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
1578	Glacial Lake Wisconsin Sand Plain	Temperate Mixed	WI	44.16	-90.02	5779	48	13
1596	Rochester/Paleozoic Plateau Upland	Temperate Mixed	MN	43.81	-92.17	5564	55	13
1765	Monongahela Transition Zone	Temperate Mixed	WV	39.24	-81.21	1717	12	13
1834	Crawford-Mammoth Cave Uplands	Southern Pine	KY	37.91	-86.78	5118	12	13
1930	Caseyville Hills	Southern Pine	KY	37.34	-86.76	4795	16	13
1569	Lake Michigan Lacustrine Clay Plain	Temperate Mixed	WI	44.12	-88.12	3582	7	12
1722	Piedmont Uplands	Southern Pine	MD	39.28	-77.02	1187	7	12
1830	Outer Bluegrass	Southern Pine	KY	38.41	-84.68	3975	15	12
1946	Western Pennyroyal Karst Plain	Southern Pine	KY	36.79	-86.93	4560	18	12
2038	Southern Table Plateaus	Temperate Mixed	AL	34.32	-86.22	2315	1	12
932	CWHws1	Pacific Northwest	BC	54.62	-128.8	58	-25	11
1580	Saginaw Lake Plain	Temperate Mixed	MI	43.51	-83.51	3638	-12	11
1600	Southeastern Wisconsin Savannah and Till Plain	Temperate Mixed	WI	43.38	-88.9	4087	22	11
1770	River Hills	Southern Pine	MO	39.12	-91.14	5882	44	11
1812	Knobs-Lower Scioto Dissected Plateau	Temperate Mixed	OH	38.8	-83.19	3834	12	11
1836	Mitchell Plain	Southern Pine	IN	38.35	-86.19	5089	12	11
1884	Northern Forested Plateau Escarpment	Temperate Mixed	KY	37.83	-83.7	2648	13	11
1965	Outer Nashville Basin	Southern Pine	TN	35.82	-86.47	2927	-1	11
797	Clyde River	Temperate Mixed	NS	43.73	-65.6	5911	8	10
1556	Erie/Ontario Lake Plain	Temperate Mixed	PA	42.57	-79.48	1929	-21	10
1572	Cadillac Hummocky	Temperate	MI	43.85	-85.3	6130	-10	10

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
	Moraines	Mixed						
1583	Long Island Sound Coastal Lowland	Temperate Mixed	CT	41.1	-72.96	1363	-14	10
1594	Michigan Lake Plain	Temperate Mixed	MI	43.01	-86.26	3947	-29	10
1601	Lansing Loamy Plain	Temperate Mixed	MI	42.94	-84.61	3374	-9	10
1612	Kettle Moraines	Temperate Mixed	WI	42.9	-88.21	4907	9	10
1635	Maumee Lake Plain	Temperate Mixed	MI	41.77	-83.66	4991	-17	10
1684	Clayey High Lime Till Plains	Temperate Mixed	OH	40.89	-84.34	6131	-7	10
1878	Southern Limestone/Dolomite Valleys and Low Rolling Hills [300-max m]	Temperate Mixed	TN	36.44	-82.75	497	2	10
1891	Southern Dissected Ridges and Knobs	Temperate Mixed	TN	36.14	-83.16	486	8	10
1970	Western Highland Rim	Southern Pine	TN	35.91	-87.63	4899	2	10
957	SBSvk	Northwest Interior	BC	54.26	-121.6	123	-16	9
1281	Oak/Conifer Foothills	Pacific Northwest	OR	45.67	-121.3	229	-3	9
1498	Hudson Valley	Temperate Mixed	NY	42.52	-73.79	602	-5	9
1509	Manistee-Leelanau Shore	Temperate Mixed	MI	44.9	-85.61	3473	-20	9
1521	Mohawk Valley	Temperate Mixed	NY	42.99	-74.77	905	-2	9
1571	Newaygo Barrens	Temperate Mixed	MI	43.86	-85.92	5624	-39	9
1603	Northern Glaciated Shale and Slate Valleys	Temperate Mixed	NY	41.37	-74.46	660	1	9
1604	Glaciated Reading Prong/Hudson Highlands	Temperate Mixed	NY	41.2	-74.24	1254	5	9

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
1625	Interlobate Dead Ice Moraines	Temperate Mixed	MI	42.45	-84.24	3995	-6	9
1640	Lake Michigan Moraines	Temperate Mixed	MI	42.64	-85.96	3652	-11	9
1641	Glaciated Triassic Lowlands	Southern Pine	NJ	40.88	-74.16	926	-19	9
1645	Trap Rock and Conglomerate Uplands	Southern Pine	PA	40.05	-76.04	1202	-12	9
1663	Hackensack Meadowlands	Southern Pine	NJ	40.72	-74.13	705	-7	9
1674	Triassic Lowlands	Southern Pine	PA	39.92	-76.13	1147	-8	9
1677	Battle Creek/Elkhart Outwash Plain	Temperate Mixed	MI	41.87	-85.74	4430	-1	9
1688	Oak Openings	Temperate Mixed	MI	41.76	-83.72	5088	-17	9
1726	Summit Interlobate Area	Temperate Mixed	OH	41.04	-81.41	3569	-7	9
1732	Chicago Lake Plain	Temperate Mixed	IL	41.72	-87.58	5111	2	9
1817	Rolling Coastal Plain	Southern Pine	NC	36.54	-77.57	3347	-2	9
1870	Southern Sandstone Ridges	Temperate Mixed	TN	35.74	-83.44	1005	10	9
1885	Inner Bluegrass	Southern Pine	KY	38.02	-84.58	3678	15	9
1943	Southern Ozarkian River Bluffs	Southern Pine	IL	37.42	-89.36	6331	31	9
2006	Inner Nashville Basin	Southern Pine	TN	35.83	-86.48	2605	-2	9
1313	Ponderosa Pine/Bitterbrush Woodland	Montane	OR	44.49	-121.5	184	5	8
1473	Cheboygan Lake Plain	Temperate Mixed	MI	45.42	-84.18	2667	2	8
1483	Onaway Moraines	Temperate Mixed	MI	45.14	-84.06	3226	0	8
1523	Central Wisconsin Undulating Till Plain	Temperate Mixed	WI	44.95	-90.63	5514	21	8
1553	Platte River Outwash	Temperate Mixed	MI	44.59	-85.92	4305	-34	8

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
1562	Lower St. Croix and Vermillion Valleys	Grass & Shrublands	WI	44.77	-92.72	3837	49	8
1637	Northern Glaciated Limestone Valleys	Temperate Mixed	NJ	41.1	-74.7	869	4	8
1669	Reading Prong	Temperate Mixed	NJ	40.62	-75.19	1208	6	8
1854	Carter Hills	Temperate Mixed	KY	38.37	-83.13	3293	12	8
1889	Green River-Southern Wabash Lowlands	Southern Pine	KY	37.77	-87.38	4785	9	8
1908	Great Bend Sand Prairie	Grass & Shrublands	KS	37.97	-98.7	5519	-2	8
1941	Northern Shawnee Hills	Southern Pine	IL	37.58	-88.72	5577	31	8
1984	Bluff Hills	Southern Pine	MS	34.22	-90.45	5048	9	8
2112	Southern Pine Plains and Hills	Southern Pine	AL	31	-88.26	5184	15	8
721	Stead	Boreal	MB	50.04	-96.2	5972	25	7
736	Grand Manan	Temperate Mixed	NB	45.23	-66.04	3107	1	7
762	Magaguadavic	Temperate Mixed	NB	45.47	-67.15	2282	-6	7
782	Tusket River	Temperate Mixed	NS	44.18	-65.91	4958	20	7
783	Rossignol	Temperate Mixed	NS	44.03	-65.16	5954	20	7
1124	DM 1.2	Boreal	AB	56.55	-118.1	2560	44	7
1223	Chelan Tephra Hills	Northwest Interior	WA	47.85	-120.3	109	14	7
1320	Lake Agassiz Plains	Grass & Shrublands	MN	47.95	-96	6776	12	7
1354	Midcoast	Temperate Mixed	ME	44.08	-69.5	1670	2	7
1378	Chippewa Plains	Temperate Mixed	MN	47.48	-94.6	6622	34	7
1382	Green Mountain Foothills	Temperate Mixed	VT	44.71	-72.91	354	-3	7
1405	Upper St. Lawrence Valley	Temperate Mixed	NY	44.46	-74.93	1407	-2	7

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
1445	Winegar Dead Ice Moraine	Temperate Mixed	MI	46.35	-88.85	4847	-2	7
1460	Foothill Shrublands-Grasslands	Montane	ID	43.53	-115	270	0	7
1479	Ontario Lowlands	Temperate Mixed	NY	43.19	-77	1778	-47	7
1510	Vanderbilt Moraines	Temperate Mixed	MI	44.98	-84.42	3756	-12	7
1524	Mio Plateau	Temperate Mixed	MI	44.51	-84.64	4846	-13	7
1544	Upper Wolf River Stagnation Moraine	Temperate Mixed	WI	44.9	-89.06	6697	8	7
1630	Low Lime Drift Plain	Temperate Mixed	OH	41.21	-81.04	4499	-6	7
1689	Inner Coastal Plain	Southern Pine	NJ	40	-74.76	1573	-7	7
1690	Rock River Drift Plain	Temperate Mixed	WI	42.56	-89.21	5201	18	7
1721	Piedmont Limestone/Dolomite Lowlands	Southern Pine	PA	40.01	-76.36	1352	-8	7
1762	Unglaciated Upper Muskingum Basin	Temperate Mixed	OH	40.34	-81.65	4105	-9	7
1763	Chesapeake Rolling Coastal Plain	Southern Pine	MD	38.79	-76.74	2255	5	7
1776	Chesapeake-Pamlico Lowlands and Tidal Marshes	Southern Pine	VA	36.85	-76.28	3761	-4	7
1826	Northern Outer Piedmont	Southern Pine	VA	36.82	-78.11	2591	-4	7
1838	Knobs-Norman Upland	Southern Pine	IN	38.39	-85.79	4655	10	7
1842	Wabash River Bluffs and Low Hills	Southern Pine	IL	38.83	-87.81	5112	24	7
1853	Hills of the Bluegrass	Southern Pine	KY	38.32	-84.6	4110	12	7
1859	Triassic Basins	Southern Pine	NC	36	-79.19	2224	6	7
1990	White River Hills	Temperate Mixed	MO	36.63	-92.77	8368	22	7
2048	Grand Prairie	Southern Pine	TX	33.52	-95.36	4165	-5	7

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
2076	Floodplains and Low Terraces	Southern Pine	LA	31.35	-93.36	5023	17	7
2249	Osage Cuestas [min-300 m]	Grass & Shrublands	OK	36.99	-95.48	5037	17	7
523	Emma Lake Upland	Boreal	SK	53.73	-106.1	6342	48	6
528	Sturgeon River Plain	Boreal	SK	53.61	-106.7	3742	43	6
582	Swan Lake	Boreal	MB	52.28	-100.7	1966	27	6
610	Atlantic	Temperate Mixed	NS	44.84	-62.92	4165	22	6
641	Narrow Islands	Boreal	MB	51.28	-96.73	6849	28	6
656	Antigonish Lowlands	Temperate Mixed	NS	45.63	-61.89	3360	2	6
710	Windsor Lowlands	Temperate Mixed	NS	45.15	-63.53	5258	-5	6
743	North Mountain	Temperate Mixed	NS	44.92	-65.22	4172	1	6
751	Annapolis Valley	Temperate Mixed	NS	44.98	-64.86	4233	-4	6
758	South Mountain	Temperate Mixed	NS	44.58	-65.14	5044	11	6
770	Steinbach	Boreal	MB	49.4	-96.61	6780	27	6
1296	Downeast Coast	Temperate Mixed	ME	44.63	-67.91	2103	-2	6
1328	Deer Lodge-Philipsburg-Avon Grassy Intermontane Hills and Valleys	Grass & Shrublands	MT	46.46	-113	219	6	6
1346	Townsend Basin	Grass & Shrublands	MT	46.08	-111.6	215	1	6
1356	Superior Mineral Ranges	Temperate Mixed	WI	46.85	-89.56	3401	-4	6
1369	Northern Connecticut Valley	Temperate Mixed	NH	44.1	-71.98	534	-16	6
1386	Dry Intermontane Sagebrush Valleys	Montane	MT	44.74	-112.9	174	1	6
1419	Lake Superior Clay Plain	Temperate Mixed	WI	46.66	-90.46	3719	-6	6
1434	Vermont Piedmont	Temperate Mixed	VT	43.5	-72.44	545	1	6
1440	St. Croix Pine Barrens	Temperate	WI	46.15	-91.91	4811	0	6

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
		Mixed						
1448	Menominee-Drummond Lakeshore	Temperate Mixed		45.92	-85.87	3140	5	6
1456	Menominee Drumlins and Ground Moraine	Temperate Mixed	MI	45.88	-87.47	4893	-4	6
1464	Western New England Marble Valleys	Temperate Mixed	MA	42.49	-73.29	495	2	6
1472	Chequamegon Moraines and Outwash Plain	Temperate Mixed	WI	46.04	-91.2	5215	3	6
1478	Wisconsin/Michigan Pine Barrens	Temperate Mixed	WI	45.59	-88.07	5971	0	6
1499	Eastern Snake River Basalt Plains	Steppe & Desert	ID	43.38	-113	749	0	6
1519	Door Peninsula	Temperate Mixed	WI	44.93	-87.32	5418	2	6
1546	Des Moines Lobe	Grass & Shrublands	IA	43.46	-94.55	5844	33	6
1547	Tawas Lake Plain	Temperate Mixed	MI	44.13	-83.96	5044	-7	6
1608	Eastern Iowa and Minnesota Drift Plains	Grass & Shrublands	IA	42.95	-92.46	5812	45	6
1658	Foothill Shrublands	Grass & Shrublands	CO	38.75	-106	300	3	6
1687	Savanna Section	Temperate Mixed	WI	42.72	-90.19	5071	26	6
1701	Erie Gorges	Temperate Mixed	OH	41.44	-81.41	3667	-6	6
1708	Forested Hills and Mountains	Temperate Mixed	WV	38.89	-80.01	1764	-5	6
1720	Rock River Hills	Temperate Mixed	IL	42.08	-89.66	5268	36	6
1740	Northern Indiana Lake Country	Temperate Mixed	IN	41.32	-85.63	5477	2	6
1756	Northern Sedimentary and Metasedimentary Ridges	Temperate Mixed	VA	38.75	-78.39	855	4	6
1757	Delmarva Uplands	Southern Pine	DE	38.73	-75.67	2783	-12	6
1781	Western Dissected Illinoian Till Plain	Southern Pine	IL	40.27	-90.5	5073	11	6

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
1805	Ohio/Kentucky Carboniferous Plateau	Temperate Mixed	OH	38.64	-82.8	3189	11	6
1840	Wabash-Ohio Bottomlands	Southern Pine	IN	38.04	-87.97	4802	3	6
1898	Eastern Ozark Border	Temperate Mixed	MO	37.9	-90.29	6975	33	6
1902	Karstic Northern Ozarkian River Bluffs	Southern Pine	IL	38.13	-89.99	5822	21	6
1945	Southern Shawnee Hills	Southern Pine	IL	37.43	-88.8	5746	23	6
1962	Cretaceous Hills	Southern Pine	IL	37.22	-88.86	6157	23	6
1968	Black River Hills Border	Temperate Mixed	MO	36.96	-90.48	7323	31	6
1972	Loess Plains	Southern Pine	MS	34.8	-89.55	5462	6	6
2016	Kings Mountain	Southern Pine	SC	35.11	-81.44	1176	-1	6
2101	Tifton Upland	Southern Pine	GA	31.11	-83.87	3983	25	6
2116	Tallahasee Hills/Valdosta Limesink	Southern Pine	FL	30.41	-83.38	5007	23	6
2120	Gulf Coast Flatwoods	Southern Pine	FL	30.06	-85.06	5179	11	6
426	Frobisher Plain	Boreal	SK	56.62	-108.2	5173	47	5
435	Garson Lake Plain	Boreal	SK	56.34	-109.5	4436	49	5
436	Palmbere Plain	Boreal	SK	56.37	-108.8	4876	47	5
449	Dillon Plain	Boreal	SK	55.74	-108.9	4948	48	5
450	Mid-Boreal Uplands 450	Boreal	SK	55.83	-108.1	5078	49	5
458	La Plonge Plain	Boreal	SK	55.41	-107.2	5335	53	5
461	Canoe Lake Lowland	Boreal	SK	55.33	-108.3	5033	53	5
474	Waterhen Plain	Boreal	SK	54.72	-108.1	5308	54	5
478	Dore Lake Lowland	Boreal	SK	54.7	-107.6	5453	54	5
479	Mahigan Lake Plain	Boreal	SK	54.87	-107	5973	57	5
489	Beaver River Plain	Boreal	SK	54.31	-109.4	5631	39	5
490	Smoothstone Plain	Boreal	SK	54.6	-107.1	6155	57	5
495	St. Cyr Plain	Boreal	SK	54.14	-108.2	5194	52	5
506	Meadow Lake Plain	Boreal	SK	54.07	-108.8	5537	39	5

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
507	Clarke Lake Plain	Boreal	SK	54.21	-107.2	5250	57	5
517	Leoville Hills	Boreal	SK	53.71	-107.4	5398	45	5
524	White Gull Plain	Boreal	SK	53.86	-104.5	6782	56	5
532	Cedar Lake	Boreal	MB	53.62	-99.82	5085	36	5
540	Whitefox Plain	Boreal	SK	53.53	-104.8	6574	52	5
544	Tobin Lake Lowland	Boreal	SK	53.6	-103.5	2840	41	5
554	Red Earth Plain	Boreal	SK	53.25	-103.4	3252	38	5
555	Pasquia Escarpment	Boreal	SK	53.26	-102.5	7110	56	5
559	Overflowing River	Boreal	MB	53.14	-101.6	4497	41	5
570	Mistatim Upland	Boreal	SK	52.94	-103.4	5362	63	5
579	Hudson Bay Plain	Boreal	SK	52.71	-102.7	5636	55	5
581	Pelican Lake	Boreal	MB	52.76	-100.3	3395	36	5
595	Chitek Lake	Boreal	MB	52.63	-99.38	5403	37	5
613	Waterhen	Boreal	MB	51.92	-99.26	4870	34	5
617	Bras d'Or Uplands - North	Temperate Mixed	NS	45.99	-60.52	3145	8	5
635	Gypsumville	Boreal	MB	51.76	-98.57	7187	33	5
637	Bras d'Or Uplands - South	Temperate Mixed	NS	45.8	-61.16	3811	2	5
646	Grandview	Grass & Shrublands	MB	51.25	-100.6	3799	21	5
650	Dauphin	Grass & Shrublands	MB	51.34	-100.1	3278	20	5
655	Hill Lands East	Temperate Mixed	PE	46.1	-62.77	4402	-8	5
657	Mulgrave Plateau	Temperate Mixed	NS	45.47	-61.69	5289	4	5
659	Gimli	Boreal	MB	50.77	-97.07	7679	28	5
660	Gridstone	Boreal	MB	51.4	-96.93	7349	36	5
674	Pictou-Cumberland Lowlands	Temperate Mixed	NS	45.84	-63.63	4270	-4	5
682	Sheet harbour	Temperate Mixed	NS	45.04	-62.69	5963	9	5
683	Ste. Rose	Grass & Shrublands	MB	51.02	-99.4	4345	20	5
730	Beaverbank	Temperate Mixed	NS	44.94	-63.71	5599	-2	5

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
761	Chester	Temperate Mixed	NS	44.67	-64.15	5604	4	5
766	Lunenburg Drumlins	Temperate Mixed	NS	44.47	-64.72	5248	10	5
798	Upper St.. Lawrence Plain	Temperate Mixed	QC	45.5	-73.63	1260	-32	5
802	North Gower-Winchester Plains	Temperate Mixed	ON	45.25	-75.16	1610	-29	5
804	Glenngary Plain	Temperate Mixed	ON	45.12	-74.89	1743	-33	5
938	ICHmc2	Northwest Interior	BC	55.29	-128	83	29	5
1131	CM 2.1	Boreal	AB	56.93	-110.7	3456	50	5
1152	DM 2.1	Boreal	AB	54.15	-111.3	4205	35	5
1245	Grand Fir Mixed Forest	Montane	WA	46.23	-121.3	217	7	5
1259	Flathead Valley	Steppe & Desert	MT	47.74	-114.2	188	5	5
1304	Glacial Lake Basins	Grass & Shrublands	ND	46.8	-99.01	5354	2	5
1316	Beach Ridges and Sand Deltas	Grass & Shrublands	MN	47.64	-96.82	5963	8	5
1325	Drift Plains	Grass & Shrublands	ND	47.1	-98.7	5972	2	5
1331	End Moraine Complex	Grass & Shrublands	ND	47.94	-99.16	5237	1	5
1335	Non-calcareous Foothill Grassland	Grass & Shrublands	MT	45.99	-109.8	278	12	5
1374	Townsend-Horseshoe-London Sedimentary Hills	Grass & Shrublands	MT	45.94	-111.5	203	4	5
1389	Low Southern Cascades Mixed Conifer Forest	Montane	CA	41.62	-122	227	10	5
1411	Northern and Western Adirondack Foothills	Temperate Mixed	NY	44.24	-74.71	1113	1	5
1412	Gulf of Maine Coastal Lowland	Temperate Mixed	ME	43.18	-70.67	1038	2	5
1428	Gulf of Maine Coastal Plain	Temperate Mixed	NH	42.87	-71.36	1243	4	5
1443	Paradise Valley	Montane	MT	45.42	-110.7	89	3	5

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
1457	Worcester/Monadnock Plateau	Temperate Mixed	NH	42.92	-71.94	1112	-1	5
1462	Brule and Paint River Drumlins	Temperate Mixed	WI	45.72	-88.68	5987	-3	5
1468	Northern Wisconsin Highlands Lakes Country	Temperate Mixed	WI	45.86	-89.59	5596	-8	5
1492	Chippewa Lobe Rocky Ground Moraines	Temperate Mixed	WI	45.56	-90.7	5662	-10	5
1512	Blue Hills	Temperate Mixed	WI	45.43	-91.43	5276	3	5
1527	Perkinstown End Moraines	Temperate Mixed	WI	45.31	-89.78	6558	-9	5
1528	Cape Cod/Long Island	Southern Pine	RI	41.3	-71.56	2327	-5	5
1548	Berkshire Transition	Temperate Mixed	CT	41.99	-73.09	1180	6	5
1557	Glaciated Low Allegheny Plateau	Temperate Mixed	NY	42.24	-76.26	2328	4	5
1633	Northern Sandstone Ridges	Temperate Mixed	PA	39.79	-78.08	1068	-5	5
1662	Passaic Basin Freshwater Wetlands	Southern Pine	NJ	40.76	-74.42	1440	-19	5
1691	Chiwaukee Prairie Region	Temperate Mixed	WI	42.63	-87.9	5239	-4	5
1696	Pine Barrens	Southern Pine	NJ	39.75	-74.6	2268	-8	5
1707	Pittsburgh Low Plateau	Temperate Mixed	PA	40.78	-79.74	2579	-9	5
1717	Valparaiso-Wheaton Morainal Complex	Temperate Mixed	IL	41.78	-87.93	5757	11	5
1718	Delaware River Terraces and Uplands	Southern Pine	NJ	39.5	-75.25	2015	-8	5
1730	Marblehead Drift/Limestone Plain	Temperate Mixed	OH	41.35	-83	5059	-7	5
1754	Sand Area	Temperate Mixed	IL	41.08	-88.34	5641	13	5
1755	Northern Igneous Ridges	Temperate Mixed	VA	38.47	-78.52	614	4	5
1795	Loamy High Lime Till Plains	Temperate Mixed	IN	39.9	-85.23	6815	12	5

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
1800	Mad River Interlobate Area	Temperate Mixed	OH	40.05	-83.79	7161	-1	5
1810	Whitewater Interlobate Area	Temperate Mixed	IN	39.87	-85.11	8130	-1	5
1850	Southern Illinoian Till Plain	Southern Pine	IL	38.59	-88.95	5586	19	5
1851	Flint Hills	Grass & Shrublands	KS	38.2	-96.57	6340	14	5
1883	Middle Mississippi Alluvial Plain	Southern Pine	IL	38.17	-89.93	5739	9	5
1897	Osage/Gasconade Hills	Temperate Mixed	MO	38.07	-92.52	7341	37	5
1913	Meramec River Hills	Temperate Mixed	MO	37.97	-91.06	7823	36	5
1926	Southeastern Floodplains and Low Terraces	Southern Pine	GA	33.05	-84.24	3576	10	5
1939	Southern Outer Piedmont	Southern Pine	GA	34.18	-82.72	1733	4	5
1973	Eastern Blue Ridge Foothills	Temperate Mixed	NC	35.77	-81.62	338	12	5
1974	Northern Holocene Meander Belts [50-max m]	Southern Pine	AR	35.55	-90.04	4039	9	5
2005	Dissected Springfield Plateau-Elk River Hills	Temperate Mixed	AR	36.22	-93.93	7125	18	5
2008	Northern Hilly Gulf Coastal Plain	Southern Pine	TN	35.12	-88.87	5691	10	5
2015	Southern Inner Piedmont	Southern Pine	GA	33.9	-84.61	829	-3	5
2082	Shale Hills	Temperate Mixed	AL	33.64	-87.27	2951	6	5
2100	Dougherty Plain	Southern Pine	GA	31.21	-85.03	3586	14	5
2109	Southern Rolling Plains	Southern Pine	MS	31.45	-90.84	6589	3	5
2124	Central Florida Ridges and Uplands	Southern Pine	FL	28.82	-81.92	4281	-5	5
2129	Baton Rouge Terrace	Southern Pine	LA	30.49	-90.92	5821	14	5
224	Champagne	Montane	YT	60.86	-136.4	754	30	4

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
498	Frog Lake Upland	Boreal	SK	54.04	-109.8	6138	39	4
504	Bronson Upland	Boreal	SK	53.9	-109.4	6197	39	4
508	Montreal Lake Plain	Boreal	SK	54.15	-105.8	6967	57	4
519	Onion Lake Plain	Boreal	SK	53.41	-108.7	7225	43	4
527	Witchekan Plain	Boreal	SK	53.35	-107.4	5212	36	4
535	The Pas Moraine	Boreal	MB	53.26	-100.2	5286	37	4
539	Shellbrook Plain	Boreal	SK	53.28	-106.4	3474	18	4
543	Meeting Lake Upland	Boreal	SK	53.23	-107.5	7881	44	4
547	Grand Rapids	Boreal	MB	53.58	-99.06	5025	32	4
549	Nisbet Plain	Boreal	SK	52.97	-106.1	2884	9	4
572	Madelaine	Temperate Mixed	QC	47.43	-61.78	3865	-4	4
573	Tiger hills Upland	Boreal	SK	52.69	-105.1	4098	11	4
584	Barrier River Upland	Boreal	SK	52.34	-103.6	6070	42	4
602	Ainslie Uplands	Temperate Mixed	NS	46.09	-61.3	3560	3	4
627	Charlottetown	Temperate Mixed	PE	46.29	-62.73	3816	-5	4
636	O'Leary	Temperate Mixed	PE	46.69	-64.1	3395	-10	4
653	Ashern	Boreal	MB	51.1	-98.01	8086	37	4
654	East Prince	Temperate Mixed	PE	46.37	-63.68	4178	-8	4
665	Alonsa	Grass & Shrublands	MB	50.8	-98.92	5172	23	4
668	Pictou-Antigonish Highlands	Temperate Mixed	NS	45.54	-62.29	6416	-4	4
689	St. Mary's Block	Temperate Mixed	NS	45.4	-62.74	6175	3	4
693	McCreary	Grass & Shrublands	MB	50.78	-99.59	4509	27	4
702	Chignecto-Minas Shore	Temperate Mixed	NS	45.56	-64.26	4202	-7	4
703	Cumberland Hills	Temperate Mixed	NS	45.59	-64.22	4347	-8	4
711	Sussex	Temperate Mixed	NB	45.71	-65.51	2827	-5	4
716	Lundar	Grass &	MB	50.48	-97.84	7460	24	4

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
		Shrublands						
745	Shilo	Grass & Shrublands	MB	49.89	-99.37	5222	4	4
746	Pinawa	Boreal	MB	50	-95.59	5783	34	4
750	Mount Pleasant	Temperate Mixed	NB	45.4	-66.44	2571	-4	4
755	Oromocto	Temperate Mixed	NB	45.71	-66.57	1952	-3	4
807	Lancaster	Temperate Mixed	QC	45.01	-74.55	1741	-28	4
808	Smith Falls Plain	Temperate Mixed	ON	44.9	-75.93	2175	-38	4
811	Frontenac	Temperate Mixed	ON	44.46	-76.11	2287	-43	4
817	Dundalk Till Plain	Temperate Mixed	ON	44.07	-80.4	5853	-21	4
824	Guelph Drumlin Fields	Temperate Mixed	ON	43.49	-80.33	4930	-51	4
832	St. Clair Plains	Temperate Mixed	ON	42.41	-82.42	3414	-26	4
919	ICHvc	Northwest Interior	BC	56.33	-129.4	79	-8	4
1130	CM 2.2	Boreal	AB	56.89	-112.7	2808	52	4
1134	PRP 1.1	Boreal	AB	55.63	-118.5	2636	44	4
1158	M 2.2	Montane	AB	53.01	-118	113	55	4
1211	Okanogan Pine/Fir Hills	Northwest Interior	WA	48.46	-119.9	127	15	4
1248	Yakima Plateau and Slopes	Montane	WA	46.46	-120.9	218	2	4
1267	Palouse Hills	Grass & Shrublands	WA	47	-117.2	688	9	4
1277	Camas Valley	Steppe & Desert	MT	47.63	-114.6	214	5	4
1306	Turtle Mountains	Grass & Shrublands	ND	48.92	-100.1	6141	22	4
1317	Central Maine Embayment	Temperate Mixed	ME	44.61	-69.56	983	-1	4
1330	Judith Basin Grassland	Grass & Shrublands	MT	46.88	-109.8	386	0	4

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
1343	John Day/Clarno Highlands	Montane	OR	44.6	-119.8	570	7	4
1353	Cold Basins	Montane	OR	44.45	-119	728	16	4
1393	Sebago-Ossipee Hills and Plains	Temperate Mixed	ME	43.84	-70.92	593	-1	4
1399	Keweenaw-Baraga Moraines	Temperate Mixed	MI	46.92	-88.49	3363	-7	4
1401	Glacial Lakes Upham and Aitkin	Temperate Mixed	MN	47.06	-92.95	5663	15	4
1413	Semiarid Foothills	Grass & Shrublands	UT	40.57	-112.5	243	-5	4
1418	Itasca and St. Louis Moraines	Temperate Mixed	MN	46.83	-94.55	6715	23	4
1420	Grand Marais Lakeshore	Temperate Mixed	MI	46.43	-86	2781	-3	4
1423	Seney-Tahquamenon Sand Plain	Temperate Mixed	MI	46.3	-85.8	2835	-3	4
1439	Minnesota/Wisconsin Upland Till Plain	Temperate Mixed	MN	46.32	-93.07	6099	12	4
1463	Taconic Mountains	Temperate Mixed	VT	43.02	-73.23	456	10	4
1513	Boston Basin	Temperate Mixed	MA	42.39	-71.13	1358	-1	4
1534	Rensselaer Plateau	Temperate Mixed	NY	42.7	-73.45	573	8	4
1554	Finger Lakes Uplands and Gorges	Temperate Mixed	NY	42.66	-76.82	2881	-13	4
1566	Lower Berkshire Hills	Temperate Mixed	MA	42.07	-73.12	1510	10	4
1602	Northern Glaciated Limestone Ridges, Valleys, and Terraces	Temperate Mixed	PA	41.26	-74.85	492	2	4
1615	Barrier Islands/Coastal Marshes	Southern Pine	NJ	39.93	-73.98	2344	-4	4
1647	Anthracite Subregion	Temperate Mixed	PA	40.95	-76.1	1604	0	4
1716	Illinois/Indiana Prairies	Temperate Mixed	IL	40.59	-88.72	5739	21	4
1741	Paulding Plains	Temperate Mixed	OH	41.26	-84.43	5802	3	4

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
1746	Upper Mississippi Alluvial Plain	Southern Pine	IL	40.45	-90.77	4589	13	4
1749	Semiarid Benchlands and Canyonlands [2100-max m]	Steppe & Desert	UT	39.08	-109.1	446	-8	4
1771	Middle Tippecanoe Plains	Temperate Mixed	IN	41	-86.41	6014	-4	4
1775	Escarpments	Steppe & Desert	UT	38.88	-110.5	357	-9	4
1794	Rolling Sand Plains	Grass & Shrublands	CO	38.41	-102.6	2778	0	4
1796	Virginian Barrier Islands and Coastal Marshes	Southern Pine	DE	37.72	-75.53	4066	-1	4
1803	Darby Plains	Temperate Mixed	OH	39.79	-83.45	6364	6	4
1863	Mid-Atlantic Flatwoods	Southern Pine	NC	36.16	-76.97	4013	0	4
1888	Prairie Ozark Border	Temperate Mixed	MO	38.59	-92.84	6206	11	4
1892	Carolina Slate Belt	Southern Pine	NC	35.26	-80.24	2444	0	4
1912	Central Plateau	Temperate Mixed	MO	37.12	-91.95	7554	15	4
1938	St. Francois Knobs and Basins	Temperate Mixed	MO	37.55	-90.54	7832	22	4
1940	Springfield Plateau	Temperate Mixed	MO	36.87	-93.81	7450	11	4
1948	Current River Hills	Temperate Mixed	MO	37.15	-91.22	8242	21	4
1959	Canadian/Cimarron Breaks	Grass & Shrublands	TX	36.36	-100.4	4797	-1	4
2019	Sequatchie Valley	Temperate Mixed	AL	34.81	-85.9	1306	-4	4
2026	Lower Boston Mountains	Temperate Mixed	AR	35.71	-93.54	6648	7	4
2043	Blackland Prairie	Southern Pine	MS	33.28	-88.66	3394	8	4
2046	Fall Line Hills	Southern Pine	AL	33.33	-87.45	3141	5	4
2051	Sea Islands/Coastal Marsh	Southern Pine	SC	32.1	-80.72	4242	22	4

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
2056	Little Mountain	Southern Pine	AL	34.57	-87.33	3311	0	4
2091	Sea Island Flatwoods	Southern Pine	GA	31.1	-81.79	4560	19	4
2118	Eastern Florida Flatwoods	Southern Pine	FL	28.24	-81.11	4796	-5	4
2125	Flatwoods	Southern Pine	TX	30.46	-93.97	7961	6	4
2135	Texas-Louisiana Coastal Marshes	Southern Pine	LA	29.82	-93.25	5987	7	4
2250	Southern Limestone/Dolomite Valleys and Low Rolling Hills [min-300 m]	Temperate Mixed	GA	34.52	-85.38	967	-4	4
174	Nordenskiold River	Boreal	YT	62.12	-136	1180	13	3
503	Mossy River Plain	Boreal	SK	54.17	-103.7	5464	40	3
510	Namew Lake Upland	Boreal	SK	54.33	-102.3	4338	35	3
531	Summerberry	Boreal	MB	53.91	-100.8	4802	32	3
534	Saskatchewan Delta	Boreal	SK	53.78	-102.3	4698	31	3
546	Nipawin Plain	Boreal	SK	53.37	-103.8	3131	42	3
552	La Come Plain	Boreal	SK	53.26	-104.7	4466	34	3
601	Northumberland Shore	Temperate Mixed	NB	47.19	-65.03	1716	3	3
603	Bras d'Or Lowlands	Temperate Mixed	NS	45.99	-60.64	2394	14	3
621	Swan River Plain	Boreal	MB	51.52	-101.6	5362	22	3
622	Allardville	Temperate Mixed	NB	47.36	-65.44	1426	7	3
647	Sevogle	Temperate Mixed	NB	46.8	-66.38	2039	-5	3
648	St. Quentin	Temperate Mixed	NB	47.37	-67.36	2403	-8	3
651	Hill Lands Central	Temperate Mixed	PE	46.34	-63.4	4546	-12	3
667	Harcourt	Temperate Mixed	NB	46.34	-65.19	2346	1	3
671	Miramichi	Temperate Mixed	NB	46.46	-66.13	1572	7	3
677	Tuadook Lake	Temperate Mixed	NB	46.96	-66.61	3623	-6	3

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
684	Juniper	Temperate Mixed	NB	46.69	-67.1	2918	-10	3
695	Cobequid Highlands	Temperate Mixed	NS	45.54	-63.6	5362	-1	3
709	Appalachian Complex of Beauce	Temperate Mixed	QC	46.32	-70.67	1825	-5	3
714	Middle St. Lawrence Plain	Temperate Mixed	QC	46.25	-72.08	1201	9	3
719	Grand Lake	Temperate Mixed	NB	45.94	-66.04	1883	4	3
726	Gladstone	Grass & Shrublands	MB	50.24	-98.82	4964	13	3
738	Winnipeg	Grass & Shrublands	MB	49.76	-97.34	6304	18	3
742	Pokiok	Temperate Mixed	NB	45.87	-67.3	1942	3	3
756	Carberry	Grass & Shrublands	MB	49.95	-99.37	5692	5	3
763	Whitemouth	Boreal	MB	49.42	-95.59	6570	34	3
778	Piney	Boreal	MB	49.29	-95.93	6902	34	3
787	Turtle Mountain	Grass & Shrublands	MB	49.05	-100.2	5864	22	3
812	Napanee - Prince Edward	Temperate Mixed	ON	44.19	-76.91	2175	-38	3
813	Sturgeon Lake	Temperate Mixed	ON	44.48	-78.35	2620	-42	3
815	Lake Scugog - Oak Ridge	Temperate Mixed	ON	44.14	-78.67	2483	-39	3
816	Peterborough	Temperate Mixed	ON	44.29	-78.31	2487	-49	3
818	Holland River	Temperate Mixed	ON	44.11	-79.51	2927	-39	3
819	Central Iroquois Plain	Temperate Mixed	ON	43.91	-79.19	2806	-40	3
820	Teeswater Drumlin Fields	Temperate Mixed	ON	43.84	-81.08	5299	-42	3
821	South Slope Oak Ridges Moraine	Temperate Mixed	ON	43.73	-79.67	3411	-42	3
822	Stratford Till Plain	Temperate Mixed	ON	43.54	-81.24	5413	-51	3

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
825	Southwest Iroquois Plain	Temperate Mixed	ON	43.24	-79.97	2979	-47	3
829	Mount Elgin Ridges	Temperate Mixed	ON	42.79	-81.73	3906	-57	3
830	Southern Horseshoe Moraine	Temperate Mixed	ON	43.04	-81.14	5704	-59	3
1008	ICHwk1	Northwest Interior	BC	51.44	-118.6	56	0	3
1050	CDFmm	Pacific Northwest	BC	49.02	-123.7	217	-4	3
1054	IDFww1	Northwest Interior	BC	50.64	-122.4	42	17	3
1260	Scattered Eastern Igneous-Core Mountains	Montane	MT	47.65	-110.2	551	2	3
1269	Eastern Maine-Southern New Brunswick Plains	Temperate Mixed	ME	45.32	-68.02	1657	2	3
1308	Maritime-Influenced Zone	Montane	OR	45.39	-118.5	419	12	3
1310	Glacial Lake Deltas	Grass & Shrublands	ND	47.79	-99.79	4697	2	3
1312	Glacial Lake Agassiz Basin	Grass & Shrublands	ND	47.41	-96.94	5671	8	3
1361	Continental Zone Foothills	Montane	OR	44.36	-117.8	354	1	3
1368	Glacial Outwash	Steppe & Desert	ND	47.38	-98.52	5859	2	3
1373	Pumice Plateau	Montane	OR	43.12	-121.4	534	3	3
1379	Nashwauk/Marcell Moraines and Uplands	Temperate Mixed	MN	47.58	-93.2	5578	4	3
1421	Eastern Adirondack Foothills	Temperate Mixed	NY	43.8	-73.75	376	9	3
1452	Sunapee Uplands	Temperate Mixed	NH	43.35	-72.07	815	8	3
1506	Tug Hill Transition	Temperate Mixed	NY	43.6	-75.69	1648	2	3
1530	Lower Worcester Plateau/Eastern Connecticut Upland	Temperate Mixed	MA	42.2	-72.21	1524	7	3
1531	Southern New	Temperate	CT	41.66	-72.41	1602	7	3

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
	England Coastal Plains and Hills	Mixed						
1535	Narragansett/Bristol Lowland	Temperate Mixed	MA	41.81	-71.09	2011	-4	3
1539	Black Hills Foothills	Grass & Shrublands	WY	44.28	-104.2	648	1	3
1568	Semiarid Hills and Low Mountains	Steppe & Desert	ID	42.27	-113.2	347	0	3
1574	Sagebrush Steppe Valleys	Steppe & Desert	ID	42.56	-112.5	387	1	3
1575	Catskills Transition	Temperate Mixed	NY	42.08	-74.7	722	7	3
1595	Cattaraugus Hills	Temperate Mixed	NY	42.67	-78.52	4756	5	3
1609	Delaware-Neversink Highlands	Temperate Mixed	PA	41.78	-75.41	1373	7	3
1610	Northern Glaciated Ridges	Temperate Mixed	NY	41.36	-74.65	757	5	3
1621	Low Poconos	Temperate Mixed	PA	41.37	-75.01	1208	8	3
1672	Northern Dissected Ridges and Knobs	Temperate Mixed	WV	39.27	-79	965	-6	3
1682	Mountain Valleys	Montane	UT	39.22	-111.8	236	-4	3
1685	Mosquito Creek/Pymatuning Lowlands	Temperate Mixed	OH	41.6	-80.71	3371	-3	3
1702	Uplands and Valleys of Mixed Land Use	Temperate Mixed	PA	40.23	-78.96	3512	-3	3
1816	Glaciated Wabash Lowlands	Southern Pine	IN	39.25	-87.26	6192	-2	3
1847	Dissected Appalachian Plateau	Temperate Mixed	KY	37.46	-82.52	1172	2	3
1862	Osage Cuestas [300-max m]	Grass & Shrublands	KS	38.44	-95.49	6404	17	3
1877	San Luis Shrublands and Hills	Steppe & Desert	CO	37.33	-105.9	294	-1	3
1882	Wooded Osage Plains	Grass & Shrublands	MO	38.49	-94.26	5839	8	3
1918	Prairie Tableland	Grass & Shrublands	OK	36.9	-97.81	5371	-2	3

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
1949	Sauratown Mountains	Temperate Mixed	NC	36.39	-80.29	787	10	3
1957	Mesa de Maya/Black Mesa	Grass & Shrublands	NM	36.97	-103.3	1132	1	3
1977	Carolina Flatwoods	Southern Pine	SC	33.8	-79.3	4186	-5	3
2003	Broad Basins	Temperate Mixed	NC	35.25	-83.34	276	3	3
2033	Arkansas Valley Hills	Temperate Mixed	AR	35.4	-92.51	2244	20	3
2034	Transition Hills	Southern Pine	AL	34.83	-88.02	4620	0	3
2039	Arkansas Valley Plains	Temperate Mixed	AR	35.19	-94.19	1462	9	3
2042	Flatwoods/Blackland Prairie Margins	Southern Pine	AL	33.21	-88	3648	8	3
2044	Lower Canadian Hills	Temperate Mixed	OK	34.88	-95.98	3621	18	3
2094	Pine Mountain Ridges	Southern Pine	GA	32.85	-84.64	2405	3	3
2110	Southern Post Oak Savanna	Southern Pine	TX	29.98	-97.08	4327	0	3
2122	Gulf Barrier Islands and Coastal Marshes	Southern Pine	AL	30.23	-87.34	4788	4	3
2126	Balcones Canyonlands	Grass & Shrublands	TX	29.95	-98.87	6146	-7	3
2233	Sand Hills [min-300 m]	Southern Pine	SC	33.77	-81.67	3070	10	3
149	Stewart Valley	Boreal	YT	63.56	-136.4	788	-12	2
156	Rosebud Creek	Boreal	YT	63.19	-137.6	1295	-23	2
173	Destruction Bay	Alpine	YT	60.94	-139.2	179	3	2
192	Tintina	Boreal	YT	62.9	-134.9	653	2	2
275	Liard River	Boreal	NT	61.76	-122.6	772	1	2
285	Sibbeston	Boreal	NT	61.41	-123.7	807	-16	2
308	Trout Lake North	Boreal	NT	60.92	-121.8	1601	-4	2
313	Etsho Plateau	Boreal	NT	60.21	-123.5	1392	11	2
318	Muskwa	Taiga	YT	60.1	-124.3	876	10	2
407	Firebag Hills	Boreal	SK	57.17	-109.5	5372	33	2
415	Black Birch Plain	Boreal	SK	57.16	-107.6	5119	25	2

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
423	North Shore	Boreal	NL	49.38	-54.77	2600	-23	2
433	North Central	Boreal	NL	49.1	-55.6	2025	-24	2
453	Red Indian	Boreal	NL	48.59	-56.75	2309	-43	2
457	Cornerbrook	Boreal	NL	48.95	-57.84	653	-42	2
485	St. Georges Bay	Boreal	NL	48.37	-58.5	694	-40	2
502	Cape St. George	Boreal	NL	48.55	-59.07	1392	-39	2
520	Cormorant Lake	Boreal	MB	54.44	-100.5	4511	38	2
526	Turtle River Plain	Boreal	SK	53.29	-109	6030	16	2
556	Gaspe Peninsula	Temperate Mixed	QC	48.58	-65.88	955	-14	2
557	Prince Albert Plain	Boreal	SK	53.04	-105.3	3394	9	2
578	Cape Breton Escarpment	Temperate Mixed	NS	46.51	-60.76	3404	-2	2
585	Goose Lake Plain	Grass & Shrublands	SK	51.78	-107.3	3724	-2	2
586	Appalachian Complex of Lower St. Lawrence	Temperate Mixed	QC	48.11	-68.6	1452	-8	2
620	Arm River Plain	Grass & Shrublands	SK	51.15	-105.9	4176	-1	2
625	Jacquet	Temperate Mixed	NB	47.74	-66.1	1562	1	2
633	Coteau Hills	Grass & Shrublands	SK	51.23	-107.3	3600	-1	2
642	Bald Mountains	Temperate Mixed	NB	47.38	-66.52	2927	-6	2
645	Beechy Hills	Grass & Shrublands	SK	50.92	-107.4	4254	-1	2
652	Eyebrow Plain	Grass & Shrublands	SK	50.86	-106.2	4486	-1	2
661	Madawaska	Temperate Mixed	NB	47.49	-68.39	2229	-4	2
670	Chaplin Plain	Grass & Shrublands	SK	50.38	-106.6	4839	-1	2
675	St. Lazre	Grass & Shrublands	MB	50.66	-101.4	4134	7	2
681	Lac Jacques-Cartier Highlands	Boreal	QC	47.53	-71.24	2469	-15	2
701	Centreville-Grand	Temperate	NB	46.54	-67.57	2035	0	2

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
	Falls	Mixed						
712	Cypress Hills	Grass & Shrublands	SK	49.62	-109.3	6064	0	2
720	Fundy Mountain	Temperate Mixed	NB	45.66	-65.18	3587	-11	2
727	MacGregor	Grass & Shrublands	MB	49.95	-98.68	4585	11	2
729	Carleton	Temperate Mixed	NB	46.16	-67.66	1852	8	2
735	Griffin Plain	Grass & Shrublands	SK	49.53	-103.1	4736	-2	2
737	Portage	Grass & Shrublands	MB	50.07	-98.14	5587	13	2
789	Rainey	Boreal	ON	48.83	-94.18	5363	4	2
790	Dumaine Plateau	Boreal	QC	46.63	-77.72	4428	-6	2
791	Mont Tremblant Highlands	Boreal	QC	46.23	-74.21	2622	-6	2
794	Mont Laurier Depression	Boreal	QC	46.1	-75.55	2069	4	2
795	Appalachian Complex of Estrie	Temperate Mixed	QC	45.4	-71.88	1233	-13	2
799	Montreal River	Boreal	ON	47.31	-84.39	6110	-10	2
800	Nipissing	Boreal	ON	46.3	-80.67	2731	-1	2
810	Manitoulin	Temperate Mixed	ON	45.54	-82.07	2878	31	2
826	Niagara Bench	Temperate Mixed	ON	43.17	-79.4	1927	-50	2
827	Haldiman Plain	Temperate Mixed	ON	42.96	-79.59	2320	-49	2
828	Norfolk Sand Plain	Temperate Mixed	ON	42.87	-80.49	4088	-56	2
831	Big Creek - Long Point	Temperate Mixed	ON	42.67	-80.42	2762	-47	2
833	Point Pelee Shores	Temperate Mixed	ON	42.01	-82.8	3987	-21	2
848	Cook Inlet	Pacific Northwest	AK	61.44	-150.8	556	-21	2
854	Northern Appalachians and Atlantic Maritime	Boreal	ME	46.17	-70.27	2219	-8	2

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
	Highlands							
899	BWBSvk	Boreal	BC	59.51	-137.7	68	-9	2
917	ESSFmc	Montane	BC	55.09	-127	231	5	2
953	ESSFmv2	Montane	BC	55.03	-121.2	442	-5	2
970	SBSmh	Northwest Interior	BC	53.1	-122.5	270	13	2
973	SBPSmk	Northwest Interior	BC	52.27	-122.2	1096	41	2
980	ESSFwk1	Montane	BC	53.04	-121.3	246	-4	2
983	IDFww	Northwest Interior	BC	50.68	-123.1	44	12	2
1005	ICHvk1	Northwest Interior	BC	51.72	-118.7	45	1	2
1013	ICHmw3	Northwest Interior	BC	51.47	-119.4	72	12	2
1016	CWHdm	Pacific Northwest	BC	49.68	-123.4	66	6	2
1019	IDFmw2	Northwest Interior	BC	51.23	-119.9	81	23	2
1053	IDFxh2	Northwest Interior	BC	50.53	-120.7	121	11	2
1056	IDFdk2	Northwest Interior	BC	50.03	-120.4	164	30	2
1084	PPxh1	Steppe & Desert	BC	49.56	-119.6	74	3	2
1092	MSdw	Northwest Interior	BC	49.58	-115.3	151	14	2
1093	ESSFdk1	Montane	BC	49.49	-115.2	518	1	2
1111	LBH 1.1	Boreal	AB	58.71	-118.9	3171	32	2
1149	M 2.1	Montane	AB	54	-119	351	45	2
1151	LF 2.1	Montane	AB	53.65	-116.7	1353	6	2
1156	M 3.2	Montane	AB	53.09	-117.9	188	34	2
1160	CP 1.1	Grass & Shrublands	AB	53.18	-112.2	4172	30	2
1173	CP 1.2	Grass & Shrublands	AB	52.21	-112.5	3314	26	2
1175	NF 1.1	Grass & Shrublands	AB	51.82	-111.8	3960	-1	2

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
1178	FF 1.1	Grass & Shrublands	AB	50.26	-113.6	984	5	2
1186	MG 1.1	Grass & Shrublands	AB	50.19	-112.9	1629	-2	2
1201	North Cascades Lowland Forests	Pacific Northwest	WA	48.38	-121.7	77	5	2
1202	Coastal Lowlands	Pacific Northwest	OR	44.02	-124.1	761	-7	2
1207	Olympic Rainshadow	Pacific Northwest	WA	48.05	-122.9	257	-1	2
1208	Pasayten/Sawtooth Highlands	Montane	WA	48.71	-120.3	237	21	2
1209	Volcanics	Pacific Northwest	OR	46.03	-123.5	481	4	2
1212	Okanogan Valley	Steppe & Desert	WA	48.38	-119.6	151	3	2
1250	Spokane Valley Outwash Plains	Northwest Interior	WA	47.85	-117.2	287	11	2
1252	Foothill Grassland	Grass & Shrublands	MT	48.06	-111.8	476	-2	2
1273	Flathead Hills and Mountains	Grass & Shrublands	MT	47.54	-114.5	242	11	2
1274	Quebec/New England Boundary Mountains	Temperate Mixed	ME	45.24	-70.43	948	-11	2
1284	Central Foothills	Temperate Mixed	ME	45.4	-69.03	529	-2	2
1291	Northern Dark Brown Prairie	Grass & Shrublands	ND	48.85	-102.7	4507	0	2
1292	Peatlands	Temperate Mixed	MN	48.49	-94.96	6187	15	2
1293	Penobscot Lowlands	Temperate Mixed	ME	45.03	-68.69	1225	3	2
1297	Lower Clearwater Canyons	Montane	ID	46.43	-116.4	337	3	2
1300	Bitterroot-Frenchtown Valley	Grass & Shrublands	MT	46.57	-114.1	133	8	2
1309	Canyons and Dissected Highlands	Montane	OR	45.64	-117.1	402	16	2
1315	Miissouri Coteau Slope	Grass & Shrublands	ND	47.83	-101.9	5831	1	2

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
1318	Umatilla Dissected Uplands	Grass & Shrublands	OR	45.37	-119.1	344	0	2
1324	Unglaciated Montana High Plains	Grass & Shrublands	MT	46.23	-109.5	721	1	2
1327	Canyons and Dissected Uplands	Grass & Shrublands	OR	45.71	-116.8	174	2	2
1329	Eastern Divide Mountains	Montane	MT	46.8	-112.2	326	11	2
1338	Limy Foothill Grassland	Grass & Shrublands	MT	46.94	-111	283	4	2
1342	White Mountains/Blue Mountains	Temperate Mixed	NH	44.4	-71.06	335	0	2
1344	Blue Mountain Basins	Grass & Shrublands	OR	45.35	-117.6	230	4	2
1348	Missouri Plateau	Grass & Shrublands	ND	46.53	-102.7	4748	-1	2
1349	Missouri Coteau	Grass & Shrublands	ND	46.46	-99.75	6381	0	2
1398	Continental Zone Highlands	Montane	OR	43.98	-119.1	992	8	2
1422	Oak Savanna Foothills	Montane	OR	42.39	-122.9	207	3	2
1426	Michigamme Highland	Temperate Mixed	MI	46.62	-87.86	4256	1	2
1427	Rudyard Clay Plain	Temperate Mixed	MI	46.27	-84.37	2194	21	2
1438	Klamath/Goose Lake Basins	Montane	OR	42.14	-121.4	357	2	2
1447	Border High-Siskiyous	Montane	OR	42.01	-123.1	278	4	2
1450	Pryor-Bighorn Foothills	Grass & Shrublands	MT	45.32	-108.2	364	3	2
1459	Klamath Juniper Woodland/Devils Garden	Montane	CA	41.96	-121.1	626	3	2
1465	Marble/Salmon Mountains-Trinity Alps	Montane	CA	41.27	-123.2	126	2	2
1470	Outer North Coast Ranges	Pacific Northwest	CA	40.03	-123.4	321	12	2
1517	Connecticut Valley	Temperate Mixed	CT	41.95	-72.67	670	10	2

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
1525	Dissected Plateaus and Teton Basin	Steppe & Desert	ID	43.76	-111.5	533	1	2
1545	Modoc/Lassen Juniper-Shrub Hills and Mountains	Montane	CA	40.9	-120.5	394	4	2
1561	Black Hills Plateau	Montane	SD	43.98	-103.7	765	15	2
1586	Fort Bragg/Fort Ross Terraces	Pacific Northwest	CA	39.09	-123.7	1893	9	2
1598	Northeastern Sierra Mixed Conifer-Pine Forests	Montane	CA	39.54	-120.2	337	1	2
1606	Northern Sierra Upper Montane Forests	Montane	CA	39.17	-120.4	280	-4	2
1607	Sierra Nevada-Influenced Semiarid Hills and Basins	Steppe & Desert	NV	39.27	-119.6	146	-2	2
1648	Napa-Sonoma-Lake Volcanic Highlands	Mediterranean	CA	38.56	-122.5	684	3	2
1656	Carbonate Woodland Zone [2150-max m]	Steppe & Desert	NV	39.42	-115.1	338	-8	2
1679	Central Sierra Lower Montane Forests	Montane	CA	38.34	-120.4	234	7	2
1719	Bay Terraces/Lower Santa Clara Valley	Mediterranean	CA	37.51	-122.1	561	5	2
1728	Rolling Loess Prairies	Grass & Shrublands	IA	41.12	-92.98	5470	1	2
1750	Kankakee Marsh	Temperate Mixed	IN	41.36	-86.92	5648	-3	2
1790	Rolling Plains and Breaks	Grass & Shrublands	KS	39.34	-99.67	5265	-1	2
1808	Interior Santa Lucia Range	Mediterranean	CA	35.56	-120.7	577	0	2
1820	Claypan Prairie	Grass & Shrublands	MO	39.45	-91.98	5598	34	2
1827	Pre-Wisconsinan Drift Plains	Temperate Mixed	IN	39.01	-84.89	5498	7	2
1841	Greenbriar Karst	Temperate Mixed	WV	37.7	-80.66	489	8	2
1865	Pinyon-Juniper Woodlands and Savannas	Grass & Shrublands	NM	35.46	-105.5	665	-1	2

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
1896	Sand Dunes and Sand Sheets	Steppe & Desert	CO	37.8	-105.7	185	-1	2
1906	Grand Canyon	Steppe & Desert	AZ	36.26	-112.4	82	0	2
1909	Mid-Atlantic Floodplains and Low Terraces	Southern Pine	NC	34.35	-78.78	4149	-4	2
1911	Cherokee Plains	Grass & Shrublands	MO	37.65	-94.38	6010	11	2
1937	Cumberland Plateau	Temperate Mixed	TN	36.01	-84.98	1580	7	2
1979	Western Lowlands Pleistocene Valley Trains	Southern Pine	AR	35.51	-90.88	3222	4	2
1992	Rolling Red Hills	Grass & Shrublands	OK	35.92	-99.31	5528	0	2
2000	Salt Plains	Grass & Shrublands	OK	36.78	-98.23	5213	-3	2
2007	Atlantic Southern Loam Plains	Southern Pine	SC	33.07	-81.51	3591	12	2
2011	Western Lowlands Holocene Meander Belts	Southern Pine	AR	35.22	-91.22	2748	6	2
2021	Northern Pleistocene Valley Trains	Southern Pine	MS	34.19	-90.37	4758	7	2
2036	Arkansas River Floodplain	Temperate Mixed	AR	35.25	-93.6	1103	11	2
2045	Scattered High Ridges and Mountains	Temperate Mixed	AR	35.1	-93.99	2113	16	2
2054	Fourche Mountains	Temperate Mixed	AR	34.82	-93.88	2357	20	2
2065	Talladega Upland	Southern Pine	AL	33.69	-85.5	1440	5	2
2083	Coastal Plain Red Uplands	Southern Pine	GA	32.57	-83.44	2995	13	2
2088	Northern Post Oak Savanna	Southern Pine	TX	33	-95.72	4542	4	2
2089	Southern Hilly Gulf Coastal Plain	Southern Pine	AL	32.21	-87.93	4195	7	2
2104	Buhrstone/Lime Hills	Southern Pine	AL	31.84	-88.01	4331	4	2

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
2108	Okefenokee Plains	Southern Pine	GA	30.8	-82.72	5411	26	2
2123	San Antonio Prairie	Southern Pine	TX	30.64	-96.57	7357	0	2
2131	Inland Swamps	Southern Pine	LA	30.07	-91.17	5726	7	2
2236	Flat to Rolling Plains [min-1100 m]	Grass & Shrublands	KS	38.68	-101.2	4216	0	2
2242	Sedimentary Mid-Elevation Forests [min-2550 m]	Montane	CO	37.87	-106.8	261	3	2
178	St. Elias	Alpine	YT	60.68	-139.6	156	0	1
215	Pelly River	Taiga	YT	62.01	-131.5	1305	-43	1
219	Auriol Range	Alpine	YT	60.62	-137.7	428	-51	1
228	Lake Labarge	Montane	YT	61.24	-135	903	19	1
277	Fort Simpson	Boreal	NT	61.62	-121.8	1038	-5	1
281	Horn River	Taiga	NT	62.37	-120.6	2646	-11	1
310	Larsen Creek	Boreal	YT	60.27	-125.1	1214	10	1
312	Trout Lake	Boreal	NT	60.49	-121.4	2983	-14	1
320	Petitot Plain	Boreal	NT	60.15	-120.4	3775	-4	1
329	Domes	Arctic	NL	57.97	-63.64	1377	-21	1
332	Cameron Hills Upland	Taiga	NT	60.06	-118.5	6444	-14	1
341	Central Ranges	Taiga	NL	57.15	-62.74	1423	-31	1
342	George Rriver Upper Plateau	Taiga	QC	57.23	-64.97	2930	-24	1
396	McTaggart Plain	Boreal	SK	58.03	-108.8	4536	24	1
412	Salmon River	Boreal	NL	50.64	-56.93	834	-35	1
413	Peninsula-White Bay	Boreal	NL	50.19	-56.68	2022	-38	1
442	Terra Nova	Boreal	NL	48.36	-54.25	3806	-37	1
466	Serpentine Range	Boreal	NL	49.15	-58.22	809	-43	1
483	Portage Pond	Boreal	NL	48.41	-57.74	2103	-44	1
501	Port au Port	Boreal	NL	48.57	-58.99	799	-36	1
513	Anticosti	Boreal	QC	49.48	-62.99	2540	-27	1
514	Codroy	Boreal	NL	47.97	-59.02	2970	-40	1
521	Norway House	Boreal	MB	54.07	-97.74	4735	28	1
525	Lloydminster Plain	Grass & Shrublands	SK	52.9	-109.2	5312	3	1

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542	Whitewood Hills Upland	Grass & Shrublands	SK	52.95	-107.7	5704	21	1
564	Berens River	Boreal	MB	52.62	-96.95	6480	24	1
566	Notre-Dame Mountains	Temperate Mixed	QC	48.78	-65.81	836	-15	1
574	Melfort Plain	Boreal	SK	52.86	-104.4	4041	22	1
577	Cudworth Plain	Grass & Shrublands	SK	52.51	-105.7	3829	2	1
591	Bear Hills	Grass & Shrublands	SK	51.97	-108	4923	-1	1
592	Quill Lake Plain	Grass & Shrublands	SK	52.07	-104.3	4555	6	1
596	Rosetown Plain	Grass & Shrublands	SK	51.51	-108.1	3659	-1	1
597	Biggar Plain	Grass & Shrublands	SK	52	-108.1	5583	0	1
598	Elstow Plain	Grass & Shrublands	SK	51.92	-106	4223	0	1
604	Fraser Lowland	Pacific Northwest	Sliver	49	-122.2	300	NA	1
624	Allan Hills	Grass & Shrublands	SK	51.57	-105.9	5162	-1	1
631	Touchwood Hills Upland	Grass & Shrublands	SK	51.32	-103.8	5294	20	1
634	Whitesand Plain	Grass & Shrublands	SK	51.59	-102.9	5066	8	1
692	Regina Plain	Grass & Shrublands	SK	50.25	-104.8	4315	-1	1
696	Dirt Hills	Grass & Shrublands	SK	50.2	-105.7	4141	-1	1
698	Kipling Plain	Grass & Shrublands	SK	50.31	-103.1	5143	1	1
699	Hamiota	Grass & Shrublands	MB	50.33	-100.5	5730	9	1
700	Plaster Rock	Temperate Mixed	NB	46.88	-67.4	2322	1	1
715	Waterton Mountains	Montane	AB	49	-113.9	801	-9	1
728	Langruth	Grass & Shrublands	MB	50.32	-98.6	5468	14	1
747	Kenora	Boreal	ON	49.5	-93.87	5177	3	1

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749	Stockton	Grass & Shrublands	MB	49.72	-99.72	4451	5	1
753	Moose Mountain	Grass & Shrublands	SK	49.82	-102.5	5891	23	1
772	Hilton	Grass & Shrublands	MB	49.45	-99.55	5445	4	1
774	Winkler	Grass & Shrublands	MB	49.28	-97.89	3855	7	1
775	Manitou	Grass & Shrublands	MB	49.2	-98.75	5424	4	1
777	Pembina Hills	Grass & Shrublands	MB	49.45	-98.77	5660	4	1
784	Emerson	Grass & Shrublands	MB	49.14	-97.3	4758	6	1
801	Russell and Prescott Plains	Temperate Mixed	ON	45.46	-75.17	1424	-21	1
803	Algonquin	Boreal	ON	45.32	-78.27	3798	-7	1
805	Muskat Lake	Temperate Mixed	ON	45.64	-76.85	1919	-24	1
806	Ottawa Valley Plain	Temperate Mixed	ON	45.39	-76.05	1739	-23	1
809	Thessalon	Boreal	ON	46.31	-83.62	2188	22	1
814	Georgian Bay South	Temperate Mixed	ON	44.46	-80.3	3559	-40	1
823	Toronto	Temperate Mixed	ON	43.71	-79.39	2837	-44	1
845	Alaska Peninsula Mountains	Pacific Northwest	AK	57.13	-157.1	599	-21	1
847	Alaska Range [1800-max m]	Alpine	AK	62.75	-149.6	445	0	1
902	BWBSdk	Boreal	BC	58.36	-129.8	204	-16	1
906	CWHwm	Pacific Northwest	BC	56.68	-131.3	51	-14	1
911	BWBSmk	Boreal	BC	58.91	-123.3	1523	28	1
914	BWBSwk3	Boreal	BC	59.21	-124.5	1305	-15	1
915	ICHwc	Northwest Interior	BC	57.07	-131	59	-12	1
926	SBSmc2	Northwest Interior	BC	54.32	-126.1	344	3	1
929	ESSFmv3	Montane	BC	55.78	-125.2	578	-6	1

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930	BWBSwk2	Boreal	BC	56.9	-122.7	560	9	1
939	ESSFwc3	Montane	BC	54.47	-121.9	391	-15	1
940	ESSFwcp	Montane	BC	52.85	-119.8	348	-14	1
941	ESSFwk2	Montane	BC	54.96	-122.1	239	-12	1
944	SBSwk2	Northwest Interior	BC	55.64	-122.8	157	2	1
951	SBSdk	Northwest Interior	BC	54.02	-125.6	432	12	1
958	BWBSwk1	Boreal	BC	55.14	-120.8	478	7	1
961	SBSdw3	Northwest Interior	BC	54.16	-124	682	5	1
962	SBSwk1	Northwest Interior	BC	54.03	-122.3	356	1	1
966	BAFAunp	Alpine	BC	52.45	-126	273	-31	1
969	SBSdw2	Northwest Interior	BC	52.83	-122.6	621	11	1
971	SBSmw	Northwest Interior	BC	53.16	-122.4	469	5	1
974	ICHwk4	Northwest Interior	BC	53.27	-121.4	88	0	1
975	ICHvk2	Northwest Interior	BC	53.91	-121.2	101	-13	1
977	ESSFxv1	Montane	BC	51.84	-124.7	139	-8	1
978	SBPSdc	Northwest Interior	BC	52.88	-123.5	1079	26	1
982	SBSdw1	Northwest Interior	BC	52.4	-121.7	400	9	1
986	ICHwk3	Northwest Interior	BC	53.56	-120.7	89	-2	1
987	ESSFmm1	Montane	BC	53.1	-119.6	183	-16	1
988	ESSFmmp	Montane	BC	52.75	-119	297	-16	1
991	ESSFwcw	Montane	BC	51.31	-118.5	219	-28	1
994	SBSdh1	Northwest Interior	BC	53.03	-119.6	75	4	1
995	IDFdk4	Northwest Interior	BC	51.89	-123.5	471	24	1
996	SBSmc1	Northwest Interior	BC	52.1	-121.3	518	21	1

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998	IDFxm	Northwest Interior	BC	51.88	-122.6	307	24	1
999	IDFdk3	Northwest Interior	BC	51.66	-121.8	518	11	1
1001	ICHwk2	Northwest Interior	BC	52.54	-120.9	86	11	1
1006	ESSFwc2	Montane	BC	51.88	-119.1	140	-23	1
1011	ESSFxv2	Montane	BC	51.24	-122.9	235	-2	1
1017	ICHdw3	Northwest Interior	BC	51.64	-119.8	76	24	1
1021	MSxk3	Northwest Interior	BC	50.96	-121.9	238	27	1
1022	ESSFdvw	Montane	BC	50.74	-122.6	112	-2	1
1023	ESSFxcw	Montane	BC	49.79	-120.9	856	3	1
1026	ESSFmmw	Montane	BC	51.26	-116.8	224	-10	1
1029	ESSFdv2	Montane	BC	50.95	-122.9	78	-8	1
1032	ESSFxvw	Montane	BC	51.14	-122.5	235	-10	1
1034	ESSFvc	Montane	BC	51.48	-118.3	67	-3	1
1040	ICHmk2	Northwest Interior	BC	51.1	-120	194	25	1
1045	IDFxc	Northwest Interior	BC	50.63	-122	41	26	1
1046	IDFdk1	Northwest Interior	BC	50.28	-120.7	231	22	1
1047	MSdm3	Northwest Interior	BC	51.03	-120.2	303	26	1
1049	MSxk2	Northwest Interior	BC	50.63	-120.8	839	34	1
1058	ESSFdcw	Montane	BC	49.7	-118.9	1273	-4	1
1059	ESSFmm3	Montane	BC	51.25	-116.9	118	-13	1
1060	MSdm2	Northwest Interior	BC	49.83	-120.3	369	22	1
1064	ICHmk5	Northwest Interior	BC	51.05	-116.5	91	14	1
1069	ICHxm1	Northwest Interior	BC	50.36	-119.2	80	35	1
1074	ESSFdkw	Montane	BC	50.17	-115.5	572	-19	1
1075	IDFdk5	Northwest Interior	BC	50.71	-116.3	82	13	1

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
1095	IDFdm2	Northwest Interior	BC	49.55	-115.6	97	34	1
1096	ICHxw	Northwest Interior	BC	49.19	-117.4	70	31	1
1099	ICHxwa	Northwest Interior	BC	49.24	-118	67	31	1
1106	ESSFwm1	Montane	BC	49.63	-115.2	293	-3	1
1107	ICHmk4	Northwest Interior	BC	49.54	-115.1	136	-12	1
1108	NM 2.1	Boreal	AB	59.67	-119.3	5060	14	1
1109	BSA 1.2	Taiga	AB	59.79	-118.2	7152	-16	1
1110	LBH 2.1	Taiga	AB	59.5	-118.7	5804	-8	1
1113	CM 1.3	Boreal	AB	58.67	-118.2	1818	30	1
1114	LBH 1.2	Boreal	AB	59.15	-115.3	5497	8	1
1127	LBH 1.3	Boreal	AB	57.24	-113.6	4608	29	1
1128	UBH 1.1	Taiga	AB	57.57	-112.9	6570	17	1
1133	DM 1.3	Boreal	AB	55.5	-117.7	2936	32	1
1135	CM 3.3	Boreal	AB	55.72	-115.8	2951	21	1
1137	CM 2.4	Boreal	AB	55.97	-113	3339	40	1
1138	LF 1.4	Montane	AB	54.48	-118.2	1571	6	1
1145	CM 3.2	Boreal	AB	54.89	-114.1	2871	7	1
1146	SA 2.1	Montane	AB	53.61	-119	786	-9	1
1148	UF 1.1	Montane	AB	54.74	-115.7	2949	13	1
1150	DM 2.2	Boreal	AB	53.99	-113.8	3072	22	1
1161	SA 2.2	Montane	AB	52.63	-117.3	409	-4	1
1163	LF 2.2	Montane	AB	52.6	-115.6	797	8	1
1174	LF 2.3	Montane	AB	51.77	-114.9	700	45	1
1179	M 4.3	Montane	AB	51.16	-115	252	32	1
1180	DMG 1.1	Grass & Shrublands	AB	50.39	-111.2	3126	-1	1
1183	SA 3.2	Grass & Shrublands	AB	50.35	-114.6	383	14	1
1187	M 4.5	Montane	AB	49.76	-114.1	407	22	1
1190	SA 3.3	Montane	AB	49.35	-114.3	779	-2	1
1191	SA 4.3	Montane	AB	49.25	-114.2	1577	-23	1
1199	Low Olympics	Pacific	WA	47.88	-124	189	1	1

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
		Northwest						
1206	Eastern Puget Riverine Lowlands	Pacific Northwest	WA	47.94	-122.2	270	-7	1
1213	Western Okanogan Semiarid Foothills	Northwest Interior	WA	48.47	-119.1	264	17	1
1214	Okanogan Highland Dry Forest	Montane	WA	48.56	-118.7	509	23	1
1216	Okanogan-Colville Xeric Valleys and Foothills	Northwest Interior	WA	48.38	-118	235	10	1
1231	Salish Mountains	Northwest Interior	MT	48.3	-115.1	352	16	1
1233	Western Cascades Montane Highlands	Pacific Northwest	OR	45.35	-122	222	-4	1
1234	Aroostook Hills	Temperate Mixed	ME	46.59	-68.39	1227	-2	1
1238	Aroostook Lowlands	Temperate Mixed	ME	46.62	-67.94	1804	2	1
1241	International Boundary Plateau	Temperate Mixed	ME	47.1	-69.42	1857	-4	1
1243	St. John Uplands	Temperate Mixed	ME	46.52	-69.39	1614	-4	1
1251	Rocky Mountain Front Foothill Potholes	Grass & Shrublands	MT	48.21	-112.8	310	3	1
1256	North Central Brown Glaciated Plains	Grass & Shrublands	MT	48.22	-111.1	909	0	1
1258	Sweetgrass Uplands	Grass & Shrublands	MT	48.94	-111.3	782	-2	1
1261	Northern Idaho Hills and Low Relief Mountains	Montane	ID	47.17	-116.7	510	25	1
1262	Upper St. John Wet Flats	Temperate Mixed	ME	46.58	-69.89	1889	-4	1
1266	Moosehead-Churchill Lakes	Temperate Mixed	ME	45.96	-69.56	886	-2	1
1268	Valley Foothills	Pacific Northwest	OR	44.71	-123	418	-6	1
1278	Upper Montane/Alpine Zone	Temperate Mixed	VT	44.52	-71.81	1469	-2	1

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
1279	Mid-Coastal Sedimentary	Pacific Northwest	OR	43.8	-123.8	955	-2	1
1280	Flathead Thrust Faulted Carbonate-Rich Mountains	Montane	MT	47.66	-113.2	303	-19	1
1285	Dissected Loess Uplands	Grass & Shrublands	WA	46.45	-117.5	404	-3	1
1289	Northern Missouri Coteau	Grass & Shrublands	ND	48.66	-103	5031	0	1
1290	Collapsed Glacial Outwash	Grass & Shrublands	ND	47.12	-100.5	6551	1	1
1295	Deep Loess Foothills	Steppe & Desert	WA	46.14	-118.1	232	1	1
1298	Montana Central Grasslands	Grass & Shrublands	MT	46.49	-106.7	2103	2	1
1302	Northern Black Prairie	Grass & Shrublands	ND	48.69	-100.3	5034	0	1
1303	Rattlesnake-Blackfoot-South Swan-Northern Garnet-Sapphire Mountains	Montane	MT	46.82	-113.4	461	4	1
1307	Mesic Forest Zone	Montane	OR	45.21	-118.2	523	6	1
1311	Pembina Escarpment	Grass & Shrublands	ND	48.73	-98.02	5589	4	1
1322	Nez Perce Prairie	Grass & Shrublands	ID	46.13	-116.3	493	1	1
1332	River Breaks	Grass & Shrublands	ND	45.97	-102.4	3876	-1	1
1339	Boundary Lakes and Hills	Temperate Mixed	MN	48.06	-91.82	4189	-8	1
1340	Forested Lake Plains	Temperate Mixed	MN	48.04	-93.51	5278	6	1
1347	Wallowas/Seven Devils Mountains	Montane	OR	45.26	-117.2	126	12	1
1350	Western Maine Foothills	Temperate Mixed	ME	44.59	-70.41	463	-3	1
1352	Saline Area	Grass & Shrublands	ND	48.03	-97.28	5752	3	1
1358	Shield-Smith Valleys	Grass & Shrublands	MT	46.26	-110.8	247	3	1

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
1365	North Shore Highlands	Temperate Mixed	MN	47.48	-91.02	3966	-9	1
1376	Northern Piedmont	Temperate Mixed	VT	44.5	-72.24	929	-14	1
1383	Green Mountains/Berkshire Highlands	Temperate Mixed	VT	43.61	-72.81	584	-1	1
1387	Mesabi Range	Temperate Mixed	MN	47.47	-92.77	5563	-7	1
1388	Toimi Drumlins	Temperate Mixed	MN	47.22	-91.98	5723	-9	1
1396	White Mountain Foothills	Temperate Mixed	NH	44.04	-71.81	323	1	1
1402	Serpentine Siskiyous	Pacific Northwest	CA	41.95	-123.7	273	19	1
1404	Pine Scoria Hills	Grass & Shrublands	MT	45.52	-106.7	1808	3	1
1410	Dry Gneissic-Schistose-Volcanic Hills	Grass & Shrublands	MT	44.69	-113	209	-4	1
1425	Rogue/Illinois/Scott Valleys	Montane	OR	42.12	-123.1	190	-3	1
1429	High Desert Wetlands	Steppe & Desert	OR	42.93	-119.3	405	0	1
1430	Semiarid Uplands	Steppe & Desert	NV	41.88	-117	433	-2	1
1433	Central Adirondacks	Temperate Mixed	NY	44.02	-74.16	421	-1	1
1435	Owyhee Uplands and Canyons	Steppe & Desert	OR	43.36	-117.5	776	1	1
1446	Western Klamath Low Elevation Forests	Pacific Northwest	CA	41.32	-123.5	119	0	1
1454	Fremont Pine/Fir Forest	Montane	OR	42.27	-120.8	502	5	1
1455	Dissected High Lava Plateau [1450-max m]	Steppe & Desert	ID	42.06	-116	552	0	1
1476	Dry Mid-elevation Sedimentary Mountains	Montane	WY	44.29	-108	192	4	1
1485	Modoc Lava Flows and Buttes	Montane	CA	41.65	-121.5	387	0	1

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
1488	Bighorn Basin	Steppe & Desert	WY	44.2	-108.5	320	0	1
1495	California Cascades Eastside Conifer Forest	Montane	CA	40.88	-121.3	407	-1	1
1500	Bighorn Salt Desert Shrub Basins	Steppe & Desert	WY	44.18	-108.2	586	1	1
1507	Foothill Shrublands and Low Mountains [2100-max m]	Grass & Shrublands	WY	42.27	-109.2	570	-7	1
1518	Warner Mountains	Montane	CA	41.61	-120.3	259	1	1
1538	Lava Fields	Steppe & Desert	ID	43.24	-113.3	696	0	1
1555	Foothill Ridges and Valleys	Mediterranean	CA	39.54	-122.5	248	3	1
1558	James River Lowland	Grass & Shrublands	SD	43.91	-97.94	4930	0	1
1564	Upper Lahontan Basin	Steppe & Desert	NV	40.87	-117.6	300	0	1
1570	Coastal Franciscan Redwood Forest	Pacific Northwest	CA	39.09	-123.4	585	-3	1
1581	Catskill High Peaks	Temperate Mixed	NY	42.07	-74.41	951	5	1
1589	Lahontan Uplands	Steppe & Desert	NV	40.44	-117.9	376	-8	1
1593	Sub-Irrigated High Valleys	Steppe & Desert	WY	42.21	-109.8	558	-1	1
1599	Saltbush-Dominated Valleys	Steppe & Desert	ID	42.17	-113.4	238	-2	1
1605	Northern Sierra Mid-Montane Forests	Montane	CA	39.64	-120.9	233	2	1
1613	Upper Humboldt Plains	Steppe & Desert	NV	41.01	-115.9	469	0	1
1624	Malad and Cache Valleys	Steppe & Desert	UT	41.91	-112	222	1	1
1626	Glaciated Allegheny Hills	Temperate Mixed	NY	42.17	-78.05	5770	5	1
1634	Sagebrush Basins and Slopes	Steppe & Desert	UT	39.58	-113	322	-1	1
1639	Woodland- and Shrub-Covered Low	Steppe & Desert	UT	38.66	-113.4	370	-7	1

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
	Mountains							
1642	Sierra Nevada-Influenced Ranges	Steppe & Desert	NV	38.38	-119	165	-3	1
1644	Glaciated High Allegheny Plateau	Temperate Mixed	PA	41.58	-76.9	3801	4	1
1646	Sierra Valley	Steppe & Desert	CA	39.72	-120.3	236	-8	1
1649	Southern River Breaks	Grass & Shrublands	SD	43.03	-98.81	4587	0	1
1652	Pocono High Plateau	Temperate Mixed	PA	41.15	-75.56	2476	6	1
1654	Ponca Plains	Grass & Shrublands	SD	43.17	-99.33	4664	0	1
1659	Crystalline Mid-Elevation Forests	Montane	CO	39.75	-105.8	219	3	1
1660	Mid-Elevation Ruby Mountains	Steppe & Desert	NV	40.66	-115.3	156	-8	1
1670	Central Nevada Mid-Slope Woodland and Brushland	Steppe & Desert	NV	39.15	-116.9	323	-6	1
1681	Moist Wasatch Front Footslopes	Steppe & Desert	UT	40.65	-111.9	147	-3	1
1686	Niobrara River Breaks	Grass & Shrublands	NE	42.79	-99.83	5679	0	1
1699	Moderate Relief Plains [1400-max m]	Grass & Shrublands	CO	39.88	-104.1	1389	-2	1
1700	Holt Tablelands	Grass & Shrublands	NE	42.54	-98.5	5358	0	1
1709	East Bay Hills/Western Diablo Range	Mediterranean	CA	37.51	-121.8	1054	0	1
1759	Tonopah Uplands	Steppe & Desert	NV	37.55	-116.9	541	-8	1
1783	Front Range Fans	Grass & Shrublands	CO	40.16	-105.1	297	-2	1
1786	Gabilan Range	Mediterranean	CA	36.6	-121.3	1020	1	1
1819	Piedmont Plains and Tablelands [1550-max m]	Grass & Shrublands	CO	38.15	-104.2	866	-1	1

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
1832	Pine-Oak Woodlands	Grass & Shrublands	CO	39.26	-104.8	478	5	1
1833	Smoky Hills	Grass & Shrublands	KS	39.15	-97.66	5301	0	1
1843	Eastern Sierra Mojavean Slopes	Montane	CA	35.52	-118.1	112	4	1
1852	South Valley Alluvium	Mediterranean	CA	35.37	-119.2	459	0	1
1866	Sandsheets	Grass & Shrublands	CO	38.37	-103.7	1310	1	1
1876	Arizona Strip Plateaus	Steppe & Desert	AZ	36.53	-113.3	307	3	1
1880	Virgin/Shivwits Woodland	Steppe & Desert	AZ	36.39	-113.7	654	4	1
1886	Swamps and Peatlands	Southern Pine	NC	35.54	-76.63	4334	1	1
1904	Southern Sedimentary Ridges	Temperate Mixed	TN	36.38	-82.07	502	4	1
1905	Southern Crystalline Ridges and Mountains [850-max m]	Temperate Mixed	NC	35.63	-82.61	589	4	1
1907	San Luis Alluvial Flats and Wetlands	Steppe & Desert	CO	37.39	-105.9	424	0	1
1914	Carolinian Barrier Islands and Coastal Marshes	Southern Pine	NC	34.94	-76.78	4221	1	1
1919	New River Plateau	Temperate Mixed	VA	36.7	-80.89	1004	6	1
1921	Lower Grand Canyon	Steppe & Desert	AZ	35.94	-113.5	93	0	1
1933	Cumberland Mountain Thrust Block	Temperate Mixed	KY	36.73	-83.5	1240	2	1
1947	Northern Cross Timbers	Grass & Shrublands	OK	35.75	-96.52	4870	-5	1
1953	Lower Mogollon Transition	Montane	AZ	34.23	-112.1	172	-1	1
1967	Upper Canadian Plateau	Grass & Shrublands	NM	36.28	-104.3	735	-3	1
1969	St. Francis Lowlands	Southern Pine	MO	36.34	-90.01	4060	19	1

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
1983	Madrean Lower Montane Woodlands [1800-max m]	Montane	NM	33.25	-107.8	348	3	1
1996	Pleistocene Sand Dunes	Grass & Shrublands	OK	36.21	-98.77	5314	-2	1
2004	Canadian Canyons	Grass & Shrublands	NM	35.65	-104.4	918	2	1
2024	Lava Malpais	Steppe & Desert	NM	34.11	-107.2	667	1	1
2028	Central New Mexico Plains [1850-max m]	Grass & Shrublands	NM	34.62	-105.8	733	-1	1
2035	Northwestern Cross Timbers	Grass & Shrublands	OK	34.81	-97.87	6040	1	1
2037	Northern Backswamps	Southern Pine	MS	33.13	-90.87	5596	0	1
2041	Caprock Canyons, Badlands, and Breaks	Grass & Shrublands	TX	33.62	-100.6	3240	-1	1
2060	Lower Madrean Woodlands	Subtropical Montane	AZ	32.17	-110	279	-2	1
2062	Arkansas/Ouachita River Backswamps	Southern Pine	AR	33.47	-91.69	4342	-1	1
2063	Central Hills, Ridges, and Valleys	Temperate Mixed	AR	34.63	-93.29	2461	4	1
2064	Dissected Plateau	Temperate Mixed	AL	34.13	-87.27	3340	-4	1
2066	Tertiary Uplands	Southern Pine	LA	32.68	-93.9	4477	13	1
2068	Western Ouachita Valleys	Temperate Mixed	OK	34.52	-95.31	3413	11	1
2073	Athens Plateau	Temperate Mixed	AR	34.28	-93.95	3428	2	1
2079	Pleistocene Fluvial Terraces	Southern Pine	AR	33.08	-92.9	4179	3	1
2081	Cretaceous Dissected Uplands	Southern Pine	OK	34.03	-94.9	3802	-6	1
2085	Eastern Cross Timbers	Grass & Shrublands	TX	33.35	-96.98	5192	-7	1
2090	Red River Bottomlands	Southern Pine	LA	32.39	-93.48	4336	5	1
2102	Bacon Terraces	Southern Pine	GA	31.54	-82.4	4467	15	1

Eco ID	Eco name	Biome	Province /state	Lat	Long	Climate velocity	2050s forest loss	2050s species at-risk
2106	Limestone Cut Plain	Grass & Shrublands	TX	31.55	-97.99	7265	-6	1
2111	Okefenokee Swamp	Southern Pine	GA	30.73	-82.33	5467	22	1
2113	Southern Backswamps	Southern Pine	LA	30.99	-91.68	6659	9	1
2114	Southern Holocene Meander Belts	Southern Pine	LA	30.53	-91.34	5930	7	1
2119	Edwards Plateau Woodland	Grass & Shrublands	TX	30.52	-99.63	6072	1	1
2127	Big Bend Coastal Marsh	Southern Pine	FL	29.35	-83.29	4897	-2	1
2128	Northern Humid Gulf Coastal Prairies	Southern Pine	TX	29.63	-95.09	5516	-2	1
2137	Southwestern Florida Flatwoods	Southern Pine	FL	27.41	-81.96	4625	0	1
2142	Southern Subhumid Gulf Coastal Prairies	Southern Pine	TX	27.93	-97.64	4641	4	1
2165	Alaska Range [min-450 m]	Alpine	AK	60.79	-153.1	323	9	1
2166	Alaska Range [450-900 m]	Alpine	AK	62.43	-150.4	424	-33	1
2169	Pacific Coastal Mountains [min-350 m]	Pacific Northwest	AK	59.57	-141	128	-21	1
2172	Pacific Coastal Mountains [1050-1400 m]	Pacific Northwest	AK	60.05	-141.7	283	-3	1
2227	SWBmk [min-1350 m]	Montane	BC	58.37	-126.7	291	-35	1
2231	Foothill Shrublands and Low Mountains [min-2100 m]	Grass & Shrublands	WY	43.02	-108.6	314	-3	1
2237	Flat to Rolling Plains [1100-1450 m]	Grass & Shrublands	CO	39.83	-102.7	3327	0	1
2251	Southern Crystalline Ridges and Mountains [min-850 m]	Temperate Mixed	NC	35.56	-82.43	289	2	1

Appendix D: Species information

The following table includes the 100 species included in this study, including the **species code, scientific name, common name**, and the following metrics:

- **1960s ecozone presence**: the number of ecozones in which the species was identified as present in the 1960s through cross-validation of plot data and Little range.
- **2050s ecozones at-risk**: the number of ecozones in which the species has been identified as at-risk under 2050s climate projections (present in 1960s, predicted to decline to below 15th percentile of species occurrence in 2050s).
- **2050s ecozones gained**: the number of ecozones in which the species has been identified to gain significant suitable climatic habitat under 2050s climate projections (absent in 1960s, predicted to rise above 30th percentile of species occurrence in 2050s).

Species code	Scientific name	Common name	1960s ecozone presence	2050s ecozones at-risk	2050s ecozones gained
abieamab	*Abies amabilis*	Pacific silver fir	95	16	102
abiebals	*Abies balsamea*	balsam fir	418	150	125
abieconc	*Abies concolor*	white fir	125	6	239
abiegran	*Abies grandis*	grand fir	103	8	167
abielasi	*Abies lasiocarpa*	subalpine fir	406	59	57
acermacr	*Acer macrophyllum*	bigleaf maple	118	1	97
acernegu	*Acer negundo*	boxelder	477	17	465
acerpens	*Acer pensylvanicum*	striped maple	167	33	101
acerrubr	*Acer rubrum*	red maple	408	23	129
acersacc	*Acer saccharinum*	silver maple	320	11	287
acersacr	*Acer saccharum*	sugar maple	341	61	125
acerspic	*Acer spicatum*	mountain maple	239	104	143

Species code	Scientific name	Common name	1960s ecozone presence	2050s ecozones at-risk	2050s ecozones gained
alnurubr	*Alnus rubra*	red alder	108	3	123
arbumenz	*Arbutus menziesii*	Pacific madrone	82	0	90
betualle	*Betula alleghaniensis*	yellow birch	295	69	108
betulent	*Betula lenta*	sweet birch	110	39	121
betunigr	*Betula nigra*	river birch	195	7	197
betupapy	*Betula papyrifera*	paper birch	907	113	288
betupopu	*Betula populifolia*	gray birch	142	27	91
carpcaro	*Carpinus caroliniana*	American hornbeam	294	19	228
carycord	*Carya cordiformis*	bitternut hickory	295	4	180
caryglab	*Carya glabra*	pignut hickory	219	37	137
caryilli	*Carya illinoensis*	pecan	105	0	152
caryovat	*Carya ovata*	shagbark hickory	231	19	182
chamnoot	*Chamaecyparis nootkatensis*	Alaska cedar	80	12	27
fagugran	*Fagus grandifolia*	American beech	326	50	118
fraxamer	*Fraxinus americana*	white ash	375	5	153
fraxnigr	*Fraxinus nigra*	black ash	306	54	245
fraxpenn	*Fraxinus pennsylvanica*	green ash	529	5	389
gledtria	*Gleditsia triacanthos*	honeylocust	175	3	228
juglcine	*Juglans cinerea*	butternut	249	58	190
juglnigr	*Juglans nigra*	black walnut	262	18	189
junivirg	*Juniperus virginiana*	eastern redcedar	326	7	257
larilari	*Larix laricina*	tamarack	624	140	160
larilyal	*Larix lyallii*	subalpine larch	60	7	87
lariocci	*Larix occidentalis*	western larch	120	15	146
liqustyr	*Liquidambar styraciflua*	sweetgum	149	0	66
lirituli	*Liriodendron tulipifera*	yellow poplar	182	54	114
nyssaqua	*Nyssa aquatica*	water tupelo	80	10	46
nysssylv	*Nyssa sylvatica*	black tupelo, blackgum	227	6	129

ostrvirg	*Ostrya virginiana*	eastern hophornbeam	395	8	174
piceenge	*Picea engelmannii*	Engelmann spruce	341	26	67
piceglau	*Picea glauca*	white spruce	766	246	193
picemari	*Picea mariana*	black spruce	729	242	167
picerube	*Picea rubens*	red spruce	139	57	109
picesitc	*Picea sitchensis*	Sitka spruce	74	4	58
pinualbi	*Pinus albicaulis*	whitebark pine	262	37	71
pinubank	*Pinus banksiana*	jack pine	392	149	160
pinucont	*Pinus contorta*	lodgepole pine	498	76	98
pinuechi	*Pinus echinata*	shortleaf pine	142	6	105
pinuelli	*Pinus elliottii*	slash pine	27	5	20
pinulamb	*Pinus lambertiana*	sugar pine	74	1	85
pinumont	*Pinus monticola*	western white pine	206	6	151
pinupalu	*Pinus palustris*	longleaf pine	57	3	27
pinupond	*Pinus ponderosa*	ponderosa pine	381	11	285
pinuresi	*Pinus resinosa*	red pine	229	12	135
pinurigi	*Pinus rigida*	pitch pine	107	42	104
pinustrb	*Pinus strobus*	eastern white pine	336	39	122
pinutaed	*Pinus taeda*	loblolly pine	89	2	67
pinuvirg	*Pinus virginiana*	Virginia pine	87	41	51
platocci	*Platanus occidentalis*	American sycamore	248	1	205
popubals	*Populus balsamifera*	balsam poplar	714	96	316
popudelt	*Populus deltoides*	eastern cottonwood	318	7	386
popugran	*Populus grandidentata*	bigtooth aspen	302	74	143
poputrem	*Populus tremuloides*	quaking aspen	1145	139	208
poputric	*Populus trichocarpa*	black cottonwood	338	26	274
prunpens	*Prunus pensylvanica*	pin cherry	372	61	249
prunsero	*Prunus serotina*	black cherry	363	4	144
pseumenz	*Pseudotsuga menziesii*	Douglas fir	445	24	148
queralba	*Quercus alba*	white oak	299	8	139
querbico	*Quercus bicolor*	swamp white oak	165	38	220
quercocc	*Quercus coccinea*	scarlet oak	157	63	131

querfalc	*Quercus falcata*	southern red oak	143	4	69
querlaur	*Quercus laurifolia*	laurel oak	63	3	26
querlyra	*Quercus lyrata*	overcup oak	105	0	99
quermacr	*Quercus macrocarpa*	bur oak	299	4	410
quermich	*Quercus michauxii*	swamp chestnut oak	114	1	88
quermueh	*Quercus muehlenbergii*	chinkapin oak	203	2	188
quernigr	*Quercus nigra*	water oak	102	0	63
querpalu	*Quercus palustris*	pin oak	148	26	194
querphel	*Quercus phellos*	willow oak	114	0	71
querprin	*Quercus prinus*	chestnut oak	133	50	103
querrubr	*Quercus rubra*	northern red oak	386	31	128
quershum	*Quercus shumardii*	Shumard oak	156	1	138
querstel	*Quercus stellata*	post oak	202	3	108
quervelu	*Quercus velutina*	black oak	247	17	160
quervirg	*Quercus virginiana*	live oak	62	0	47
robipseu	*Robinia pseudoacacia*	black locust	80	11	307
salinigr	*Salix nigra*	black willow	309	5	302
sequsemp	*Sequoia sempervirens*	redwood	23	6	15
sorbamer	*Sorbus americana*	American mountain ash	223	53	123
taxodist	*Taxodium distichum*	baldcypress	91	5	48
thujocci	*Thuja occidentalis*	northern white cedar	259	77	80
thujplic	*Thuja plicata*	western redcedar	222	9	148
tiliamer	*Tilia americana*	American basswood	316	33	182
tsugcana	*Tsuga canadensis*	eastern hemlock	256	82	118
tsughete	*Tsuga heterophylla*	western hemlock	198	9	125
tsugmert	*Tsuga mertensiana*	mountain hemlock	162	13	130
ulmuamer	*Ulmus americana*	American elm	539	0	260
ulmurubr	*Ulmus rubra*	slippery elm	310	1	179