Trait-based fire sensitivity analysis for British Columbia's bird species

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Report Summary
Historically, periodic wildfires in British Columbia (BC) created diverse habitat mosaics that supported numerous bird species. However, fire regimes are changing in response to climate change. Wildfires are increasing in severity, intensity and extent across the province. Understanding how these novel fire conditions might impact bird species is key for informing conservation efforts. Our study uses a trait-based analysis to forecast bird species responses to wildfire. By combining life-history and functional characteristics - such as habitat preference, nesting behavior, and foraging methods - we aim to predict species responses to fire even for species with limited direct fire-response data.

We reviewed 25 North American studies on bird responses to fire, extracting species-specific responses and separating results by time since fire. We combined these data with life-history and functional traits from global databases and used ANOVA statistical tests and PCA to identify trait-fire response relationships and predict responses for 243 BC bird species without direct data. In our review we found that 77 bird species responded positively to wildfire, 57 negatively, and 84 showed neutral effects, with responses varying somewhat by time since fire (0–5 vs. 5–10 years). A few species showed time-dependent shifts in response, but overall patterns were consistent. Our study also found that species' responses to fire are often linked to specific traits: bird species foraging in high forest canopies requiring dense, mature forests are most likely to be negatively impacted. Conversely, ground nesters, aerial insectivores, and those preferring open or semi-open habitats tend to respond positively to post-fire environments. These patterns were generally consistent across immediate and short-term post-fire periods, with only minor differences.

Based on these findings, we developed a Wildfire Sensitivity Index to rank species sensitivity across BC. By pairing this index with future fire weather projections, we can identify high-risk regions where conservation and habitat restoration efforts should be prioritized. Ultimately, this framework provides a practical starting point for land managers to support resilient ecosystems and targeted species protection under a shifting climate.

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Background

Wildfire is a key component of ecosystems in British Columbia, where periodic burns historically created a dynamic mosaic of habitats that supported a diversity of bird species across different successional stages. However, climate change is resulting in changes of fire regime in British Columbia, where fires are becoming more severe, extensive and a larger fires are occurring at higher extent (Mulverhill et al. 2025). Predicting how these novel fire conditions will impact bird species is key for informing conservation efforts under climate change.

Wildfires have complex effects on bird populations (Kotliar et al. 2002). Fire can reduce or increase habitat suitability, depending on the habitat preference of individual bird species across ecosystem successional stages. For example, species that rely on open or semi-open habitat can benefit from fire (i.e., aerial insectivores), while species that are associated with certain shrub or tree species, including old growth associated species, will be negatively affected after fires (Azeria et al. 2011; Bagne and Purcell 2011; Batista et al. 2023). Species reliant on dead trees for nesting or foraging, for example some but not all woodpecker species, depend on fires for creating suitable snags (Saab et al. 2004; Farris et al. 2010; Tingley et al. 2020). Another study identified positive effects of fire for some woodpeckers, secondary cavity nesting birds, aerial insectivores, and understory species, but negative effects for open cup nesting, and foliage and bark insectivores (Latif et al., 2021).

Bird responses to fire have been documented to be influenced by the time since fire, fire severity, and the type of ecosystem the fire occurred in (Smucker et al. 2005; Hutto et al. 2015). Time since fire describes the state of vegetation, or the successional stage, after fires. For example, forbs and grasses can recruit soon after fire, followed by shrubs in the years after fire. Within 5 years, juvenile trees may become available, and snags decompose after about 5 years (Saab and Powell 2005). However, this successional timing is dependent on the habitat type and composition of plant species. Severity of fire, for example if the fire cleared all vegetation, versus if only the understory burned, will also affect which species use the habitat post-fire (Fontaine and Kennedy 2012).

Despite these general relationships, making specific predictions for species across broad geographical ranges is challenging. Making associations between species and fire activity is a key step in understanding wildfire impacts on bird populations (Stillman et al., 2025). As species responses to fire may be driven by habitat preference and species traits (Scridel et al., 2025), trait-based and comparative analyses can be used to identify life history and functional traits associated with fire response (Mahony et al. 2022; Latif et al. 2021; Scridel et al. 2025). As trait data are readily available for bird species across the world, this approach leverages data that are openly available to inform predictions for understudied species, for example in British Columbia where there have been few studies examining bird-fire relationships across the wide range of habitat types in the province.

Trait-based analyses are a novel tool to inform fire responses using readily available data for BC's bird species. We use a trait-based approach to investigate the life history and functional traits that are associated with observed species sensitivity to fire (Figure 1). We also investigated trait-based differences for species responding immediately (0-5 years post fire) or in the short term since fire (5-10 years post fire). We then used these trait-fire relationships from the trait analysis, as well as traits informed by a literature search and expert knowledge, to build a wildfire trait-based sensitivity index for each British Columbia bird species. We then demonstrate how to use these indices paired with future wildfire projections to make broad scale predictions for bird species conservation under future conditions.

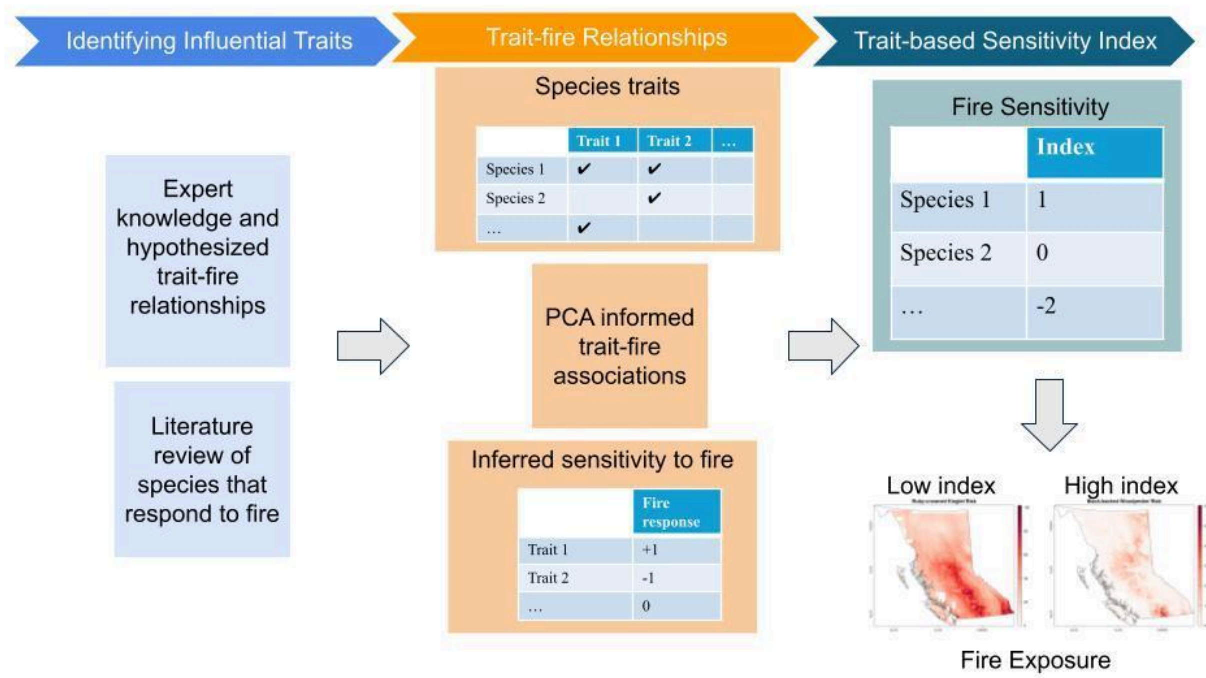

Figure 1. Workflow for linking bird traits to fire impacts using a trait-based fire sensitivity index. We began by doing a literature review to identify traits that influence species responses to fire, and to identify species that are negatively or positively impacted by fires across North America. We then used traits obtained from open-source trait databases for birds of British Columbia in a PCA analysis to infer how traits influence sensitivity to fire. Using these trait-fire relationships, we built a sensitivity index for bird species of British Columbia. Then, using species distributions, we mapped areas of high future fire weather, a component of future fire risk, to identify locations of high wildfire risk and species occurrence.

Methods.

Birds of British Columbia

We accessed a list of BC birds from Avibase's Checklist of the Birds of BC (accessed from Lepage 2025). We removed species that were listed as accidental, rare, of uncertain origin, or were introduced. We excluded the Charadriiformes, Podicipediformes, Procellariiformes, Suliformes, and Pelecaniformes orders, as these are mostly marine or strongly associated with water, and we did not find evidence in the literature that species in these orders are affected by fire. We also removed American Black Duck, Acorn Woodpecker, Blue-headed Vireo, Hermit Warbler, Chestnut-sided Warbler, Nelson's Sparrow, Green-tailed Towhee, Redpoll, and

Mountain Quail, which are species that do not meaningfully occur in BC (Andrew Huang, pers. comm.). This resulted in a list of 243 BC species.

Literature Review

We reviewed literature that examined bird responses to wildfire in North America to identify species-specific responses to fire (for example whether positive, neutral, negative, or mixed responses have been documented for the species), and to identify morphological or ecological traits that may influence species' responses. We assigned species a "mixed" category when species exhibited both positive and negative responses to fire across studies. We included studies in the review that quantified bird abundance, occupancy, or population density before and after fire, or between burned and unburned areas. A total of 25 papers were compiled according to these criteria, which included two review papers (references can be found in Appendix 1)

First, we created a list of the BC bird species identified in each study that had positive, negative, neutral, or mixed responses to fire, quantified as species abundance or occupancy in burned areas relative to unburned areas or time periods. We then used these species lists to examine which traits were associated with fire response (positive, negative, neutral, or mixed responses). We only included North America studies and included results from species that occur in BC.

In addition to this overall list, we also collated lists for immediate-term (1-5 years post fire, 17 studies) and short-term (5-10 years post fire, 3 studies) responses to fire, as fire responses are influenced by time since fire (Smucker et al. 2005; Hutto et al. 2015). We did not differentiate responses according to fire severity (e.g. stand-replacing fires versus understory-clearing fires) as few of the reviewed studies quantified severity, although we acknowledge that severity also impacts species response (Smucker et al. 2005; Fontaine and Kennedy 2012; Hutto et al. 2015). We also did not separate lists by habitat type due to low replication of studies across habitats.

Trait Data

We compiled life history and functional trait data for BC bird species using the Avonet (Tobias et al. 2022), EltonTraits (Wilman et al. 2014), Birdbase (Şekercioğlu et al. 2025), and Dubovyk (Dubovyk 2024) databases (see Table 1 for a description of traits and sources). Included traits were hypothesized to affect bird species' response to wildfire, which was informed by the literature review described in the previous section in addition to expert knowledge (trait data are available at https://github.com/jloesberg/BCBirdsandFire.

PCA

To examine the relationship between bird traits identified in the previous sections and their response to fire, we performed a principal component analysis (PCA) to examine trait associations with species that had positive, negative, neutral, or mixed responses to fire. PCA can be used to identify variables that contribute strongly to variance across species, and can be used to identify the trait loadings that are associated with fire responses. Species documented in the literature, for which there are data on species-specific fire responses, were overlaid in PCA space to estimate trait-fire relationship for species without fire response data but with trait data available.

Species on PC axes 1 and 2 were grouped by four categories: positive responses identified in the literature, negative responses, neutral responses, and mixed responses (where the literature search identified both positive and negative responses). Where species had either a positive or negative response as well as a neutral response, the final response was categorized as either positive or negative. We then tested for differences in the first and second PC axes for each fire response group using an ANOVA and Tukey HSD test. This identified the traits with the highest loadings that are associated with positive, negative, neutral, or mixed responses to wildfire.

Table 1. Trait descriptions, sources, and hypothesized trait-fire relationships determined from the literature. Each trait occupied a single row, where a trait occupied 2 rows indicates that there are multiple hypotheses for how the trait will affect species fire responses (for example, differing hypotheses for migration. Sources for fire impacts indicate research from the literature review that support the hypothesized fire impacts. NA indicates that there are not clear predictions for trait-fire relationships in the literature, although they potentially could influence species responses (e.g. range size).

variable type	trait type	trait	description	values	trait source	Hypothesized fire impacts	source for fire impacts
continuous	diet	diet_inv	extent that foraging category: invertebrate	%	EltonTraits	Insectivores will be benefited due to increased insect activity in burned areas (bark beetles, etc)	Dickson et al 2009; Saab et al. 2004; Kotliar et al. 2002; Morissette et al. 2002; Latif et al. 2021; Knaggs et al. 2020; Duquette et al. 2019; Edenius et al. 2011; Edenius et al. 2011; Duchac et al. 2021; Bagne & Purcell 2011
continuous	diet	diet_breadth	the number of major food types consumed	Lower = more diet specialized, higher = broader diet	Birdbase	Generalists will be less negatively affected	Morissette et al. 2002; Knaggs et al. 2020; Duquette et al. 2019; Edenius et al. 2011
continuous	diet	diet_seed	Percent use of: Seed, maize, nuts, spores, wheat, grains	%	EltonTraits	Seed availability increased after fire	Smucker et al. 2005; Kotliar et al. 2002
continuous	diet	diet_nectar	Percent use of: Nectar, pollen, plant exudates, gums	%	EltonTraits	Increased flowers (from early succession plants, ie fireweed) after fire will benefit nectivores	Kotliar et al. 2002; Quijano-Chacon et al. 2025
continuous	foraging location	for_strat_ground	Prevalence of: Foraging on ground	%	EltonTraits	Ground foragers will be positively affected	Latif et al. 2021; Azeria et al. 2011; Rainsford et al. 2011; Edenius et al. 2011
continuous	foraging location	for_stat_understory	Prevalence of: Foraging below 2m in understory in forest, forest edges, bushes or shrubs	%	EltonTraits	Understory foragers will be positively affected	Latif et al. 2021
continuous	foraging location	for_strat_canopy	Prevalence of: Foraging mid to high levels in trees or high bushes to in or just above (from) tree canopy	%	EltonTraits	Fire will negatively impact canopy species	Latif et al. 2021; Azeria et al. 2011; Bagne & Purcell 2011; Rainsford et al. 2011; Edenius et al. 2011; Hannon et al. 2005
continuous	foraging strategy	for_hawking	extent that foraging method is hawking (perching/incessorial. short flights from a perch)	%	Dubovyk	Aerial insectivores are benefited by increased open areas	Saab et al 2004; Kotliar et al. 2002; Morissette et al. 2002; Latif et al. 2021; Knaggs et al. 2020; Edenius et al. 2011; Bagne & Purcell 2011
continuous	foraging strategy	for_foliage_gleaning	extent that foraging method is foliage gleaning ((taking items from foliage and small branches)	%	Dubovyk	Foliage gleaners will be negatively impacted	Dickson et al 2009; Smucker et al. 2005; Fontaine et al. 2009; Kotliar et al. 2002; Latif et al. 2021

continuous	foraging strategy	for_bark_gleaning	extent that foraging method is bark gleaning (excavating, drilling, and removing items from bark)	%	Dubovyk	Bark gleaners will be negatively impacted (if foraging on live trees)	Kotliar et al. 2002; Latif et al. 2021
continuous	foraging strategy	for_bark_gleaning	extent that foraging method is bark gleaning (excavating, drilling, and removing items from bark)	%	Dubovyk	Bark gleaners will be positively impacted (if foraging on dead trees)	Azeria et al. 2011; Gyug et al. 2012; Farris et al. 2009; Hannon et al. 2005; Bagne & Purcell 2011
continuous	habitat	habitat_density	How dense habitat is	1 = Dense habitats, 2 = Semi-open habitats, 3 = Open habitats.	Avonet	Species with preference for open habitat will be benefitted by fire	Kotliar et al. 2002; Schieck & Song 2006; Morissette et al. 2002; Latif et al. 2021; Stephens et al. 2019; Cadieux et a;. 2020; Knaggs et al. 2020; Gyug et al. 2012 ; Puig-Gironès et al. 2022; Hannon et al. 2005
continuous	habitat	forest_use	Extent to which forest is preferred as a habitat	Ranges from 1-6, where 1 = forest is most preferred, 6 = least preferred. NA indicates forest not used at all	Birdbase	Species with high preference for forests will be more impacted by fire	Lewis et al 2016; Puig-Gironès et al. 2023
continuous	habitat	habitat_breadth	The number of major habitats used	Lower = more habitat specialized, higher = broader habitat use	Birdbase	Generalists will be less negatively affected	Morissette et al. 2002; Knaggs et al. 2020; Duquette et al. 2019; Edenius et al. 2011
continuous	habitat	old_growth	Is the species associated with old growth forests?	0 or 1	Schuster & Arcese, 2013 and https://databasin.org/datasets/302399b1e9164ce6ae94347d32852b48/	Old growth associated species will be negatively affected	Fontaine et al. 2009; Kotliar et al. 2002; Schieck & Song 2006; Morissette et al. 2002; Seavy & Alexander 2014; Stephens et al. 2019; Cadieux et al. 2020; Knaggs et al. 2020; Batista et al. 2023; Gyug et al. 2012; Bunnell et al. 1995; DellaSala et al. 2021
discrete	habitat	primary_habitat	The main habitat type utilized by a species	Forest, Shrubland, Savanna, Grasslands, Plains, Rocky areas, Desert, Artificial, Sea coast, Riparian, Wetlands, Open sea, Woodland:	Birdbase	Species with high preference for forests will be more impacted by fire	Lewis et al 2016; Puig-Gironès et al. 2023

continuous	life history	migration	Extent of migration	1 = Sedentary. 2 = Partially migratory, i.e. minority of population migrates long distances, or most of population undergoes short-distance migration, nomadic movements, distinct altitudinal migration, etc. 3 = Migratory, i.e. majority of population undertakes long-distance migration"	Avonet	Resident species may be more directly affected by local fire	Franklin et al. 2021; Batista et al. 2023
continuous	life history	migration	Extent of migration	1 = Sedentary. 2 = Partially migratory, i.e. minority of population migrates long distances, or most of population undergoes short-distance migration, nomadic movements, distinct altitudinal migration, etc. 3 = Migratory, i.e. majority of population undertakes long-distance migration"	Avonet	Migratory species are negatively affected by fire because they are vulnerable to disruption during migration and changes in suitable habitat	Overton et al. 2022; Bagne & Purcell 2011
continuous	life history	range_size	The total area of the mapped range of the species	km^2	Avonet	NA	NA
continuous	life history	lifespan	maximum observed lifespan	years	Dubovyk	NA	NA
continuous	life history	average_mass	the average value across males, females, and unsexed individuals in the database	g	Birdbase	Small body species are negatively impacted	Franklin et al. 2021
continuous	life history	hand_wing_index	Proxy for dispersal ability	Index: 100*DK/Lw, where DK is Kipp's distance and Lw is wing length (i.e., Kipp's distance corrected for wing size).	Avonet	Limited dispersers may struggle to track shifting suitable habitats.	Franklin et al. 2021
continuous	life history	hand_wing_index	Proxy for dispersal ability	Index: 100*DK/Lw, where DK is Kipp's distance and Lw is wing length (i.e., Kipp's distance corrected for wing size).	Avonet	Higher dispersing species will be positively affected because they can disperse to preferred habitat (recolonize burned areas)	Franklin et al . 2021; Puig-Gironès et al. 2023

discrete	life history	primary_lifestyle	General life style	Aerial, Terrestrial; Insessorial; Aquatic; Generalist	Avonet	Incessoral species may be benefitted from more open habitat (ie aerial insectivores)	Knagss et al. 2020; Bagne & Purcell 2011
discrete	life history	nest_type	majority nesting type	built.structure (includes "cup", "gourd", "sphere", "gourd", "saucer", "chamber", "oven", "pendant"), open (includes "scrape" or "no"), platform, cavity, crevice, burrow, parasitic	Dubovyk	Cavity nesters will be benefited by increased availability of dead trees	Fontaine et al. 2009; Kotliar et al. 2002; Schieck & Song 2006; Latif et al. 2021; Knaggs et al. 2020; Azeria et al. 2011; Duchac et al. 2021; Bunnell et al. 1995; Hannon et al. 2005
continuous	nest	live_tree_nest	% of nesting preference for live trees out of 100%	%	Dubovyk	Species that build nests in live tree foliage will be negatively impacted	Smucker et al 2005; Latif et al. 2021; Hannon et al. 2005
continuous	nest	snag_nest	% of nesting preference for snags out of 100%	%	Dubovyk	Snag nesters will be benefited by increased availability of dead trees	Fontaine et al. 2009; Kotliar et al. 2002; Schieck & Song 2006; Latif et al. 2021; Knaggs et al. 2020; Farris et al. 2009; Hannon et al. 2005; Bagne & Purcell 2011;
continuous	nest	deciduous_nest	% of nesting preference for deciduous trees	%	Dubovyk	Deciduous tree associated species will be negatively impacted by fire	Bagne & Purcell 2011
continuous	nest	coniferous_nest	% of nesting preference for coniferous trees	%	Dubovyk	Fire will decrease availability of conifers for longer than deciduous trees (late successional stages)	Fontaine et al. 2009; Bagne & Purcell 2011
continuous	nest	cavity_nest	is species a cavity nester	0 or 1	EltonTraits	Cavity nesters will be benefited by increased availability of dead trees	Fontaine et al. 2009; Kotliar et al. 2002; Schieck & Song 2006; Latif et al. 2021; Knaggs et al. 2020; Azeria et al. 2011; Duchac et al. 2021; Bunnell et al. 1995; Hannon et al. 2005; Bagne & Purcell 2011
continuous	nest	ground_nest	extent that species is a ground nester	%	EltonTraits	Ground nesters will be positively increased by fire and the increase in open habitat	Latif et al. 2021
continuous	nest	shrub_nest	extent that species is a shrub nester	%	EltonTraits	Shrub nesters are positively impacted because of increased shrub regrowth	Fontaine et al. 2009; Schieck & Song 2006; Latif et al. 2021
continuous	nest	shrub_nest	extent that species is a shrub nester	%	EltonTraits	Shrub nesters are negatively impacted because of loss of understory	Morissette et al. 2002; Brunk et al. 2023

Fire Sensitivity Index

Using traits of birds in the literature, as well as traits identified in the PCA to be associated with birds responding to fires, we then built a trait-based sensitivity index (fire sensitivity step in Figure 1). For the trait categories in the leftmost column of Table 2, we assigned a +1 or -1 for the traits held by each species in the Positive and Negative columns. For example, species that had trait values for a preference of incessorial or hawking foraging methods received a "+1" value, while foliage gleaning species received a "-1" value. These values were then summed for each species to create an index for fire sensitivity.

Table 2. Trait fire relationships used to build the Fire Sensitivity Index. Species that met the defined trait-fire relationships in the Positive or Negative columns were assigned a +1 or -1 value, respectively, when building the index. Species specific values can be found in Table A1.

Trait Category	Positive (+1)	Negative (-1)
Foraging	>51% Insessorial OR hawking as foraging method	>51% preference for foliage gleaning as foraging method
primary_habitat	Shrub / Grassland / Plains	Forest / Woodland
habitat_density	sparse	dense
forest_use		Only habitat used is forest
foraging_location	ground / understory	canopy
trophic_niche	Invertivore / Nectarivore / Granivore / Frugivore	
migration		sedentary
snag_use	>51% preference for snag nesting	
oldgrowth		Old growth associates
nesting_location	ground / grass / shrub nesting preference	>51% preference for nesting in live trees
nest_type	cavity	
Handwing index	> mean(hand_wing_index)	

Fire Predictions

To demonstrate how this index can be used to examine BC bird response to future fire, we used species distributions from eBird (distributions were downloaded from 2022 data; Fink et al.

2023) paired with projections of future Fire Weather Index (FWI) for Canada (Van Vliet et al. 2024; accessed from https://climatedata.ca/app/fire-weather-projections/). This open-source dataset predicts a FWI, which is a measure of potential wildfire intensity determined by weather conditions that promote fire risk. Although this incorporates only one component of fire risk and only exists for 50 km resolution, it is able to provide Canada-wide future predictions across Representative Concentration Pathways (climate change emission scenarios) and time periods up to 2100. For demonstration purposes, we used projections for RCP8.5 for 2021-2050, the "business as usual" emission scenario that is estimated to accurately project current emissions to mid-century (Schwalm et al. 2020). To identify areas of high species occurrence where FWI is predicted to be highest, we aligned the FWI and species distribution rasters using nearest-neighbor resampling, which preserves the original FWI values. We then multiplied the two layers together to visualize areas of high bird abundance and high fire risk.

We used R version 4.4.1 for all analyses. The data and code used to perform these analyses are available at https://github.com/jloesberg/BCBirdsandFire. Tidyverse (version 2.0.0) was used to clean and visualize data, Terra (version 1.8-15) was used for mapping, bcmaps (version 2.2.1) was used to crop datasets to BC borders, PCAs were run using the stats package (version 4.4.1).

Results

Literature review

We reviewed 25 peer-reviewed papers, and two review papers. Nineteen papers examined immediate bird response (0-5 years post-fire, or the time period when snag-dependent species generally favor postfire habitats, Saab and Powell 2005); five papers examined short term responses (5-10 years post-fire). Across all time frames, the literature review documented 77 species as positively responding to fire, 57 species as negatively affected, and 84 species showed no impact from fire (lists of species for each response can be found in Table 3). Positive species responses documented in the immediate (0-5 years post-fire) but not short term (5-10 years post-fire) were American Three-toed Woodpecker, Black-backed Woodpecker, Olive-sided Flycatcher, and Western Bluebird. On the other hand, positive species responses in the short term but not immediate term were Alder Flycatcher, Canada Goose, Mountain Bluebird, Clark's Nutcracker, and Common Yellowthroat. Negatively responding species between immediate and short term were the same.

Species that were consistently identified as positive fire responders (higher occurrence immediately post fire) were Black-backed Woodpecker (bark gleaning, cavity nesting) and Olive-sided Flycatcher (aerial insectivores). Many species had mixed responses across the literature (evidence of both positive, negative, and neutral responses).

PCA

The PCA analysis identified traits associated with positive and negative fire responses. Species that are negatively affected by fire tend to have canopy foraging as a trait, and species that are positively affected have high body masses, ground nesting, and prefer open habitats. Across the all time periods analysis (0-100 years postfire), midpoints of PC1 clusters for each fire response (averaged value of PC1 for each positive, negative, neutral, and mixed response) were significantly different (ANOVA, $F = 16.08$, $df = 3$, $p = 5.63e-09$; Figure 2). Positive fire responses had significantly lower PC1 loadings (-1.2 ± 1 difference) compared to negative responses (Tukey HSD; $p = 0.0117$). Responses were not significantly different on PC2 (ANOVA; $df = 3$, $F = 1.144$, $p == 0.334$). Negative loadings were associated with positive fire responses, and positive loadings were associated with negative fire responses (Figure 2). The greatest PC1 loadings were habitat density (habitat density was loaded negatively, meaning that species that prefer less dense habitats were associated with positive fire responses), canopy foragers (species that forage in the canopy were positively loaded, meaning that species that primarily forage in the canopy were associated with negative fire responses), ground nesting (negatively loaded, meaning that species that primarily nest on the ground were associated with positive fire responses), and body mass (negatively loaded, meaning that higher body mass was associated with positive fire responses).

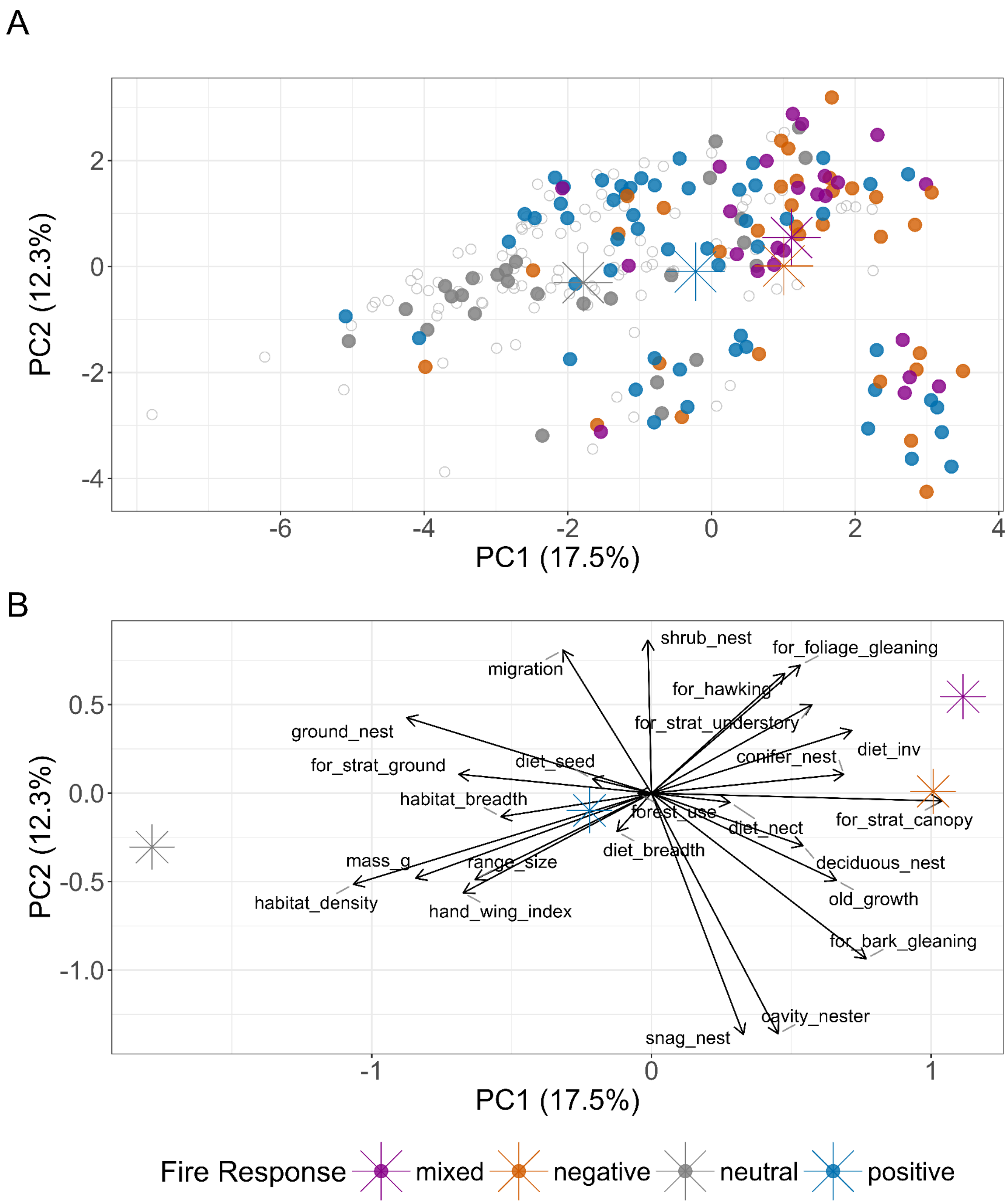

Figure 2. PCA for all species responses to fire. (A) Solid points indicate species identified in the literature review that responded to fire. Hollow points indicate BC species that were not listed in the literature to respond to fire. Stars indicate centers of each fire response for PC1 and PC2. (B) Loadings in the PCA. See Table 1 for trait descriptions.

For immediate term responses (0-5 years post-fire), midpoints of PC1 clusters for each fire response were significantly different (ANOVA, $F = 7.249$, $df = 3$, $p = 0.000172$; Figure 3). Positive fire responses did not have significantly lower PC1 loadings compared to negative responses (Tukey HSD; $p = 0.251$), nor were responses significantly different on PC2 (ANOVA; $df = 3$, $F = 1.344$, $p = 0.264$). Negative loadings were associated with positive fire responses, and positive loadings were associated with negative fire responses (Figure 3). Similar to the all time periods analysis, the greatest PC1 loadings were habitat density (higher habitat density was negatively loaded), canopy foragers (positively loaded), ground nesting (negatively loaded), and body mass (negatively loaded).

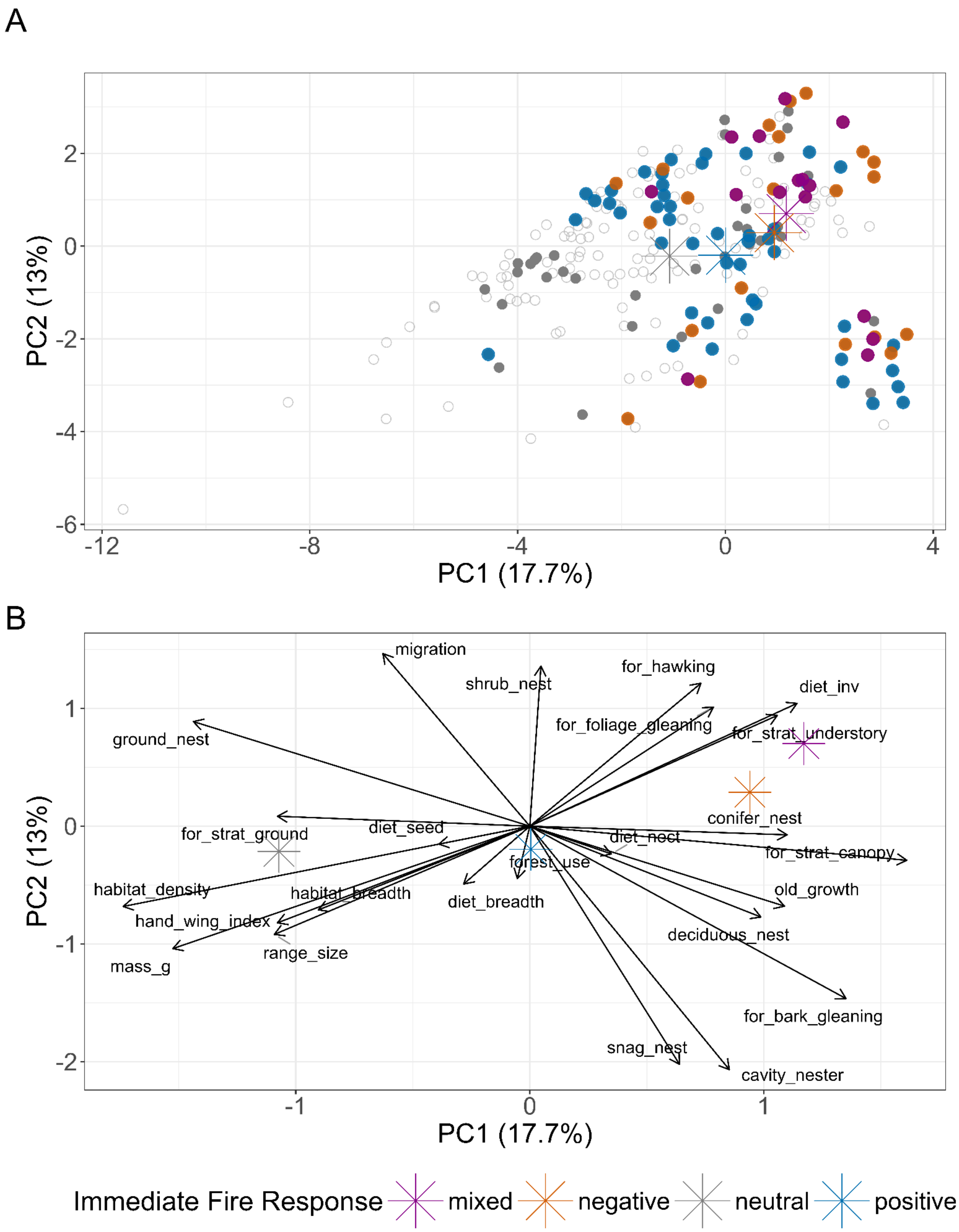

Figure 3. PCA for only immediate (0-5 year post fire) species responses to fire. (A) Solid points indicate species identified in the literature review that responded to fire. Hollow points indicate BC species that were not listed in the literature to respond to fire. Stars indicate centers of each fire response for PC1 and PC2. (B) Loadings in the PCA. See Table 1 for trait descriptions.

For short term responses (5-10 years post-fire), midpoints of PC1 clusters for each fire response were significantly different (ANOVA, F = 7.017, df = 3, p = 0.00023; Figure 4). Positive fire responses were marginally lower PC1 loadings compared to negative responses (Tukey HSD; p = 0.065). Responses were significantly different on PC2 (ANOVA; df = 3, F = 3.004, p = 0.0.036). On PC2, only neutral groups (Tukey HSD, p = 0.038) and positive groups (Tukey HSD, p = 0.022) had lower PC2 values than mixed groups and positive groups. Similarly to the previous analyses, negative loadings were associated with positive fire responses, and positive loadings were associated with negative fire responses (Figure 4). The greatest PC1 loadings were habitat density (greater density was loaded negatively), canopy foragers (positively loaded), ground nesting (negatively loaded), and body mass (negatively loaded).

We did not see strong evidence that trait-fire relationships shifted with time since fire, as trait-fire relationships were very similar across PC1 and PC2 for across all time periods.

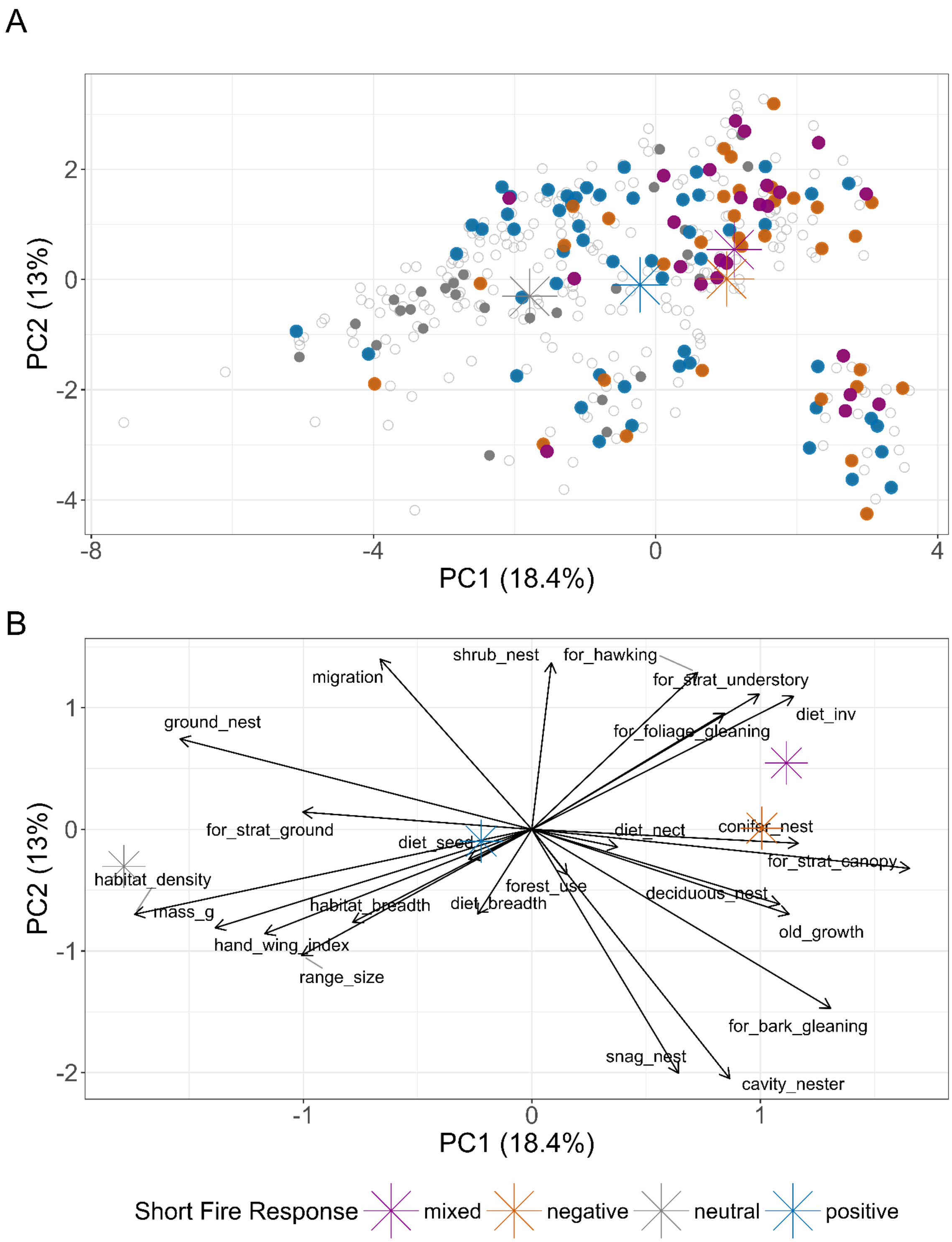

Figure 4. PCA for only short (5-10 year post fire) species responses to fire. (A) Solid points indicate species identified in the literature review that responded to fire. Hollow points indicate BC species that were not listed in the literature to respond to fire. Stars indicate centers of each fire response for PC1 and PC2. (B) Loadings in the PCA. See Table 1 for trait descriptions.

Table 3. Lists of species from the literature for each overall, immediate term, and moderate term fire response (mixed, negative, neutral, and positive).

Fire Response	Overall Response	Immediate Response	Moderate Response
mixed	Black-headed Grosbeak, Black-throated Gray Warbler, Brown Creeper, Canada Jay, Chestnut-backed Chickadee, Common Yellowthroat, Dark-eyed Junco, Dusky Flycatcher, Golden-crowned Kinglet, Great Horned Owl, Hermit Thrush, MacGillivray's Warbler, Mountain Chickadee, Nashville Warbler, Pacific Wren, Pine Siskin, Red-breasted Nuthatch, Steller's Jay, Swamp Sparrow, Warbling Vireo, Western Tanager, Western Wood-Pewee, Winter Wren, Yellow-rumped Warbler	Black-headed Grosbeak, Black-throated Gray Warbler, Brown Creeper, Cassin's Vireo, Dusky Flycatcher, Hermit Thrush, MacGillivray's Warbler, Mountain Chickadee, Nashville Warbler, Northern Flicker, Red-breasted Nuthatch, Spotted Towhee, Warbling Vireo, Western Wood-Pewee, Yellow-rumped Warbler	Alder Flycatcher, Black-throated Gray Warbler, Brown Creeper, Common Yellowthroat, Dusky Flycatcher, Hermit Thrush, MacGillivray's Warbler, Red-breasted Nuthatch, Swamp Sparrow, Warbling Vireo, Western Wood-Pewee, Yellow-rumped Warbler
negative	Alder Flycatcher, Barred Owl, Bay-breasted Warbler, Black-and-white Warbler, Boreal Chickadee, Cape May Warbler, Cassin's Vireo, Common Goldeneye, Common Raven, Hutton's Vireo, Northern Saw-whet Owl, Northern Waterthrush, Orange-crowned Warbler, Ovenbird, Philadelphia Vireo, Pileated Woodpecker, Pine Grosbeak, Purple Finch, Pygmy Nuthatch, Red-breasted Sapsucker, Red-eyed Vireo, Red-naped Sapsucker, Red Crossbill, Ruby-crowned Kinglet, Ruffed Grouse, Sooty Grouse, Swainson's Thrush, Townsend's Warbler, Vaux's Swift, White-winged Crossbill, Williamson's Sapsucker, Wilson's Warbler, Yellow Warbler	Alder Flycatcher, Anna's Hummingbird, Barred Owl, Boreal Chickadee, Chestnut-backed Chickadee, Common Yellowthroat, Golden-crowned Kinglet, Great Horned Owl, Hammond's Flycatcher, Northern Saw-whet Owl, Northern Waterthrush, Orange-crowned Warbler, Ovenbird, Pygmy Nuthatch, Red-eyed Vireo, Red-naped Sapsucker, Ruby-crowned Kinglet, Ruffed Grouse, Swainson's Thrush, Swamp Sparrow, Townsend's Warbler	Barred Owl, Black-headed Grosbeak, Boreal Chickadee, Cassin's Vireo, Chestnut-backed Chickadee, Golden-crowned Kinglet, Great Horned Owl, Mountain Chickadee, Nashville Warbler, Northern Saw-whet Owl, Northern Waterthrush, Orange-crowned Warbler, Ovenbird, Pygmy Nuthatch, Red-eyed Vireo, Red-naped Sapsucker, Ruby-crowned Kinglet, Ruffed Grouse, Swainson's Thrush, Townsend's Warbler

neutral	American Wigeon, Barrow's Goldeneye, Bufflehead, Calliope Hummingbird, Canvasback, Clark's Nutcracker, Common Loon, Common Merganser, Common Nighthawk, Eastern Phoebe, Green-winged Teal, House Finch, Lesser Scaup, Mallard, Marsh Wren, Mourning Dove, Northern Pintail, Northern Shoveler, Red-breasted Merganser, Red-tailed Hawk, Ring-necked Duck, Surf Scoter, Varied Thrush, Violet-green Swallow, White-winged Scoter, Willow Flycatcher, Yellow-bellied Flycatcher	American Goldfinch, American Wigeon, Bufflehead, Calliope Hummingbird, Canvasback, Clark's Nutcracker, Common Merganser, Common Raven, Eastern Phoebe, Evening Grosbeak, Green-winged Teal, House Finch, Lesser Scaup, Mallard, Marsh Wren, Mourning Dove, Northern Pintail, Northern Shoveler, Pacific Wren, Pileated Woodpecker, Pine Grosbeak, Purple Finch, Red-breasted Merganser, Red-tailed Hawk, Red Crossbill, Ring-necked Duck, Surf Scoter, Varied Thrush, Violet-green Swallow, White-winged Scoter, Williamson's Sapsucker, Willow Flycatcher, Wilson's Warbler, Yellow-bellied Flycatcher, Yellow Warbler	American Goldfinch, American Wigeon, Brown-headed Cowbird, Bufflehead, Calliope Hummingbird, Canvasback, Common Goldeneye, Common Loon, Common Merganser, Common Raven, Eastern Phoebe, Evening Grosbeak, Green-winged Teal, Hammond's Flycatcher, House Finch, Lesser Scaup, Mallard, Marsh Wren, Mourning Dove, Northern Pintail, Northern Shoveler, Olive-sided Flycatcher, Pacific Wren, Pileated Woodpecker, Pine Grosbeak, Red-breasted Merganser, Red-tailed Hawk, Red Crossbill, Ring-necked Duck, Surf Scoter, Varied Thrush, Violet-green Swallow, White-winged Scoter, Williamson's Sapsucker, Willow Flycatcher, Wilson's Warbler, Yellow-bellied Flycatcher, Yellow Warbler

positive	American Crow, American Goldfinch, American Kestrel, American Robin, American Three-toed Woodpecker, Baltimore Oriole, Black-backed Woodpecker, Black-billed Magpie, Black-capped Chickadee, Brewer's Blackbird, Brewer's Sparrow, Brown-headed Cowbird, Canada Goose, Cassin's Finch, Cedar Waxwing, Chipping Sparrow, Clay-colored Sparrow, Connecticut Warbler, Downy Woodpecker, Eastern Kingbird, Evening Grosbeak, Fox Sparrow, Hairy Woodpecker, Hammond's Flycatcher, Lazuli Bunting, Least Flycatcher, Lewis's Woodpecker, Lincoln's Sparrow, Mountain Bluebird, Northern Flicker, Northern Hawk Owl, Northern House Wren, Northern Pygmy-Owl, Olive-sided Flycatcher, Palm Warbler, Red-winged Blackbird, Rock Wren, Rufous Hummingbird, Savannah Sparrow, Say's Phoebe, Song Sparrow, Spotted Towhee, Tennessee Warbler, Townsend's Solitaire, Tree Swallow, Turkey Vulture, Veery, Western Bluebird, Western Screech-Owl, White-breasted Nuthatch, White-crowned Sparrow, White-throated Sparrow, Yellow-bellied Sapsucker	American Kestrel, American Robin, American Three-toed Woodpecker, Black-backed Woodpecker, Black-capped Chickadee, Brewer's Blackbird, Brewer's Sparrow, Brown-headed Cowbird, Canada Jay, Cassin's Finch, Cedar Waxwing, Chipping Sparrow, Connecticut Warbler, Dark-eyed Junco, Downy Woodpecker, Fox Sparrow, Hairy Woodpecker, Lazuli Bunting, Least Flycatcher, Lewis's Woodpecker, Lincoln's Sparrow, Mountain Bluebird, Northern House Wren, Northern Pygmy-Owl, Olive-sided Flycatcher, Pine Siskin, Red-winged Blackbird, Rock Wren, Rufous Hummingbird, Savannah Sparrow, Say's Phoebe, Song Sparrow, Steller's Jay, Tennessee Warbler, Townsend's Solitaire, Tree Swallow, Turkey Vulture, Veery, Western Bluebird, Western Screech-Owl, Western Tanager, White-breasted Nuthatch, White-crowned Sparrow, White-throated Sparrow, Winter Wren, Yellow-bellied Sapsucker	American Kestrel, American Robin, American Three-toed Woodpecker, Black-capped Chickadee, Brewer's Blackbird, Brewer's Sparrow, Canada Goose, Canada Jay, Cassin's Finch, Cedar Waxwing, Chipping Sparrow, Clark's Nutcracker, Connecticut Warbler, Dark-eyed Junco, Downy Woodpecker, Fox Sparrow, Hairy Woodpecker, Lazuli Bunting, Least Flycatcher, Lewis's Woodpecker, Lincoln's Sparrow, Northern Flicker, Northern House Wren, Northern Pygmy-Owl, Pine Siskin, Red-winged Blackbird, Rock Wren, Rufous Hummingbird, Savannah Sparrow, Say's Phoebe, Song Sparrow, Spotted Towhee, Steller's Jay, Tennessee Warbler, Townsend's Solitaire, Tree Swallow, Turkey Vulture, Veery, Western Screech-Owl, Western Tanager, White-breasted Nuthatch, White-crowned Sparrow, White-throated Sparrow, Winter Wren, Yellow-bellied Sapsucker

Index

We visualized species that had the highest and lowest index scores (Figure 5) and for families of interest in BC (Figure 6). Species with negative index values are predicted to be negatively impacted by fire in BC, and species with positive values are predicted to be benefited by fire in BC. Waterfowl (Anatidae) generally were shown to have slightly positive responses to fire, and the thrush (Turdidae) and warbler (Parulidae) families generally showed negative responses to fire (Figure 5, Figure A1). In contrast to general expectations for fire-bird relationships that predict that woodpeckers are benefited by fire, woodpeckers (Picidae) showed both positive and negative responses (Figure 5, Figure A1). Flycatchers (Tyrannidae) showed generally positive fire responses (Figure 5, Figure A1).

Fire Weather

In Figure 7 we demonstrate how species distributions can be overlaid with fire projections to estimate risk under future conditions for the Black-backed Woodpecker. This workflow highlights areas of high current bird abundance and areas at high risk of fire (high FWI) under future climate change.

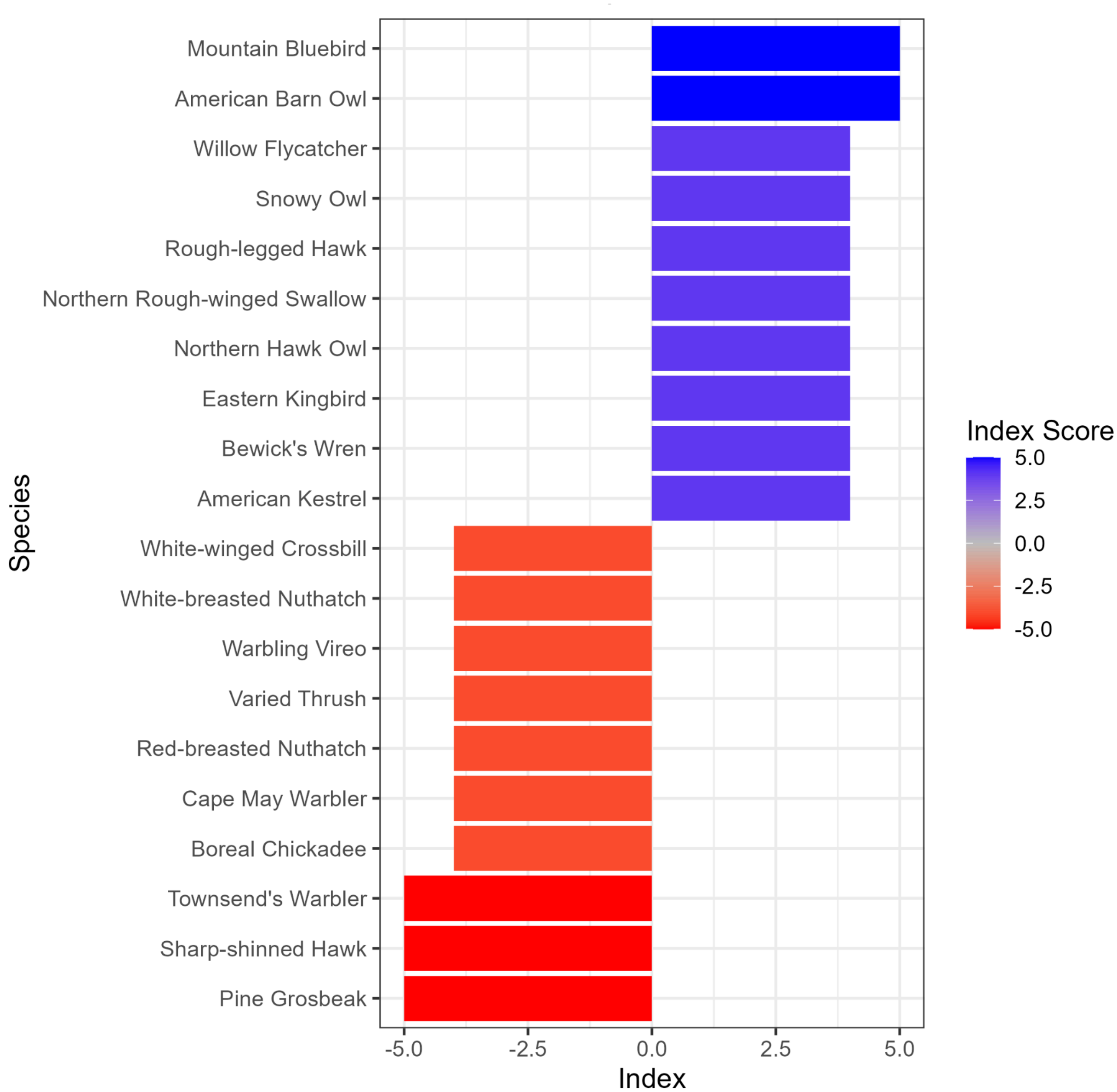

Figure 5. Predicted trait-based fire sensitivity for species with the highest and lowest indices, or the species that are most benefitted by fire and species that are most negatively impacted by fire. High index scores (blue) indicate species that are benefitted by fire, and low values (red) are species that are negatively affected by fire.

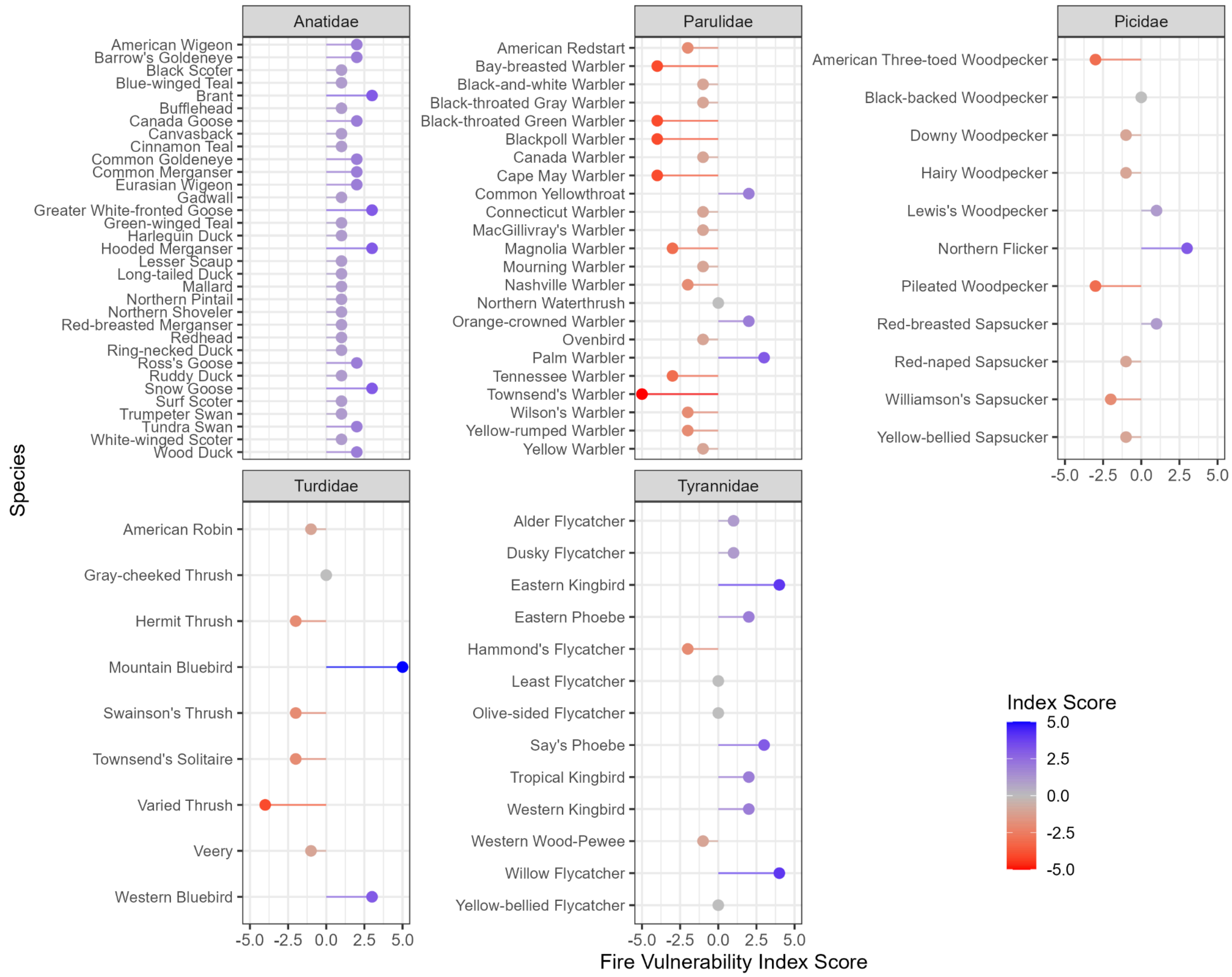

Figure 6. Index values for species in the Anatidae, Parulidae, Picidae, Turdidae, and Tyrannidae families. Low index values (red) indicate species more negatively impacted by fire, high values (blue) indicate species positively affected by fire.

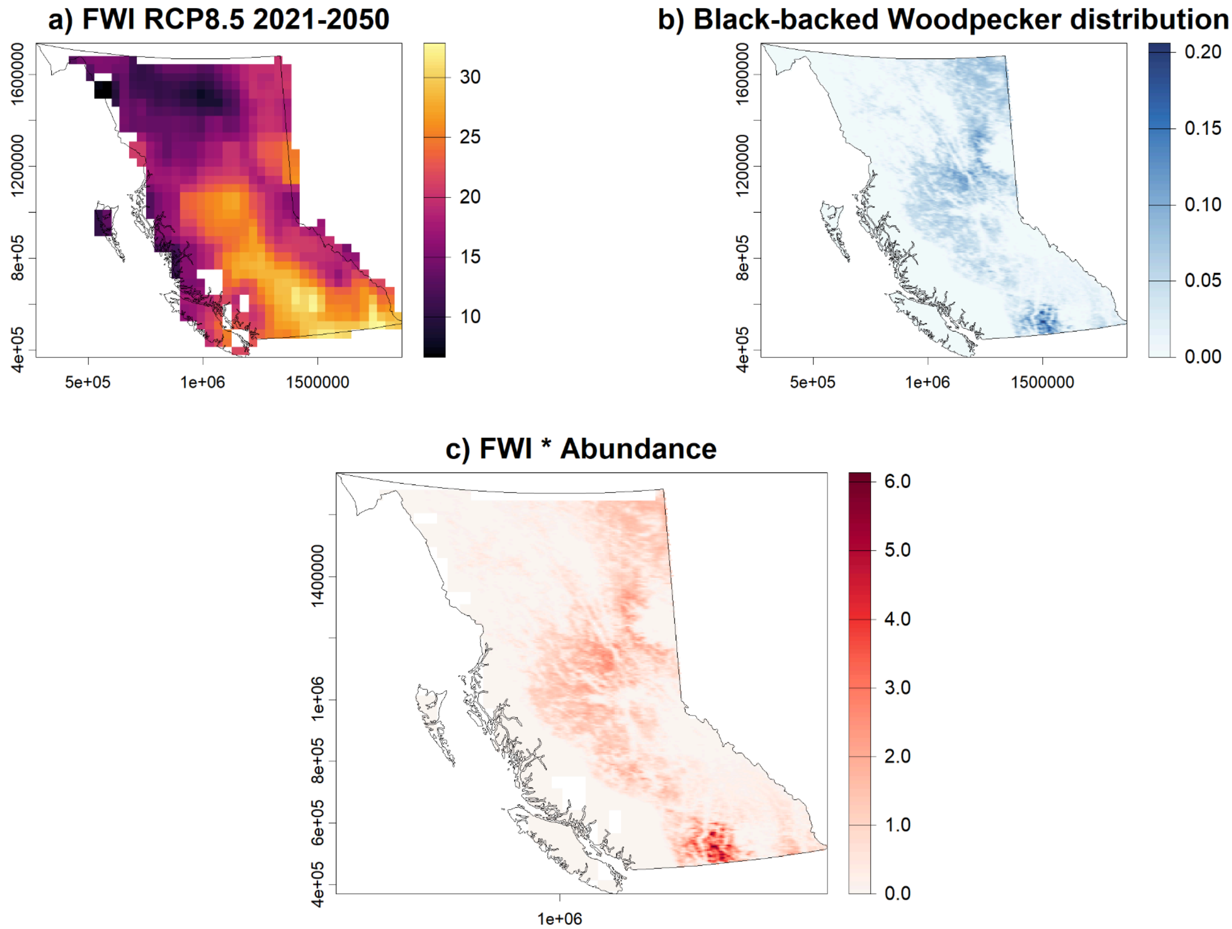

Figure 7. Example workflow of mapping species distributions under future fire projections. A) Fire weather index projections for BC under RCP8.5 emission scenarios for 2021-2050. Lighter colors indicate areas of higher fire-favorable weather. B) species distribution for Black-backed Woodpeckers derived from eBird observations. Darker colors indicate higher species abundance. (C) aligned areas of black-backed woodpecker abundance and future FWI, where darker values indicate areas of high black-backed woodpecker abundance and high future FWI.

Discussion

Here, we conducted a literature review of birds' responses to fire, used a multidimensional, trait-based approach to assess wildfire sensitivity, and identified species as positive, negative, or mixed responders based on ecological and morphological traits. We demonstrate general workflows for spatial analysis to determine where species may be most affected, or areas that may act as refugia under future climate change. This novel approach combines open-source data to answer pressing conservation concerns, and we discuss these applications and caveats below.

In our analysis, species that were negatively affected by fire tended to have canopy foraging as a trait and preferred dense habitats, and species that were positively affected had high body masses, nested on the ground, and preferred open habitats. Across the literature, cavity nesters and aerial insectivores are traits that are generally associated with positive fire responses. In contrast to this, our results showed that cavity nesting was not a trait that significantly contributed to differences in species with positive or negative fire responses. In general, this was driven by woodpecker reliance on mature forest and dense habitats leading to negative values in the index. Species in the Tyrannidae family, which generally are aerial insectivores that require open habitat to forage, showed mostly neutral or positive responses to fire. Our results demonstrate that predictions for fire-trait associations require the combination of multiple traits, rather than relying on single traits to make predictions across species.

This work can be used to support management decisions like identifying species most vulnerable to wildfire based on their traits (e.g. canopy-foragers, dense-forest specialists) to target for habitat protection, restoration, or post-fire management interventions; making predictions for species for which we do not have existing hypotheses for fire responses; and identifying management areas that can act as fire refugia under future conditions. This approach can also be applied to monitoring efforts of controlled burns, for example informing which species to use as bioindicators for evaluating effectiveness of prescribed wildfire burns; or using species predicted to benefit or be negatively impacted by fire to monitor and evaluate the ecological outcomes of controlled burns or fuel reduction efforts. Our work can also be applied to species-specific recovery strategies (for example, if Mountain Bluebird ever becomes listed as a Species at Risk, prescribed fire may be a strategy to recover their habitat). Lastly, it may be applied to post-fire restoration planning, where emergency responders and conservation teams can incorporate these priorities into post-fire recovery operations.

Our analysis comes with some important caveats. First, we assume that species' fire responses across North America will be similar to their fire response in BC. Some research suggests that a species' fire response will differ across the range of the species (Stillman et al., 2025). Secondly, we were ultimately restricted to bird traits available for all of the BC bird species. Notably, the PCAs rely on continuous variables, while informing the index would have been best with categorical data. Lastly, our workflow for linking species distributions to future fire projections relies on the availability of accurate fire projection datasets. The fire weather index is projected across a relatively broad geographical scale, making comparisons potentially too coarse. Further, fire weather is only one component of fire risk. Utilizing fire projections at fine-scale resolutions will be important for making conservation inferences from this workflow.

We also have some suggestions for future research. In the literature search, few studies examined bird of prey responses. A study in Oregon that explicitly examined owl responses to fire saw strong reductions in habitat use for one species but increased habitat use post-fire for other owl species (Duchac et al. 2021), but owls were infrequently identified in other studies. Most studies had biases towards diurnal species because species were identified during point counts. Some studies also noted difficulties for ARUs to identify drumming woodpeckers to species (Knaggs et al. 2020). Thus, some reviewed studies could have omitted species when identifying habitat use before and after fires. Further research examining fire responses across a broader range of forest species is critical for understanding community responses to fire. In addition, across the bird-fire literature, the majority of studies have been conducted in the US, Australia, and Europe. Studies that have occurred in Canada focused on the boreal forest and migratory waterbirds. We emphasize the importance for more research to be done in British Columbia, considering the rapid change in wildfires predicted under climate change. Lastly, the majority of studies examined immediate-term fire responses (0-5 years), and few documented fire severity. Although we did not detect trait differences across species between time periods since fire, time since fire and fire severity impact species responses to fire, so we also suggest future research consider these responses across broader time scales and fire severity.

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Appendix.

Appendix 1. Papers used in the literature review

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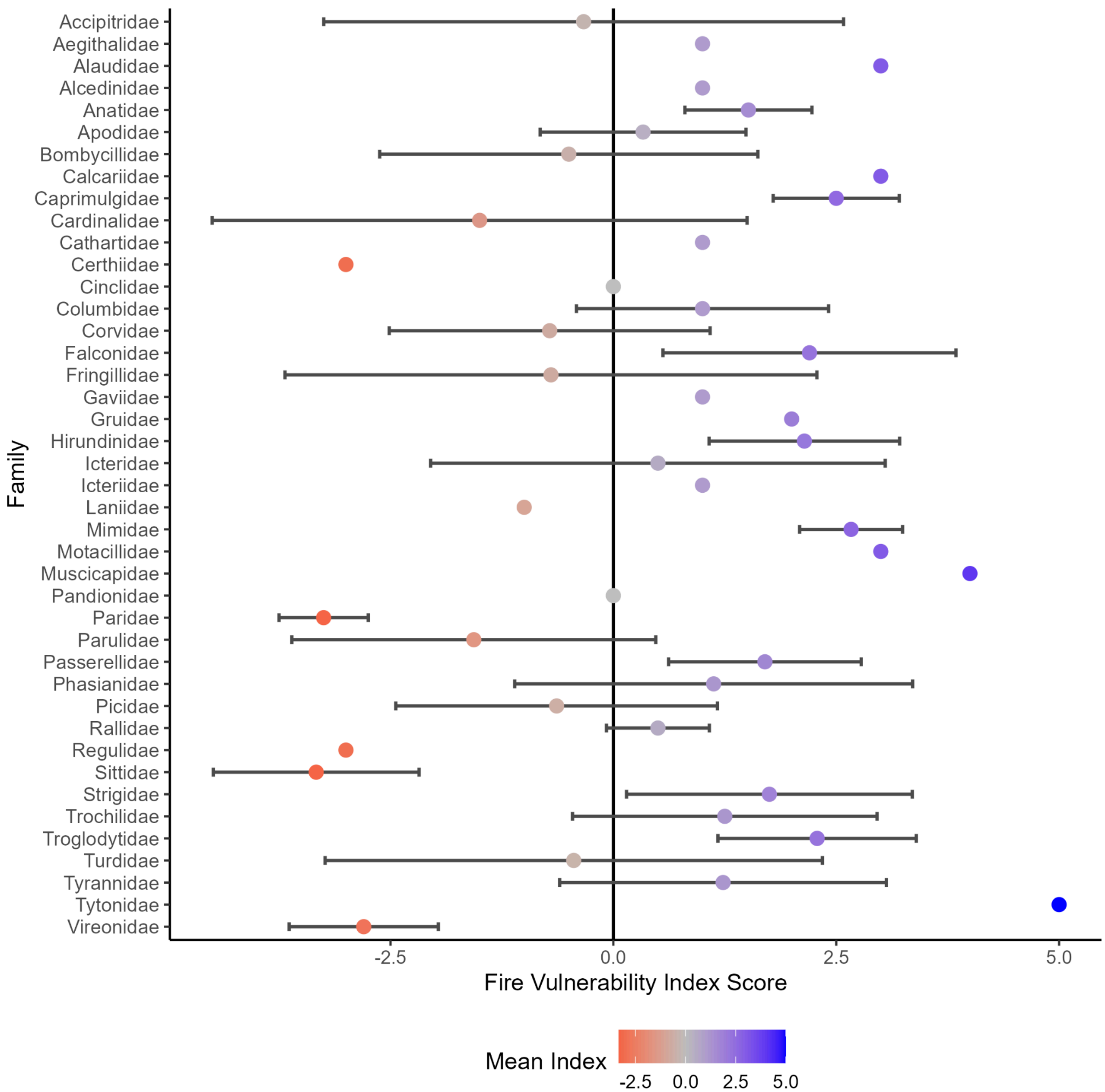

Figure 1A. Average fire sensitivity index values for each bird family. Error bars indicate standard deviation.

Table A1. Index values and summed index (right most column) for each BC species (trait-fire relationships used to build the index can be viewed in Table 2). The Index Total is the summed value from other columns for each species (right most column).

family	common_name	Foliage Gleaning	Foraging Location	Forest Use	Habitat Density	Handwing Index	Migration	Nesting Location	Nest Type	Old Growth Associate	Primary Lifestyle	Primary Habitat	Snag Use	Trophic Niche	Index Total
Anatidae	Snow Goose	0	1	0	0	1	0	0	0	0	0	1	0	0	3
Anatidae	Ross's Goose	0	1	0	0	1	0	0	0	0	0	0	0	0	2
Anatidae	Greater White-fronted Goose	0	1	0	0	1	0	0	0	0	0	1	0	0	3
Anatidae	Brant	0	1	0	0	1	0	0	0	0	0	1	0	0	3
Anatidae	Canada Goose	0	1	0	0	1	0	0	0	0	0	0	0	0	2
Anatidae	Trumpeter Swan	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Anatidae	Tundra Swan	0	1	0	0	1	0	0	0	0	0	0	0	0	2
Anatidae	Wood Duck	0	0	0	0	1	0	0	1	0	0	0	0	0	2
Anatidae	Blue-winged Teal	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Anatidae	Cinnamon Teal	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Anatidae	Northern Shoveler	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Anatidae	Gadwall	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Anatidae	Eurasian Wigeon	0	1	0	0	1	0	0	0	0	0	0	0	0	2
Anatidae	American Wigeon	0	1	0	0	1	0	0	0	0	0	0	0	0	2

Anatidae	Mallard	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Anatidae	Northern Pintail	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Anatidae	Green-winged Teal	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Anatidae	Canvasback	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Anatidae	Redhead	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Anatidae	Ring-necked Duck	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Anatidae	Lesser Scaup	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Anatidae	Harlequin Duck	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Anatidae	Surf Scoter	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Anatidae	White-winged Scoter	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Anatidae	Black Scoter	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Anatidae	Long-tailed Duck	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Anatidae	Bufflehead	0	0	0	0	1	0	-1	1	0	0	0	0	0	1
Anatidae	Common Goldeneye	0	0	0	0	1	0	0	1	0	0	0	0	0	2
Anatidae	Barrow's Goldeneye	0	0	0	0	1	0	0	1	0	0	0	0	0	2
Anatidae	Hooded Merganser	0	0	0	0	1	0	0	1	0	0	0	1	0	3

Anatidae	Common Merganser	0	0	0	0	1	0	0	1	0	0	0	0	0	2
Anatidae	Red-breasted Merganser	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Anatidae	Ruddy Duck	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Phasianidae	Ruffed Grouse	-1	1	0	-1	1	0	0	0	0	0	1	0	0	1
Phasianidae	Dusky Grouse	0	1	-1	-1	1	0	0	0	-1	0	-1	0	0	-2
Phasianidae	Sooty Grouse	0	1	-1	0	1	0	0	0	0	0	-1	0	0	0
Phasianidae	Sharp-tailed Grouse	0	1	0	0	1	0	0	0	0	0	1	0	0	3
Phasianidae	White-tailed Ptarmigan	0	1	0	0	1	0	0	0	0	0	1	0	0	3
Phasianidae	Willow Ptarmigan	0	1	0	0	1	0	0	0	0	0	1	0	0	3
Phasianidae	Rock Ptarmigan	0	1	0	0	1	0	0	0	0	0	1	0	0	3
Phasianidae	Spruce Grouse	0	1	-1	-1	1	0	0	0	-1	0	-1	0	0	-2
Columbidae	Band-tailed Pigeon	0	1	-1	0	1	0	-1	0	0	0	-1	0	1	0
Columbidae	Mourning Dove	0	1	0	0	1	0	-1	0	0	0	0	0	1	2
Caprimulgidae	Common Nighthawk	0	0	0	0	1	0	0	0	0	0	1	0	1	3
Caprimulgidae	Common Poorwill	0	-1	0	0	1	0	0	0	0	0	1	0	1	2

Apodidae	Black Swift	0	0	0	-1	1	0	0	0	0	0	0	0	1	1
Apodidae	Vaux's Swift	0	0	-1	-1	1	0	0	0	-1	0	-1	1	1	-1
Apodidae	White-throate d Swift	0	0	0	-1	1	0	0	0	0	0	0	0	1	1
Trochilidae	Black-chinne d Hummingbird	0	1	0	0	1	0	0	0	0	0	-1	0	1	2
Trochilidae	Anna's Hummingbird	0	-1	0	0	1	0	-1	0	0	0	-1	0	1	-1
Trochilidae	Calliope Hummingbird	0	1	0	0	1	0	-1	0	0	0	1	0	1	3
Trochilidae	Rufous Hummingbird	0	1	-1	0	1	0	0	0	0	0	-1	0	1	1
Rallidae	Virginia Rail	0	1	0	-1	0	0	0	0	0	0	0	0	0	0
Rallidae	Sora	0	1	0	-1	0	0	0	0	0	0	0	0	0	0
Rallidae	American Coot	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Rallidae	Yellow Rail	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Gruidae	Sandhill Crane	0	1	0	0	1	0	0	0	0	0	0	0	0	2
Gaviidae	Red-throated Loon	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Gaviidae	Pacific Loon	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Gaviidae	Common Loon	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Cathartida e	Turkey Vulture	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Pandionida e	Osprey	0	0	0	0	1	0	-1	0	0	0	0	0	0	0

Accipitridae	Golden Eagle	0	1	0	0	1	0	0	0	0	0	1	0	0	3
Accipitridae	Sharp-shinned Hawk	0	-1	-1	-1	0	0	-1	0	0	0	-1	0	0	-5
Accipitridae	Cooper's Hawk	0	1	-1	0	0	0	-1	0	0	0	-1	0	0	-2
Accipitridae	American Goshawk	0	1	-1	-1	1	0	-1	0	-1	0	-1	0	0	-3
Accipitridae	Northern Harrier	0	1	0	0	1	0	0	0	0	0	0	0	0	2
Accipitridae	Bald Eagle	0	0	0	0	1	0	-1	0	0	0	0	0	0	0
Accipitridae	Swainson's Hawk	0	-1	0	0	1	0	-1	0	0	1	-1	0	0	-1
Accipitridae	Red-tailed Hawk	0	-1	0	0	1	0	-1	0	0	1	-1	0	0	-1
Accipitridae	Rough-legged Hawk	0	1	0	0	1	0	0	0	0	1	1	0	0	4
Tytonidae	American Barn Owl	0	1	0	0	1	0	0	1	0	1	1	0	0	5
Strigidae	Flammulated Owl	0	1	-1	-1	0	0	-1	1	0	1	-1	0	1	0
Strigidae	Western Screech-Owl	0	1	0	0	0	0	0	1	0	1	-1	0	1	3
Strigidae	Snowy Owl	0	1	0	0	1	0	0	0	0	1	1	0	0	4
Strigidae	Great Horned Owl	0	1	0	0	0	0	0	1	-1	1	-1	0	0	1
Strigidae	Northern Hawk Owl	0	1	0	0	1	0	0	0	0	1	1	0	0	4

Strigidae	Northern Pygmy-Owl	0	1	-1	0	0	0	-1	1	0	1	-1	0	1	1
Strigidae	Barred Owl	0	1	-1	0	0	0	0	1	0	1	-1	1	0	2
Strigidae	Great Gray Owl	0	1	-1	0	0	0	-1	1	0	1	-1	0	0	0
Strigidae	Long-eared Owl	0	1	0	0	1	0	-1	0	0	0	1	0	0	2
Strigidae	Short-eared Owl	0	1	0	0	1	0	0	0	0	0	1	0	0	3
Strigidae	Boreal Owl	0	1	-1	-1	0	0	0	1	-1	1	-1	0	0	-1
Strigidae	Northern Saw-whet Owl	0	1	0	0	0	0	0	1	0	1	-1	0	0	2
Alcedinidae	Belted Kingfisher	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Picidae	Williamson's Sapsucker	0	-1	-1	-1	0	0	-1	1	0	1	-1	0	1	-2
Picidae	Yellow-bellied Sapsucker	0	-1	0	-1	1	0	-1	1	0	1	-1	0	0	-1
Picidae	Red-naped Sapsucker	0	-1	0	0	0	0	-1	1	0	1	-1	0	0	-1
Picidae	Red-breasted Sapsucker	0	-1	0	0	0	0	0	1	-1	1	-1	1	1	1
Picidae	Lewis's Woodpecker	0	1	0	0	0	0	-1	1	-1	1	-1	0	1	1
Picidae	American Three-toed Woodpecker	0	-1	-1	-1	0	0	-1	1	-1	1	-1	0	1	-3

Picidae	Black-backed Woodpecker	0	1	-1	-1	0	0	-1	1	0	1	-1	0	1	0
Picidae	Downy Woodpecker	0	-1	-1	0	0	0	-1	1	0	1	-1	0	1	-1
Picidae	Hairy Woodpecker	0	-1	-1	-1	0	0	0	1	-1	1	-1	1	1	-1
Picidae	Pileated Woodpecker	0	-1	-1	-1	0	0	-1	1	-1	1	-1	0	1	-3
Picidae	Northern Flicker	0	1	0	0	0	0	0	1	0	0	-1	1	1	3
Falconidae	American Kestrel	0	1	0	0	1	0	0	1	0	1	-1	1	0	4
Falconidae	Merlin	0	1	0	0	1	0	-1	0	0	0	-1	0	0	0
Falconidae	Gyrfalcon	0	1	0	0	1	0	0	0	0	0	1	0	0	3
Falconidae	Peregrine Falcon	0	-1	0	0	1	0	0	0	0	0	1	0	0	1
Falconidae	Prairie Falcon	0	1	0	0	1	0	0	0	0	0	1	0	0	3
Tyrannidae	Olive-sided Flycatcher	0	1	-1	-1	1	0	-1	0	0	1	-1	0	1	0
Tyrannidae	Western Wood-Pewee	0	1	-1	-1	0	0	-1	0	0	1	-1	0	1	-1
Tyrannidae	Yellow-bellied Flycatcher	0	1	-1	-1	0	0	0	0	0	1	-1	0	1	0
Tyrannidae	Alder Flycatcher	0	-1	0	-1	0	0	0	0	0	1	1	0	1	1
Tyrannidae	Willow Flycatcher	0	1	0	0	0	0	0	0	0	1	1	0	1	4

Tyrannidae	Least Flycatcher	0	1	0	-1	0	0	-1	0	0	1	-1	0	1	0
Tyrannidae	Hammond's Flycatcher	0	1	-1	-1	0	0	-1	0	-1	1	-1	0	1	-2
Tyrannidae	Dusky Flycatcher	0	1	-1	0	0	0	0	0	0	1	-1	0	1	1
Tyrannidae	Eastern Phoebe	0	1	0	0	0	0	0	0	0	1	-1	0	1	2
Tyrannidae	Say's Phoebe	0	1	0	0	0	0	0	0	0	1	0	0	1	3
Tyrannidae	Tropical Kingbird	0	-1	0	0	0	0	0	0	0	1	1	0	1	2
Tyrannidae	Western Kingbird	0	-1	0	0	0	0	0	0	0	1	1	0	1	2
Tyrannidae	Eastern Kingbird	0	1	0	0	0	0	0	0	0	1	1	0	1	4
Vireonidae	Hutton's Vireo	-1	-1	0	-1	0	0	-1	0	0	1	-1	0	1	-3
Vireonidae	Cassin's Vireo	-1	-1	-1	0	0	0	-1	0	0	1	-1	0	1	-3
Vireonidae	Philadelphia Vireo	0	-1	0	-1	0	0	-1	0	0	1	-1	0	1	-2
Vireonidae	Warbling Vireo	-1	-1	-1	-1	0	0	-1	0	0	1	-1	0	1	-4
Vireonidae	Red-eyed Vireo	0	-1	-1	-1	0	0	0	0	0	1	-1	0	1	-2
Laniidae	Northern Shrike	0	1	-1	0	0	0	-1	0	0	1	-1	0	0	-1
Corvidae	Canada Jay	0	1	-1	-1	0	0	-1	0	0	1	-1	0	0	-2

Corvidae	Steller's Jay	0	1	-1	-1	0	0	-1	0	0	1	-1	0	0	-2
Corvidae	Blue Jay	0	1	0	0	0	0	-1	0	0	0	-1	0	0	-1
Corvidae	Black-billed Magpie	0	1	0	0	0	0	0	0	0	0	1	0	0	2
Corvidae	Clark's Nutcracker	-1	1	-1	-1	0	0	-1	0	0	1	-1	0	0	-3
Corvidae	American Crow	0	1	0	0	1	0	-1	0	0	0	0	0	0	1
Corvidae	Common Raven	0	1	-1	0	1	0	0	0	0	0	-1	0	0	0
Paridae	Black-capped Chickadee	-1	-1	-1	-1	0	0	0	1	-1	1	-1	0	1	-3
Paridae	Mountain Chickadee	-1	-1	-1	-1	0	0	-1	1	0	1	-1	0	1	-3
Paridae	Chestnut-backed Chickadee	-1	-1	-1	-1	0	0	0	1	-1	1	-1	0	1	-3
Paridae	Boreal Chickadee	-1	-1	-1	-1	0	0	-1	1	-1	1	-1	0	1	-4
Alaudidae	Horned Lark	0	1	0	0	1	0	0	0	0	0	1	0	0	3
Hirundinidae	Bank Swallow	0	-1	0	0	1	0	0	0	0	0	0	0	1	1
Hirundinidae	Tree Swallow	0	-1	0	0	1	0	0	1	0	0	0	1	1	3
Hirundinidae	Violet-green Swallow	0	-1	0	0	1	0	0	1	0	0	-1	0	1	1
Hirundinidae	Purple Martin	0	-1	0	0	1	0	0	1	0	0	0	0	1	2

Hirundinidae	Northern Rough-winged Swallow	0	1	0	0	1	0	0	0	0	0	1	0	1	4
Hirundinidae	Barn Swallow	0	-1	0	0	1	0	0	0	0	0	1	0	1	2
Hirundinidae	Cliff Swallow	0	0	0	0	1	0	0	0	0	0	0	0	1	2
Aegithalidae	Bushtit	-1	1	0	0	0	0	0	0	0	1	-1	0	1	1
Regulidae	Ruby-crowned Kinglet	-1	1	-1	-1	0	0	-1	0	-1	1	-1	0	1	-3
Regulidae	Golden-crowned Kinglet	-1	1	-1	-1	0	0	-1	0	-1	1	-1	0	1	-3
Sittidae	White-breasted Nuthatch	0	-1	-1	-1	0	0	-1	1	-1	1	-1	0	0	-4
Sittidae	Pygmy Nuthatch	0	-1	-1	-1	0	0	-1	1	0	1	-1	0	1	-2
Sittidae	Red-breasted Nuthatch	0	-1	-1	-1	0	0	-1	1	-1	1	-1	0	0	-4
Certhiidae	Brown Creeper	0	-1	-1	-1	0	0	0	0	-1	1	-1	0	1	-3
Troglodytidae	Rock Wren	0	1	0	0	0	0	0	0	0	0	0	0	1	2
Troglodytidae	Canyon Wren	0	1	0	0	0	0	0	0	0	1	0	0	1	3
Troglodytidae	Northern House Wren	0	1	-1	0	0	0	0	1	0	1	-1	0	1	2
Troglodytidae	Pacific Wren	0	1	-1	-1	0	0	0	1	0	1	-1	0	1	1

Troglodytidae	Winter Wren	0	1	-1	-1	0	0	0	1	0	1	-1	0	1	1
Troglodytidae	Marsh Wren	0	1	0	0	0	0	0	0	0	1	0	0	1	3
Troglodytidae	Bewick's Wren	0	1	0	0	0	0	0	1	0	0	1	0	1	4
Cinclidae	American Dipper	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mimidae	Gray Catbird	0	1	0	-1	0	0	0	0	0	1	1	0	1	3
Mimidae	Sage Thrasher	0	1	0	0	0	0	0	0	0	0	1	0	1	3
Mimidae	Northern Mockingbird	0	1	0	0	0	0	0	0	0	0	1	0	0	2
Turdidae	Western Bluebird	0	1	0	0	1	0	0	1	0	1	-1	0	0	3
Turdidae	Mountain Bluebird	0	1	0	0	1	0	-1	1	0	1	1	0	1	5
Turdidae	Townsend's Solitaire	0	-1	-1	0	0	0	0	0	0	1	-1	0	0	-2
Turdidae	Varied Thrush	0	1	-1	-1	0	0	-1	0	-1	0	-1	0	0	-4
Turdidae	Veery	0	1	-1	-1	0	0	0	0	0	0	-1	0	1	-1
Turdidae	Gray-cheeked Thrush	0	1	-1	0	0	0	0	0	0	0	-1	0	1	0
Turdidae	Swainson's Thrush	-1	1	-1	-1	0	0	0	0	-1	1	-1	0	1	-2
Turdidae	Hermit Thrush	0	1	-1	-1	0	0	0	0	-1	0	-1	0	1	-2

Turdidae	American Robin	0	1	-1	0	0	0	-1	0	0	0	-1	0	1	-1
Muscicapidae	Northern Wheatear	0	1	0	0	0	0	0	0	0	1	1	0	1	4
Bombycillidae	Bohemian Waxwing	-1	1	-1	-1	1	0	-1	0	0	1	-1	0	0	-2
Bombycillidae	Cedar Waxwing	-1	1	0	0	1	0	-1	0	0	1	-1	0	1	1
Motacillidae	Sprague's Pipit	0	1	0	0	0	0	0	0	0	0	1	0	1	3
Fringillidae	Pine Grosbeak	-1	-1	-1	-1	0	0	-1	0	0	1	-1	0	0	-5
Fringillidae	Gray-crowned Rosy-Finch	0	1	0	0	1	0	0	0	0	0	1	0	0	3
Fringillidae	House Finch	0	1	0	0	0	0	0	0	0	1	1	0	1	4
Fringillidae	Purple Finch	0	1	-1	0	0	0	-1	0	0	1	-1	0	0	-1
Fringillidae	Cassin's Finch	0	1	-1	0	0	0	-1	0	0	1	-1	0	1	0
Fringillidae	Red Crossbill	-1	-1	-1	-1	1	0	-1	0	0	1	-1	0	1	-3
Fringillidae	White-winged Crossbill	-1	-1	-1	-1	1	0	-1	0	0	1	-1	0	0	-4
Fringillidae	Pine Siskin	-1	1	-1	-1	1	0	-1	0	0	1	-1	0	1	-1
Fringillidae	American Goldfinch	-1	1	0	-1	0	0	0	0	0	1	1	0	1	2
Calcariidae	Lapland Longspur	0	1	0	0	0	0	0	0	0	0	1	0	1	3
Calcariidae	Smith's Longspur	0	1	0	0	0	0	0	0	0	0	1	0	1	3

Calcariidae	Snow Bunting	0	1	0	0	1	0	0	0	0	0	0	0	1	3
Passerellidae	Grasshopper Sparrow	0	1	0	0	0	0	0	0	0	0	1	0	1	3
Passerellidae	Chipping Sparrow	0	1	0	0	0	0	0	0	0	0	-1	0	0	0
Passerellidae	Clay-colored Sparrow	0	1	0	0	0	0	0	0	0	0	1	0	1	3
Passerellidae	Brewer's Sparrow	0	1	0	0	0	0	0	0	0	0	1	0	0	2
Passerellidae	Lark Sparrow	0	1	0	0	0	0	0	0	0	0	1	0	1	3
Passerellidae	Fox Sparrow	0	1	0	-1	0	0	0	0	0	0	1	0	0	1
Passerellidae	Dark-eyed Junco	0	1	0	0	0	0	0	1	0	0	-1	0	1	2
Passerellidae	White-crowned Sparrow	0	1	0	0	0	0	0	0	0	0	1	0	0	2
Passerellidae	Golden-crowned Sparrow	0	1	0	0	0	0	0	0	0	0	1	0	0	2
Passerellidae	Harris's Sparrow	0	1	0	0	0	0	0	0	0	0	1	0	0	2
Passerellidae	White-throated Sparrow	0	1	0	0	0	0	0	0	0	0	-1	0	0	0
Passerellidae	Vesper Sparrow	0	1	0	0	0	0	0	0	0	0	1	0	0	2
Passerellidae	LeConte's Sparrow	0	1	0	0	0	0	0	0	0	0	1	0	1	3

Passerellidae	Nelson's Sparrow	0	1	0	0	0	0	0	0	0	0	0	0	1	2
Passerellidae	Savannah Sparrow	0	1	0	0	0	0	0	0	0	0	1	0	0	2
Passerellidae	Song Sparrow	0	1	0	0	0	0	0	0	0	0	1	0	0	2
Passerellidae	Lincoln's Sparrow	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Passerellidae	Swamp Sparrow	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Passerellidae	Spotted Towhee	0	1	-1	0	0	0	0	0	0	0	-1	0	0	-1
Icteriidae	Yellow-breasted Chat	-1	1	0	0	0	0	0	0	0	1	-1	0	1	1
Icteridae	Yellow-headed Blackbird	0	1	0	0	0	0	0	0	0	0	0	0	1	2
Icteridae	Bobolink	0	1	0	-1	1	0	0	0	0	0	1	0	1	3
Icteridae	Western Meadowlark	0	1	0	0	0	0	0	0	0	0	1	0	1	3
Icteridae	Bullock's Oriole	-1	-1	0	-1	0	0	-1	0	0	1	-1	0	1	-3
Icteridae	Red-winged Blackbird	0	1	0	0	0	0	0	0	0	0	0	0	1	2
Icteridae	Brown-headed Cowbird	0	1	0	0	0	0	0	0	0	0	1	0	1	3
Icteridae	Rusty Blackbird	0	1	0	0	0	0	-1	0	0	0	0	0	0	0

Icteridae	Brewer's Blackbird	0	1	0	0	0	0	-1	0	0	0	0	0	0	0
Icteridae	Common Grackle	0	1	0	0	0	0	-1	0	0	0	-1	0	0	-1
Parulidae	Ovenbird	0	1	-1	-1	0	0	0	0	0	0	-1	0	1	-1
Parulidae	Northern Waterthrush	0	1	0	-1	0	0	0	0	-1	0	0	0	1	0
Parulidae	Black-and-white Warbler	0	-1	0	-1	0	0	0	0	0	1	-1	0	1	-1
Parulidae	Tennessee Warbler	-1	-1	-1	-1	0	0	0	0	0	1	-1	0	1	-3
Parulidae	Orange-crowned Warbler	-1	1	0	-1	0	0	0	0	0	1	1	0	1	2
Parulidae	Nashville Warbler	-1	-1	0	-1	0	0	0	0	0	1	-1	0	1	-2
Parulidae	Connecticut Warbler	0	1	-1	-1	0	0	0	0	0	0	-1	0	1	-1
Parulidae	MacGillivray's Warbler	0	1	-1	-1	0	0	0	0	0	0	-1	0	1	-1
Parulidae	Mourning Warbler	-1	1	-1	-1	0	0	0	0	0	1	-1	0	1	-1
Parulidae	Common Yellowthroat	0	1	0	-1	0	0	0	0	0	1	0	0	1	2
Parulidae	American Redstart	0	-1	0	-1	0	0	-1	0	0	1	-1	0	1	-2
Parulidae	Cape May Warbler	-1	-1	-1	-1	0	0	-1	0	0	1	-1	0	1	-4

Parulidae	Magnolia Warbler	0	-1	-1	-1	0	0	-1	0	0	1	-1	0	1	-3
Parulidae	Bay-breasted Warbler	0	-1	-1	-1	0	0	-1	0	-1	1	-1	0	1	-4
Parulidae	Yellow Warbler	-1	-1	0	-1	0	0	0	0	0	1	0	0	1	-1
Parulidae	Blackpoll Warbler	-1	-1	-1	-1	0	0	-1	0	0	1	-1	0	1	-4
Parulidae	Palm Warbler	0	1	0	-1	0	0	0	0	0	1	1	0	1	3
Parulidae	Yellow-rumped Warbler	-1	1	-1	-1	0	0	-1	0	0	1	-1	0	1	-2
Parulidae	Black-throated Gray Warbler	-1	1	0	-1	0	0	-1	0	0	1	-1	0	1	-1
Parulidae	Townsend's Warbler	-1	-1	-1	-1	0	0	-1	0	-1	1	-1	0	1	-5
Parulidae	Black-throated Green Warbler	-1	-1	-1	-1	0	0	-1	0	0	1	-1	0	1	-4
Parulidae	Canada Warbler	0	1	-1	-1	0	0	0	0	-1	1	-1	0	1	-1
Parulidae	Wilson's Warbler	-1	-1	0	-1	0	0	0	0	0	1	-1	0	1	-2
Cardinalidae	Western Tanager	-1	-1	0	-1	0	0	-1	0	0	1	-1	0	1	-3
Cardinalidae	Rose-breasted Grosbeak	-1	-1	-1	0	0	0	0	0	0	1	-1	0	0	-3

Cardinalidae	Black-headed Grosbeak	-1	-1	-1	0	0	0	-1	0	0	1	-1	0	1	-3
Cardinalidae	Lazuli Bunting	0	1	0	0	0	0	0	0	0	1	1	0	0	3
Motacillidae	American Pipit	0	1	0	0	0	0	0	0	0	0	1	0	1	3
Fringillidae	Evening Grosbeak	-1	1	-1	-1	1	0	-1	0	0	1	-1	0	0	-2
Passerellidae	American Tree Sparrow	0	1	0	0	0	0	0	0	0	0	1	0	0	2
Icteridae	Baltimore Oriole	-1	-1	-1	-1	0	0	-1	0	0	1	-1	0	1	-4