University of Alberta

A Process to Identify High Quality Avian Habitat for the Yellowstone to Yukon Reserve Design

by

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Chapter 1. Introduction

1.1 Background and rationale

Species are declining and becoming extinct at faster rates than at any time in history due primarily to habitat loss, over-exploitation and introduction of non-native species (Van Kooten et al. 2000). Approaches to species preservation aim to identify optimal or underrepresented places for conservation action that typically protects these sites in a reserve system (Flather et al. 1997, Coppolillo et al. 2004). This approach has limitations, however, as areas large enough to encompass entire ecosystems and associated processes needed to sustain biodiversity usually cannot be set aside due to conflicting economic and anthropogenic demands (Bennett 2004). Small, isolated reserves are often created that are inadequate to conserve wide ranging species (e.g. carnivores), and do not address connectivity issues essential for metapopulation persistence (Noss et al. 1996). The World Conservation Union has recommended an alternative strategy in which protected areas are planned and managed within a broader context of ecological networks that protect ecosystem processes while simultaneously allowing sustainable human use (Bennett 2004). Ecological networks achieve these two goals by surrounding core areas of high conservation value and movement corridors with buffer zones allowing human use to increase with distance from core areas (Noss et al. 1996, Bennett 2004). Over 150 landscape and regional scale ecological networks are presently being developed throughout the world (Bennett 2004). The Yellowstone to Yukon (Y2Y) Conservation Initiative is an example of this approach in North America.

1.2 Yellowstone to Yukon Conservation Initiative (Y2Y)

Y2Y is an umbrella organization for 180 Canadian and U.S. organizations, institutions, foundations and individuals that have been working since 1997 to develop a conservation area design to restore and maintain biological diversity throughout North America's Rocky and Mackenzie Mountains. This ecoregion contains a rich diversity of habitats and species that are presently threatened by industrial and recreational interests, river diversions and suburban sprawl (Willcox 1998b). Y2Y provides a broad vision for biodiversity conservation in the region, scientific research, conservation tools, organizational training and some financial support to its partners, who engage in conservation action at local and regional levels (Bennett 2004). Y2Y adopted the ecological network concept as a strategy to conserve viable populations of large wide-ranging carnivores, such as grizzly bear (*Ursus arctos*) and gray wolf (*Canis lupus*), that require more space than can be provided by existing protected areas in the region. Scientific research by Y2Y has been expanded to include aquatic organisms and birds, whose conservation needs will be integrated with carnivores to produce the final conservation area design.

1.3 Study scope and rationale

The Y2Y ecoregion contains approximately 275 bird species (Holroyd 1998). My study extended work by a group of scientists (see Acknowledgements) brought together to develop aspects of the Y2Y conservation area design to protect the region's current avian species diversity and population viability. This group identified 23 broad-scale habitat cover types used by bird communities within Y2Y (Table 1-1), based on cover types identified by Montana Partners in Flight as important to bird conservation, and

Table 1-1: 23 Y2Y broad-scale habitat cover types used by bird communities within the Y2Y region.

Agriculture*
Alpine/Tundra
Aspen
Boreal mixed wood (spruce/pine/aspen)
Boreal spruce (predominantly black and white spruce)
Burned*
Cedar/Hemlock
Coniferous riparian
Deciduous riparian
Dry ponderosa pine/Douglas fir mix
Grassland
Lakes
Lodgepole pine
Marsh
Moist Douglas fir/Mixed/Grand fir
Montane shrub*
Northern shrubfields (willow/birch/alder shrubs)
Sagebrush steppe
Spruce/tamarack bog
Subalpine spruce/fir
Urban*
Whitebark pine
Willow riparian

* Habitat types that were removed for my study

extended by the avian working group to include missing northern habitats. I removed agriculture and urban habitats, as they were not conservation priorities. I also removed montane shrub and burned habitats that were not represented in the original habitat cover map provided to me by Y2Y. The group also developed a list of 109 conservation priority bird species (Appendix I) using the Partners in Flight prioritization method that ranks species for conservation action based on population trends, amount of habitat and regional responsibility (Panjabi 2001).

My thesis work identified candidate core areas for the conservation priority birds in the conservation area design. These core areas represented high quality avian breeding habitat within each of the Y2Y habitat cover types. I defined high quality habitat as areas that had higher amounts and more stable resources for birds, and lower levels of predation, parasitism and anthropogenic disturbance (Cody 1985, McLoughlin, et al. 2000, Suryan and Irons 2001).

1.4 Description and justification of approach

Common approaches to identify and prioritize sites for conservation typically fall into two categories: those that concentrate on species ("fine-filter"), or those that focus on ecosystems ("coarse filter") (Poiani et al. 2000). One fine-filter approach is hotspot analysis that identifies areas of high species richness, or with high numbers of endemic (native), rare or threatened species (Reid 1998, Baydack et al. 1999, Rutledge et al. 2001). A second is the focal species approach that prioritizes sites based on the habitat needs of one or more species of interest (Lambeck 1997). Fine-filter approaches can be effective at protecting rare or specialized species (Poiani et al. 2000), but implementation may be logistically difficult, costly and time consuming, as comprehensive survey data and natural history for a species are required (Franklin 1993, Kintsch and Urban 2002). Fine-filter approaches also often assume that the species or taxa used for conservation planning adequately represents the needs of other species and taxa of interest. These assumptions are usually untested or unsupported (Flather et al. 1997, Caro and O'Doherty 1999, Lindenmayer et al. 2000). As well, a species' ability to act as a proxy for another species may be limited, as no two species share exactly the same niche or respond in identical ways to disturbance (Lindenmayer et al. 2000, Carignan and Villard 2002).

Coarse-filter approaches aim to represent communities, ecosystems and habitats, assuming this will protect all the species contained within them (Hunter et al. 1988, Franklin 1993, Carignan and Villard 2002). These approaches assume that the spatial distribution of a species is correlated with habitat availability (Edwards et al. 1996, Carignan and Villard 2002). Hence, identifying core areas that represent all habitat types or ecosystems in the region of interest should protect all species within it (Franklin 1993, Noss 1999). Coarse-filter approaches have the potential to conserve organisms and processes in poorly known or understood habitats and ecological subsystems (Franklin 1993). However, they may select sites that are sink habitats with negative population growth rates (Pulliam 1988), and may not adequately determine the amount and configuration of habitat needed for conservation purposes (Lambeck 1997, Carignan and Villard 2002).

Recent work has addressed the weaknesses in the fine-filter and coarse-filter strategies by blending them into a habitat-based, multi-species approach to conservation planning (Lambeck 1997, Chase et al. 2000, Carignan and Villard 2002). For example, Chase et al. (2000) suggested that conservation efforts for the California coastal sage scrub community should focus on a diverse suite of species that represented the various habitats in the community. I applied this blended approach to my study by identifying high quality avian breeding habitat within Y2Y for a group of focal bird species that collectively represented the nineteen Y2Y habitat cover types. The large size and remoteness of the Y2Y ecoregion made it logistically impossible to directly determine avian habitat quality by measuring bird habitat use and breeding success. Hence, I adopted a broad-scale modelling approach to prioritize habitat based on a home range level of habitat selection (Johnson 1980) for each focal species.

My approach consisted of three main steps. First, I identified a group of focal bird species that represented users of all Y2Y habitat cover types. I then modelled habitat selection for each focal bird, and used the models to predict habitat selection, and thus relative habitat quality, for each focal bird within Y2Y. Finally, I integrated the model predictions across species to identify prime habitat within each Y2Y habitat cover type.

The remaining chapters in this thesis describe the methods and results for each of these steps. Chapter 2 summarizes the methods used to select a group of focal bird species from the 109 Y2Y conservation priority species and identifies the final list of focal birds. Chapter 3 discusses the model development for eleven of the focal birds that represented high elevation, northern, riparian, wetland and lake habitats, and reports the results of extrapolating the models throughout each bird's breeding range in Y2Y. It also presents the results of integration of the model predictions to identify locations of high quality avian habitat within each habitat cover type. Chapter 4 discusses the overall findings of the project and makes recommendations for using these findings.

1.5 Study area

The Y2Y ecoregion (Figure 1-1) covers an area of about approximately 1.36 million square kilometres in the northwest part of the North America western cordillera, a region of mountain ranges stretching from southern Mexico to western Alaska (Gadd 1998). Y2Y follows the spine of the Rocky and Mackenzie Mountains, ranging 200-800 km in width, and extending 3200 km from the Wind River Range in Wyoming, U.S.A. to the Peel River watershed in the Yukon Territory, Canada, 60 km south of the Arctic Circle.

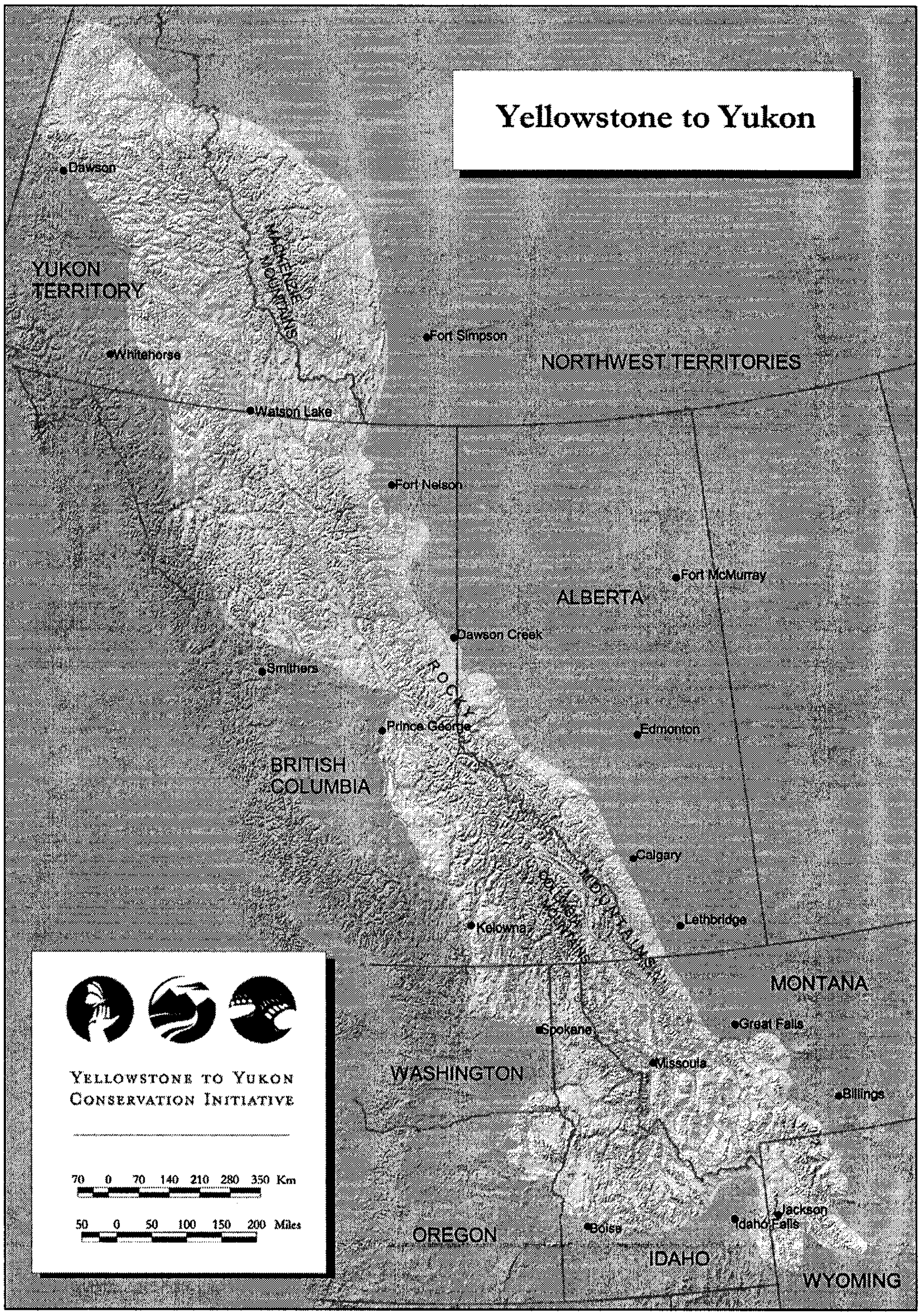

Figure 1-1. The Y2Y ecoregion (lighter colour). Map provided by the Yellowstone to Yukon Conservation Initiative.

Sixty-two percent of the region is in Canada (Chadwick 2000). Y2Y contains two continental divides that separate it into 3 oceanic watersheds: the Atlantic, the Pacific and the Arctic (Gadd 1998). It also contains the headwaters for ten large river systems, including the Columbia, Fraser, Mackenzie and Missouri (Willcox 1998a).

Most of the study area is above 1075m in elevation, but ranges in elevation from 60m in the MacKenzie lowlands in the NWT to 4207m at Gannet Peak, Wyoming (Gadd 1998). The climate is cool to cold, with abundant soil moisture (Gadd 1998). The crest of the Rockies acts as a climatic divide with the western slope having generally wetter and warmer conditions, particularly in winter, and a lower seasonal contrast in temperatures compared with the eastern side (Gadd 1995, Carroll et al. 2001). The eastern slope also experiences strong summer Chinook winds that produce sudden temperature increases (Gadd 1995).

The Y2Y ecoregion includes mountain habitats (alpine, subalpine and montane) and interior lowland plains, foothills and plateaus (Achuff 1998). The forest cover below timberline is nearly continuous and occupies almost 60% of the Y2Y region (Gadd 1998, Chadwick 2000). Alpine tundra exists throughout more than 20% of Y2Y, and occurs wherever the mountains extend above timberline, with timberline elevation decreasing from about 3500m in the south to 1000m in northwest BC and the Yukon (Achuff 1998, Chadwick 2000). Subalpine habitat consists mainly of Englemann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*), but also includes white spruce (*Picea glauca*), willow (*Salix* spp) and dwarf birch (*Betula glandulosa*) shrubfields in northern BC, the Yukon and Northwest Territories, and western red cedar (*Thuja plicata*)/ western hemlock (*Tsuga heterophylla*) forests in western Montana, Idaho and southeastern BC.

Plant communities below the subalpine are determined mainly by their location within the Y2Y ecoregion (Gadd 1995). Grassy lowlands are present along the southeast edge of Y2Y from southern Alberta to central Wyoming (Achuff 1998, Gadd 1998). Other east slope montane vegetation types include Douglas fir (*Pseudotsuga menziesii*), limber pine (*Pinus flexilus*), lodgepole pine (*Pinus contorta*), white spruce and aspen (*Populus tremuloides*) (Achuff 1998). Ponderosa pine (*Pinus ponderosa*), interior Douglas fir, white and black spruce (*Picea mariana*) boreal forest, and mixed wood stands of white and black spruce, balsam fir (*Abies balsamea*), jack pine (*Pinus banksiana*), aspen, balsam poplar (*Populus balsamifera*) and paper birch (*Betula papyrifera*) are found in other parts of Y2Y (Achuff 1998).

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Chapter 2. Focal Bird Species Selection

2.1 Introduction

Conservation planning is usually undertaken with limited funds to support scientific research, and in response to an urgent need to establish priorities for conservation action before valuable habitat is lost, or before species become extinct or extirpated. A common approach is to delineate a small group of focal species, rather than trying to plan specifically for every species in the region of interest (Niemi et al. 1997, Andelman and Fagan 2000, Fleishman et al. 2000). Examples of focal species include charismatic species, or *flagships*, such as grizzly bear (*Ursus arctos*) and giant panda (*Ailuropoda melanoleuca*), used to gain public support for conservation action (Caro and O'Doherty 1999, Zacharias and Roff 2001) and *keystones*, species whose presence has large effects on the abundance or incidence of other species (Mills and Soule 1993, Lindenmayer et al. 2000). When the main goal is to identify sites for conservation action, three other categories of focal species are typically used. These include *umbrellas,* whose habitat requirements include those of sympatric species, *biodiversity indicators* whose occurrence acts as a surrogate for the presence of other species, and *composition indicators* that characterize a particular habitat, community or ecosystem (Caro and O'Doherty 1999, Andelman and Fagan 2000, Zacharias and Roff 2001).

The purpose of my project is to identify high quality avian breeding habitat, which could form potential core areas for birds in the Yellowstone to Yukon (Y2Y) conservation area design (refer to sections 1.1 and 1.2 for a description of the core/corridor strategy and Y2Y). While biodiversity indicators can be useful to identify hotspots of species richness or areas with high numbers of endemic (native), rare or threatened species (e.g. Kerr 1997, Mittermeier et al. 1998), these sites do not necessarily protect all species of interest (Dufrene and Legendre 1997). Thus I chose to use composition indicators and umbrellas for the Y2Y habitat cover types to identify prime conservation sites. Composition indicators for all of the Y2Y cover types will support my coarse-filter approach that aims to represent broad-scale habitat cover types important to the bird communities found in Y2Y. However, this will not identify high quality habitat within each cover type. If these birds also act as umbrella species, their physical habitat needs, specifically their preferred habitat, can act as surrogates for high quality habitat that should encompass and protect the remaining Y2Y conservation priority bird species (Berger 1997, Caro and O'Doherty 1999, Suter et al. 2002).

Umbrella species approaches focus on the physical habitat needs for a species (Caro and O'Doherty 1999), and have traditionally selected a single umbrella species with large area needs, such as the grizzly bear (Carroll et al. 2001) or large herbivores (Wallis de Vries 1995, Berger 1997). This assumes their habitat location and area requirements will support viable populations of sympatric species with similar, but less extensive habitat requirements (Berger 1997, Suter et al. 2002). More recent studies have used smaller species such as Capercaillie (*Tetrao urogallus*) (Suter et al. 2002), butterflies (Fleishman et al. 2000) and White-backed woodpecker (*Dendrocopos leucotos*) (Martikainen et al. 1998) as umbrellas. Often a single species is proposed as an umbrella for others within its own taxon and across other taxa. However, this approach has often been unsuccessful due to differing requirements among species (Lambeck 1997), leading to recommendations for using combinations of species with complementary habitat use (Carroll et al. 2001, Poiani et al. 2001). My approach selected a group of complementary focal bird species were hypothesized to act as both composition indicators and umbrellas for each of the Y2Y broad scale habitat types. This chapter presents the methods I developed to identify these focal bird species and the additional bird species that each focal bird was intended to protect. I also tested the focal bird species effectiveness as umbrellas for the species they aimed to protect.

2.2 Methods and results

2.2.1 General approach

I selected focal bird species whose primary habitat collectively represented each of the broad habitat cover types (Table 1-1), and whose geographic range enabled them to act as umbrella species for their primary habitats. I chose species with specialized habitat use, since generalists tolerate a variety of habitat and are not the most effective umbrellas (Linnell et al. 2000, Coppolillo et al. 2004). Kintsch and Urban (2002) also found that habitat specialists were the most reliable community indicators. I minimized the total number of focal species to reduce propagation errors when combining the model predictions in the final stage of my study (Flather et al. 1997, Boone and Krohn 2000).

I identified a set of focal species by first establishing species assemblages of similar habitat use for the Y2Y conservation priority species, and selecting the most representative species from each assemblage. Using species assemblages to select the focal birds had several advantages. It identified groups of birds with similar combinations of habitat use. It also designated the species that were associated with each focal bird, which then allowed the focal birds effectiveness as umbrella species to be tested. I then subjected these focal species candidates to a set of secondary tests to ensure they satisfied requirements to act as effective umbrellas, and had sufficient detections to develop a statistical model (refer to section 2.2.5 for more details regarding conditions for the secondary tests). Finally, I used bird survey data within the Y2Y region to test the focal species effectiveness as umbrellas by determining the strength of their association with the conservation priority species they aimed to protect.

2.2.2 Bird survey data

A common method to census breeding birds involves point count surveys which use a standardized methodology to record all birds seen or heard within a fixed distance and during a specific time interval from widely separated locations (Farnsworth et al. 2002). I collated 18,700 point counts of existing breeding bird survey data with their associated geographic locations throughout the Y2Y region ((Appendix II, see Acknowledgments). Data were predominantly from 1990 to 2000, but were supplemented with data sets from 1970 to 1990 to represent missing northern and high elevation habitats. Approximately one half of these data points were from the North American Breeding Bird Survey (BBS) that was established in 1966 to monitor North American bird populations (http://www.mp2-pwrc.usgs.gov/bbs/about). The BBS takes place along permanent 39.4 km routes that are randomly located along secondary roads throughout North America. Routes are surveyed once each year during the breeding season, with a 3-minute point count performed at each of 50 stops, located at 800 m intervals along the route. All bird species seen and heard within 400m from each stop are recorded. Another 25% of the survey points were from the Northern Region Landbird Monitoring Program in Idaho and Montana, and the remaining surveys were obtained from government agencies, naturalist groups, and academics.

I calculated the average yearly count during the breeding season for each Y2Y conservation priority species at each point count location. I then constructed a Geographic Information System (GIS) layer that spatially located the point count stations with their associated average yearly counts in the Y2Y region (Figure 2-1).

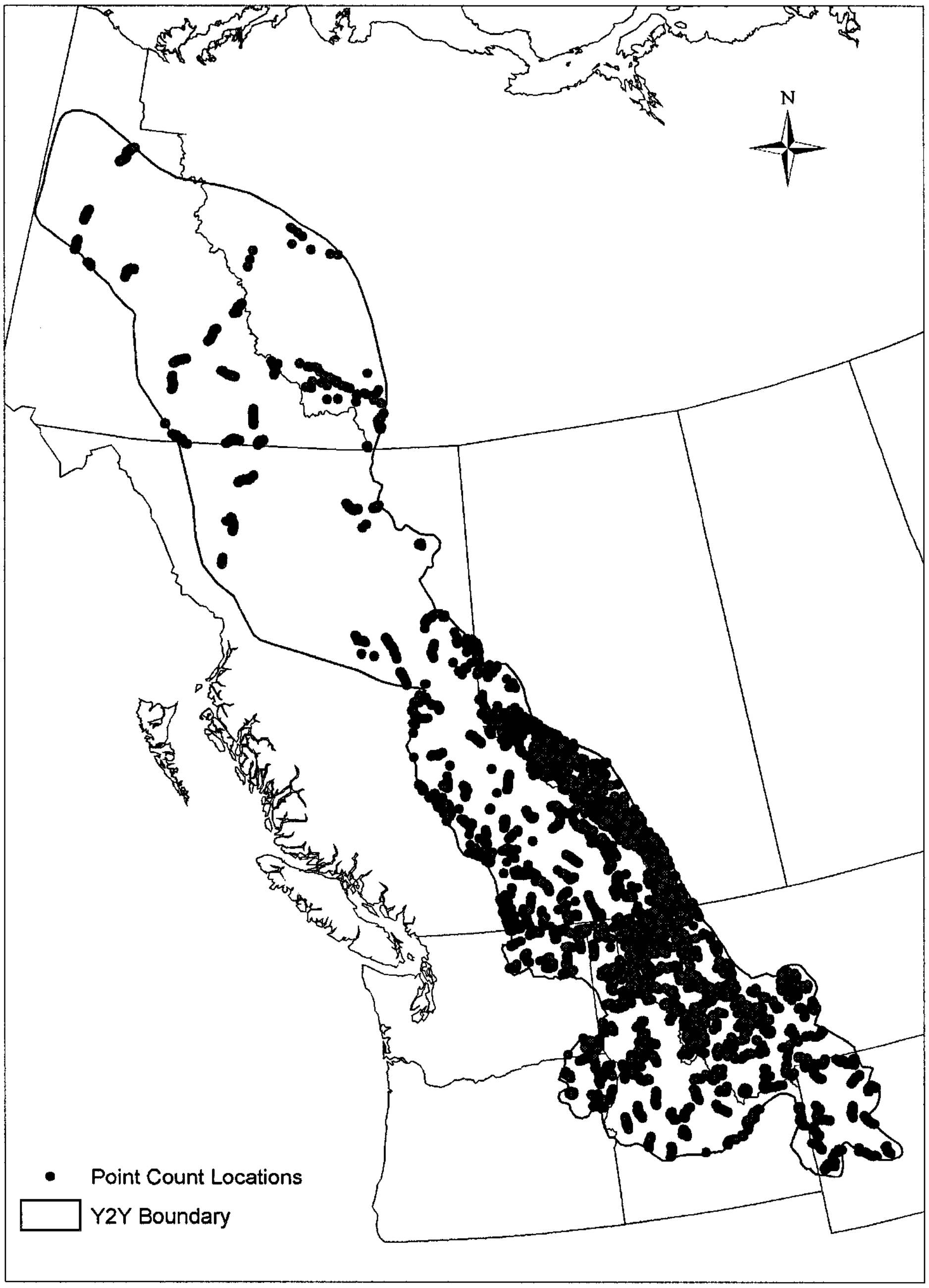

Figure 2-1: Point count locations (N = 18,700) for all bird survey data collected throughout the Y2Y region.

2.2.3 Bird detectability

Bird survey data were collected using a variety of protocols that may have resulted in different species detectability (probability of observing a bird present) among the survey points (Hutto et al. 1995, Farnsworth et al. 2002). Surveys differed in point count duration, distance at which a bird was recorded, number of visits, on-road versus off-road sampling and observers (Appendix II). As well, the habitat type in which the point count location was located may affect the detectability of a bird species (Schieck 1997). Species detectability differences can introduce errors into the analysis of species-habitat relationships because the locations at which a bird was present, but not detected, will mistakenly be treated as unused sites (Dettmers et al. 1999, Drapeau et al. 1999). The detectability of a bird is affected by two factors: the probability that the bird will sing or move sufficiently to be observed during the count interval, and secondly, the probability that the bird will be detected if it does (Farnsworth et al. 2002). Methods to estimate species' detection probabilities and correct data for bias due to detectability differences include the use of distance measurements to each detected bird, and separating counts into time intervals to compare the detectability of a species from the beginning to end of the count (Farnsworth et al. 2002).

My bird survey data did not provide adequate information to allow construction of distance detectability functions or comparison of detectability among different protocols. Few surveys provided distance measurements, and only two of the 10-minute point count surveys divided the counts into time intervals. The lack of time intervals also meant that I could not use only the first 3 minutes of point count data from the longer surveys to standardize them with BBS surveys. I attempted to mitigate detectability differences by favouring the most detectable bird species when selecting the umbrella species (refer to section 2.2.5 "Secondary tests used to finalize the suite of focal bird species"). As well, using specialists as umbrella species, rather than generalists, likely reduced bias when detections were made across multiple habitat types (Schieck 1997).

2.2.4 Identifying candidate focal species

2.2.4.1 Bird habitat associations

There are two common ways of determining species assemblages: using species abundance data (e.g. Dufrene and Legendre 1997, Fleishman et al. 2000), or grouping species into communities or guilds based on some common environmental trait, such as habitat associations, foraging or nesting behaviour (Kremen 1992, Kintsch and Urban 2002). While there is a lot of bird survey information for the southern part of the Y2Y region, there is little information for bird species' distribution and abundance in the northern half. Using habitat associations to define species assemblages does not require studies throughout the entire Y2Y region, but can use expert opinion and literature review to define broad scale habitat associations for each species.

The Y2Y avian working group identified primary and secondary habitat types for each conservation priority species from the Y2Y broad habitat cover types. In addition, I used habitat information from field guides (National Geographic Society 1987, Stokes and Stokes 1996), bird habitat databases (WILDSPACE^{tm} 2002 and NatureServe), the Yukon Breeding Bird Atlas (Sinclair et al. 2003) and Canadian Wildlife Service reports (Scotter et al. 1977, Cairns et al. 1978) to resolve gaps and uncertainties in these original species-habitat associations. I found that some habitat types assigned to species by the Y2Y avian working group were not supported by my literature review. As well, some additional habitat types were suggested for most species. My findings were sent to members of the avian working group for review to attempt to resolve these discrepancies. I also asked four ornithologists and biologists in the Yukon and Northwest Territories to verify the habitat associations for conservation priority birds found in the northern part of Y2Y. I then updated the original species-habitat association matrix to reflect these reviewers' comments (Appendix I) as follows:

- I included any additional habitat types suggested by the literature review that were supported by at least one reviewer
- I added new habitat types for a species when suggested by a reviewer
- I deleted habitat types suggested by the literature review but not supported by any reviewer
- I retained the original species-habitat associations if no reviewer indicated errors

I next created a similarity matrix of species habitat use by weighting a species' primary habitat twice that of its secondary habitats and ensuring the weights for each species totalled 1.0. All primary habitats for a species were assigned equal weights. Similarly, multiple secondary habitats were weighted equally. For example, Cassin's Finch (species' scientific names are in Appendix I) had Ponderosa Pine/Douglas Fir as its primary habitat, and two secondary habitats of Lodgepole Pine and Subalpine Spruce/Fir. I assigned weights of 0.5 to the primary habitat and 0.25 to each secondary habitat. Gyrfalcon had two primary habitat types: alpine/tundra and northern shrubfields, and no secondary habitat types. I assigned a weight of 0.5 to each primary habitat type. Finally, I removed 38 generalist species (those that used more than three habitat types) from the matrix of habitat weights (Appendix I). I also removed four species (Bank Swallow, Northern Rough-winged Swallow, Peregrine Falcon and Prairie Falcon) that were highly dependent on microhabitat features for nesting (e.g. river banks and cliffs) that cannot be modelled at the resolution I am working at. This resulted in a matrix of habitat weights for 67 bird species.

2.2.4.2 Determining species assemblages based on bird habitat use

2.2.4.2.1 Hierarchical cluster analysis

I created groups of species using similar primary and secondary habitats using clustering routines in SPLUS v6.1 based on the matrix of habitat weights for the 67 bird species. Cluster analysis is an exploratory statistical approach that classifies data into discrete groups or "clusters" based on their similarity according to specified criteria such as environmental factors (McGarigal et al. 2000, Everitt et al. 2001). Hierarchical clustering determines both the clusters and relationship among them, typically showing results in a tree structure called a "dendrogram", whose branch lengths indicate the degree of similarity among groups (McGarigal et al. 2000). I used four different hierarchical clustering algorithms (average linkage or UPGMA, complete linkage, Ward and divisive) to explore the data structure, identify outliers and determine a range of optimal cluster numbers for the data. I used Manhattan distance to measure the similarity among the species in the clustering algorithms.

Cluster analysis is sensitive to the variables used in the analysis, the clustering algorithm and the distance measure used (Sneath and Sokal 1973, Kaufman and Rousseeuw 1990, Everitt et al. 2001, Halkidi et al. 2001). Clustering techniques will generate a set of clusters even when applied to random data with no particular structure (Dunn and Everitt 1982). As well, algorithms make assumptions based on their parameters to find the best grouping of the data, and may not find the optimal solution (Halkidi et al. 2001). For these reasons, cluster analysis is considered an exploratory and fairly subjective technique and it is essential to validate the results for consistency, and test if the clusters are reasonable for the underlying data (Halkidi et al. 2001). I verified that the distances among species in the dendrograms reflected the similarity of their habitat requirements. I found dendrograms produced by the four hierarchical clustering methods were fairly similar, so only the dendrogram for average linkage (UPGMA) hierarchical cluster analysis is shown (Figure 2-2). Several species formed distinct groups, well separated from the other clusters. These were species specializing in one of coniferous riparian, willow riparian, lakes, alpine/tundra, grassland and sagebrush steppe habitats, or species with similar use of two habitat types (e.g. grassland/sagebrush steppe; marsh/lakes). More diffuse and less consistent clusters were evident for species using mixes of the habitat types, but clusters were still characterized by a few predominant habitat types that were used in varying combinations by the species in the cluster. For example, the cluster containing Boreal Chickadee, Gray-cheeked Thrush, White-winged Crossbill and White-crowned Sparrow was characterized by subalpine spruce/fir as primary habitat for most species, boreal spruce as primary or secondary habitat, and either mixed wood or northern shrubfields as additional secondary habitat.

2.2.4.2.2 K-Medoid Cluster Analysis

I used a second clustering technique, k-medoid optimization clustering, to assign bird species into a number of clusters specified *a priori*, as optimization methods are usually better than hierarchical methods at isolating clusters from each other. The number of clusters to be produced must be specified *a priori*, which requires knowledge of the data structure. One way around this dilemma is to first use hierarchical cluster analysis and compare habitat characteristics of clusters at different levels in the dendrograms to

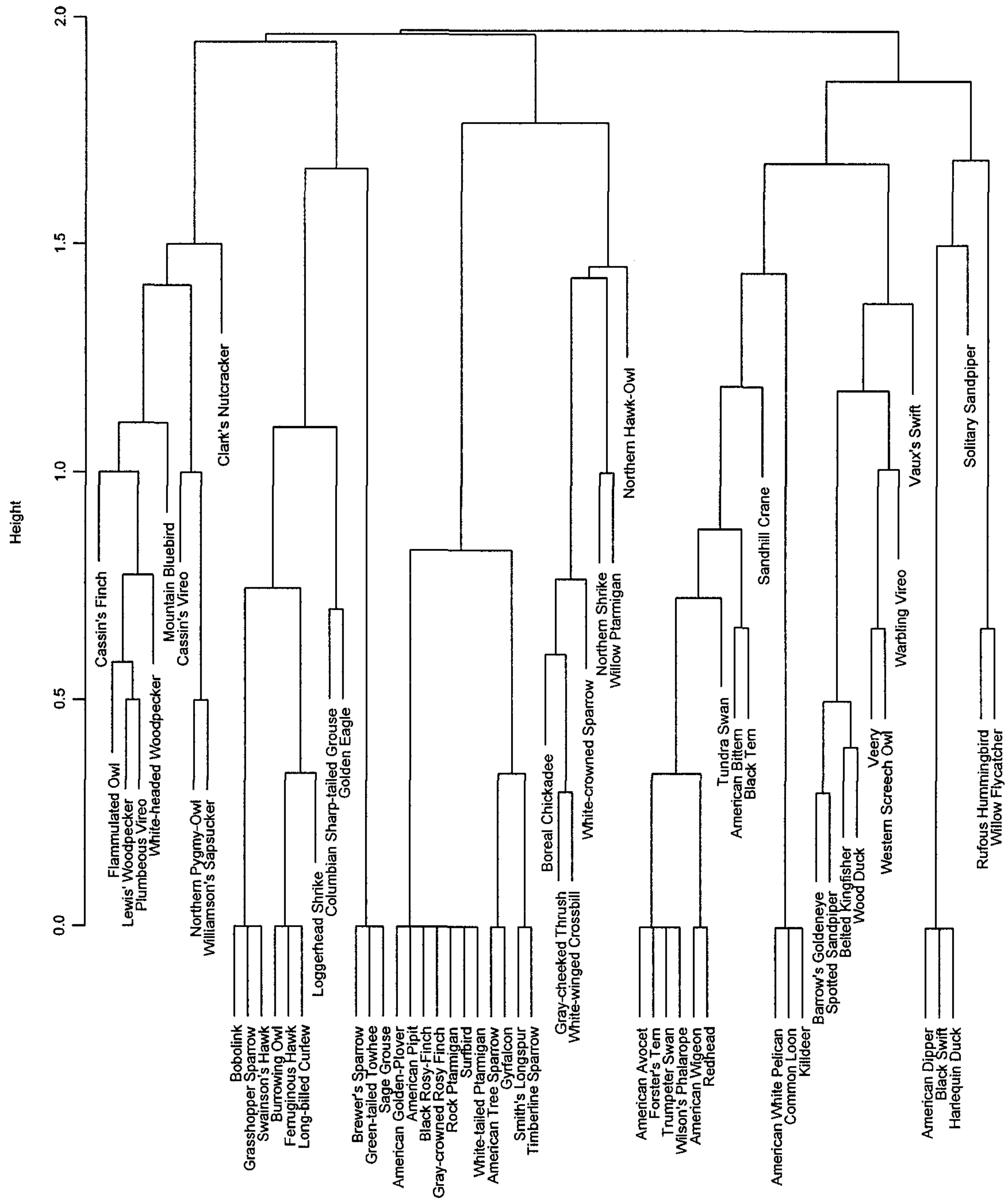

Figure 2-2. The dendrogram produced by Average Linkage Cluster Analysis for the group of 67 non-generalist bird species. Clusters were based on similarity in habitat use among the species. The height of a branch corresponds to the degree of similarity among individual species and groups of species.

determine a range of optimal cluster numbers, and then use optimization methods to test each cluster number in this range (McGarigal et al 2000, Barbaranelli 2002). I found that hierarchical cluster analysis produced well-defined groups with characteristic habitat types and similar use among the species in a group for a range of 15 to 19 clusters.

I then ran k-medoid cluster analysis on the matrix of habitat weights for the 67 bird species, specifying the number of groups (k) for each optimum number of 15 to 19 clusters. I compared results for each solution for consistency and verified that groupings were reasonable for the habitat characteristics of the birds found within them. I also compared silhouette widths for each solution. The silhouette width for each cluster is an indication of the cohesiveness of the cluster, and its separation from the other clusters in the solution. Higher values for each cluster, as well as the average for all clusters indicate better solutions (Kauffman and Rousseeuw 1990). I found the average silhouette width peaked at 17 clusters, dropped for 18 clusters, and then increased again with 19 clusters. I tested cluster numbers at either end of the range to see if the trend continued (Figure 2-3).

Twenty and 21 clusters had a slightly higher average silhouette width than 17 clusters, while average silhouette width was lower for 18 and 19 clusters, and steadily decreased with fewer than 17 clusters. Increasing the cluster number from 17 to 18 caused several species to be reshuffled among the clusters. This had a mixed effect on the silhouette widths, as 2 clusters improved, and 4 clusters had decreased values, which resulted in an overall lower average silhouette width for the 18 cluster solution. The clusters produced by the solutions with the highest silhouette values (k=17, 21 and 22) were very similar to each other, and to the dendrogram groupings for comparable

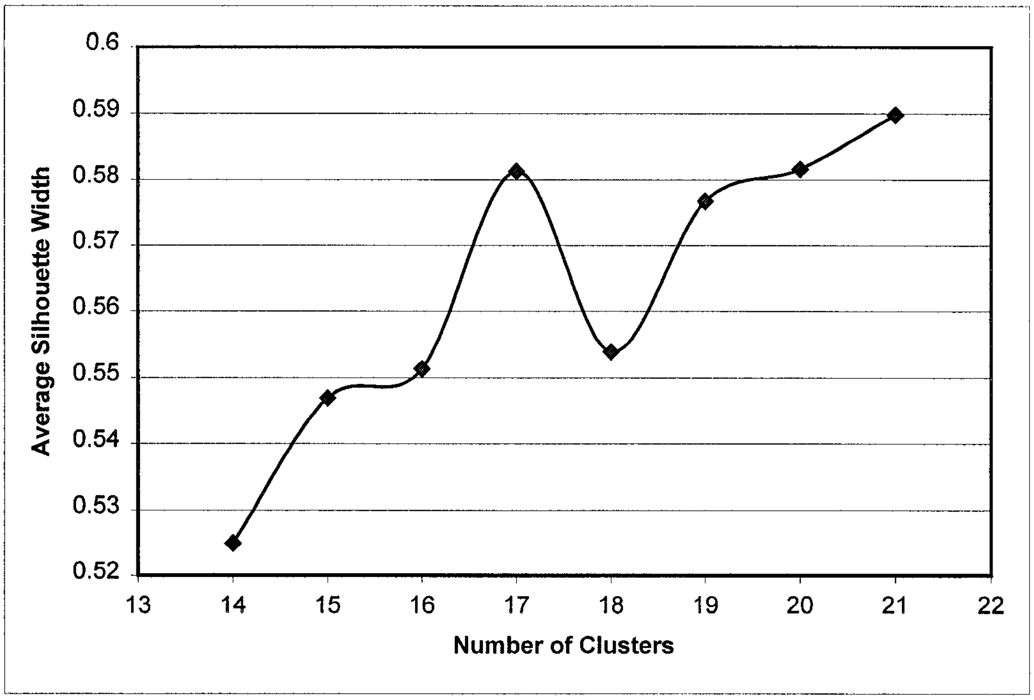

Figure 2-3: Average silhouette widths using varying cluster numbers in k-medoid analysis. Higher values indicate more cohesive clusters for the k-medoid solution. Silhouette widths increase from 14 to 17 clusters, then drop and start to increase again from 19 to 21 clusters.

numbers of clusters. All solutions separated specialist species using coniferous riparian, alpine/tundra, lakes, sagebrush steppe and willow riparian habitats. The 20 cluster solution was identical with k=17, except Sandhill Crane, Solitary Sandpiper and Willow Ptarmigan were each isolated into a separate cluster. The 21 cluster solution also put Vaux's Swift into its own cluster. These 4 species did not fit well into the clusters that were produced by the K=17 solution. For example Solitary Sandpiper (bog as primary habitat, lakes and coniferous riparian as secondary habitats) was grouped with species using deciduous riparian as primary habitat, lakes as primary or secondary habitat, and coniferous riparian as secondary habitat. The isolation of these "troublesome" species in the k=20 and k=21 solutions had the effect of increasing the similarity, and thus the silhouette width in the species' original cluster. It also created new clusters with perfect similarity that were well separated from the other clusters, thus increasing the average silhouette width. However, single species clusters are not useful for identifying umbrellas, as these species do not represent any others. Therefore I discarded the solutions for k=20 and 21, and selected k=17 as the optimum (Appendix III).

Optimization methods can identify the object in each group that has the smallest average dissimilarity to all the other objects in the group (Kauffman and Rousseeuw 1990). I considered this object to be the most representative of the species assemblage contained in a cluster, and designated it as the candidate focal species for its group. I used these candidates to form the initial group of focal bird species. The candidate species list was then checked according to criteria described in the next section.

2.2.5 Secondary tests used to finalize the suite of focal bird species

I subjected the candidate focal birds to several tests to evaluate whether they might act as effective umbrellas. Fleishman et al. (2000) recommended that an umbrella species have a large part of its range within the study region, and this portion should cover at least 5% of the region of interest. As well, an umbrella's geographic range needs to encompass the species it aims to protect (Noss et al. 1996). I also required each umbrella to have a minimum of 100 detections, since I planned to develop a statistical model for each umbrella based on existing bird survey data that I had collected for the Y2Y region.

Of the 17 candidate focal species, only Clarks' Nutcracker, Long-billed Curlew, Golden Eagle, and Veery satisfied the secondary tests and were retained as the focal species for their clusters. I immediately rejected candidates with insufficient detections to model (Wilson's Phalarope, White-tailed Ptarmigan, Timberline Sparrow, Barrow's Goldeneye, Sage Grouse, Flammulated Owl and Northern Shrike). I then considered the home range size of the candidate species and considered alternatives for wide-ranging species whose detection locations may not be tightly coupled to their nesting habitat. I replaced the grassland specialist Swainson's Hawk, a wide ranging species, with Grasshopper Sparrow which has a much smaller home range size. I also replaced the Killdeer with Common Loon as I had survey data specific to loons. Finally, I replaced the White-winged Crossbill with White-crowned Sparrow, as the former is an irruptive species and may occupy non-preferred habitat in years of high abundance (Gutsell et al. 2000)

I used digital species range maps from WILDSPACE^{tm} (2002) for 64 species and Birds of North America range maps (Pool and Gill 2002) for the remaining 3 species (Black Rosy-Finch, Timberline Sparrow and Green-Tailed Towhee) to conduct the remaining tests. I determined the proportion of a bird's breeding range that was contained in Y2Y, and the percentage of the Y2Y region that was covered by the breeding range. I also calculated the amount of coverage a candidate focal species provided to its cluster members, and to other conservation priority species having the same primary habitat. I found that all candidates satisfied the first two conditions, but replaced Williamson's Sapsucker, Harlequin Duck and Willow Flycatcher since these birds provided poor range coverage for their cluster members.

If a proposed focal species did not pass the secondary criteria, I replaced it with the species in its cluster that was most similar in habitat use and re-ran the tests. I preferentially selected a replacement species with the highest number of detections, and that expert opinion suggested was most likely species to be observed in bird surveys. If no species in a cluster satisfied all the tests, I selected the species in the cluster that provided the best trade-off between the number of detections, detectability, range coverage of the Y2Y region and range overlap with its cluster members and the other conservation priority species with the same primary habitat.

Finally, I checked that all habitat cover types in Table 1-1 were represented by the focal species that satisfied the secondary tests, and added other species, as needed, to include missing habitat types. If none of the non-generalist species in my analysis were able to represent a missing habitat type, I reconsidered a generalist species previously removed from my analysis. I only allowed a generalist to be a candidate if its primary habitat represented a missing habitat type. I then subjected these candidate species to the suite of secondary tests and selected those species that provided the best trade-off between the number of detections, range coverage of the Y2Y region and range overlap with the other conservation priority species having the same primary habitat.

The focal species' primary habitats represented all habitat types except cedar/hemlock, aspen, bog, lodgepole pine, and boreal mixed wood. I added Brown Creeper, Ruffed Grouse and Wilson's Warbler to act as focal species for the first three habitats respectively. Lodgepole pine, and boreal mixed wood are not primary habitats for any of the conservation priority species. However, Cassin's Vireo and Brown Creeper used lodgepole pine as secondary habitat, and Yellow Warbler and Ruffed Grouse used boreal mixed wood as secondary habitat. The final list of focal bird species totalled 20 (Table 2-1).

The individual focal species provided between 8.5 to 100 percent geographic overlap with their cluster members, and from 0 to 100 percent overlap with other conservation priority species with the same primary habitat type (Table 2-2, Appendix IV).

Table 2-1: Final list of 20 focal bird species after applying the secondary filter to the candidates proposed by cluster analysis based on species' habitat usage. Primary habitat is indicated in **BOLD;** The 11 species selected for modelling are indicated in **BOLD.**

Focal Bird Species	**# of Detections**	**Habitat types**
American Dipper*	151	**Coniferous Riparian** specialist
American Tree Sparrow*	146	**Northern Shrubfields, Alpine/Tundra**
American Wigeon*	128	**Marsh; Lakes**
Blackpoll Warbler*	235	**Boreal Spruce**; Bog; Marsh, Subalpine Spruce/Fir
Brewer's Sparrow*	960	**Sagebrush Steppe** specialist
Brown Creeper⁺	509	**Cedar/Hemlock, Subalpine Spruce/Fir,** Lodgepole pine, Moist Douglas fir/Mixed/Grand fir
Cassin's Vireo*	1287	**Moist Douglas fir/Mixed/Grand fir**; Lodgepole pine, Aspen
Clark's Nutcracker	1180	**Whitebark pine**; Subalpine Spruce/Fir; Dry Ponderosa pine/Douglas fir mix
Common Loon*	220	**Lake** specialist
Golden Eagle	66	**Subalpine Spruce/Fir; Grassland**; Alpine/Tundra
Grasshopper Sparrow*	158	**Grassland** specialist
Gray-crowned Rosy-Finch*	60	**Alpine/Tundra** specialist
Lewis' Woodpecker*	53	**Dry Ponderosa Pine/Douglas fir mix**; Deciduous Riparian
Long-billed Curlew	280	**Grassland**; Sagebrush Steppe
Ruffed Grouse⁺	921	**Aspen**; Deciduous Riparian; Willow Riparian; Boreal Mixed Wood
Spotted Sandpiper*	944	**Deciduous Riparian,** Lakes, Coniferous Riparian
Veery	635	**Deciduous Riparian**, Aspen
White-crowned Sparrow*	1756	**Subalpine;** Alpine/Tundra, Northern Shrubfields
Wilson's Warbler⁺	1550	**Bog, Deciduous Riparian; Willow Riparian;** Northern Shrubfields
Yellow Warbler*	2598	**Willow Riparian, Deciduous Riparian,** Marsh, Boreal Mixed Wood

*Indicates species that replaced the original candidate focal species for the cluster.
⁺Indicates species that were added to represent missing habitat types.

Table 2-2: The focal bird species effectiveness as umbrellas for their primary habitats. The percentage overlap of the focal species' primary habitat with the species in its cluster, and with all Y2Y conservation priority species with the same primary habitat usage calculated by overlaying digital range maps is shown.

Focal Species (Primary Habitat)	**% Range Overlap with Cluster Members Number of other species in cluster)**	**Mean % Range Overlap with Cluster Members (SE)**	**% Range Overlap with Other Species with the Same Primary Habitat (Number of species)**	**Mean % Range Overlap with Other Species with same primary habitat (SE)**
American Dipper (Coniferous Riparian specialist)	91.9 - 96.6 (2)	94.3 (2.3)	No species	-
American Tree Sparrow (Alpine/Tundra and Northern Shrubfields)	100 (2) *	100 (0)	*Alpine/Tundra*: 0 – 100 (8)	58.3 (14.5)
			Northern Shrubfields: 57.4 – 79.0 (2)	68.2 (10.8)
American Wigeon (Marsh/Lakes)	100 (9)	100 (0)	*Marsh*: No species	-
			Lakes: 100 (7)	100 (0)
Blackpoll Warbler (Boreal Spruce)	96.3 – 100 (3)	98.6 (1.1)	69.6 – 100 (3)	85.5 (8.8)
Brewers Sparrow (Sagebrush Steppe specialist)	100 (2)	100 (0)	100 (1)	100 (n/a)
Brown Creeper (Cedar/hemlock and Subalpine Spruce/Fir)	No species	-	*Cedar/hemlock*: 39.3 – 99.8 (2)	69.6 (30.3)
			Subalpine Spruce/Fir: 3.3 – 52.1 (10)	38.4 (4.3)
Cassin's Vireo (Douglas fir/ Mixed/Grand fir)	63.7 - 65.7 (2)	64.7 (1.0)	32.8 – 62.1 (8)	44.9 (4.2)
Clark's Nutcracker (Whitebark pine)	96.9 (1)	96.9 (n/a)	No species	-
Common Loon (Lake specialist)	56.1 – 71.5 (2)	63.8 (7.7)	41.2 – 83.0 (6)	67.1 (7.9)
Golden Eagle (Subalpine and Grassland)	100 (1)	100 (n/a)	*Subalpine*: 100 (10)	100 (0)
			Grassland: 100 (10)	100 (0)

Focal Species (Primary Habitat)	% Range Overlap with Cluster Members Number of other species in cluster)	Mean % Range Overlap with Cluster Members (SE)	% Range Overlap with Other Species with the Same Primary Habitat (Number of species)	Mean % Range Overlap with Other Species with same primary habitat (SE)
Grasshopper Sparrow (Grassland specialist)	8.5 - 41.9 (2)	25.2 (16.8)	8.4 – 40.3	18.3 (4.0)
Gray-crowned Rosy Finch (Alpine/Tundra specialist)	75.2 – 100 (6)	87.7 (4.5)	60.4 – 84.5 (4)*	68.9 (8.2)
Lewis' Woodpecker (Dry Ponderosa pine/Douglas fir mix)	54.3 – 97.6 (3)	74.0 (12.7)	48.7 - 94.8 (4)	68.8 (11.7)
Long-billed Curlew (Grassland)	51.5 - 55.4 (3)	53.6 (1.1)	14.4 - 74.7 (7)	34.0 (9.4)
Ruffed Grouse (Aspen)	No species	-	98.1 (1)	98.1 (n/a)
Spotted Sandpiper (Deciduous Riparian)	100 (5)	100 (0)	100 (8)	100 (0)
Veery (Deciduous Riparian)	58.5 - 82.7 (2)	70.6 (12.1)	37.3 – 94.2 (10)	56.1 (6.8)
White-crowned Sparrow (Subalpine Spruce/Fir)	95.8 – 100 (3)	97.5 (1.3)	91.4 - 98.2(7)	95.9 (0.9)
Wilson's Warbler (Bog, Deciduous Riparian and Willow Riparian)	No species	-	*Bog*: 100 (5)	100 (0)
			Deciduous Riparian: 100 (11)	100 (0)
			Willow Riparian: 100 (4)	100 (0)
Yellow Warbler (Willow Riparian and Deciduous Riparian)	100 (2)	100 (0)	*Willow Riparian*: 91.9 (1)	91.9 (n/a)
			Deciduous Riparian: 91.9 – 100 (11)	96.1 (1.1)

* doesn't include Smith's Longspur as this species' breeding range is outside the Y2Y region.

2.2.6 Focal species validation

In order to be effective surrogates, umbrella species must co-occur with the species they are intended to protect (Flather et al. 1997, Andelman and Fagan 2000). I performed the following steps with the Y2Y bird survey data to test if each focal species co-occurred more often with the species it aimed to protect compared with the other Y2Y conservation priority species:

1. I discarded 7 generalist species that did not have a primary habitat type since they were unlikely to be coupled with any umbrella species and could be found in multiple habitats. I also removed 4 conservation priority species that had no detections in my data set (Flammulated Owl, Northern Pygmy Owl, Surfbird and Timberline Sparrow).

2. I identified the target and non-target species for each focal bird from the remaining 97 conservation priority species. Target species are assumed to be protected by a focal bird and include the focal bird's cluster members plus other species with the same primary habitat use as the focal bird. Note that targets may include other focal birds. Non-targets are non-generalist species assumed not to be protected by the focal bird.

3. I calculated the proportion of each focal bird's point count stations where it co-occurred with each of its target and non-target species identified in step 2.

4. For each focal species, I calculated the median proportion of co-occurring point count locations of its targets (Table 2-3). Because the proportions tended to be skewed, with lots of 0 values, the median was a less biased measure than the mean (Zar 1999).

5. I used randomization tests to compare the median co-occurrence of each focal bird's target species and non-target species. To control for unequal numbers of a focal bird's target and non-target species, I randomly drew, without replacement, a sample of the non-target birds for each focal species. The sample was equal in size to the number of target species for that focal bird. I then calculated the median proportion of co-occurring survey points in the non-target sample for each focal bird. I compared the median co-occurrence of the target and non-target species for each focal species using a non parametric, one-tailed paired t-test (Wilcoxon). I performed 1000 trials, and determined the mean Z score and p-value across the 1000 trials. I also calculated the average of each focal bird's median co-occurrence with its non-targets over the 1000 trials.

The median co-occurrence of protected species was significantly higher than the non-protected species ($Z = 3.65$, $df = 20$, $p < 0.001$), demonstrating that, as a group, the focal birds did co-occur more often with the species they were intended to protect. Eighteen of the 20 focal birds had a higher median co-occurrence with their target species than their non-targets (Table 2-3). American Dipper co-occurred more often with its non-targets. Gray-crowned Rosy Finch showed no difference, as it did not co-occur with either of its two groups. However, overall the spatial overlap between focal species and their targets was low.

Table 2-3: The median proportion of co-occurring survey points between each focal bird and its target, and non-target species. The average and standard deviation (SD) of the non-target species median co-occurrence was determined across the 1000 samples drawn for the randomization tests.

Focal Species (# of Point Count Stations at which this focal bird was detected)	**Target Species Median (# of target species for this focal bird)**	**Average Non-target Species Median (SD)**
American Dipper (151)	0.01 (2)	0.03 (0.06)
American Tree Sparrow (146)	0.01 (11)	0 (0)
American Wigeon (128)	0.08 (16)	0.02 (0.01)
Blackpoll Warbler (320)	0.01 (6)	0 (0.01)
Brewer's Sparrow (960)	0.03 (3)	0.01 (0.02)
Brown Creeper (509)	0.05 (12)	0 (0)
Cassin's Vireo (1287)	0.5 (9)	0 (0.01)
Clark's Nutcracker (1180)	0.17 (1)	0.02 (0.06)
Common Loon (243)	0.04 (9)	0.01 (0.01)
Golden Eagle (66)	0.02 (20)	0.01 (0)
Grasshopper Sparrow (158)	0.02 (10)	0 (0.01)
Gray-crowned Rosy-Finch (60)	0 (9)	0 (0)
Lewis' Woodpecker (53)	0.08 (7)	0 (0.01)
Long-billed Curlew (280)	0.03 (10)	0 (0)
Ruffed Grouse (895)	0.12 (1)	0.03 (0.08)
Spotted Sandpiper (944)	0.10 (13)	0.01 (0.01)
Veery (635)	0.12 (12)	0 (0)
White-crowned Sparrow (1756)	0.03 (10)	0.01 (0.01)
Wilson's Warbler (1984)	0.02 (18)	0 (0)
Yellow Warbler (3089)	0.10 (13)	0.01 (0)

2.3 Discussion

The methods I used successfully identified a group of 20 focal species to act as effective umbrellas for Y2Y's conservation priority species. In addition, these focal birds supported the coarse filter approach of my study by collectively representing the 19 Y2Y habitat cover types. Only a few studies have assessed how well the suitable habitat for an umbrella species coincided with that of the species the umbrella was assumed to protect. Studies that found high levels of overlap supported the key assumption that the protected species' habitat needs are similar to those of the umbrella (Martikainen et al.1998, Carroll et al. 2001, Suter et al. 2002). Because the selection of my focal species was based on similar use of habitat types, this assumption was satisfied. As well, an effective umbrella species needs to be positively associated with the species it aims to protect (Flather et al. 1997, Niemi et al. 1997, Andelman and Fagan 2000, Fleishman et al. 2000). My focal species generally had good range overlap with their cluster members, with the exception of Grasshopper Sparrow that only covered 8.5% of the Swainson's Hawk's breeding range. The average geographic overlap of cluster members for the remaining umbrellas ranged from 53.6% to 100%. Most focal species also had good overlap with other Y2Y conservation priority species with the same primary habitat. Again, the exception was Grasshopper Sparrow that only provided an average of 18.3 % with other grassland birds. Since Grasshopper Sparrow seems to be a poor umbrella species, it may have been better to retain Swainson's Hawk as the focal species for this cluster despite its large home range. The bird survey data also showed that the focal species co-occurred more often with their cluster members and birds with the same primary habitat use, when compared with the other Y2Y conservation priority species. However, the co-occurrence with target species was low. This may be due to sampling bias, as the number of detections for all the Y2Y conservation priority species was a small percentage of the total number of point count stations. Therefore the likelihood of any two species being detected at the same point count station was low.

Cluster analysis based on species habitat use effectively grouped the 67 non-generalist conservation priority species, and identified birds that represented most of the Y2Y habitat cover types. Species needed to be added for 3 missing habitat types (boreal spruce, cedar/hemlock and aspen) that were only primary habitats for generalist species not included in the cluster analysis. As well, focal birds were not specifically selected for lodgepole pine and boreal mixed wood, as these were not prime habitat for any of the conservation priority species. Instead, these habitats were covered by focal species chosen to represent other habitat types. The cluster analysis approach clearly identified which bird species were represented by each focal species. This allowed assumptions of surrogacy to be clearly stated and tested using the bird survey data, as recommended by several authors (Franklin 1993, Flather et al. 1997, Niemi et al. 1997, Caro and O'Doherty 1999, Lindenmayer *et al.* 2000).

Only 4 of the 17 initial focal species derived by cluster analysis were retained after running the secondary tests. This was somewhat discouraging, but not entirely unexpected, since the clustering process was based only on primary and secondary habitat types, and did not take into account other important criteria for umbrella species. As well, the choice of a candidate focal species was arbitrarily made by the clustering algorithm for 5 clusters that had multiple species with identical habitat use. In each of these cases, the candidate species selected by the clustering algorithm was replaced. The most common reason for rejecting candidate species was that they had too few detections to construct statistical models. This resulted in 7 candidate focal species being rejected. The Y2Y conservation priority species included shorebirds, waterfowl, owls, raptors and woodpeckers that are not well surveyed by point counts. This suggests that selecting focal species with my method is more appropriate when the focal species will not be used for modelling. Alternatively, if the aim is to construct statistical models, my approach is better suited for songbirds that are well surveyed, or in a region with more intensive sampling and that uses a variety of survey methods to adequately sample all species of interest.

My method was useful for situations where bird survey data is sparse, as focal species could be identified using expert opinion and habitat use by literature review. Other approaches that used quantitative methods to identify composition indicators and umbrella species (e.g. Dufrene and Legendre 1997, Fleishman et al. 2000, Kintsch and Urban 2002) had the advantage of using small study areas, with comprehensive surveys and detailed knowledge of the habitat at each survey point. I attempted to use the method described by Fleishman et al. (2000) to identify umbrella species for Y2Y, but I found that the number of species detections biased this method. Common bird species with high numbers of detections had the highest co-occurrence rates with other species, and were selected as the umbrella species. These species also tended to be habitat generalists, and thus were not good composition indicators. For my purposes, the method proposed by Dufrene and Legendre (1997) to select composition indicators was more appropriate, but it required habitat cover type information specific to each survey point. This information was only available at 1 sq km resolution for most of my survey areas and was not of sufficient resolution to assign to my bird survey points. Habitat is patchy in mountain terrain, with rapid changes over small distances in elevation, moisture and temperature. Birds, especially small bodied songbirds, have small territories and home ranges and thus can select a small patch of a habitat cover type that is not captured by the coarse land cover classification available to us for the huge Y2Y area. Thirty metre Landsat cover type data are available for the United States (John Sauer pers. comm.). If comparable land cover data become available for the Canadian portion of Y2Y it may be possible to use more quantitative methods such as that by Dufrene and Legendre (1997) to classify bird species into assemblages.

As with any coarse-filter approach, certain species with specialized resource needs (e.g. river banks, cliffs and snags) need specific management plans as high quality habitat identified for the umbrellas may not include these features. In addition, managers may want to monitor species at risk (Appendix I) to assess population trends.

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Chapter 3. Model Development and Identification of High Quality Avian Habitat

3.1 Introduction

Conservation planning for specific bird species must identify high quality habitat to prioritize sites for conservation action, as no species is distributed uniformly throughout its range. Individuals live in particular areas, or habitat, that provide the resources (i.e. food, water, nesting and perching sites, and cover) and environmental conditions (e.g. climate, elevation, topography and soil) needed to survive and reproduce (Baydack et al. 1999, Fernandez-Juricic and Jokimaki 2001, Johnson and O'Neil 2001). I defined high quality habitat as areas that had higher amounts and more stable resources for birds, and lower levels of predation, parasitism and anthropogenic disturbance (Cody 1985, McLoughlin, et al. 2000, Suryan and Irons 2001). One approach to identify high quality habitat uses population productivity measures, such as nesting success or population growth rate, to pinpoint areas that have relatively high reproductive success (Suryan and Irons 2001, Hansen and Rotella 2002). Another method locates sites that are associated with species-specific resource requirements, such as food, cover types or nesting sites (Raphael and Marcot 1986, Johnson and O'Neil 2001). It is difficult, however, to obtain productivity or resource specific data for many species, particularly at the regional scale where inventory data are often meagre or absent (Fleishman et al. 2001).

An alternative approach links habitat quality to the potential occurrence of a species, since habitat is associated with the distribution and abundance of species (Pausas et al. 1997, Johnson and O'Neil 2001). This approach models species' presence/absence as a function of large-scale environmental variables, such as topography and climate, that can be quantified easily over large spatial scales (Fleishman et al. 2001, Pearce and Ferrier 2001). These models are then applied to environmental layers in a Geographic Information System (GIS) to extrapolate the predicted likelihood of the species' occurrence across the entire region of interest (Pearce and Ferrier 2001). The predictions of species' occurrence help to identify the spatial extent of important habitat for conservation and management (Boone and Krohn 2000). This method is particularly applicable to continental scale planning in vast and remote regions such as Y2Y, where bird surveys are sparse or non-existent in many areas (Guisan et al. 2002).

I adopted this broad-scale modelling approach to prioritize habitat for the focal birds in the Y2Y region. The large size and remoteness of this ecoregion made it logistically impossible to directly determine avian habitat quality by measuring bird habitat use and breeding success. The models were based on a home range level of habitat selection, i.e. the geographic area where a species conducts its daily and seasonal activities (Johnson 1980, Johnson and O'Neil 2001), that I hypothesized could be predicted using broad-scale environmental and anthropogenic variables.

I selected 11 of the focal species to model as a first cut at identifying candidate core areas for the Y2Y conservation area design (Table 2-1). These species represented northern (boreal spruce, boreal mixed wood, aspen, northern shrubfields), high elevation (alpine/tundra, subalpine spruce/fir), coniferous, deciduous and willow riparian, whitebark pine, wetland and lake habitat. This process identified high quality avian habitat and candidate core avian areas in the conservation area design to support conservation planning efforts in the north and recognized the high conservation value of riparian, wetland and lake habitat. It also provided information regarding high quality avian habitat in high elevation habitats that form an extensive corridor throughout the Y2Y ecoregion. I also included whitebark pine habitat, the primary habitat of Clark's Nutcracker, an important seed disperser for whitebark pine (*Pinus albicaulis*), limber pine (*Pinus flexilus*) and southwestern white pine *(Pinus monticola*) (Pool and Gill 2002).

3.2 Methods

3.2.1 Habitat cover type data

I created a separate Geographic Information System (GIS) layer for each Y2Y habitat cover type (Table 1-1) using ARC/INFO software (version 8.3; ESRI 2002). Each GIS layer was a grid surface at 1 sq. km. resolution. Each sq. km. for marsh and lake cover types represented the percent area of the cover type per square kilometre calculated from digital maps of wetlands and lakes at 1:250000 scale (NTDB Canada, USGS 1994) and digital lake data at 1:100000 scale (Idaho, Montana, Oregon, Washington and Wyoming GIS clearinghouses). Marshes had a minimum mapping unit (mmu) of 2 ha in Canada, and 5 ha in the U.S. The mmu was 1 ha for lakes in both countries. For the remaining 17 Y2Y habitat cover types, each sq. km. of the cover type's GIS layer indicated if that cover type was present or absent within that square kilometre.

I extracted the Whitebark pine GIS layer from a habitat cover type map provided by Y2Y and derived the remaining 16 Y2Y habitat cover types from the North America seasonal land cover region (SLCR) data (version 2.0, LP DAAC). The SLCR data contains 202 land cover classes (Appendix V) at 1 sq. km. resolution. Each sq. km. is assigned a single SLCR land cover value classified from 1992-1993 AVHRR (Advanced Very High Resolution Radiometer) digital imagery in combination with broad-scale elevation, vegetation and ecoregion data (Loveland et al. 1991). I reclassified the SLCR land cover classes to the Y2Y habitat cover types, allowing a single SLCR land cover class to map to multiple Y2Y habitat cover types when reasonable (Table 3-1). For example, SLCR land cover class 24 is "Needleleaf Forest (Douglas fir, lodgepole pine and western white pine)" that mapped to two Y2Y habitat cover types: Douglas fir/mixed/grand fir and lodgepole pine. I also mapped SLCR land cover classes to willow habitat for later construction of the willow riparian habitat type. I created the riparian habitat types by first merging the Y2Y cover type GIS layers into a coniferous layer (boreal spruce, cedar hemlock, Douglas fir mix, lodgepole pine, ponderosa pine mix, boreal mixed wood, subalpine spruce/fir) and a deciduous layer (aspen, mixed wood,

Table 3-1: Crosswalk used to map the North America seasonal land cover region (SLCR) classes to Y2Y habitat cover types.

Y2Y Habitat Cover Type	**SLCR 2.0 Classes**
Alpine/Tundra	80, 85, 86, 88, 89, 90, 91, 92, 93, 95, 97, 198, 199, 200
Aspen	3, 11, 16, 46, 47, 48, 59, 64, 65, 66, 67, 68, 69, 70, 74, 179
Boreal Mixed Wood (Spruce/Pine/Aspen)	3, 11, 13, 16, 58, 59, 64, 65, 66, 67, 68, 69, 70, 73, 74
Boreal Spruce	1, 3, 5, 11, 13, 16, 23, 55, 56, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 74, 80, 95, 96, 101, 103, 104, 137
Cedar/Hemlock	2, 7, 9, 14, 15, 18, 28, 32
Dry Ponderosa Pine/Douglas fir mix	4, 8, 10, 12, 17, 19, 20, 21, 22, 26, 29, 35
Grassland	100, 102,106, 107, 115, 118, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 139, 140, 143, 160, 162, 168, 174, 176, 177, 178, 180, 182, 184, 185, 189, 194,
Lodgepole pine	4, 6, 10, 12, 15, 17, 18, 19, 21, 24
Moist Douglas fir/Mixed/Grand Fir	6, 7, 9, 14, 15, 18, 24, 27, 28, 31, 32, 54
Northern Shrubfields	55, 56, 63, 78, 79, 80, 81, 82, 85, 88, 89, 90, 92, 93, 95, 96, 97, 104, 137
Sagebrush Steppe	94, 98, 99, 100, 102, 105, 106
Spruce/Tamarack Bog	56, 96, 101, 137
Subalpine Spruce/Fir	10, 19, 54, 57
Willow	78,79,81,82,104

northern shrubfields). I then calculated the total length of streams per square kilometre from digital stream data at 1:250000 scale (mmu 3750m) (NTDB Canada), and 1:100000 scale (state GIS clearinghouses) and used this grid to identify the square kilometre cells in the coniferous, deciduous and willow habitat cover type layers that also contained stream. I assigned these cells to the coniferous, deciduous and willow riparian habitat cover type layers respectively.

3.2.2 Landscape data

I used several biophysical and anthropogenic variables as broad-scale correlates of the amounts and stability of food and water, and levels of predation, parasitism and anthropogenic disturbance that I could not directly measure in the vast Y2Y region. I created GIS layers for the biophysical and anthropogenic variables to use as predictors in model development and subsequent extrapolation (Table 3-2, PowerPoint presentation "Predictors" Figures 3-1 to 3-8). Biophysical factors influence avian habitat quality at a macrohabitat scale by affecting the levels and stability of resources important to survival and reproductive success. For example, higher primary productivity levels supply more food, supporting more individuals and reducing the risk of population extinction (Gaston 2000). Venier et al. (1999) found that temperature and precipitation were strongly associated with the breeding distributions of five forest bird species. As well, longer nesting seasons that are associated with warmer climates at lower elevations provide more opportunities for renesting attempts, thus improving reproductive success (Hansen and Rotella 2002).

I used two measures of net primary productivity as predictors: actual evapotranspiration (AET) and normalized difference vegetation index (NDVI). I

Table 3-2. Biophysical and anthropogenic variables used as predictors in umbrella species models, and to extrapolate the models throughout the Y2Y region. All variables were represented as 1 square kilometre raster grids except NDVI data that was at 500m resolution.

Variable Code	*Description*
AET	Actual evapotranspiration for Canada
NDAVSEA	NDVI average for May 9 to September 13, 2001-2003
NDAVMJ	NDVI average for May 9 to June 9, 2001-2003
NDAVJJ	NDVI average for June 10 to July 11, 2001-2003
NDAVJA	NDVI average for July 12 to August 12, 2001-2003
NDAVAS	NDVI average for August 13 to September 13, 2001-2003
NDSDSEA	NDVI standard deviation for May 9 to September 13, 2001-2003
NDSDMJ	NDVI standard deviation for May 9 to June 9, 2001-2003
NDSDJJ	NDVI standard deviation for June 10 to July 11, 2001-2003
NDSDJA	NDVI standard deviation for July 12 to August 12, 2001-2003
NDSDAS	NDVI standard deviation for August 13 to September 13, 2001-2003
ELEV	Elevation (m)
TEMPSEAS	Average temperature seasonality from 1970 - 2001
PRECIPSEAS	Average precipitation seasonality from 1970 - 2001
DAY1GROW	Average julian day number of start of growing season
ENDGROW	Average julian day number of end of growing season
TOTDAYSGRO	Average number of days of growing season
GDD	Growing degree days above 5 degrees Celsius base temperature during the growing season
PRECIP	Total precipitation (mm) during the growing season
EASTING	UTM Easting for point count location
NORTHING	UTM Northing for point count location
TOTRRLEN	Metres of railroad
INDUSTDIS	Distance from bird point count location to nearest mine/oil or gas well in m
PERWET	Percentage of wetland
STREAMLEN	Total metres of stream

obtained a GIS layer of total AET in 1996 for Canada (Liu et al. 2003) and calculated monthly and breeding season NDVI averages (PowerPoint presentation "Predictors" Figure 3-1), and standard deviation from MODIS data (GLCF 2001-2003). Climate variables for measures of the growing season length (DAY1GROW, ENDGROW, TOTDAYSGRO, GDD), total precipitation during the growing season (PRECIP), and variation in temperature and precipitation (TEMPSEAS, PRECIPSEAS) from climate surface averages for 1971 to 2000 (PowerPoint presentation “Predictors” Figures 3-2 to 3-7), and elevation data from digital elevation models (PowerPoint presentation “Predictors” Figure 3-8) were provided by the Great Lakes Forestry Centre (Environment Canada 2003). I derived geographic locations (Easting, Northing) for the point count locations, and the center points of each sq km. grid cell directly from the GIS layers to model potential trends in species occurrence with geographic location (Franklin 1998).

Human activities stress and degrade avian habitat quality in many ways. Suburban development and industrial activities contribute to higher road densities that lower wetland and stream quality, increase predation and brood parasitism rates, and increase mortality due to roadkill (Trombulak and Frissell 2000). Human activities also result in habitat loss and fragmentation that reduce survival and reproductive success (Robinson et al. 1995, Weinberg and Roth 1998). I used total length of railroad track in a square kilometre (TOTRRLEN) and distance to the nearest oil/gas well or mine (INDUSTDIS) as indicators of predation, parasitism and anthropogenic disturbance levels. I collected GIS layers for railroads, mine, oil and gas wells from federal, provincial, territorial and state agencies. I planned to use road density as an indicator of population density and recreational disturbance, but the survey points were positively associated with roads due to access issues. Since this factor was subject to sampling bias, I removed it from the models.

I also included the percent wetland (PERWET) and total streamlength (STREAMLEN) per square kilometre GIS layers as predictors (refer to section 3.2.1

"Habitat cover type data") to provide indices of water availability. The streams layers were at different scales for Canada and the U.S, and this was reflected in a lower density of streams in Oregon and Montana. I only used STREAMLEN as a predictor variable for an umbrella bird when the bird's range did not include these states.

3.2.3 Model development

I developed a model for each focal bird to predict the probability of occurrence within its breeding range, constrained to locations of its primary and secondary Y2Y habitat cover types. Predictive models for species occurrence are commonly based on presence/absence data (e.g. Franklin 1998, Beard et al. 1999, Venier et al. 1999), but models may be confounded by "false negatives" due to detectability issues or unsaturated habitat, or by absences due to factors not included in the model, such as inter/intra species competition (Fielding and Bell 1997, Zaniewski et al. 2002). Presence/absence models also cannot make use of data sets collected on an ad-hoc or non-stratified basis with unreliable information regarding species absence. Zaniewski et al. (2002) suggested creating "pseudo" absences to allow statistical models to be used with presence only data, and this approach has been well developed with resource selection functions (RSF) by way of a "used/available" sampling protocol (Manly et al. 2002). RSF models provide a relative estimate of the probability an organism will use a site based on a statistical analysis of the association between its presence in a landscape and selected habitat attributes (Boyce and McDonald 1999, Manly et al. 2002). For example, RSF models have been used to determine habitat characteristics of marten (*Martes america*) den sites (Ruggiero et al. 1998), Eurasian lynx (*Lynx lynx*) habitat suitability (Schadt et al. 2002) and grizzly bear (*Ursus arctos*) distribution (Apps et al. 2004).

I used an RSF approach with a used/available sampling protocol to develop a unique model for each umbrella bird to predict the probability of its occurrence throughout the Y2Y ecoregion. Detectability issues with the bird survey data did not allow me to be confident that point count locations at which a bird was not recorded were truly unused. In addition, the survey points were biased to southern and low elevation habitats and did not sample the full gradient of predictor variables in Y2Y. Using "available" points that spanned the Y2Y region provided more confidence that the predictors were sampled over their full gradient.

I considered a square kilometre sample unit "used" by a species if it was detected at least once at a point count location within the sample unit. I allocated double the number of used, as "available" sample units for a species. I made an exception for Gray-crowned Rosy Finch as it only had 51 detections. I allocated ten times the number of detections for this species as available sample units. I constrained a species' available sample units to be within the bird's breeding range, and randomly distributed the available sample units through the bird's habitats using the same weighting system as that used to determine the umbrella species (refer to section 2.2.4.1 "Bird habitat associations"). For example, Long-billed Curlew has 1 primary habitat type (grassland) and one secondary habitat (sagebrush steppe), so I randomly selected 67% of its available sample units from grassland and the remaining 33% from sagebrush habitat within its range. Since multiple habitat types could occur within a square kilometre, occasionally a species' available sample units from different habitats coincided. I removed duplicated available sample units for a species from the analysis.

I developed a logistic regression RSF model for each umbrella bird with available and used samples assigned values of 0 and 1 respectively. All statistical analysis was performed using S-PLUS v6.1 (Insightful Corporation 2002). I first identified groups of correlated predictor variables (Pearson's $r >= 0.7$) for each umbrella bird as two highly correlated significant predictors can both appear non-significant if modelled together (Guisan et al. 2002). I then defined a set of models *a priori* for the umbrella whereby each model included all uncorrelated predictors, and a different variable from each group of correlated predictors. Thus the full set of *a priori* models for the umbrella encompassed all predictor variables.

Standard multiple regression models make some assumptions about the mathematical characteristics of the response variable (constant variance and normal distribution of errors) that are often violated with ecological data (Guisan et al. 2002). Generalized linear models (GLMs) are extensions of standard multiple regression analysis that address violations in these assumptions (Guisan and Zimmerman 2000, Crawley 2002). GLMs also keep the predictions within the range of feasible values for the response variable (e.g. probability values from 0 to 1 for a 1/0 presence/available response) (Guisan and Zimmerman 2000) and easily model non-linear species responses to environmental gradients (Austin 2002, Oksanen and Minchin 2002). I developed each *a priori* model for an umbrella species using the following steps:

1. I created a generalized additive model (GAM) with spline smoothers for all continuous variables to test for significant non-linear responses in these variables. I also examined plots of the GAM fit for each significant non-linear predictor to determine which mathematical transformation (i.e. second or third order polynomial, logarithmic, exponential or piecewise linear) best fit the response curve (Franklin 1998, Guisan et al. 2002, Miller and Franklin 2002). GAMs are semi-parametric extensions of GLMs that use the data to determine the shape of

the relationship between the response and the set of explanatory variables rather than assuming some form of parametric relationship (Guisan et al. 2002).

2. I modelled a GLM with the transformations suggested by the GAM for all variables with significant non-linear effects, and used simple linear terms for the other predictor variables. If the plot for a significant non-linear predictor suggested more than one possible transformation, I modelled each transformation and selected the one that minimized the residual deviance of the model.

3. I built the final, reduced model with a backwards stepwise technique to determine which factor had the least explanatory power (using Mallows' Cp statistic (Roland et al. 2000)). I eliminated this factor from the model, and then compared the new model with the previous model. If there was a significant difference in explanatory power, I retained the previous model, otherwise I repeated this step with the simpler model.

Finally, I compared the residual deviance and number of parameters used in the final models retained for the set of *a priori* models, and selected the model that had the best trade-off between minimizing the residual deviance and number of parameters.

3.2.4 Spatial autocorrelation

Species occurrence or abundance is often positively autocorrelated, with samples close together being more similar than expected due to chance (Lichstein et al. 2002). This may be due to spatial structure in environmental variables, or biotic factors such as conspecific attraction and dispersal (Lichstein et al. 2002). Spatial autocorrelation violates statistical assumptions of sample point independence and independently distributed errors, and may cause predictors to be mistakenly kept in regression models (Legendre and Fortin 1989). I attempted to reduce potential spatial autocorrelation by only allowing one sample per square kilometre. I also examined model residuals in semivariograms to test for spatial correlation (Legendre and Fortin 1989).

3.2.5 Model evaluation

I evaluated the models by examining model fit i.e. how well the predictors explained the response variable (Guisan et al. 2002), and by testing how well model predictions discriminated, or classified, used and available points (Guisan and Zimmerman 2000, Pearce and Ferrier 2000). GLMs are fit by maximum likelihood rather than the least squares method of standard regression models, with "deviance" rather than R^2 being the measure of the goodness of model fit (Crawley 2002). I used the percent deviance explained by a model as a measure of its fit.

I tested the discrimination ability of the final model for each umbrella species using a K-fold partitioning technique that allows a model to be tested without independent data. The data for a model is divided into K partitions, then a training model is developed on all combinations of K-1 partitions of the data and used to predict the probability of occurrence for test data consisting of the unused partition (Fielding and Bell 1997, Pearce and Ferrier 2000). I used Huberty's rule of thumb to determine the number of partitions (Fielding and Bell 1997). I developed each training model for an umbrella species by fitting the umbrella's final model to the training data. I then assessed how well the model's predictions correctly classified the used and available points.

Often a single threshold probability is used to determine the classification, but this results in biased discrimination measures sensitive to the choice of threshold and number of samples in used/available groups (Fielding and Bell 1997). Receiver operating characteristic (ROC) curves are threshold independent tests that provide a measure of classification accuracy by testing a range of probability thresholds to determine the classification (Miller and Franklin 2002). The sensitivity (probability that the model correctly predicts the presence of a species at a "used" sample point) and the proportion of false positives are calculated for a range of probability thresholds to produce pairs of sensitivity/false positive fraction values that are plotted with sensitivity on the Y axis and the false positive fraction on the X axis (Fielding and Bell 1997, Pearce and Ferrier 2000, Boyce et al. 2002). A model with no discrimination ability will produce a ROC curve with a 45 degree line, whereas a model with perfect discrimination will follow the y-axis and then move horizontally along the top of the graph (Pearce and Ferrier 2000). The measure of classification accuracy is the area under the ROC curve (AUC) with AUC values over 0.9 indicating very good discrimination, 0.7 to 0.9 reasonable and values less than 0.7 indicating poor discrimination (Pearce and Ferrier 2000).

Boyce et al. (2002) argue that ROC curves should not be used to assess predictions for used/available RSF models, as the used sites are a subset of available sites. This means that a site may be represented twice in the data set, i.e. as both used and available, resulting in a lower classification success. This was not an issue for my data sets, as the sparseness of the bird survey data throughout each focal bird's range resulted in little overlap between used and available sample units. The data sets had at most 4 points that were represented as both used and available. Hence, I used ROC curves as a conservative estimate of the classification ability of my models. I used SPSS v11.5.0 (2002) to produce ROC curves for each umbrella's predicted probabilities, and to calculate the associated AUC and its standard error.

3.2.6 Model extrapolation

I used the final model for each umbrella species to predict the probability of its occurrence for each square kilometre within habitats used by the bird over its breeding range in Y2Y. I used the predicted probability of occurrence as an index of relative habitat quality for a species, and created GIS maps showing relative habitat quality for each umbrella bird by ranking its predicted probabilities of occurrence into 5 classes (Table 3-3). I used the same quantile values and categories as that for the Y2Y carnivore habitat suitability maps (Carroll et al.1999). I then created maps showing the most suitable habitat within each Y2Y habitat cover type. Since multiple species could have primary or secondary habitat within each cover type, I combined the "most suitable" habitat (Table 3-3) for each bird that used a cover type. I partitioned a species' contribution among its habitat types using the same weighting system as that used to determine the umbrella species (refer to section 2.2.4.1 "Bird habitat associations"). For example, White-crowned Sparrow has 1 primary habitat type (subalpine spruce/fir) and two secondary habitats (alpine/tundra and northern shrubfields), so I weighted subalpine spruce/fir by 0.5 and the secondary habitats by 0.25 each. I then took the top 5% of White-crowned Sparrow's predicted probabilities for subalpine spruce/fir, and the top

Table 3-3. Relative habitat quality rankings for each focal bird's predicted habitat quality. The predicted probability of occurrence for the focal bird was used as an index of relative habitat quality.

Habitat Ranking	**Predicted Relative Habitat Value Quantile**
Least Suitable	0 - 25
Low	25 - 50
Fair	50 -75
Good	75 - 90
Most Suitable	90 -100

2.5% probabilities for each of its secondary habitat types. Overall, each species contributed 10% of its habitat area to these maps.

I developed maps separately for the north and south parts of Y2Y, as probabilities of species' occurrence tended to increase from north to south due to warmer temperatures, longer growing seasons and higher primary productivity in southern regions that biased high quality habitat to the southern parts of Y2Y. As well, northern planning is of particular interest to Y2Y so it was important to identify the highest quality habitat within this region. I used the southern boundary of a Y2Y ecological priority area "Peace River Break" (see PowerPoint presentation "Habitat Quality Maps" Figure 3-20) to delineate the boundary separating the two halves.

3.2.7 Most suitable habitat protection

I calculated the total area of the "most suitable" habitat (Table 3-3) within each Y2Y habitat cover type that fell within a GIS map of existing protected areas in the Y2Y ecoregion to assess how much of the "most suitable" habitat within each cover type was already protected. I also tested if locations of RAMSAR sites (designated wetlands of international importance) and important bird areas (IBAs) corresponded to the most suitable habitat within each cover type.

3.3 Results

3.3.1 Probability of occurrence models

The models explained from 19.6% (Clark's Nutcracker) to 78.5% (Gray-crowned Rosy-Finch) of the deviance, and included from 3 to 8 significant predictors ($p < 0.05$) (Table 3-4). Most predictor relationships were non-linear, with second order polynomials predominating. Piecewise linear relationships (thresholds) were also common,

Table 3-4: Species model results (parameters shown have $p<0.05$) in decreasing order of significance. Superscripts denote the type of non-linear transformation used for the predictor: natural log transformation^1 , second order polynomial^2, third order polynomial^3 and threshold^4 (value)

Species	% Deviance Explained	Predictor Variables	Area under the ROC curve (SE)
American Dipper	46.6	Easting^2, elevation, PRECIP^4(345), PRECIPSEAS	0.89 (0.02)
American Tree Sparrow	50.7	ENDDAYGROW, Elevation^4 (1100), Easting^2, PRECIP^2, ndavja^2, StreamLen, Northing^2	0.81 (0.02)
American Wigeon	31.7	Easting^2, ndavas, ndavmj^2, ndsdas	0.84 (0.02)
Blackpoll Warbler	22.0	Elevation^2, PRECIPSEAS^4 (35), ENDDAYGROW	0.72 (0.02)
Clark's Nutcracker	19.6	PRECIP^2, ndavmj^2, DAY1GROW^4(160), TEMPSEAS^2, Easting^4(1850000), ndsdsea, ndsdjj^2, ndsdmj	0.78 (0.01)
Common Loon	25.5	Easting^2, ndavmj, PRECIP^3 (325), PRECIPSEAS^2	0.81 (0.02)
Gray-crowned Rosy-Finch	78.5	Elevation^4 (1650), PRECIP, ENDDAYGROW^2, ndsdja	0.92 (0.03)
Ruffed Grouse	54.6	Easting^2, PRECIP^4 (250), Elevation^4 (850)	0.94 (0.01)
White-crowned Sparrow	38.5	Easting^4(1075000), DAY1GROW^4(160), ndavja^2, PRECIPSEAS^2, PRECIP^4 (325)	0.88 (0.01)
Wilson's Warbler	59.6	Northing^3, ndavja^1, PRECIP^2, elevation^2, GDD^4 (425)	0.94 (0.00)
Yellow Warbler	60.9	Easting^3, elevation^2, PRECIPSEAS^2, PRECIP^4 (320), ENDDAYGROW^2	0.95 (0.00)

particularly for PRECIP and elevation. PRECIP, Easting, variation in primary productivity, a measure of growing season length (DAY1GROW, ENDDAYGROW or PER3GDD) and elevation were important predictors in several models. No anthropogenic factor was a significant predictor in any model. Several variables were highly correlated and were placed in separate *a priori* models for an umbrella bird.

Semivariograms constructed with model residuals showed no spatial autocorrelation for any species. The area under the ROC curve ranged from 0.72 (Blackpoll Warbler) to 0.95 (Yellow Warbler) (Table 3-4), and was highly correlated with the model's percent deviance explained (Pearson's correlation coefficient, $r = 0.83$).

3.3.2 Species and habitat suitability maps

The species habitat ranking maps (PowerPoint presentation "Species Habitat Suitability Maps" Figures 3-9 to 3-19) showed the most suitable habitat tended to be patchy and spread throughout a species' range. This may be reflecting the patchy nature of many habitat types that were modelled (e.g. marsh, bog, riparian and lakes), and the variation in topography and associated climatic conditions that occur over short distances in mountainous terrain. Concentrations of high quality habitat could be seen, however, for several species (American Dipper, American Tree Sparrow, Blackpoll Warbler, Ruffed Grouse, White-crowned Sparrow, Wilson's Warbler and Yellow Warbler). Species generally showed little overlap among the most suitable habitat, with the exception of 3 areas in the northern part of the Y2Y region. These were the extreme northwest corner of Y2Y in the Yukon Territory (American Dipper, American Tree Sparrow, Gray-crowned Rosy-Finch and White-crowned Sparrow), the eastern edge of Y2Y in the Northwest Territories (American Dipper, Ruffed Grouse, White-crowned Sparrow and Yellow Warbler) and north-central British Columbia (Blackpoll Warbler, Common Loon, Ruffed Grouse, Wilson's Warbler and Yellow Warbler).

The maps for the best quality habitat in each habitat cover type indicated similar patterns to the species habitat maps (PowerPoint presentation "Habitat Quality Maps"

Figures 3-21 to 3-28). The high quality habitat in the northwest part of Y2Y (Yukon Territory) was due to high quality alpine and northern shrubfields habitat. Aspen, all riparian habitats, boreal mixed wood and northern shrubfields all had good quality habitat along the eastern edge of Y2Y in the Northwest Territories. Alpine, spruce/tamarack bog, deciduous and willow riparian, boreal spruce, and northern shrubfields also showed a concentration of high quality habitat in north-central British Columbia. In addition, alpine/tundra had a patch of high quality habitat in northern B.C. and there was a concentration of high quality habitat for boreal mixed wood, deciduous riparian and marsh on the eastern border of Y2Y between Fort Nelson and Fort St. John, B.C.

The regions of high quality habitat shared some common biophysical traits (Table 3-5). These included low to moderate elevation, relatively high numbers of growing degree days for the north, moderate precipitation and high average primary productivity (NDVI). In addition, the Yukon and NWT areas were characterized by high seasonality in precipitation and temperature, whereas the area in British Columbia had low precipitation/temperature seasonality. The NWT and British Columbia regions also had relatively long growing seasons for the north.

Table 3-5: Mean values for biophysical factors found in the three areas of high quality avian habitat. The range of the biophysical factor throughout the Y2Y ecoregion is shown for comparison.

Biophysical Factor	Range	Yukon	NWT	BC
Elevation (m)	76 - 3932	861	607	1331
Growing Degree Days	0 - 2753	445	776	437
Growing Season Precipitation (mm)	17 - 553	177	266	271
Temperature Seasonality	2.3 – 6.3	5.8	5.6	3.4
Precipitation Seasonality	10 - 74	54.2	52.2	31.9
Start Growing Season (Julian Day)	57 - 204	151	137	148
End Growing Season (Julian Day)	212 - 343	251	267	269
Length Growing Season (Days) [Start – End]	NA	100	130	121
Average Primary Productivity (NDVI)	-0.85 to 0.95	0.65	0.69	0.56

3.3.3 Most suitable habitat protection

The amount of highest quality habitat that was covered by protected areas ranged from 1.2% for boreal mixed wood to 35.6% for spruce/tamarack bog (Table 3-6). Alpine/tundra, boreal spruce, ponderosa pine and subalpine spruce/fir were represented quite well by protected areas having > 25% of their prime habitat protected. Aspen, coniferous riparian and deciduous riparian habitats were poorly protected with less than 10% of their prime habitat overlapped by protected areas.

Creston Valley RAMSAR site in southern BC was located within a couple of kilometres of several patches of high quality lake, marsh, deciduous riparian and coniferous riparian habitat. Only two Important Bird Areas coincided with prime habitat. Lock Katrine Wetland in Wyoming overlapped with high quality marsh habitat, and Skookumchuk Prairie in southern BC was associated with high quality boreal mixed wood and aspen habitat.

Table 3-6: Percent of "Best" habitat by Y2Y habitat cover type in protected areas by IUCN category (IUCN 2004). IUCN categories 3 (Natural Monument, 2 sites in Y2Y) and 6 (Managed Resource Area, 1 site in Y2Y) did not overlap with any high quality habitat for a cover type.

Y2Y Habitat Cover Type (Total Area of Most Suitable Habitat in km^2)	**1: Strict Nature Reserve**	**2: National Park**	**4: Habitat/ Species Management Area**	**5: Protected Landscape/ Seascape**	**No Designation**	**% of total area protected**
Alpine/Tundra (31773)	1.5	16.4	-	-	8.8	26.7
Aspen (9699)	0.6	1.8	0.1	0.2	0.3	3.0
Boreal Mixed Wood (7739)	0.3	0.6	0.1	-	0.2	1.2
Boreal Spruce (16539)	0.7	32.5	0.1		1.0	34.3
Coniferous Riparian (42319)	0.5	7.5	0.2	0.1	0.5	8.8
Deciduous Riparian (27337)	0.5	5.1	0.1	-	1.1	6.8
Lakes (11755)	0.1	10.4	-	-	0.9	11.4
Marsh (3411)	0.6	8.1	0.8	0.1	1.2	10.8
Northern Shrubfields (36449)	0.7	6.7	-	-	6.7	14.1
Ponderosa (2996)	11.8	15.2	0.3	0.2	1.8	29.3
Spruce/Tamarack Bog (967)	2.0	32.2	-	-	1.5	35.7
Subalpine Spruce/Fir(4629)	8.3	24.5	0.1	-	1.9	34.8
Whitebark Pine (266)	12.7	0.5	0.3	3.7	-	17.2
Willow Riparian (6542)	0.1	14.2	-	-	0.9	15.2

3.4 Discussion

3.4.1 Model performance

The species occurrence models varied considerably in explanatory power, ranging from 19.6% (Clark's Nutcracker) to 78.5% (Gray-crowned Rosy-Finch) of deviance explained. My approach assumed that variation in a bird's occurrence resulted from the direct effects of relatively few habitat factors, such as climate, topography and vegetation (Liverman 1986). However, most bird-habitat models explain only a portion of the variance (Young and Hutto 2002), as habitat selection occurs over multiple scales (Wiens et al. 1987, Orians and Wittenberger 1991). For example, Neave et al. (1996) found a large proportion of the variance in bird species occurrence was explained by climate, with local site variables explaining a smaller portion. My models also did not incorporate the effect of historical factors such as past climatic or geological events on the distribution of organisms (Guisan and Zimmerman 2000).

Some of the models with poor explanatory power, such as those for Clark's Nutcracker and Common Loon, are for species that are closely associated with specific habitat types. For example, Clark's Nutcracker is found where there is whitebark pine, and other predictors may not be important (pers. comm. Cyndi Smith). Similarly the Common Loon is strongly associated with lakes of specific size, depth and shoreline composition (Pool and Gill 2002). These factors may override biophysical factors in explaining its occurrence.

The models demonstrated that birds in the Y2Y ecoregion are broadly associated with climatic and topographic features. Important predictors in the models were amount of precipitation and length of the growing season, elevation, geographic location and variation in primary productivity. Other studies have also found temperature, precipitation, geographic location and elevation to be important predictors of bird species distribution (Neave et al. 1996, Beard et al. 1999, Jarvis and Robertson 1999, Venier et al. 1999, Osborne and Suarez-Seoane 2002). Most of these factors had non-linear relationships with bird occurrence, and high levels of these factors do not necessarily correspond to a high probability of species occurrence. Simply looking for high levels of these factors within Y2Y will not identify high quality bird habitat.

Anthropogenic factors were not significant predictors in the models. This is partly due to sampling bias, as bird surveys are not likely to be conducted close to mines, oil/gas wells or railroads unless these effects are of particular interest in the study. The distance to industrial sites tended to be very large, and few point count locations were associated with railroads. It is also possible that the effects of these factors occur at a local scale and were not detectable in the models. Studies could be designed to test explicitly for effects of these anthropogenic factors.

I did not include interaction terms in my models due to the large number of independent variables. However, interactions between predictors can modify the shape of the response curves, and not including interactions may have reduced the explanatory power and predictive ability of my models (Austin 2002, Guisan and Zimmerman 2000). One approach to improve my models could be the use of classification and regression tree (CART) techniques to explore and identify interactions, which could then be incorporated into the models (Guisan et al. 2002, Miller and Franklin 2002).

3.4.2 Model assumptions and constraints

The species-habitat models made several assumptions and were subject to sources of error that weakened the models and their associated predictions of high quality avian habitat in the Y2Y ecoregion. In particular, the models assumed a bird's distribution was in equilibrium with the environment, that both the habitat characteristics and species-habitat relationships were consistent throughout the study area, and that the full gradient of the species-response relationship was sampled (Hamel et al. 1986, Guisan et al. 2002, Miller and Franklin 2002). In addition, RSF models assumed that locations available to the birds were correctly identified (Manly et al. 2002).

These assumptions were only partially supported. The bird survey data spanned different years and showed temporal variation, with inconsistent species detections at survey locations over multiple survey years. Some predictors such as elevation and geographic location did not change over the study period. However, climate and primary productivity varied over years, and their values at sample points with species' detections may not have been measured in the same year as the detection. Most broad-scale Y2Y habitat cover types were fairly uniform throughout the Y2Y region as they reflected the gradients in temperature, moisture and elevation. However, coniferous and deciduous riparian habitat types did change, as they were associated with different tree species in different parts of Y2Y.

Inconsistencies were likely present in a bird's habitat relationships throughout the Y2Y region as I preferentially selected umbrella species with large geographic ranges in Y2Y. Osborne and Suarez-Seoane (2002) suggested that a species' habitat selection might fluctuate throughout its range due to variability in habitat availability. As well, a bird's habitat relationship determined by a regression model based on empirical data may be confounded by biotic interactions and stochastic effects that can change from one region to another (Guisan et al. 2002).

The "available" samples for a bird were constrained to its breeding season range and the habitat types it used. This improved the likelihood that available samples were correctly identified and represented the full gradient of the predictor variables for the bird, but inaccuracies in the habitat cover type GIS maps undoubtedly caused some samples to be incorrectly denoted. In addition, since the bird survey data were sparse in northern and high elevation habitats, the "used" samples likely did not sample the full ranges of the response curves and all environmental combinations for the predictors used in my models. I performed an exhaustive search to locate data in missing regions of Y2Y, but there are little available. This bias in the bird survey data may have produced truncated response curves that did not reflect the true relationship between a predictor and the species occurrence (Hirzel and Guisan 2002). This may also have weakened model predictions, as multiple regression models that predict species occurrence are based on the relationship between the species' detections and associated values of predictor variables. This means that the model is only useful over the numerical range of the habitat variables used to construct the model, and predictions resulting from extrapolation beyond these ranges are unreliable (Wiens and Rotenberry 1981). In addition, spurious effects may have been created in my models, since the available samples likely represented a greater portion of the response gradient compared with used samples. Thus, it may have seemed that a bird was selecting for a portion of the response gradient, when in reality, only that portion was sampled by the bird survey data. I examined plots of the significant predictors in my models to compare values of the data ranges sampled by used and available samples. I found that used samples generally represented subsets of the available sample gradient for climate, primary productivity and elevation, but not geographic location. This may explain why geographic location was a significant predictor in 9 of 11 models, and often explained the most deviance of any predictor. However, since the effect of geographic location was likely spurious, the model fit and ROC values were overestimated for several models. In addition, model extrapolations may have not identified areas with high probability of bird occurrence outside the geographic range of the used samples.

Finally, of particular concern to my study is the fact that using the regression models of umbrella species occurrence to predict high quality avian habitat assumes that the response curves for an umbrella species are the same as those for the species it represents. Modelling species assumed to be protected by an umbrella and then comparing the response curves could test this assumption. Modelling target species would also allow predictions of high quality habitat for a "protected" species to be used to test how effectively the high quality habitat for an umbrella overlaps that for species it aims to protect.

3.4.3 Other sources of error

Ad hoc or non-stratified presence-only data sets have unknown sampling bias that decreases the interpretability and significance of results. This occurs when the sample is dependent upon factors such as distance to cities, accessibility and the environment type, rather than on a stratified or systematic strategy (Zaniewski et al. 2002). This bias applied even to the BBS data, where attempts were made to have random and stratified samples, as road access is sparse in northern and high elevation habitats.

I didn't find evidence of spatial autocorrelation in species occurrence that may have confounded the models. My sample distance (at least 1 km between points) is larger than autocorrelated distances for birds found in literature. For example, Lichstein et al. (2002) found autocorrelation occurred over distances less than 500 m for 19 bird species, with the exception of Veery, that was autocorrelated over distances greater than 2 km. Koenig (1998) tested spatial autocorrelation at distances up to 1.2 km for 88 California bird species and found only 1 species (mourning dove) showed spatial autocorrelation during the breeding season. The species he tested included 3 that I modelled: American Dipper, Wilson's Warbler and Yellow Warbler.

The SLCR land cover data classification is estimated to be about 75% accurate (Scepan 1999). The whitebark pine layer I used was of uncertain origin and accuracy. As well, the riparian habitat cover type GIS layers that I constructed were based on broad scale GIS stream layers that did not include small streams, thus potential riparian habitat was underrepresented. I used these land cover classes to delineate the spatial extent for the "available" species points, and model extrapolation throughout Y2Y. The inaccuracies in habitat cover type certainly introduced errors in identifying available points for a species, and likely caused the locations of some of the high quality avian habitat for a Y2Y habitat cover type to be incorrectly identified.

Error propagation in the GIS is another source of error that is difficult to quantify (Boone and Krohn 2000). My GIS data were from multiple sources that used different geographic projections and mapping scales; a substantial amount of reformatting and recalculation was needed to create the final GIS layers for the predictor variables. This undoubtedly introduced inaccuracies in these layers (Guisan and Zimmerman 2000).

3.4.4 High quality habitat protection

Prime habitat for the umbrella species tended to be patchy, and did not overlap much among species. However, three areas with high concentrations of quality habitat stood out. These were located in the extreme northwest corner of the Y2Y ecoregion in the Yukon Territory, along the eastern edge of Y2Y in the NWT, and in north-central British Columbia. High quality habitat in several habitat types (alpine, bog, boreal forest, ponderosa pine and subalpine) was well covered by existing protected areas in Y2Y. However, my analysis did not assess how this protection was distributed across Y2Y or partitioned among Y2Y ecological priority areas. Existing protected areas in Y2Y poorly covered prime habitat in coniferous, deciduous and willow riparian, aspen, marsh and boreal mixed wood habitat types. This is likely a reflection of the fact that these habitat types occur at lower elevations in the Y2Y region. Scott et al. (2001) found that in the coterminous United States, nature reserves are found mainly at higher elevations. Similarly, many of the protected areas in the Canadian portion of Y2Y are mountain parks. High quality avian habitat was not identified for cedar/hemlock, grassland, lodgepole pine, Douglas fir or sagebrush steppe as birds representing these habitats were not modelled. Some of these birds (Brown Creeper, Golden Eagle, Lewis' Woodpecker, Spotted Sandpiper and Veery) also represent subalpine, aspen, alpine and riparian habitat, and their models may identify additional high quality habitat for these habitat types.

While static predictive models are useful for identifying conservation priority sites, these models do not incorporate dynamic factors such as disturbances (e.g. fire, avalanche), disease (e.g. white pine blister rust) and infestation (e.g. mountain pine beetle *Dendroctonus ponderosae*). These factors may impact the high quality avian habitat identified by the models. As well, climate change may affect the habitat cover types and the values of the biophysical factors that were used to identify high quality avian habitat. For example, Environment Canada climate projection models predict that temperatures will rise over Canada by 5-10 degrees Celsius by 2090 (Environment Canada 2003). This has the potential to change the location of high quality habitat for birds within the Y2Y ecoregion.

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Chapter 4 Conclusions and Management Recommendations

4.1 Summary and conclusions

1. The Yellowstone to Yukon Conservation Initiative (Y2Y) is developing a conservation area design to restore and maintain biological diversity throughout North America's Rocky and Mackenzie Mountains. My study extended work by a group of scientists brought together to develop aspects of the Y2Y conservation area design to ensure the region's current avian species diversity and population viability will be maintained. This group identified broad-scale habitat cover types representing all bird communities within Y2Y, and developed a list of 109 conservation priority bird species for the Y2Y region. I used broad-scale models to identify high quality breeding season habitat within the Y2Y region for the conservation priority bird species. These prime habitat locations represented 14 of the broad-scale habitat cover types, and suggested potential avian core habitat in the Y2Y region.

2. I used a focal species approach to identify the high quality breeding season habitat. I identified 20 focal bird species that collectively represented the Y2Y habitat cover types, and acted as umbrellas for Y2Y's conservation priority species. I selected 11 of the focal species to model as a first cut of identifying candidate core areas for the Y2Y conservation area design. These species represented northern, high elevation, coniferous, deciduous and willow riparian, whitebark pine, wetland and lake habitat. This supported conservation planning efforts in the north and recognized the high conservation value of riparian, wetland and lake habitat. It also provided information regarding prime habitat in high elevation habitats that form an extensive corridor throughout the Y2Y ecoregion. Whitebark pine habitat was included as it is used by an important seed dispersering species, Clark's Nutcracker.

3. The focal species approach was a practical way to deal with the time and funding constraints of this project. In addition, my method was useful for situations where bird survey data are sparse, as focal species could be identified using expert opinion and habitat use from literature review. The methods I used to identify the focal birds also clearly identified which bird species were intended to be represented by each focal species. This allowed assumptions of surrogacy to be clearly stated and tested using breeding season bird survey data for the Y2Y region.

4. The method I used to select the focal bird species was constrained by the fact that I planned to build models to predict habitat quality for these focal birds based on survey data during the breeding season. I replaced 7 of the original group of 20 focal birds simply because they had too few detections to model. The Y2Y conservation priority species included shorebirds, waterfowl, owls, raptors and woodpeckers that are not well surveyed by point counts. This suggests that

selecting focal species with my method is more appropriate when the focal species will not be used for modelling. Alternatively, if the aim is to construct statistical models, my approach is better suited for songbirds that are well surveyed, or in a region with more intensive sampling and that uses a variety of survey methods to adequately sample all species of interest.

5. The models for the 11 birds successfully identified prime breeding season habitat in the Y2Y ecoregion for 14 broad-scale habitat cover types. However, my approach assumes that high quality habitat for the focal birds also represents high quality habitat for the remaining Y2Y conservation priority bird species. This assumption is untested.

6. While prime habitat for the focal bird species tended to be patchy, and not overlap among species, three areas with high concentrations of quality habitat stood out. These were located in the extreme northwest corner of the Y2Y ecoregion in the Yukon Territory, along the eastern edge of Y2Y in the NWT, and in north-central British Columbia.

7. My study demonstrated that birds in the Y2Y ecoregion are broadly associated with climatic and topographic features. It is important to recognize that most of these factors had non-linear relationships with bird occurrence, and high levels of these factors do not necessarily correspond to a high probability of species occurrence. Simply looking for high levels of these factors within Y2Y will not identify high quality bird habitat.

8. The broad-scale modelling approach to predict habitat quality was an effective way to address the large size of the Y2Y region and the poor survey data in the northern half. The large size and remoteness of the Y2Y ecoregion made it logistically impossible to directly determine avian habitat quality by measuring bird habitat use and breeding success. The broad-scale modelling approach allowed the use of Geographic Information System (GIS) layers as predictors that were provided by various agencies rather than time consuming and expensive field surveys. One drawback to a modelling approach is that the high quality habitat I identified was based on several assumptions and subject to sources of error. The scarce bird survey data in northern Y2Y did not adequately sample the full gradients of the predictor variables used in the models. This sampling bias may have introduced substantial errors into the models and their predicted locations of high quality habitat. Furthermore, the lack of survey data also meant that I could not test model predictions on independent data.

4.2 Management recommendations and future work

1. Several habitat types (alpine, bog, boreal forest, ponderosa pine and subalpine) were well covered by existing protected areas in Y2Y. My analysis did not assess how this protection was distributed across Y2Y or partitioned among Y2Y ecological priority areas. This would be worth analyzing to verify that habitat types are protected throughout their range in Y2Y.

2. Coniferous, deciduous and willow riparian, aspen, marsh and boreal mixed wood habitat types were poorly covered by existing protected areas in Y2Y. Some planning effort should be directed at conserving the high quality habitat I identified for these habitat cover types.

3. I recommend that models be developed for the remaining umbrella species to complete the identification of high quality avian habitat.

4. While all models showed good discriminatory power, and hence predictive ability, my models were weakened by the scarcity of bird survey locations in northern and high elevation areas. This sampling bias may have introduced substantial error into the models' predictions of high quality habitat locations. As well, I used survey data from several different sources that used a variety of survey protocols. This resulted in variation of sample effort across the bird data that also introduced error into the models. It is imperative to do some level of ground-truthing to verify that the high quality habitat identified by the models within each Y2Y habitat cover type does indeed correspond to good bird breeding season habitat for both the focal birds representing the habitat type and their target species.

5. I performed an exhaustive search to locate data in poorly sampled regions of Y2Y, but there are little available. I recommend that Y2Y try to establish collaborations with conservation groups and researchers to obtain more representative survey data and redo the models with these additional data.

6. A broad scale modelling approach has limitations in predicting distributions for microhabitat specialists whose habitat needs cannot be modelled at a broad scale. These Y2Y conservation priority species include those requiring banks and cliffs for nesting sites (Prairie Falcon, Peregrine Falcon, Golden Eagle, Bank Swallow and Northern Rough-winged Swallow).

7. Specific management plans should be considered for Y2Y conservation priority species that are Canadian species at risk, i.e. endangered (Burrowing Owl, White-headed Woodpecker, Sage Grouse), threatened (Loggerhead Shrike) and species of special concern (Short-eared Owl, Ferruginous Hawk, Flammulated Owl, Lewis' Woodpecker, Long billed Curlew, Tundra Swan and Peregrine Falcon), and American endangered/threatened species (Bald Eagle). These species may

also require specific habitat features to ensure their persistence that were not considered in the identification of high quality avian habitat by my models.

8. Using regression models of umbrella species occurrence to predict high quality avian habitat assumes that the response curves for an umbrella species are the same as those for the species it represents. It is imperative to test this assumption by modelling some species assumed to be protected by an umbrella and then comparing the response curves. Predictions of high quality habitat for a "protected" species could also then be used to test how effectively the high quality habitat for an umbrella overlaps that for species it aims to protect.

Appendix I: 109 Y2Y conservation priority bird species with updated habitat associations based on literature review and reviewer comments. Note that some finer detailed habitat information provided by reviewers is included to keep track of this information.The species-habitat associations indicate primary habitat in **bold**. The sources supporting each habitat type used by a species are denoted by numbers in parentheses, referring to table footnotes.

Species *(scientific name)*	**Y2Y broad scale habitat type with supporting references in ()** (Primary habitat in **BOLD**)
Alder Flycatcher (*Empidonax alnorum*)*	**Bog** (1,2,4), Marsh (2, 6), alder flats associated with fens (8), dense, shrubby habitats, primarily those associated with open areas around wetlands and rivers (11). Northern shrubfields (11).
American Avocet (*Recurvirostra americana*)	**Marsh** (1,4), Lakes (2,3,4,6,8)
American Bittern (*Botaurus lentiginosus*)	**Marsh** (1-6)
American Dipper (*Cinclus mexicanus*)	**Coniferous Riparian** (1-5,11)
American Golden-Plover (*Pluvialis dominicus*)	**Alpine/Tundra** (1,3,13)
American Pipit (*Anthus rubescens*)	**Alpine/Tundra** (1,3,11)
American Tree Sparrow (*Spizella arborea*)	**Northern Shrubfields** (1,3,11) **Alpine/Tundra** (1,2,4,11), Marsh (4,6), Willow Riparian (6)
American White Pelican (*Pelecanus erythrorhynchos*)	**Lakes** (1,3), Large rivers (8,9)
American Wigeon (*Anas americana*)	**Lakes** (1, 2,3, 10,11), **Marsh** (2, 3, 4, 6, 10)
Bald Eagle (*Haliaeetus leucocephalus*)*	**Lakes** (1-5, 11), Coniferous/Deciduous Riparian (1, 2,3,4,6), Marsh (1, 11)
Bank Swallow (*Riparia riparia*)[#]	**Deciduous Riparian** (1), Coniferous Riparian (6), near water with cutaway banks (1,3,7,11), steep riverbank cliffs (1,4,7)
Barrow's Goldeneye (*Bucephala islandica*)	**Lakes** (1-6), **Deciduous Riparian** (1,6), Coniferous Riparian (1,6), ponds and lakes in forested areas where it uses tree cavities (11)
Belted Kingfisher (*Ceryle alcyon*)	**Lakes** (all, 11), **Deciduous Riparian** (1,6, 10), Also need banks/cliffs for nesting habitat (7), wetlands (11).
Black Rosy-Finch (*Leucosticte atrata*)	**Alpine/Tundra** (1, 3, 4), in winter are recorded in mixed pine mosaics (9)

Species *(scientific name)*	**Y2Y broad scale habitat type with supporting references in ()** (Primary habitat in **BOLD**)
Black Swift (*Cypseloides niger*)	**Coniferous Riparian**, cliffs beneath waterfalls (1, 4)
Black Tern (*Chlidonias niger*)	**Marsh** (1-5,6,11), Willow Riparian (6)
Black-backed Woodpecker (*Picoides arcticus*)*	**Burned**[~] (1,4,11), Lodgepole (1,6), Subalpine Spruce/Fir (6), Douglas fir/Mixed/Grand Fir (6), Subboreal mixed wood (11)
Blackpoll Warbler (*Dendroica striata*)*	**Boreal spruce** (1,3,6), Bog (1,2,6), wetland areas with shrubby habitats bordering black spruce forest, and less commonly, white spruce (11), Subalpine Spruce/Fir (14)
Blue Grouse (*Dendragapus obscurus*)*	**Ponderosa Pine/Douglas fir mix (1,6)**, Burned (1,2), Aspen (6), Subalpine spruce/fir (11), Lodgepole Pine (14)
Bobolink (*Dolichonyx oryzivorus*)	Grass (1,2,3,4)
Bohemian Waxwing (*Bombycilla garrulus*)*	**Boreal Spruce** (1,11), Lodgepole (1,11), Burned (2,6), Marshes (6), Subboreal mixed wood (11)
Boreal Chickadee (*Parus hudsonicus*)	**Subalpine Spruce/Fir** (1,6), Boreal spruce (1,3, 6,11,12,13), Subboreal mixed wood (11).
Boreal Owl (*Aegolius funereus*)*	**Boreal spruce** (1,4+,11), Subalpine Spruce/Fir (1,7), Bog (1,4), Douglas fir/Mixed/Grand Fir (6), Subboreal mixed wood (11), Lodgepole Pine (11),
Brewer's Sparrow (*Spizella breweri*)	**Sage** (all)
Brown Creeper (*Certhia americana*)*	**Cedar/Hemlock** (1,6), **Subalpine Spruce/Fir** (1,6), Lodgepole (1,6), Douglas fir/Mixed/Grand Fir (1,2,4,6),
Burrowing Owl (*Speotyto cunicularia*)[#]	**Grass** (1,2,3), Sagebrush steppe (6)
Calliope Hummingbird (*Stellula calliope*)*	**Montane shrub**[~] (1), Ponderosa Pine/Douglas fir mix (1,6), Burned (2,6), Subalpine Spruce/Fir (6), "mountain meadows"(6), Douglas fir/Mixed/Grand Fir (6), Aspen (9)
Cassin's Finch (*Carpodacus cassinii*)	**Ponderosa Pine/Douglas Fir mix** (1), Lodgepole (1), Subalpine Spruce/Fir (1,3,4,7)
Cassin's Vireo (*Vireo cassinii*)	**Douglas fir/Mixed/Grand Fir** (1), Lodgepole (1), Aspen (1)

Species *(scientific name)*	**Y2Y broad scale habitat type with supporting references in ()** (Primary habitat in **BOLD**)
Clark's Nutcracker (*Nucifraga columbiana*)	**Whitebark pine** (1), Ponderosa Pine/Douglas fir mix (1), Subalpine Spruce/Fir (6), If the "montane shrub-forest" includes limber pine on the eastern slopes, then we have CLNU in that habitat here (7)
Columbian Sharp-tailed Grouse (*Tympanuchus phasianellus*)	**Grass** (1,3,4), parkland including river outwash meadows (11), subalpine areas (11), bogs (11)
Common Loon (*Gavia immer*)	**Lakes** (all, 6, 11)
Dark-eyed Junco (*Junco hyemalis*)*	**Douglas fir/Mixed/Grand Fir** (1,2,4), Whitebark Pine (1), Lodgepole (1), Ponderosa Pine/Douglas fir mix (1), Cedar/Hemlock (1), Burned (1), Subalpine Spruce/Fir (1,13), Boreal Spruce (1), wide variety of habitats (4,7,11), Generalist – they like it all with trees (6)
Dusky Flycatcher (*Empidonax oberholseri*)*	**Ponderosa Pine/Douglas fir mix** (1,3), **Deciduous Riparian** (1), Cedar/Hemlock (1), Douglas fir/Mixed/Grand Fir (1), Aspen (1,7), Burned (1), northern shrubfields (11)
Ferruginous Hawk (*Buteo regalis*)#	**Grassland** (1,2,3,6), Sage (1,6)
Flammulated Owl (*Otus flammeolus*)#	**Ponderosa Pine/Douglas fir mix** (1,3,4,6), Aspen (6)
Forster's Tern (*Sterna forsteri*)	**Marsh** (1-5), Lakes (2,3,6)
Golden Eagle (*Aquila chrysaetos*)	**Grassland** (1,3), **Subalpine Spruce/Fir** (1), Alpine/tundra (2,6,7,11, 14), all forest types (6). More of a generalist species (6). Nests exclusively on cliff faces in remote mountainous terrain (11).
Golden-crowned Sparrow (*Zonotrichia atricapilla*)*	**Northern shrubfields** (3,4,11), Subalpine Spruce/Fir (1,4,11,13,14), Alpine/tundra (2,7,11,13,14), Boreal spruce (6)
Grasshopper Sparrow (*Ammodramus savannarus*)	**Grassland** (all)
Gray Jay (*Perisoreus canadensis*)*	**Subalpine Spruce/Fir** (1,11), Boreal spruce (1,2,11,12), Lodgepole (6), Douglas fir/Mixed/Grand Fir (6), Ponderosa Pine/Douglas fir mix (6). Bog (11). Widespread depending on time of year (7), Subboreal mixed wood (11,12)

Species *(scientific name)*	**Y2Y broad scale habitat type with supporting references in ()** (Primary habitat in **BOLD**)
Gray-cheeked Thrush (*Catharus minimus*)	**Subalpine Spruce/Fir** (1,3,6), **Boreal spruce** (1,6,12), Northern Shrubfields (1,6,11,12)
Gray-crowned Rosy Finch (*Leucosticte tephrocotis*)	**Alpine/Tundra** (1-5,11,13), in winter are recorded in mixed pine mosaics (9)
Green-tailed Towhee (*Pipilo chlorurus*)	**Sagebrush Steppe** (1,3), Montane shrub (10)
Gyrfalcon (*Falco rusticolus*)	**Alpine/Tundra** (1-5, 11), **Northern shrubfields** (1)
Hammond's Flycatcher (*Empidonax hammondii*)*	**Douglas fir/Mixed/Grand Fir** (1,2,3), Cedar/Hemlock (1), Subalpine Spruce/Fir (6), Coniferous Riparian (10,11), Deciduous Riparian (11), Subboreal mixed wood (11)
Harlequin Duck (*Histrionicus histrionicus*)	**Coniferous Riparian** (1,6), swiftly flowing streams and rivers above/below treeline (11)
Killdeer (*Charadrius vociferus*)	**Lakes** (1,4)
Lazuli Bunting (*Passerina amoena*)*	**Montane shrub**~ (1), Deciduous Riparian (1), Sagebrush steppe (2,6), burned (2,6), Open ponderosa pine (6), Aspen woodlands around Waterton (7)
Lesser Yellowlegs (*Tringa flavipes*)*	**Bog** (1,2,3,11), Lakes (2,6), marsh (11), subalpine spruce/fir (11)
Lewis' Woodpecker (*Melanerpes lewis*)#	**Ponderosa Pine/Douglas fir mix** (1,3,6), Burned (1,6), Deciduous Riparian (1,6)
Loggerhead Shrike (*Lanius ludovicianus*)#	**Grassland** (1,6), **Sagebrush steppe** (1,6)
Long-billed Curlew (*Numenius americanus*)#	**Grassland** (1,2,3,6), Sagebrush steppe (1,6)
MacGillivray's Warbler (*Oporornis tolmiei*)*	**Montane shrub**~ (1), Cedar/Hemlock (1), Aspen (1,7), Burned (1,11), northern shrubfields (11), willow riparian (11)
Mountain Bluebird (*Sialia currocoides*)	**Burned** (1, 10,11), Aspen (1), Sagebrush steppe(3,6), Open ponderosa pine (6, 10), open lowland habitats (11), live and dead standing trees that provide nest cavities are important (11).

Species *(scientific name)*	**Y2Y broad scale habitat type with supporting references in ()** (Primary habitat in **BOLD**)
Mountain Chickadee (*Parus gambeli*)*	**Douglas fir/Mixed/Grand Fir** (1,4), Ponderosa Pine/Douglas fir mix (1), Lodgepole (1,11), Aspen (1), Subalpine Spruce/Fir (6,7), Open dry forests with mix of mature White Spruce and Lodgepole pine (11). In Yukon, found at relatively low elevations (11).
Northern Goshawk (*Accipiter gentilis*)*	**Douglas fir/Mixed/Grand Fir** (1,4), Cedar/Hemlock (1), Subalpine Spruce/Fir (1), Boreal spruce (1,11,14), Ponderosa Pine/Douglas fir mix (6,10), Boreal mixed wood (11). Mature and old-growth white spruce and mixed spruce/aspen (11).
Northern Hawk-Owl (*Surnia ulula*)	**Boreal spruce** (1,3,4,6), Bog (1,2,3,6), Burned (2,6), open coniferous or mixed forest, wooded swamps and older burned areas with standing dead trees (11).
Northern Pygmy-Owl (*Glaucidium gnoma*)	**Douglas fir/Mixed/Grand Fir** (1,2,6), Cedar/Hemlock (1,6), Ponderosa Pine/Douglas fir mix (1,6)
Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)*	**Deciduous Riparian** (1,6), Coniferous Riparian (1,6), Lakes (2,6), riverbanks, cliffs necessities for nesting habitat (4,7), wetlands (11)
Northern Shrike (*Lanius excubitor*)	Boreal spruce (1,6), Northern shrubfields (1,6,11)
Northern Waterthrush (*Seiurus noveboracensis*)*	**Deciduous Riparian** (1,2,6), **willow Riparian** (1,2,6), Coniferous Riparian (1,2,6), Bog (1,2,4,6), needs water and shrubs (11), shrubby marsh (11)
Olive-sided Flycatcher (*Contopus borealis*)*	**Subalpine Spruce/Fir** (1), Boreal spruce (1,2,11), Bog (1,2,4,14), Ponderosa Pine/Douglas fir mix (1), Douglas fir/Mixed/Grand Fir (1), Cedar/Hemlock, Burned (1,2,10), Aspen (6), Lodgepole Pine (11). Will use edges of lakes if surrounded by forest and They REALLY like edges of Coniferous forests and moist to wet meadows or shrub (6). Often at the edges of wetlands or bogs with dead trees (11). Subboreal mixed wood? (11 => mixed forest from lowland areas to treeline)

Species *(scientific name)*	**Y2Y broad scale habitat type with supporting references in ()** (Primary habitat in **BOLD**)
Peregrine Falcon (*Falco peregrinus*)[+#]	Marsh (1, 10), Cliffs (2,6,10), Grasslands (6), Sagebrush steppe near cliffs (6), lakes near cliffs (6) [Dan Casey: cliffs are most important feature], cliffs adjacent to or near bodies of water, most frequently on rocky cliffs along major rivers (11)
Pine Grosbeak (*Pinicola enucleator*)*	**Subalpine Spruce/Fir** (1), Boreal spruce (1,11), Douglas fir/Mixed/Grand Fir(6), Ponderosa Pine/Douglas fir mix (6), Subboreal mixed wood (11), Lodgepole pine (11)
Plumbeous Vireo (*Vireo plumbeus*)	**Dry P-Pine** (1,5), Aspen (5,6), Deciduous Riparian (6)
Prairie Falcon (*Falco mexicanus*)[+]	**Grassland** (all), **Alpine/Tundra** (1,2), Shrub-steppe (2,6), Requires some kind of cliff for nesting, such as valley sides in the prairies (7)
Red Crossbill (*Loxia curvirostra*)*	**Ponderosa Pine/Douglas fir mix** (1,3,6,10), Douglas fir/Mixed/Grand Fir (1,2,6,10), Cedar/Hemlock (1,6,10), Subalpine Spruce/Fir (1,6,10), Boreal spruce (1,6,10,11), Lodgepole Pine (10,11), lowland coniferous (11)
Red-breasted Nuthatch (*Sitta canadensis*)*	**Douglas fir/Mixed/Grand Fir** (1,2,6), Ponderosa Pine/Douglas fir mix (1,6), Cedar/Hemlock (1,6), Lodgepole (1,6,11), Aspen (1,6), Subalpine Spruce/Fir (1,4,6), Boreal spruce (11), Subboreal mixed wood (11), seldom observed outside of spruce-dominated or mixed forest, primarily seen at lower elevations, particularly in riparian areas (11).
Redhead (*Aythya americana*)	**Marsh** (1,2,3, 11), **Lakes** (all)
Red-naped Sapsucker (*Sphyrapicus nuchalis*)*	**Aspen** (1,6), Ponderosa Pine/Douglas fir mix (1,6), Douglas fir/Mixed/Grand Fir (1,2,6), Deciduous Riparian (1,6), Not really in pure Coniferous forest types (8)
Rock Ptarmigan (*Lagopus leucurus*)	**Alpine/tundra** (1-5,11)
Ruffed Grouse (*Bonasa umbellus*)*	**Aspen** (1,6,11), Deciduous Riparian (1,11,12), Ponderosa Pine/Douglas fir mix (6, questioned by 10), willow riparian (11), Subboreal mixed wood (11,12), northern shrubfield(12?)

Species *(scientific name)*	**Y2Y broad scale habitat type with supporting references in ()** (Primary habitat in **BOLD**)
Rufous Hummingbird (*Selasphorus rufus*)	**Willow Riparian (8,10)**, Coniferous Riparian (1,7), Coniferous woodlands (2,6)
Rusty Blackbird (*Euphagus carolinus*)*	**Bog** (1,2,3,11), Coniferous Riparian (1), lakes (2,6), marsh (11)
Sage Grouse (*Centrocercus urophasianus*)#	**Sagebrush-steppe** (1,3,4,6)
Sandhill Crane (*Grus canadensis*)	**Bog** (1,2), **Marsh** (1,2,4), higher elevation meadows (6), moist tussock (alpine?) tundra (11)
Short-eared Owl (*Asio flammeus*)* #	**Grassland** (1,2,3), Marsh (all,11), Northern Shrubfields (1, 11=> seen hunting in this habitat), Alpine/Tundra (2,4,6,11)
Smith's Longspur (*Calcarius pictus*)	**Alpine/Tundra** (1-5,6,11), Northern shrubfields (11)
Solitary Sandpiper (*Tringa solitaria*)	**Bog** (1,2,3, 11), Coniferous Riparian (1), Lakes (2,6), forested areas at the edges of beaver ponds, marshes and rivers, especially boggy areas with Black Spruce (11).
Spotted Sandpiper (*Actitis macularia*)	**Deciduous Riparian** (1,6), Coniferous Riparian (1,6), Lakes (all, 6), sparsely vegetated sand, gravel and rocky edges of rivers, lakes, creeks and ponds (11).
Spruce Grouse (*Dendragapus canadensis*)*	**Subalpine Spruce/Fir** (1, 11), Boreal Spruce (1,11,12), Douglas fir/Mixed/Grand Fir (6), Lodgepole Pine (10)
Surfbird (*Aphriza virgata*)	**Alpine/Tundra** (1-5, 11)
Swainson's Hawk (*Buteo swainsoni*)	**Grassland** (1-5), Deciduous Riparian (10 => only true east of the mountains), summer sightings mostly near riverside cliffs where there is close access to open tundra (11)
Swainson's Thrush (*Catharus ustulatus*)*	**Douglas fir/Mixed/Grand Fir** (1-6), Cedar/Hemlock (1,6), Subalpine Spruce/Fir (1,6), Aspen (11), Subboreal mixed wood (11,12,14), Coniferous riparian (11), boreal spruce (11,12,13,14), Burn (13)
Three-toed Woodpecker (*Picoides tridactylus*)*	**Burned**~ (1,4,11,13), Lodgepole (1,11), Subalpine Spruce/Fir (1,11), Boreal spruce (1,3,11,13), Douglas fir/Mixed/Grand Fir(6), Aspen (6), Subboreal mixed wood (11), wetlands (11)

Species *(scientific name)*	**Y2Y broad scale habitat type with supporting references in ()** (Primary habitat in **BOLD**)
Timberline Sparrow (*Spizella taverneri*)	**Alpine/Tundra** (1), Northern shrubfields (1,11)
Townsend's Solitaire (*Myadestes townsendi*)*	**Subalpine Spruce/Fir** (1,11), Alpine/Tundra (1), Ponderosa Pine/Douglas fir mix (1), Burned (1), Lodgepole (6,11), Douglas fir/Mixed/Grand Fir (6), In winter, specifically use juniper habitat (7). Boreal spruce (11). Open forests, usually white spruce, alpine fir or lodgepole pine at or near treeline (11). Subboreal mixed wood (11). At middle and lower elevations inhabits white spruce, lodgepole pine, and trembling aspen forests, especially in drier habitats, occasionally burns (11).
Townsend's Warbler (*Dendroica townsendi*)*	**Douglas fir/Mixed/Grand Fir** (1,2), Cedar/Hemlock (1), Subalpine Spruce/Fir (1,7), Ponderosa Pine/Douglas fir mix (6), Lodgepole Pine (10), coniferous riparian (11), boreal spruce (11)
Trumpeter Swan (*Cygnus buccinator*)	**Marsh** (1,2, 11), Lakes (1,2,3, 11), major rivers in fall/winter (9)
Tundra Swan (*Cygnus columbianus*)#	**Lakes** (1,3, 11), Tundra (2,3,4,6,11), Wetlands (11)
Varied Thrush (*Ixoreus naevius*)*	**Cedar/Hemlock** (1), Subalpine Spruce/Fir (1,7), Boreal spruce (1,11,12,14), Douglas fir/Mixed/Grand Fir (3,4,6), Coniferous Riparian (6,11), Subboreal mixed wood (11). variety of forested and tall shrub habitats from the lowlands to treeline (11).
Vaux's swift (*Chaetura vauxi*)	**Cedar/Hemlock** (1,6), Deciduous Riparian (1,6), Coniferous Riparian (1,6)
Veery (*Catharus fuscescens*)	**Deciduous Riparian** (1,3,6), Aspen (1,6)
Warbling Vireo (*Vireo gilvus*)	Deciduous Riparian (1,3,6,7,11), Willow Riparian (1,6), Aspen (1,3,6,7,11)
Western Screech Owl (*Otus kennicottii*)	**Deciduous Riparian (1,6)**
Western Tanager (*Piranga ludoviciana*)*	**Douglas fir/Mixed/Grand Fir** (1,2,3,6), Ponderosa Pine/Douglas fir mix (1,6), Cedar/Hemlock (1,6), Subalpine Spruce/Fir (1,6), Drier open coniferous, not nearly as common in the moist stuff (8), Subboreal mixed wood (11), Boreal spruce (11)
Western Wood-Pewee (*Contopus*	Ponderosa Pine/Douglas fir mix (1,6), Aspen (1,6), Bog (1,7), Deciduous

Species *(scientific name)*	**Y2Y broad scale habitat type with supporting references in ()** (Primary habitat in **BOLD**)
sordidulus)*	Riparian (1,7), Burned (8), Subboreal mixed wood (11), Lodgepole (11)
White-crowned Sparrow (*Zonotrichia leucophrys*)	**Subalpine Spruce/Fir** (1,6,11,13), Northern shrubfields (1,11), Alpine/Tundra (2,4,6,11), variety of open habitats (11)
White-headed Woodpecker (*Picoides albolarvatus*)#	**Ponderosa Pine/Douglas fir mix** (1,4,6)
White-tailed Ptarmigan (*Lagopus leucurus*)	**Alpine/Tundra** (1-5,11,13)
White-winged Crossbill (*Loxia leucoptera*)	**Subalpine Spruce/Fir** (1,6), Boreal spruce (1,3,6,11,13), Northern shrubfield (13), Burn (13)
Williamson's Sapsucker (*Sphyrapicus thyroideus*)	**Douglas fir/Mixed/Grand Fir** (1), Ponderosa Pine/Douglas fir mix (3,4,6), Open, dry conifer, not moist stuff as much (8), Mixed Forest with a heavy larch component, which can really vary from wet to dry (10), Burned (10)
Willow Flycatcher (*Empidonax traillii*)	**Willow Riparian (1,6)**
Willow Ptarmigan (*Lagopus lagopus*)	**Northern Shrubfields** (1,3,11), High elevation Willow Riparian in alpine (6,11), riparian willow in winter (11)
Wilson's Phalarope (*Phalaropus tricolor*)	**Marsh** (1-5,11), Lakes (2,4,6,11)
Wilson's Warbler (*Wilsonia pusilla*)*	**Bog** (1,2,4), **Deciduous Riparian** (1,11), **Willow Riparian** (1,11), Not bogs (8), northern shrubfields (11)
Wood Duck (*Aix sponsa*)	**Deciduous Riparian** (1,6), **Lakes** (1,2,6)
Yellow Warbler (*Dendroica petechia*)*	**Willow Riparian** (1,3,4,11,12), **Deciduous Riparian** (8,11,12), marsh (2,6), deciduous and mixed forest (12)

References supporting each habitat type used by a species:

1. Y2Y avian working group (Dan Casey, Susan Hannon, Andy Hansen, Richard Hutto, Kingsford Jones, Marcy Mahr, Kathy Martin and Troy Merrill).
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7. Cyndi Smith: Conservation Biologist. Parks Canada. Waterton Lakes National Park.
8. Dick Hutto: Division of Biological Sciences. University of Montana. Missoula, MT.
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10. Dan Casey: Northern Rockies BCR Coordinator, American Bird Conservancy. Kalispell, MT.
11. Birds of the Yukon Territory. 2003. Edited by Sinclair, P.H., Nixon, W.A., Eckert, C.D. and Hughes, N.L. UBC Press. Vancouver, B.C.
12. Vegetation, Wildlife, and Recreation Assessment of the Flat-South Nahanni Rivers Confluence Area, Nahanni National Park. 1978. Cairns, A.L., Henry, J.D. and Scotter, G.W. Canadian Wildlife Service unpublished report.
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14. Doug Tate: Conservation Biologist. Nahanni National Park, Parks Canada.

* Indicates generalist bird species using at least 4 habitat types that were removed from the original 109 priority species before running cluster analysis (N=38).
\+ Indicates microhabitat specialists that were removed from the original 109 priority species before running cluster analysis (N=4).
\# Indicates species at risk (Canadian endangered, threatened or species of special concern, and American endangered/threatened species).
~This habitat type was not used in the focal species analysis as it was not represented in the habitat cover type map provided by Y2Y.

Appendix II: Bird survey data sets collected for the Y2Y ecoregion.

Survey/Location	**# Points**	**Survey Dates**	**Source**	**Sampling Protocol**
Alberta Biodiversity Species Occurrence Database	277	1975-2002	Alberta Sustainable Resource Development	Anecdotal sightings/miscellaneous surveys
Alberta Foothills	60	1990-1992	Dan Farr, Biota Research	Unknown
Alberta Natural Heritage Information Centre	85	1975-2000	Alberta Sustainable Resource Development	Anecdotal sightings/miscellaneous surveys
Breeding Bird Survey	9863	Mainly 1997-2002. Some routes from 1969-1996	Patuxent Wildlife Research Centre, Canadian Wildlife Service	400m fixed radius, 3 minute point counts
Banff and Jasper National Parks, Canada.	1697	1977-1979	Parks Canada	500 m long transects. Unlimited distance.
Bow Valley, Alberta	55	1996-1999	Mike and Diane McIvor, Banff, Alberta	100m fixed radius, 10 minute point counts
British Columbia sensitive species occurrences	423	1971-2001	BC Conservation Data Centre	Anecdotal sightings/miscellaneous surveys
Canadian Lakes Loon Survey, BC, Alberta, Yukon and NWT	59	1997 - 2000	Bird Studies Canada	Volunteer reports
Del Rio, 60 km northeast of Chetwynd, B.C.	42	1993-1995, 1997, 1999, 2002	BC government, Ministry of Water, Land and Air Protection	80m fixed radius, 10 minute point counts
Federation of Alberta Naturalists	200	1975-2003	Federation of Alberta Naturalists	Anecdotal sightings/ miscellaneous surveys

Survey/Location	# Points	Survey Dates	Source	Sampling Protocol
Fort Liard, NWT	60	1995-2000?	Canadian Wildlife Service	Variable radius, 10 minute point counts
La Biche River Watershed, SE Yukon	8	1997	Canadian Wildlife Service	Point counts
Liard River, South Yukon	84	1994	Yukon Renewable Resources	75m fixed radius, 10 minute point counts
MacKenzie Monitoring Station, Parsnip Reach, Williston Lake, BC	22	1996-2002	Mackenzie Nature Observatory	50m wide transects
McGregor Model Forest, BC	247	1997	BC government, Ministry of Water, Land and Air Protection	50m fixed radius, 10 minute point counts
Montana Loon Survey	92	1996 - 2002	Montana Fish and Wildlife	Volunteer reports
Northern Region Landbird Monitoring Program, Montana/Idaho	4886	1994-2000	University of Montana, Landbird Monitoring Lab	100m fixed radius, 10 minute point counts
NWT/NU bird checklist database, Northwest Territories.	59	1997-2002	Canadian Wildlife Service	Anecdotal sightings/ miscellaneous surveys
Riske Creek (Williams Lake), B.C.	217	1995-2002	Kathy Martin, UBC	50m fixed radius, 6 minute point counts
Southern Rockies Landscape Planning Project (C5), Alberta	155	1997	Alberta Sustainable Resource Development	~200m radius, 15 to 30 minute point counts
Teslin, South Yukon	106	2001	Canadian Wildlife Service	Point counts
Waterton National Park, Alberta.	64	1997-2002	Parks Canada	100m fixed radius, 10 minute point counts
Wells Gray Provincial Park, BC.	15	1998-2001	Scott Wilson and Kathy Martin, UBC	100m wide transects

Appendix III: Bird Species Clusters produced by k-medoid analysis, using k = 17. The predominant habitat use for the cluster is specified. The representative species (medoid) for each cluster is indicated by *. The number of detections in the bird survey data for each species is indicated in ()

Cluster 1: Ponderosa Pine/Douglas Fir 1° or 2° habitat; Subalpine Spruce/Fir 2° habitat; Lodgepole Pine or Whitebark Pine 2° habitat

- Clark's Nutcracker* (1180)
- Cassin's Finch (1138)

Cluster 2: Douglas Fir/Mixed 1° habitat; Ponderosa Pine/Douglas Fir, Aspen, Lodgepole Pine 2° habitat

- Northern Pygmy-Owl (0)
- Cassin's Vireo (1287)
- Williamson's Sapsucker* (251)

Cluster 3: Marsh 1° habitat; Lakes 2° habitat

- American Avocet (18)
- Forster's Tern (2)
- Trumpeter Swan (148)
- Wilson's Phalarope* (69)
- American Bittern (29)
- American Wigeon (128)
- Redhead (50)
- Black Tern (50)
- Sandhill Crane (376)
- Tundra Swan (1)

Cluster 4: Coniferous Riparian specialists.

- American Dipper (151)
- Black Swift (38)
- Harlequin Duck* (17)

Cluster 5: Alpine Tundra specialists.

- American Golden-Plover (3)
- American Pipit (25)
- Black Rosy-Finch (1)
- Gray-crowned Rosy Finch (60)
- Rock Ptarmigan (7)
- Surfbird (0)
- White-tailed Ptarmigan* (12)

Cluster 6: Northern Shrubfields, Alpine Tundra as 1° or 2° habitat

American Tree Sparrow (146)
Gyrfalcon (1)
Smith's Longspur (1)
Timberline Sparrow* (0)

Cluster 7: Lake specialists.

American White Pelican (47)
Common Loon (220)
Killdeer* (1076)

Cluster 8: Deciduous Riparian 1° habitat; Lakes 1° or 2° habitat; Coniferous Riparian 2° habitat

Barrow's Goldeneye* (112)
Spotted Sandpiper (944)
Belted Kingfisher (356)
Wood Duck (55)
Solitary Sandpiper (63)
Vaux's Swift (168)

Cluster 9: Grassland specialists.

Bobolink (89)
Grasshopper Sparrow (158)
Swainson's Hawk* (141)

Cluster 10: Subalpine Spruce/Fir 1° habitat; Boreal Spruce 1° or 2° habitat; Northern Shrubfield 2° habitat

White-winged Crossbill* (497)
Gray-cheeked Thrush (77)
Boreal Chickadee (415)
White-crowned Sparrow (1756)

Cluster 11: Sagebrush Steppe specialists.

Brewer's Sparrow (960)
Green-tailed Towhee (283)
Sage Grouse* (16)

Cluster 12: Grassland 1° habitat; Sagebrush Steppe 2° habitat.

Burrowing Owl (4)
Ferruginous Hawk (56)
Long-billed Curlew* (280)
Loggerhead Shrike (29)

Cluster 13: Subalpine 1^{o} or 2^{o} habitat; Grassland 1^{o} or 2^{o} habitat
Golden Eagle* (66)
Columbian Sharp-tailed Grouse (8)

Cluster 14: Dry Ponderosa Pine/Douglas Fir specialists
(except Blue Grouse: Dry P-Pine 0.67, Burned 0.33).
Flammulated Owl* (0)
Plumbeous Vireo (36)
Lewis' Woodpecker (53)
White-headed Woodpecker* (6)
Mountain Bluebird (1125)

Cluster 15: Boreal Spruce 1^{o} habitat; Northern Shrubfield 1^{o} or 2^{o} habitat
Northern Shrike* (6)
Northern Hawk-Owl (6)
Willow Ptarmigan (15)

Cluster 16: Willow riparian 1^{o} habitat.
Willow Flycatcher* (1123)
Rufous Hummingbird (459)

Cluster 17: Deciduous Riparian 1^{o} or 2^{o} habitat
Veery* (635)
Warbling Vireo (5405)
Western Screech Owl (1)

Appendix IV: The focal bird species effectiveness as umbrellas for their primary habitats during the breeding season. The percentage overlap of the focal species' primary habitat with the species in its cluster, and with all Y2Y conservation priority species with the same primary habitat use was calculated by overlaying digital range maps.

Focal Species (Primary Habitat)	**Cluster Members**	**% Range Overlap in Y2Y**	**Other Species with the same primary habitat**	**% Range Overlap in Y2Y**
Clark's Nutcracker (Whitebark Pine)	Cassin's Finch	96.9	none	
Cassin's Vireo (Douglas Fir/ Mixed/Grand Fir)	Williamson's Sapsucker	63.7	Dark-eyed Junco	33.1
	Northern Pygmy-Owl	65.7	Hammond's Flycatcher	48.3
			Mountain Chickadee	62.1
			Northern Goshawk	33.2
			Red-breasted Nuthatch	41.6
			Swainson's Thrush	32.8
			Townsend's Warbler	59.5
			Western Tanager	48.9
American Wigeon (Marsh/Lakes)	American Avocet	100	*Marsh*: none	
	American Bittern	100	*Lakes*:	
	Black Tern	100	American White Pelican	100
	Forster's Tern	100	Bald Eagle	100
	Redhead	100	Barrow's Goldeneye	100
	Sandhill Crane	100	Belted Kingfisher	100
	Trumpeter Swan	100	Common Loon	100
	Tundra Swan	100	Killdeer	100
	Wilson's Phalarope	100	Wood Duck	100
American Dipper (Coniferous Riparian)	Black Swift	96.6	none	
	Harlequin Duck	91.9		
Gray-crowned Rosy-Finch (Alpine/	American Golden Plover	90.6	American Tree Sparrow	80.6
	American Pipit	83.8	Gyrfalcon	84.5

Focal Species (Primary Habitat)	Cluster Members	% Range Overlap in Y2Y	Other Species with the same primary habitat	% Range Overlap in Y2Y
Tundra)	Black Rosy-Finch	100	Prairie Falcon	60.4
	Rock Ptarmigan	76.3	Smith's Longspur	0 (Range Not in Y2Y)
	Surfbird	100	Timberline Sparrow	50*
	White-tailed Ptarmigan	75.2		
American Tree Sparrow (Northern Shrubfields and Alpine/ Tundra)	Gyrfalcon	100	*Northern Shrubfield:*	
	Smith's Longspur	0 (not in Y2Y)	Golden-crowned Sparrow	57.4
	Timberline Sparrow	100*	Willow Ptarmigan	79.0
			Alpine/Tundra:	
			American Golden Plover	100
			American Pipit	56.6
			Black Rosy-Finch	0
			Gray-crowned Rosy-Finch	56.3
			Prairie Falcon	0
			Rock Ptarmigan	97.4
			Surfbird	100
			White-tailed Ptarmigan	55.9
Common Loon (Lakes)	American White Pelican	56.1	American Wigeon	77.8
	Killdeer	71.5	Bald Eagle	79.7
			Barrow's Goldeneye	83.0
			Belted Kingfisher	77.8
			Redhead	41.2
			Tundra Swan	Only winter range in Y2Y
			Wood Duck	43.1
Spotted Sandpiper (Deciduous Riparian)	Barrow's Goldeneye	100	Bank Swallow	100
	Belted Kingfisher	100	Dusky Flycatcher	100
	Wood Duck	100	Northern Waterthrush	100

Focal Species (Primary Habitat)	Cluster Members	% Range Overlap in Y2Y	Other Species with the same primary habitat	% Range Overlap in Y2Y
	Solitary Sandpiper	100	Northern Rough-Winged Swallow	100
	Vaux's Swift	100	Veery	100
			Western Screech Owl	100
			Wilson's Warbler	100
			Yellow Warbler	100
Grasshopper Sparrow (Grassland specialist)	Bobolink	41.9	Burrowing Owl	15.1
	Swainson's Hawk	8.5	Ferruginous Hawk	13.1
			Golden Eagle	8.4
			Loggerhead Shrike	27.4
			Long-billed Curlew	40.3
			Prairie Falcon	24.1
			Sharp-tailed Grouse	9.3
			Short-eared Owl	8.4
White-crowned Sparrow (Subalpine)	Boreal Chickadee	95.8	Brown Creeper	91.4
	Gray-cheeked Thrush	100	Golden Eagle	95.7
	White-winged Crossbill	96.7	Gray Jay	98.2
			Olive-sided Flycatcher	95.6
			Pine Grosbeak	98.0
			Spruce Grouse	96.5
			Townsend's Solitaire	96.2
Brewers Sparrow (Sagebrush Steppe specialist)	Green-tailed Towhee	100	Loggerhead Shrike	100
	Sage Grouse	100		
Long-billed Curlew (Grassland)	Burrowing Owl	53.9	Bobolink	55.5
	Ferruginous Hawk	51.5	Grasshopper Sparrow	74.7
	Loggerhead Shrike	55.4	Golden Eagle	15.5
			Prairie Falcon	46.9
			Sharp-tailed Grouse	14.4
			Short-eared Owl	15.5
			Swainson's Hawk	15.8
Golden Eagle (Subalpine/ Grassland)	Sharp-tailed Grouse	100	*Subalpine*	
			Boreal Chickadee	100
			Brown Creeper	100
			Gray Jay	100

Focal Species (Primary Habitat)	**Cluster Members**	**% Range Overlap in Y2Y**	**Other Species with the same primary habitat**	**% Range Overlap in Y2Y**
			Gray-cheeked Thrush	100
			Olive-sided Flycatcher	100
			Pine Grosbeak	100
			Spruce Grouse	100
			Townsend's Solitaire	100
			White-crowned Sparrow	100
			White-winged Crossbill	100
			Grassland	
			Bobolink	100
			Burrowing Owl	100
			Ferruginous Hawk	100
			Grasshopper Sparrow	100
			Loggerhead Shrike	100
			Long-billed Curlew	100
			Prairie Falcon	100
			Sharp-tailed Grouse	100
			Short-eared Owl	100
			Swainson's Hawk	100
Lewis' Woodpecker (Ponderosa/ DougFir)	Flammulated Owl	70.2	Blue Grouse	49.5
	Mountain Bluebird	54.3	Caffin's Finch	94.8
	Plumbeous Vireo	0 (Range not in Y2Y)	Dusky Flycatcher	82.2
	White-headed Woodpecker	97.6	Red Crossbill	48.7
Blackpoll Warbler (Boreal Spruce)	Northern Hawk Owl	96.3	Boreal Owl	69.6
	Northern Shrike	100	Bohemian Waxwing	87.0
	Willow Ptarmigan	99.4	Gray-cheeked Thrush	100
Yellow Warbler	Rufous Hummingbird	100	*Willow Riparian:*	

Focal Species (Primary Habitat)	Cluster Members	% Range Overlap in Y2Y	Other Species with the same primary habitat	% Range Overlap in Y2Y
Warbler (Willow Riparian/ Deciduous Riparian)	Willow Flycatcher	100	Northern Waterthrush	91.9
			Deciduous Riparian:	
			Bank Swallow	93.2
			Barrow's Goldeneye	92.9
			Belted Kingfisher	93.2
			Dusky Flycatcher	100
			Northern Rough-winged Swallow	100
			Northern Waterthrush	91.9
			Spotted Sandpiper	93.2
			Veery	100
			Western Screech Owl	100
			Wilson's Warbler	93.2
			Wood Duck	100
Veery (Deciduous Riparian)	Warbling Vireo	58.5	Bank Swallow	44.3
	Western Screech Owl	82.7	Barrow's Goldeneye	40.1
			Belted Kingfisher	44.2
			Dusky Flycatcher	78.7
			Northern Waterthrush	37.3
			Northern Rough-Winged Swallow	86.6
			Spotted Sandpiper	44.2
			Wilson's Warbler	44.2
			Wood Duck	94.2
			Yellow Warbler	47.4
Brown Creeper (Cedar-hemlock/ Subalpine)	None	-	*Cedar-Hemlock*:	
			Vaux's Swift	99.8
			Varied Thrush	39.3
			Subalpine:	
			Boreal Chickadee	31.2
			Golden Eagle	46.3
			Gray Jay	42.0
			Gray-cheeked Thrush	3.3
			Olive-sided Flycatcher	46.5
			Pine Grosbeak	42.3

Focal Species (Primary Habitat)	**Cluster Members**	**% Range Overlap in Y2Y**	**Other Species with the same primary habitat**	**% Range Overlap in Y2Y**
			Spruce Grouse	39.1
			Townsend's Solitaire	52.1
			White-crowned Sparrow	44.2
			White-winged Crossbill	37.4
Ruffed Grouse (Aspen)	None	-	Red-naped Sapsucker	98.1
Wilson's Warbler (Bog/ Deciduous Riparian/ Willow Riparian)	None	-	*Bog:*	
			Alder Flycatcher	100
			Lesser Yellowlegs	100
			Rusty Blackbird	100
			Sandhill Crane	100
			Solitary Sandpiper	100
			Deciduous Riparian:	
			Bank Swallow	100
			Barrow's Goldeneye	100
			Belted Kingfisher	100
			Dusky Flycatcher	100
			Northern Rough-winged Swallow	100
			Northern Waterthrush	100
			Spotted Sandpiper	100
			Veery	100
			Western Screech Owl	100
			Wood Duck	100
			Yellow Warbler	100
			Willow Riparian:	100
			Northern Waterthrush	100
			Rufous Hummingbird	100
			Willow Flycatcher	100
			Yellow Warbler	100

* Based on the known breeding range for the Timberline Sparrow. However, the exact range throughout the BC mountains is still uncertain (Pool and Gill 2002).

Appendix V. The 202 North America seasonal land cover region habitat classes that were reclassified to the Y2Y habitat cover types.

SLCR2.0 Land Cover Class	Label
1	Spruce Forest
2	Needleleaf Forest (Sitka Spruce, Western Hemlock)
3	Needleleaf Boreal Forest (Black and White Spruce, Aspen, Birch)
4	Ponderosa, Lodgepole Pine Forest
5	Black Spruce Forest with Balsam Fir
6	Evergreen Needleleaf Forest (Lodgepole Pine and Douglas Fir)
7	Needleleaf Forest (Dougland Fir, Spruce, Western Red Cedar)
8	Open Evergreen Needleleaf Forest (Ponderosa Pine)
9	Needleleaf Forest (Hemlock, Spruce, Douglas Fir)
10	Evergreen Needleleaf Forest (Lodgepole Pine, Englemann Spruce, Ponderosa Pine)
11	Needleleaf Forest (Spruce, Jack Pine, Aspen, Birch, Tamarack)
12	Ponderosa/Lodgepole Pine Woodland
13	Spruce and Pine Forest
14	Evergreen Needleleaf Forest (Ponderosa Pine, Douglas Fir, Western Red Cedar)
15	Evergreen Needleleaf Forest (Douglas Fir, Lodgepole Pine, Larch, Western Red Cedar)
16	Mixed Boreal Forest (Aspen, Birch, Spruce, Pine)
17	Open Needleleaf Forest (Ponderosa Pine and Lodgepole Pine)
18	Needleleaf Forest (Western Red Cedar, Lodgepole Pine, Douglas Fir, Larch, Ponderosa Pine)
19	Needleleaf Forest (Lodgepole Pine, Ponderosa Pine, Englemann Spruce, Subalpine Fir)
20	Needleleaf Forest (Ponderosa Pine)
21	Needleleaf Forest (Ponderosa, Lodgepole and White Pine, Douglas Fir)
22	Ponderosa Pine Forest
23	Evergreen Needleleaf Forest (Spruce, Balsam Fir, Eastern White Pine, Eastern Hemlock)
24	Needleleaf Forest (Douglas Fir, Lodgepole Pine, Western White Pine)
25	Evergreen Needleleaf Forest (Chihuahua Pine, Apache Pine)

26	Evergreen Needleleaf Forest (Douglas Fir, Ponderosa, Jeffrey Pine)
27	Needleleaf Forest (Douglas Fir) with Mixed Hardwoods
28	Needleleaf Forest (Western Hemlock, Sitka Spruce, Douglas Fir)
29	Open Needleleaf Forest (Ponderosa Pine, Pinyon-Juniper)
30	Evergreen Needleleaf Forest (Pine Species)
31	Needleleaf Forest (Douglas Fir)
32	Evergreen Needleleaf Forest (Douglas Fir, Western Hemlock, Ponderosa Pine)
33	Evergreen Needleleaf Forest (Loblolly, Slash Pine) with Hardwoods (Gum, Cypress)
34	Evergreen Needleleaf Forest (Longleaf, Slash Pine)
35	Evergreen Needleleaf Forest (Douglas Fir, Ponderosa Pine, Redwoods)
36	Tropical Dry Forest
37	Montane Tropical Broadleaf Forest
38	Tropical Broadleaf Forest
39	Tropical Dry Forest
40	Tropical Broadleaf Forest
41	Degraded Tropical Forest
42	Degraded Tropical Forest
43	Semi-Deciduous Dry Forest
44	Semi-Deciduous Tropical Forest
45	Evergreen Broadleaf Tropical Forest
46	Deciduous Woodlands (Aspen)/Shrubland (Mountain Mahogany)
47	Deciduous Forest (Aspen) with Cropland
48	Deciduous Forest (Aspen)
49	Deciduous Tropical Dry Woodland
50	Deciduous Forest (Maple, Beech, Birch) with Cropland (Pasture, Hay)
51	Deciduous Forest (Oak)
52	Deciduous Forest (Maple, Beech, Birch, Oak, Hickory) with Pasture
53	Deciduous Forest (Oak, Hickory, Sweet Gum, Southern Pines) with Cropland and Pasture
54	Subalpine Forest (Englemann Spruce, Subalpine Fir, Douglas Fir)
55	Tall/Low Shrubs with Spruce Woodlands
56	Spruce Woodlands and Shrub Bogs

57	Subalpine Transitional Forest
58	Evergreen Needleleaf Forest (Balsam Fir, White Spruce, Black Spruce)
59	Mixed Forest (Aspen, Birch, Spruce)
60	Evergreen Needleleaf Forest and Woodland (Black and White Spruce)
61	White, Black Spruce Forest
62	Evergreen Needleleaf Forest (Balsam Fir, Black Spruce, White Spruce)
63	Spruce Woodlands with Low/Tall Shrubs
64	Open Mixed Forest (Aspen, Birch, White Spruce, Black Spruce)
65	Mixed Forest (Aspen, Birch, Balsam Poplar, Black and White Spruce)
66	Open Needleleaf Boreal Forest (Black and White Spruce, Tamarack, Aspen)
67	Mixed Forest (Black and White Spruce, Aspen, Birch)
68	Mixed Forest (Balsam Fir, Jack Pine, Black and White Spruce, Jack Pine, Aspen, Birch)
69	Needleleaf Forest (Red Pine, Jack Pine, Spruce, Aspen, Birch, Tamarack)
70	Mixed Forest (Aspen, Birch, Spruce, Balsam Fir)
71	Mixed Forest (Pine and Oak)
72	Mixed Forest (Pine and Oak)
73	Northern Mixed Forest (Maple, Beech, Birch, Pine)
74	Mixed Forest (Aspen, Maple, Oak, Jack Pine, Red Pine, Spruce)
75	Mixed Forest (Pine, Oak)
76	Caribbean Montane Mixed Forest
77	Mixed Forest (Oak, Pine Species)
78	Tall Shrubs (Willow, Birch, Alder)
79	Tall/Low Shrubs (Willow, Alder) and Wet Herbaceous
80	Tall/Low Shrubs, Tundra, Spruce
81	Tall Shrubs (Willow, Birch, Alder) and Wet Herbaceous Meadows
82	Artic Tall Shrubs (Willow, Birch, Alder)
83	Chapparral
84	Deciduous Shrubland (Oak) with Pinyon Juniper
85	Herbaceous Alpine Tundra with Low/Dwarf Shrubs
86	Herbaceous Alpine Tundra

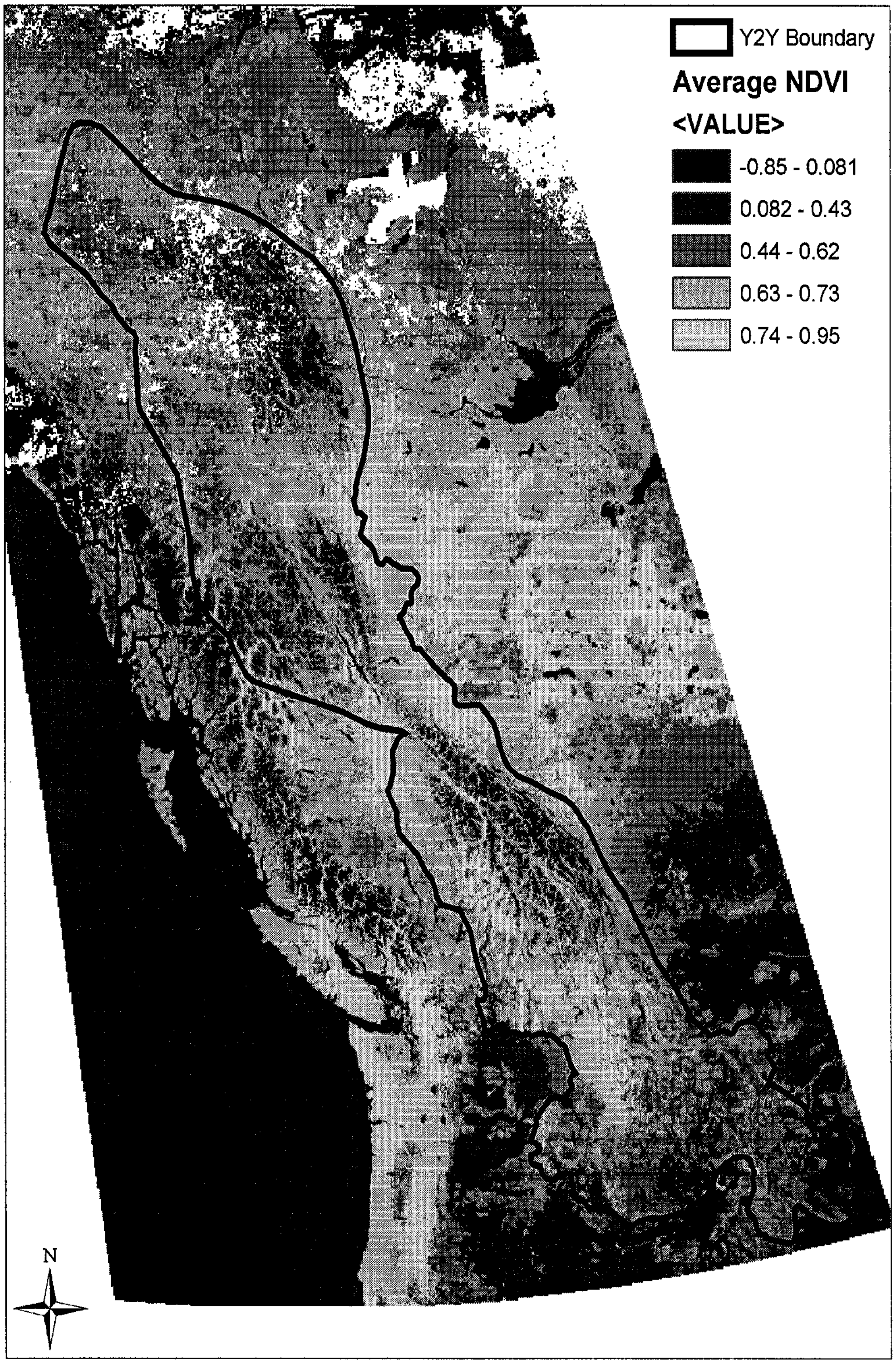
87	Sparsely Vegetated Desert Shrubland
88	Herbaceous Arctic Tundra with Low/Dwarf Shrubs
89	Open Arctic Shrubland
90	Open Alpine Shrubland
91	Woody Arctic Tundra with Lichen
92	Woody Arctic Tundra, Tall, Low, and Dwarf Shrubland
93	Herbaceous Alpine Tundra with Low/Dwarf Shrubs
94	Desert Shrublands (Creosote, Saltbush, Sand Sage) - Sonoran
95	Tall/Low Shrubs, Tundra, Spruce
96	Black Spruce Woodlands, Bogs with Dwarf/Tall Shrubs
97	Woody Arctic Tundra (Dwarf and Low Shrubs)
98	Desert Shrubland (Creosote, Saltbush, Sand Sage, Mesquite) - Chihuahan
99	Desert Shrubland (Creosote, Saltbush, Mesquite, Sand Sage)
100	Shrubland/Grassland (Saltbush, Sand Sage, Rabbitbrush)
101	White Spruce and Black Spruce Fens
102	Shrubland/Grassland (Needlegrass, Big Sage, Rabbitbrush)
103	Black Spruce, Tamarack, Lichen Woodland
104	Open Spruce Forest with Tall Shrubs (Willow, Birch, Alder)
105	Desert Shrubland (Creosote, Saltbush, Mesquite, Sand Sage)
106	Desert Shrubland/Grassland (Creasote, Saltbush, Mesquite, Sand Sage)
107	Desert Shrubland (Creosote, Saltbush, Mesquite, Cactus) with Grasses
108	Juniper Woodland
109	Pinyon-Juniper Woodland
110	Open Deciduous Woodland (Oak, Populus) with Evergreen Needleleaf Species
111	Pinyon-Juniper Woodland
112	Pinyon-Juniper Woodland
113	Woody Savanna
114	Oak Woodlands
115	Grassland/Woodland (Oak) Mosaic with Cropland
116	Deciduous Dry Forest

117	Open Mixed Forest (Pine, Oak)
118	Grassland/Forest
119	Oak Savanna
120	Savanna
121	Wet Herbaceous Meadows
122	Grassland (Short Grass Prairie)
123	Grassland (Short- Mid Grass Prairie)
124	Grassland with Cropland (Small Grains)
125	Grassland with Shrubland
126	Grassland
127	Grassland with Shrubland
128	Grassland (Warm Season Grasses)
129	Grassland with Cropland (Small Grains, Pasture)
130	Grassland with Shrubland
131	Grassland/Shrubland with Crops, Fallow
132	Grassland with Cropland
133	Grassland with Woodland and Wetlands
134	Grassland with Cropland
135	Grassland (Tall Grass Prairie)
136	Grassland
137	Wetlands with Tall/Low Shrubs, Tundra, Spruce
138	Herbaceous Wetlands
139	Cropland (Small Grains and Pasture) with Grasslands
140	Cropland (Small Grains) with Grasslands
141	Cropland (Sugar Cane)
142	Cropland
143	Cropland (Small Grains, Pasture) with Grasslands
144	Irrigated Agriculture
145	Cropland (Truck Crops) with Deciduous Woodlands (Oak)
146	Cropland (Winter Wheat)
147	Cropland (Small Grains, Row Crops)
148	Irrigated Agriculture
149	Irrigated Agriculture
150	Irrigated Agriculture
151	Cropland (Corn, other Row Crops, Forage Crops) with Woodland
152	Irrigated Agriculture
153	Cropland (Small Grains, Hay, Pasture) with Wetlands

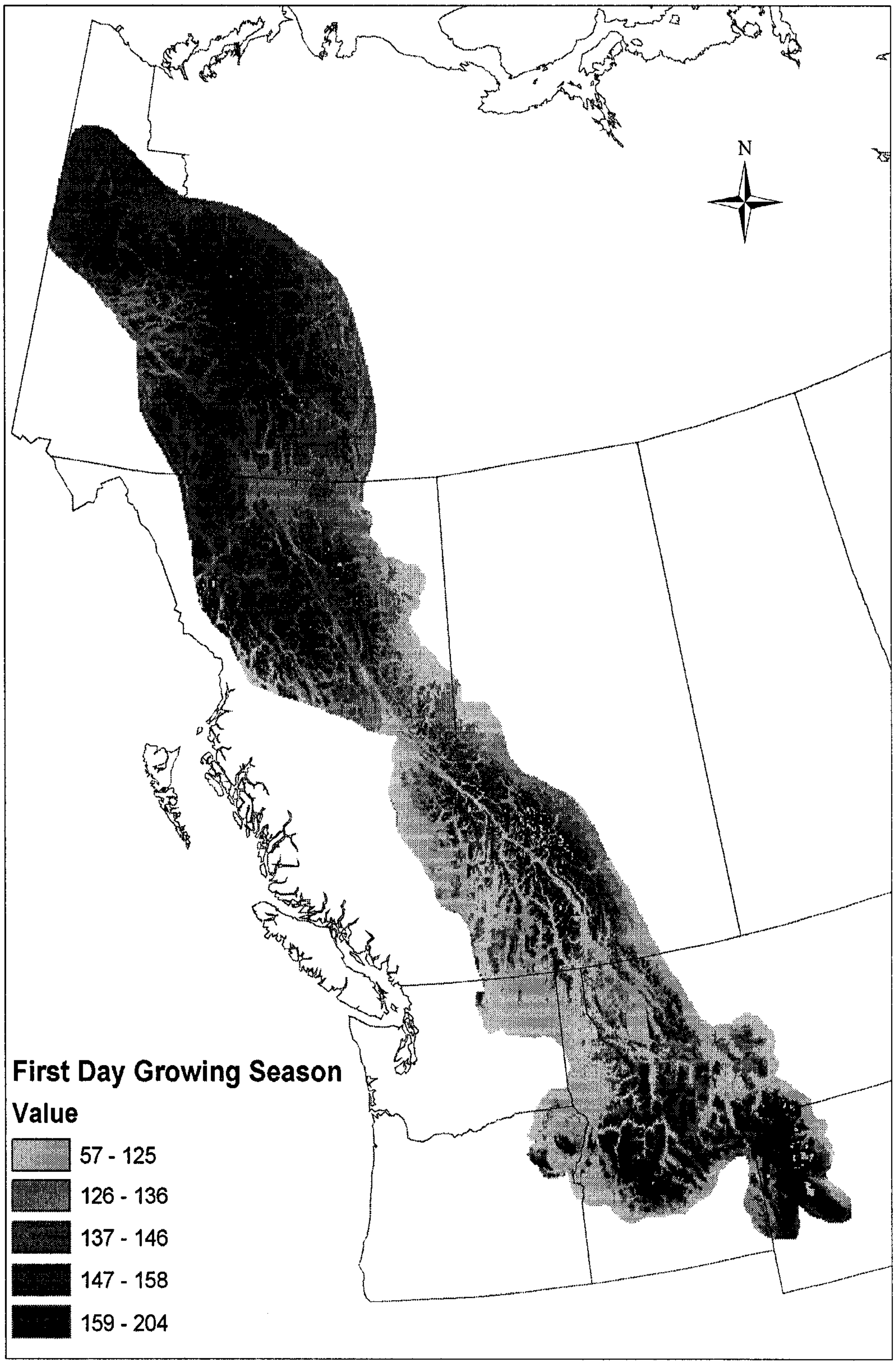
154	Cropland (Corn and Soybeans)
155	Irrigated Agriculture
156	Cropland (Corn and Soybeans)
157	Irrigated Agriculture
158	Cropland (Corn and Soybeans)
159	Irrigated Agriculture
160	Cropland (Cultivated Grassland)
161	Cropland (Mixed Row Crops) with Woodland
162	Cropland (Grass Seed, Small Grains) with Mixed Woodlands
163	Cropland (Winter Wheat)
164	Cropland (Cotton, Soybeans, Rice)
165	Cropland (Sugar Cane)
166	Irrigated Agriculture
167	Cropland with Savanna
168	Cropland (Cultivated Grasses) with Savanna
169	Irrigated Agriculture
170	Cropland (Corn, Soybeans, Cotton, Rice) with Pasture
171	Cropland
172	Cropland
173	Cropland with Woodland
174	Grassland, Cropland (Small Grains), Fallow Mosaic
175	Cropland, Woodland, Urban Mosaic
176	Cropland (Small Grains, Pasture)/Grassland Mosaic
177	Grassland/Cropland (Wheat, Corn) Mosaic
178	Cropland (Row Crops, Small Grains)/Grassland Mosaic
179	Cropland/Deciduous Forest (Aspen) Mosaic
180	Cropland (Small Grains, Row Crops)/Grassland
181	Deciduous Forest (Maple, Beech, Birch)/Cropland
182	Cropland (Corn, Sorghum, Small Grains)/Grassland Mosaic
183	Cropland (Corn, Soybeans, Alfalfa)/Woodlands Mosaic
184	Cropland/Grassland
185	Cropland (Corn, Cotton, Sorghum, Pasture)/Grassland Mosaic
186	Deciduous Forest (Maple, Elm)/Cropland (Corn, Soybeans, Pasture)
187	Cropland/Deciduous Dry Forest Mosaic

188	Cropland (Corn, Small Grains)/Deciduous Forest (Oak, Hickory) Mosaic
189	Cropland (Cultivated Grasses)/Deciduous Forest Mosaic
190	Cropland/Deciduous Forest Mosaic
191	Cropland/Woodland
192	Cropland (Corn, Soybeans, Pasture)/Woodland (Oak, Hickory) Mosaic
193	Cropland(Corn, Cotton, Soybeans)/Evergreen Needleleaf Forest (Slash Pine) Mosaic
194	Cropland (Pasture)/Grassland Mosaic
195	Ice and Snow
196	Barren
197	Barren Or Sparsely Vegetated
198	Sparsely Vegetated Arctic Tundra
199	Herbaceous Arctic Tundra
200	Herbaceous Arctic Tundra
201	Inland Water
202	Ocean

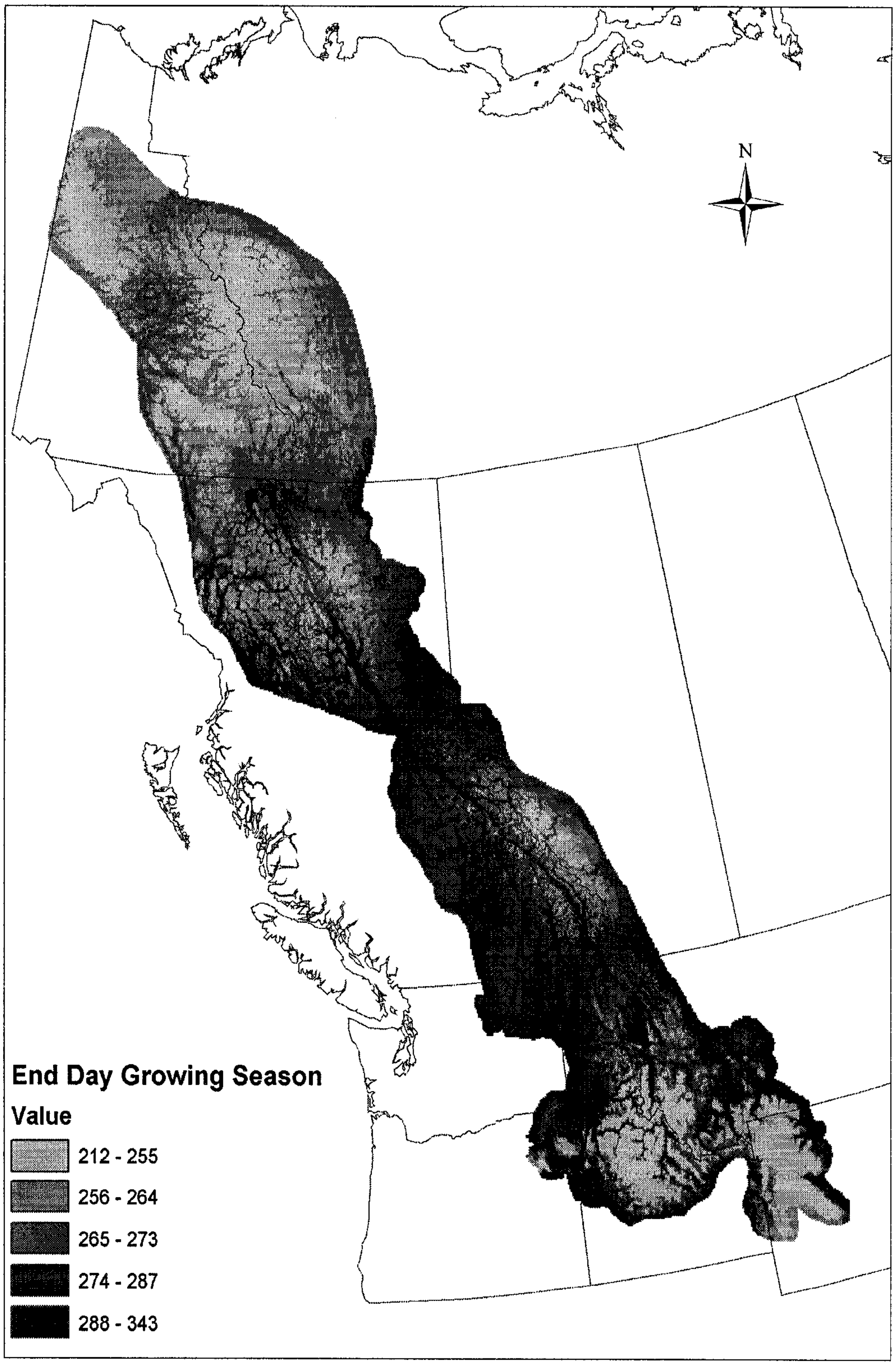
Average Seasonal NDVI



First Day Growing Season

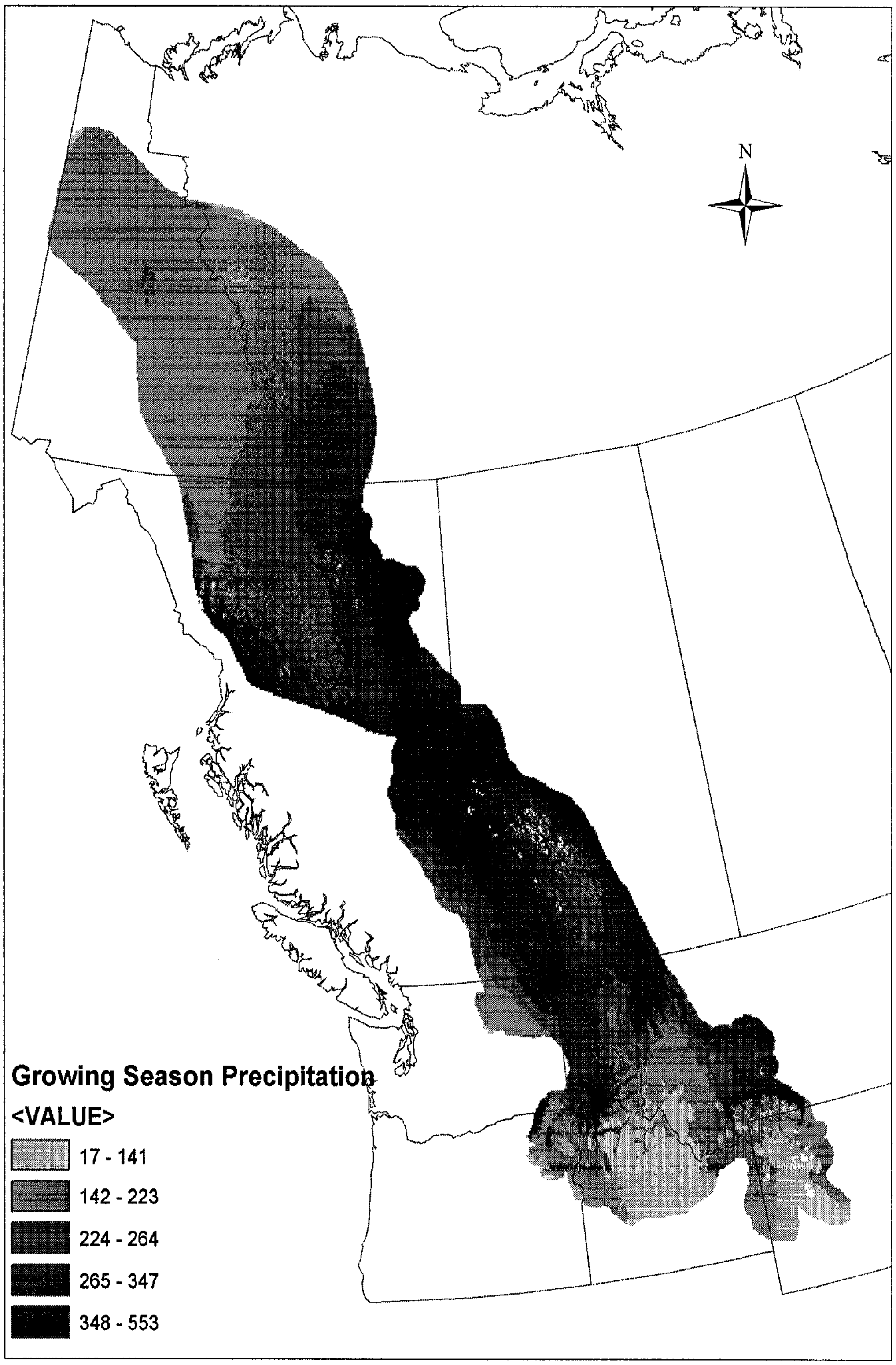


End Day Growing Season

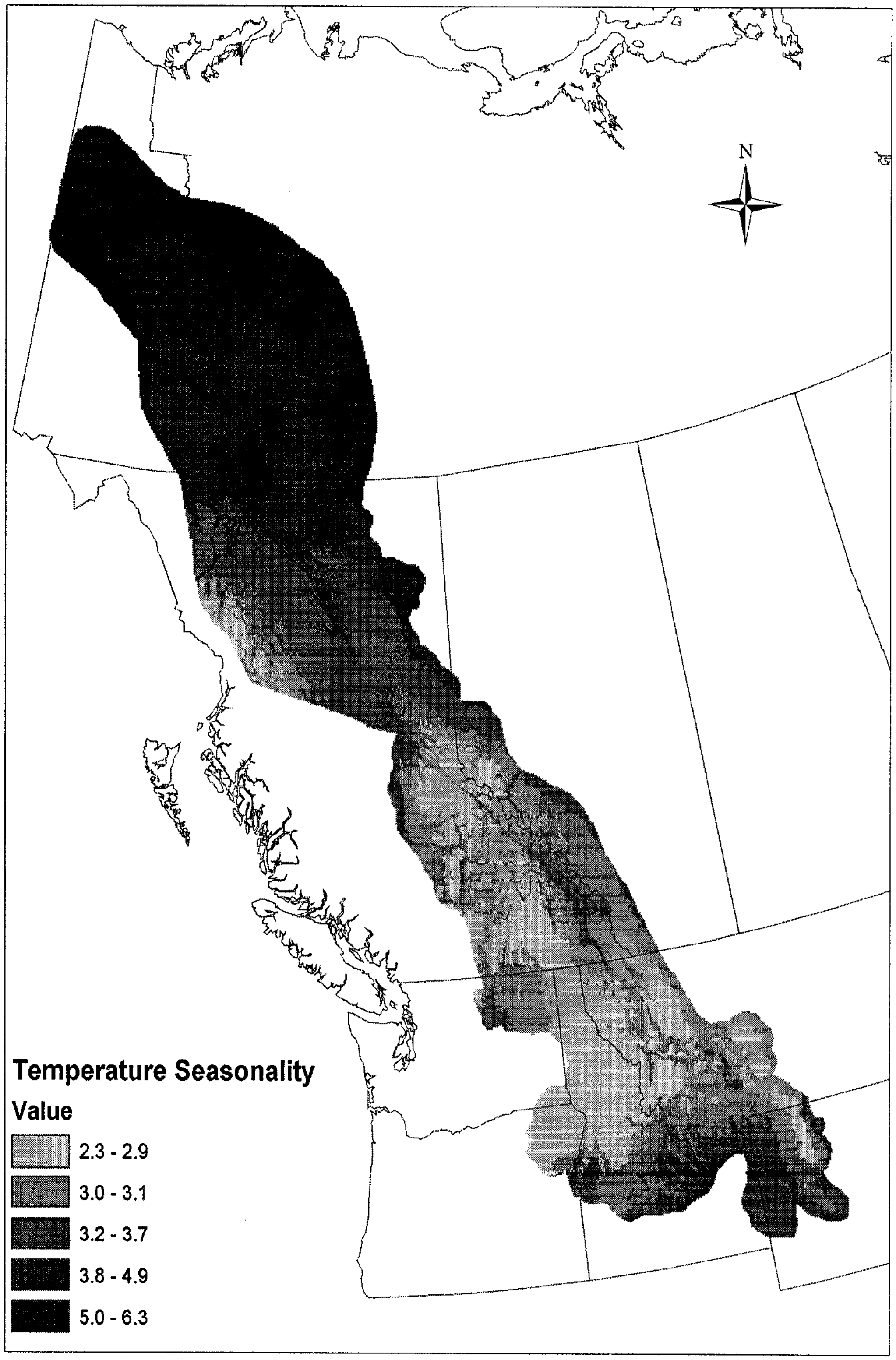


Growing Degree Days

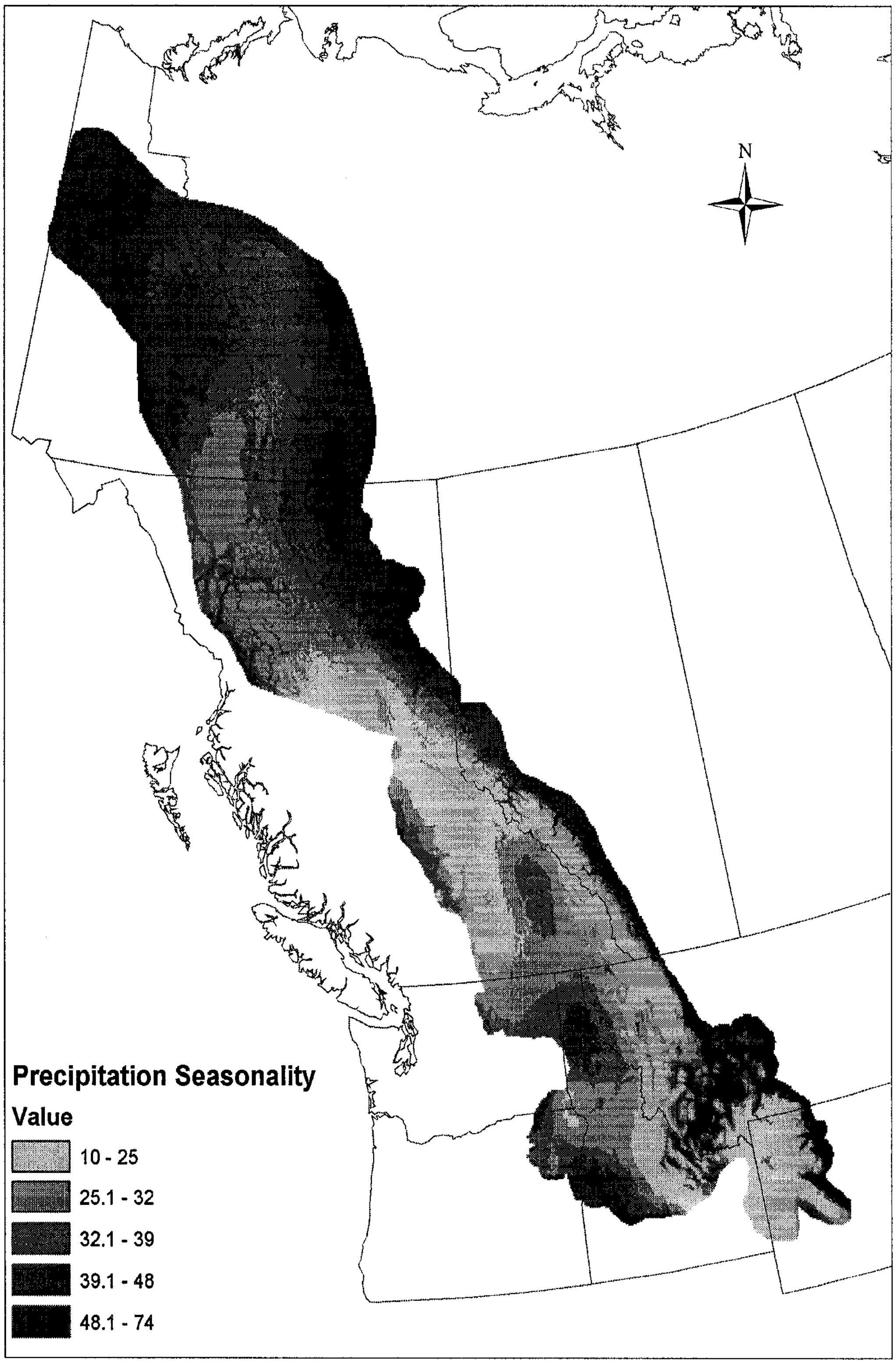
Growing Season Precipitation



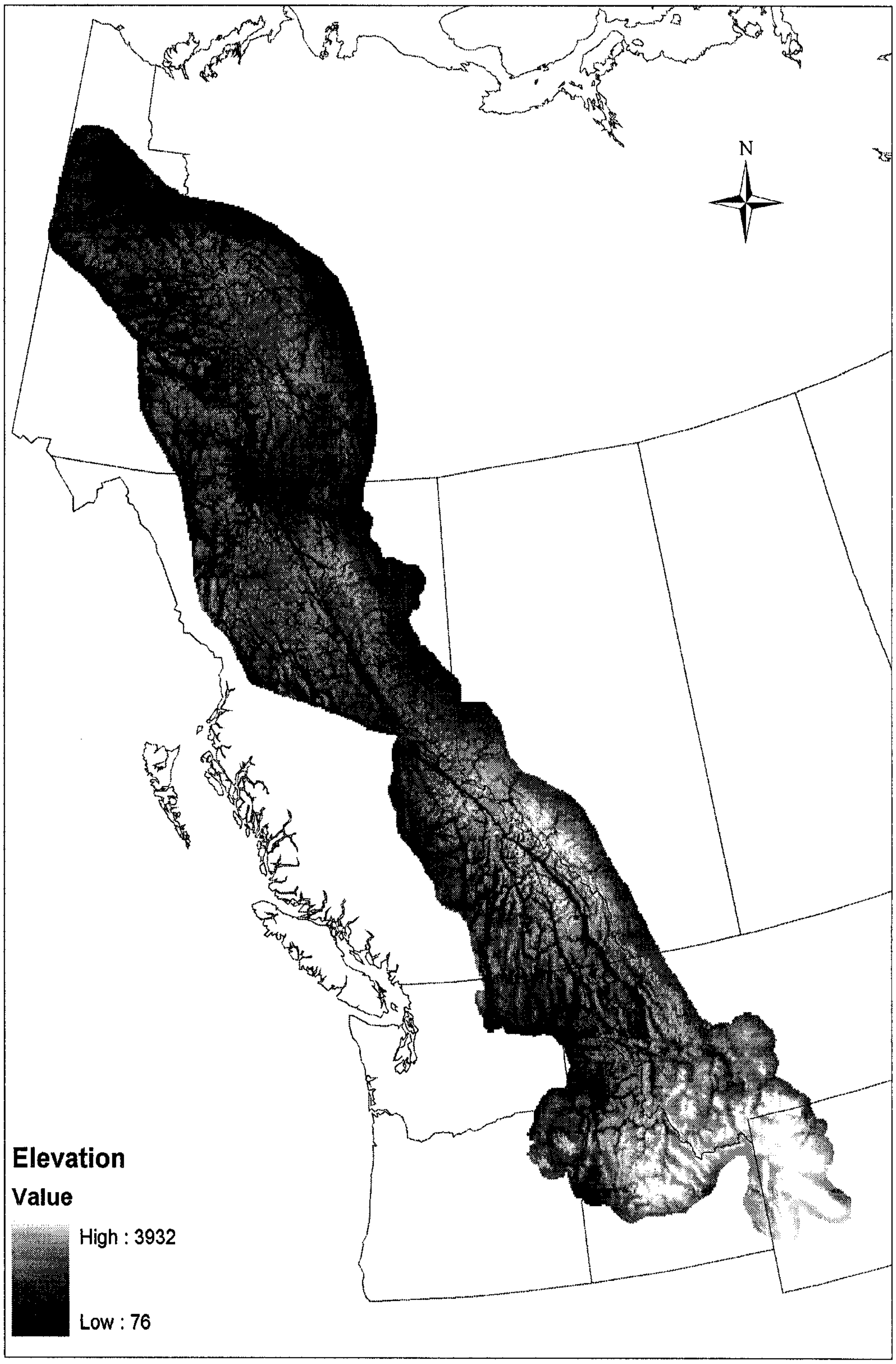
Temperature Seasonality



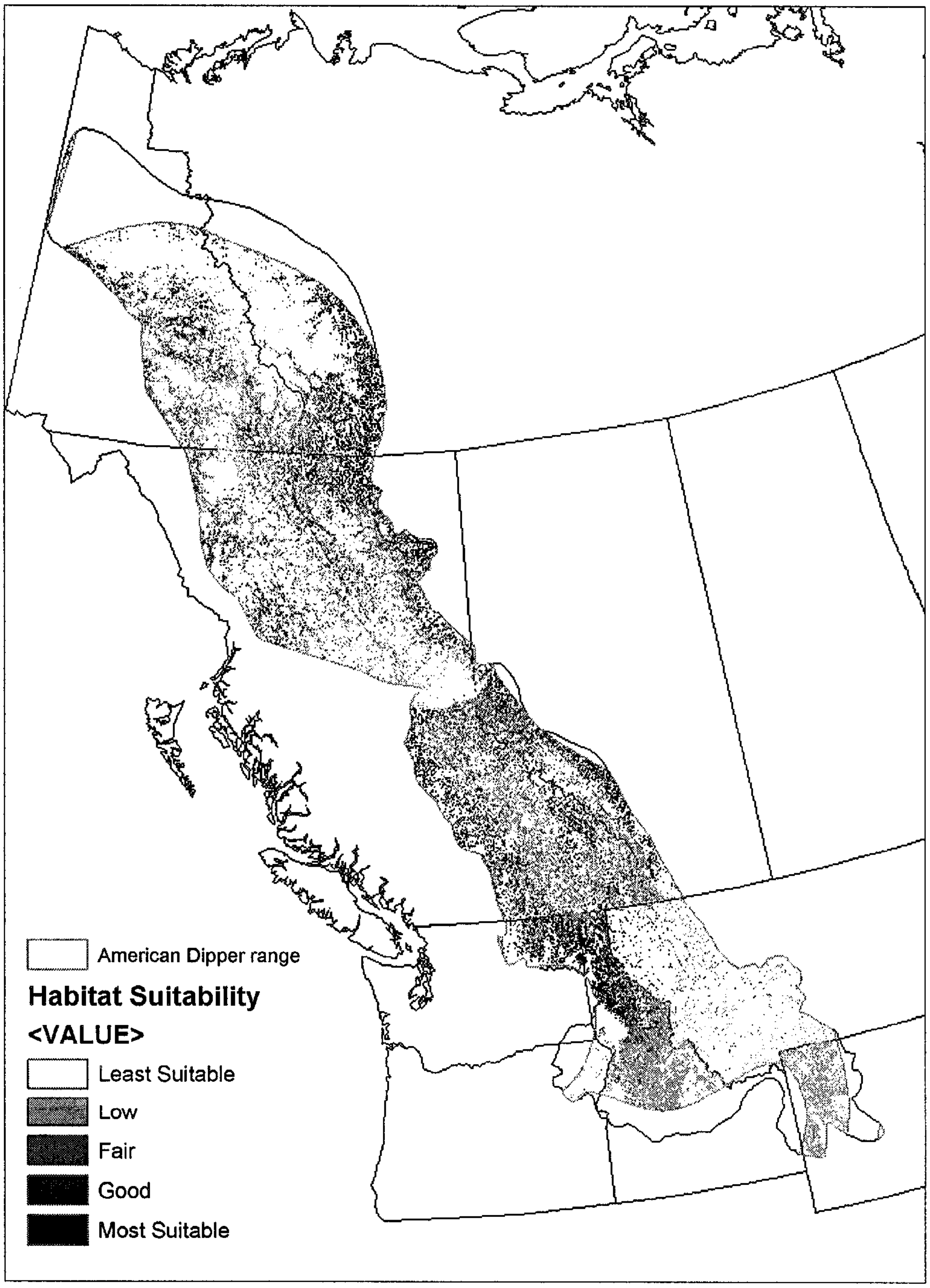
Precipitation Seasonality



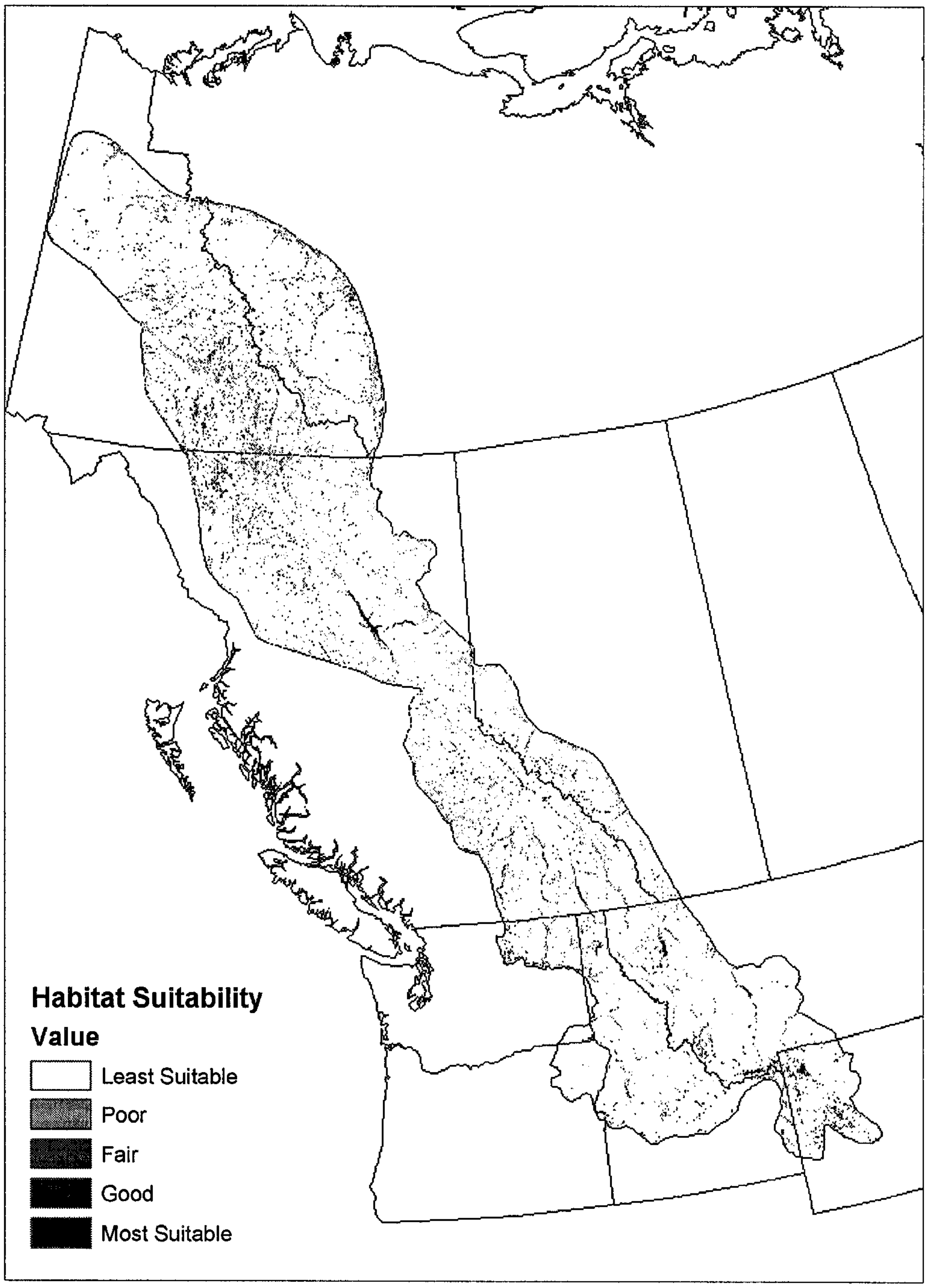
Elevation



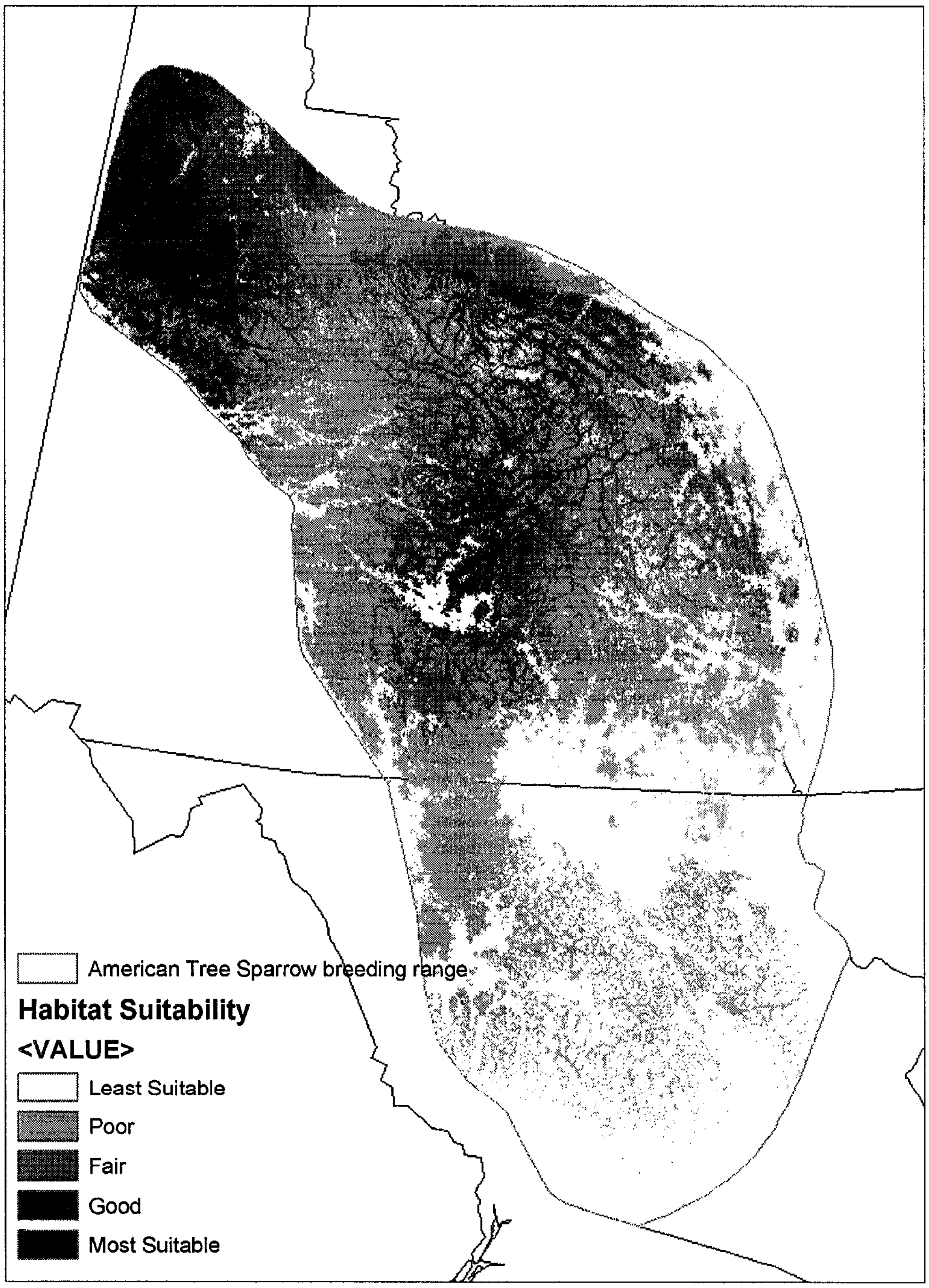
American Dipper (AMDI) Habitat Suitability



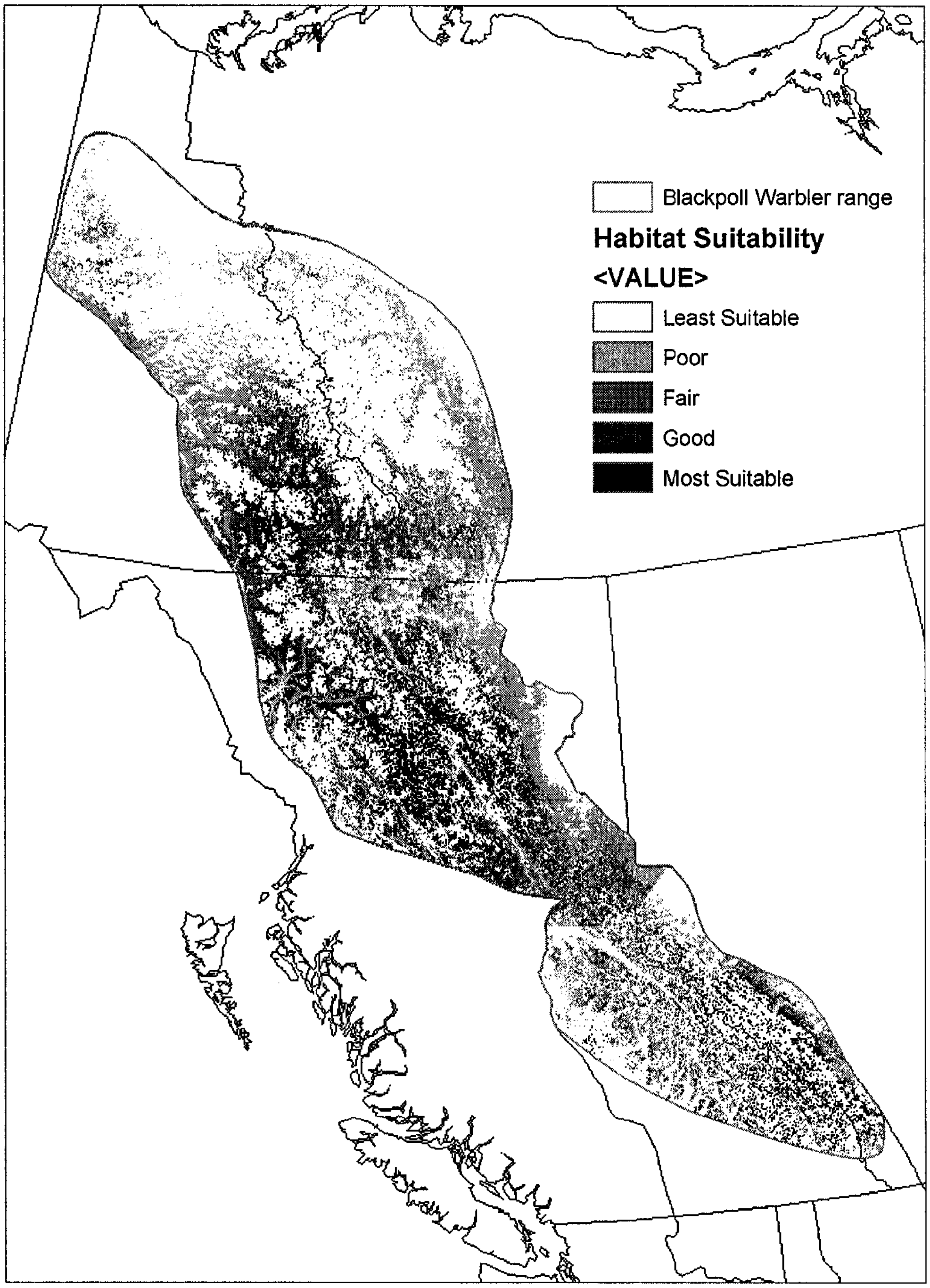
American Wigeon (AMWI)
Habitat Suitability



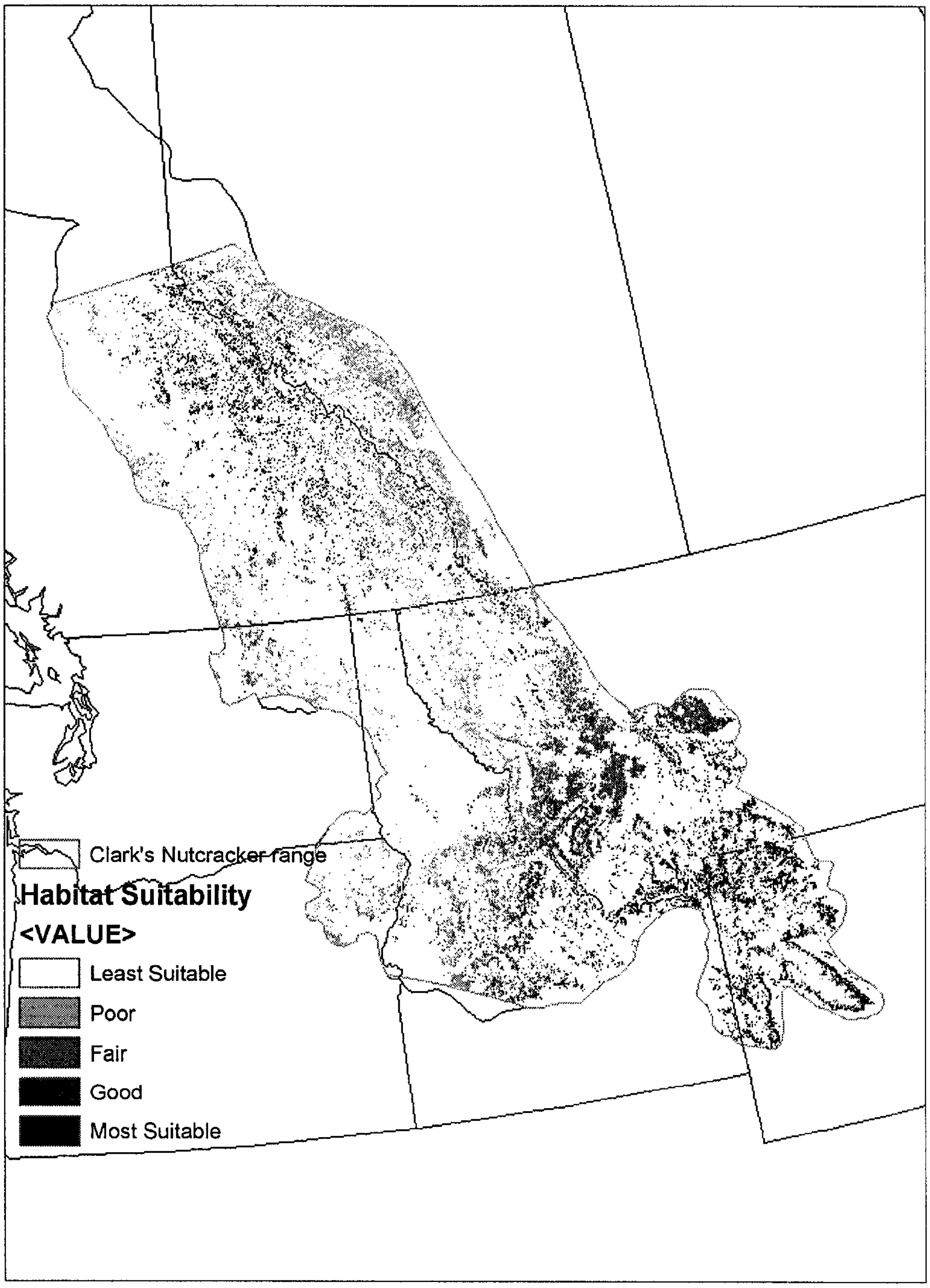
American Tree Sparrow (ATSP) Habitat Suitability



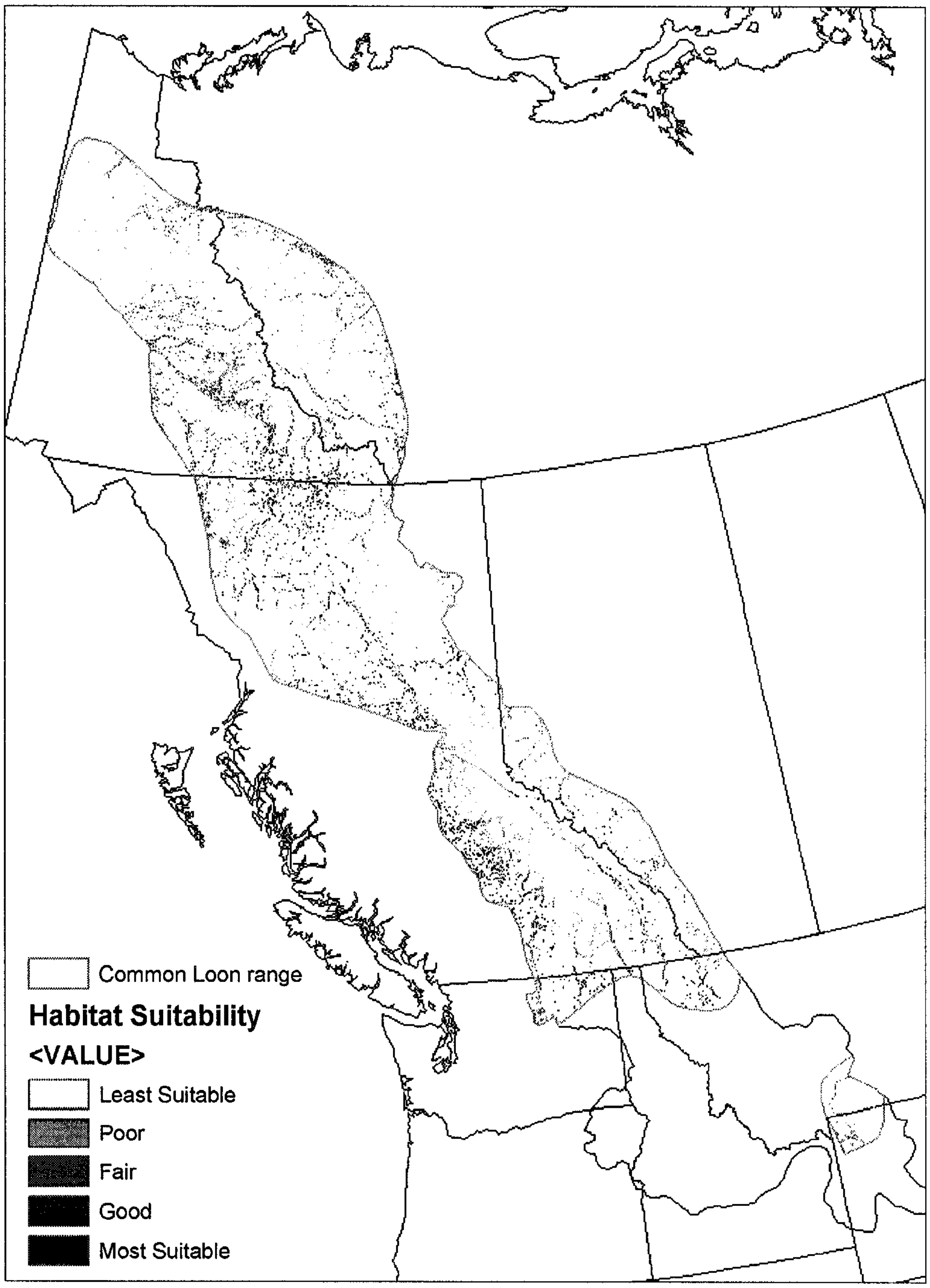
Blackpoll Warbler (BLPW)
Habitat Suitability



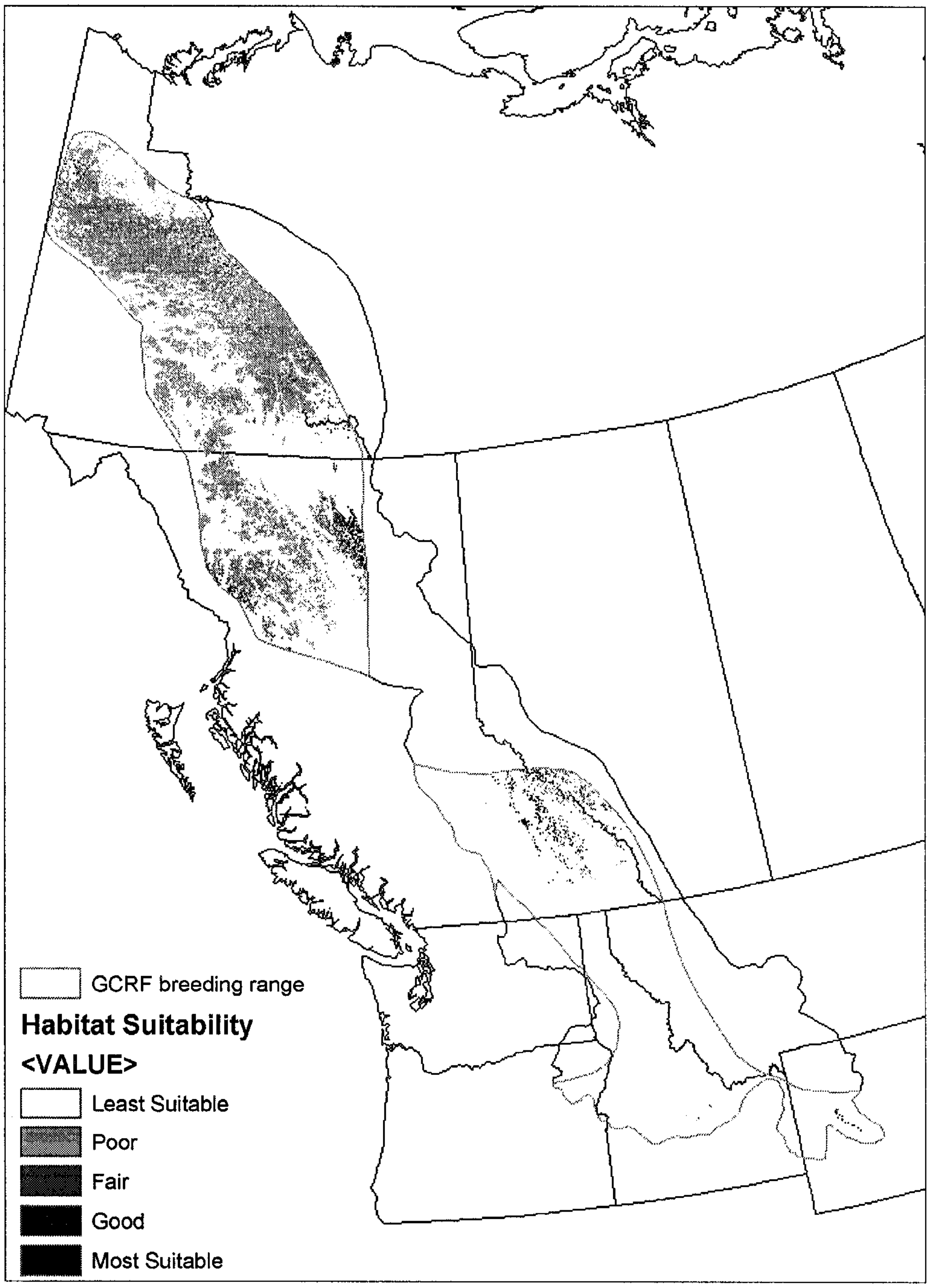
Clark's Nutcracker (CLNU) Habitat Suitability



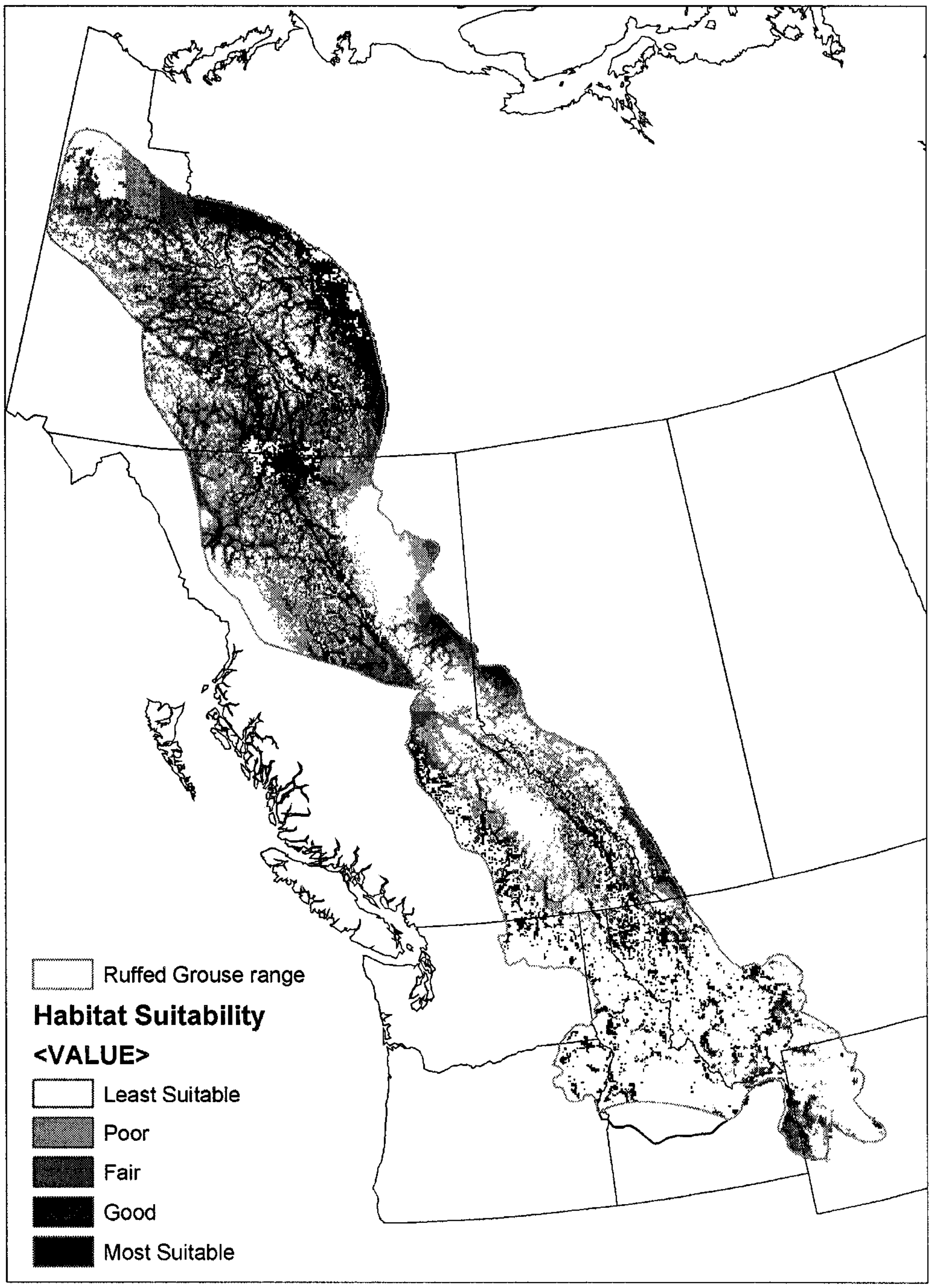
Common Loon (COLO)
Habitat Suitability



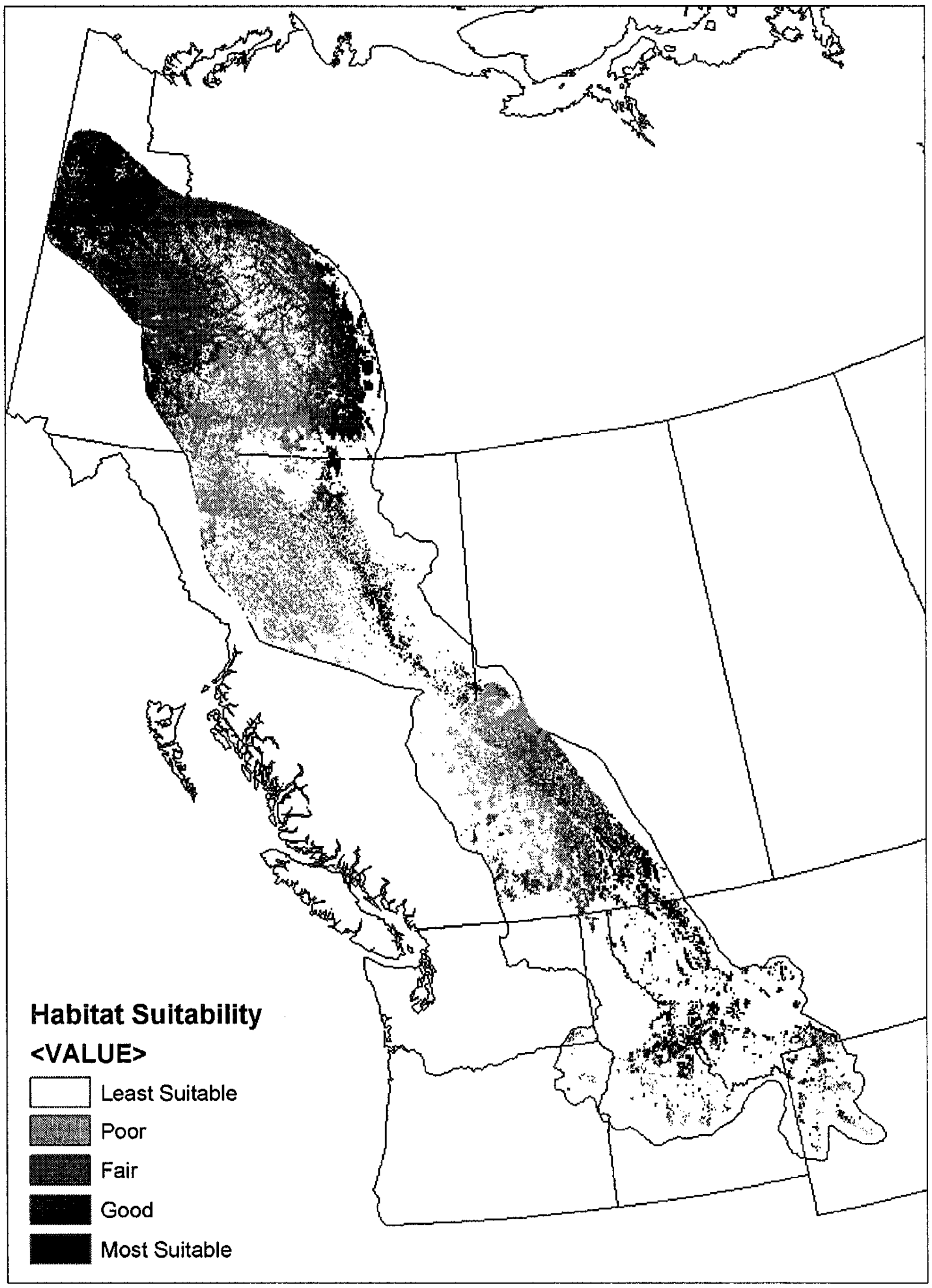
Gray-crowned Rosy-Finch (GCRF) Habitat Suitability



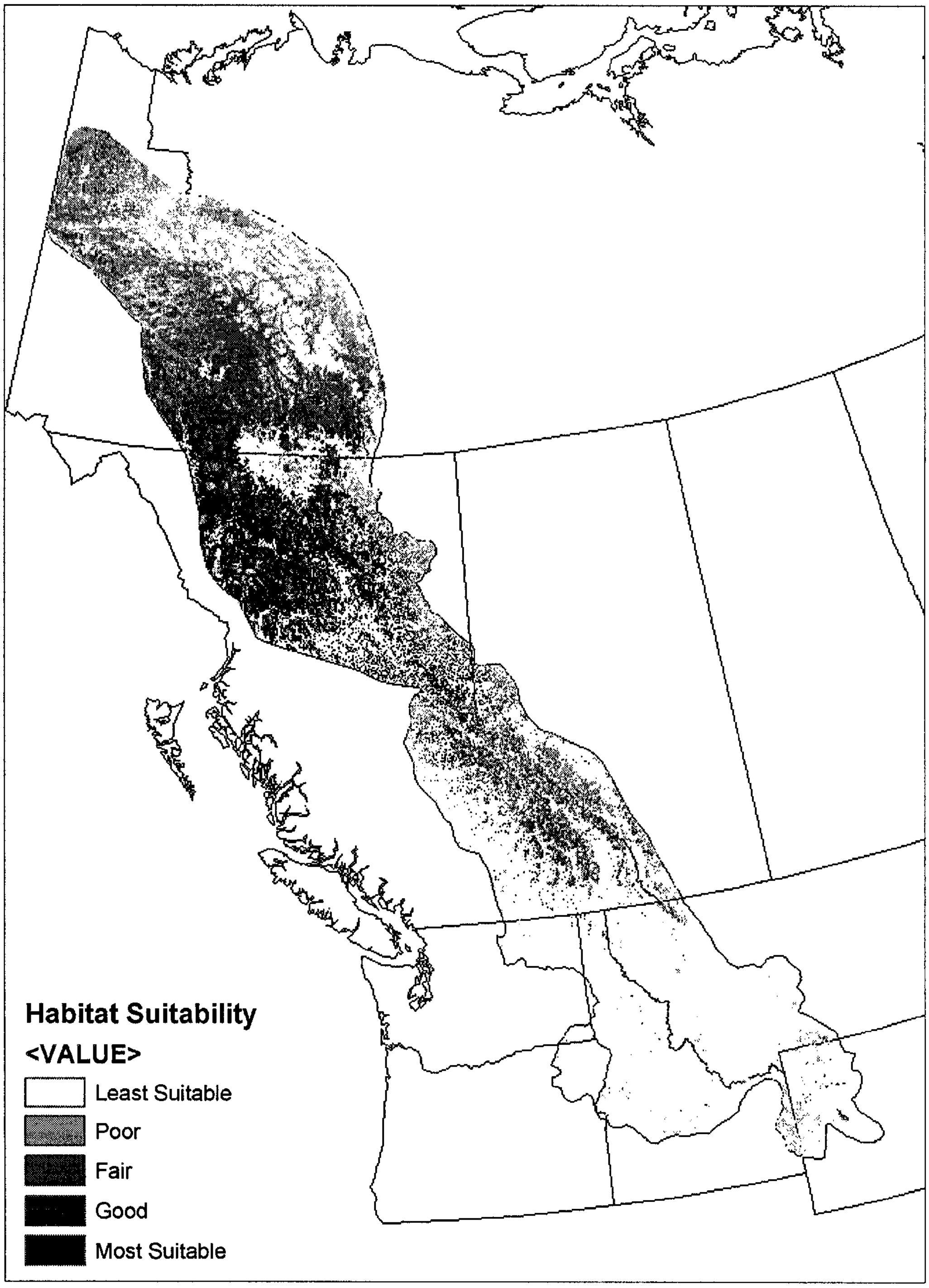
Ruffed Grouse (RUGR) Habitat Suitability



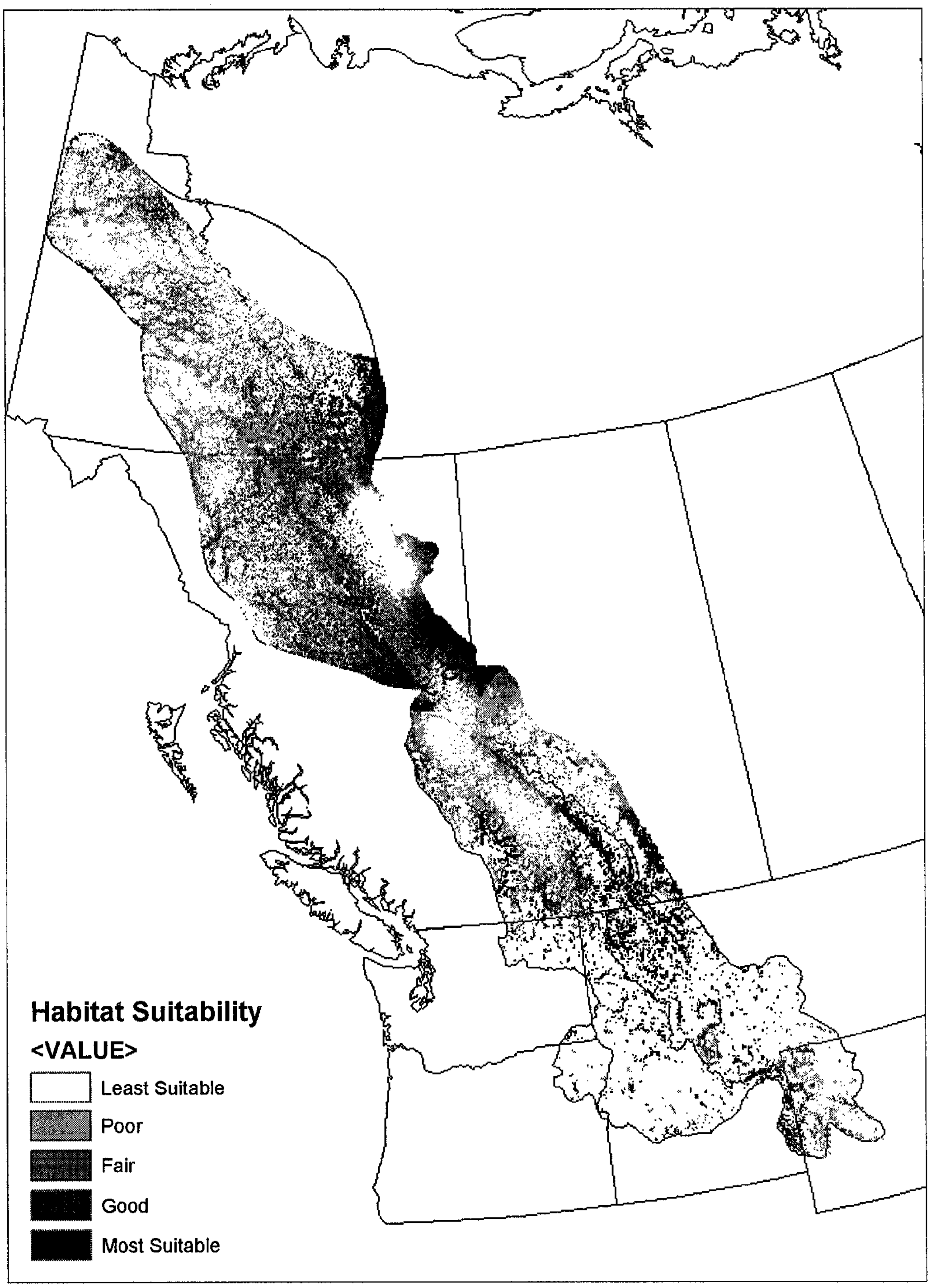
White-crowned Sparrow (WCSP) Habitat Suitability



Wilson's Warbler (WIWA) Habitat Suitability

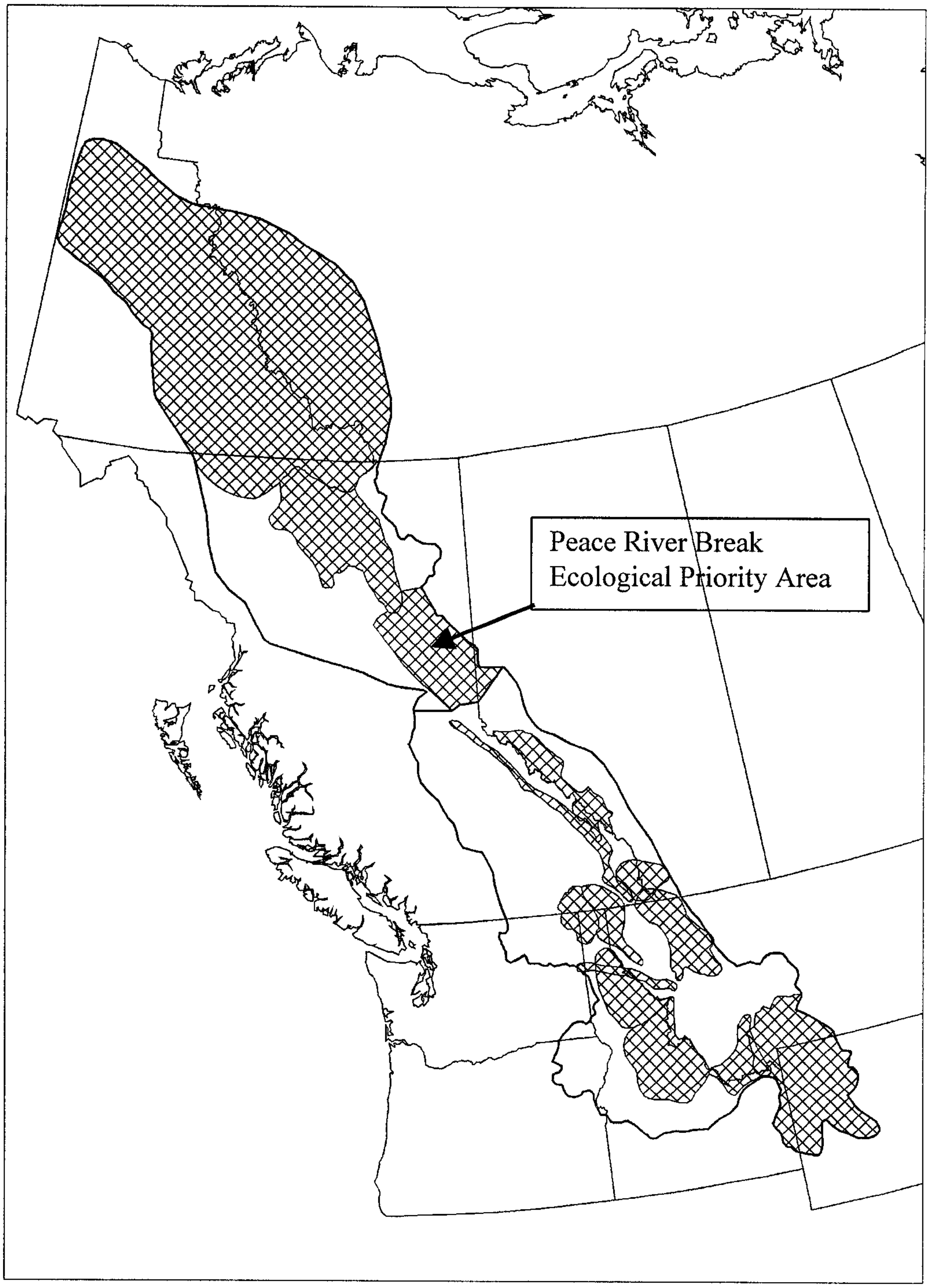


Yellow Warbler (YEWA)
Habitat Suitability

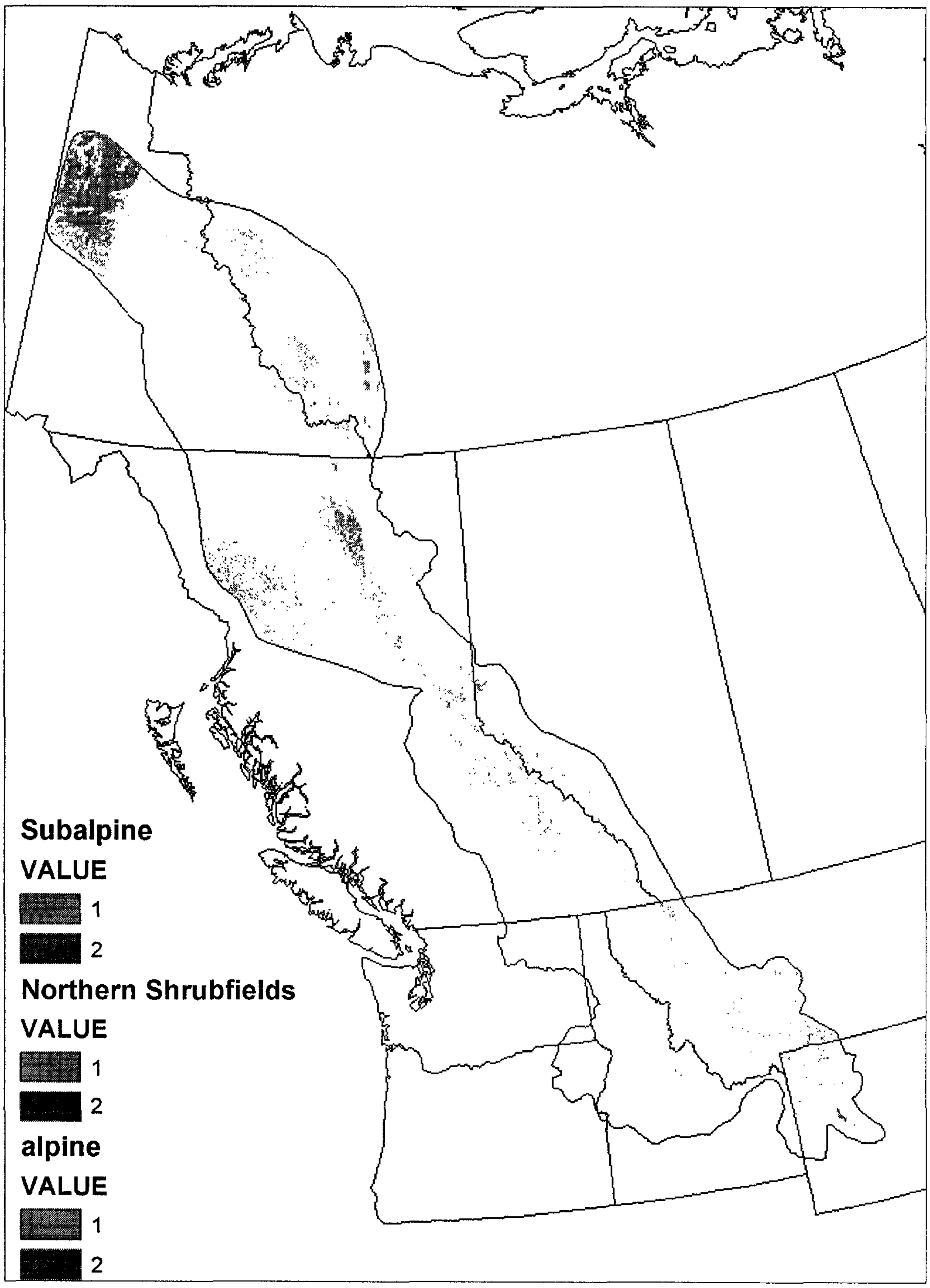


Appendix VIII: PowerPoint presentation "Habitat Quality Maps"

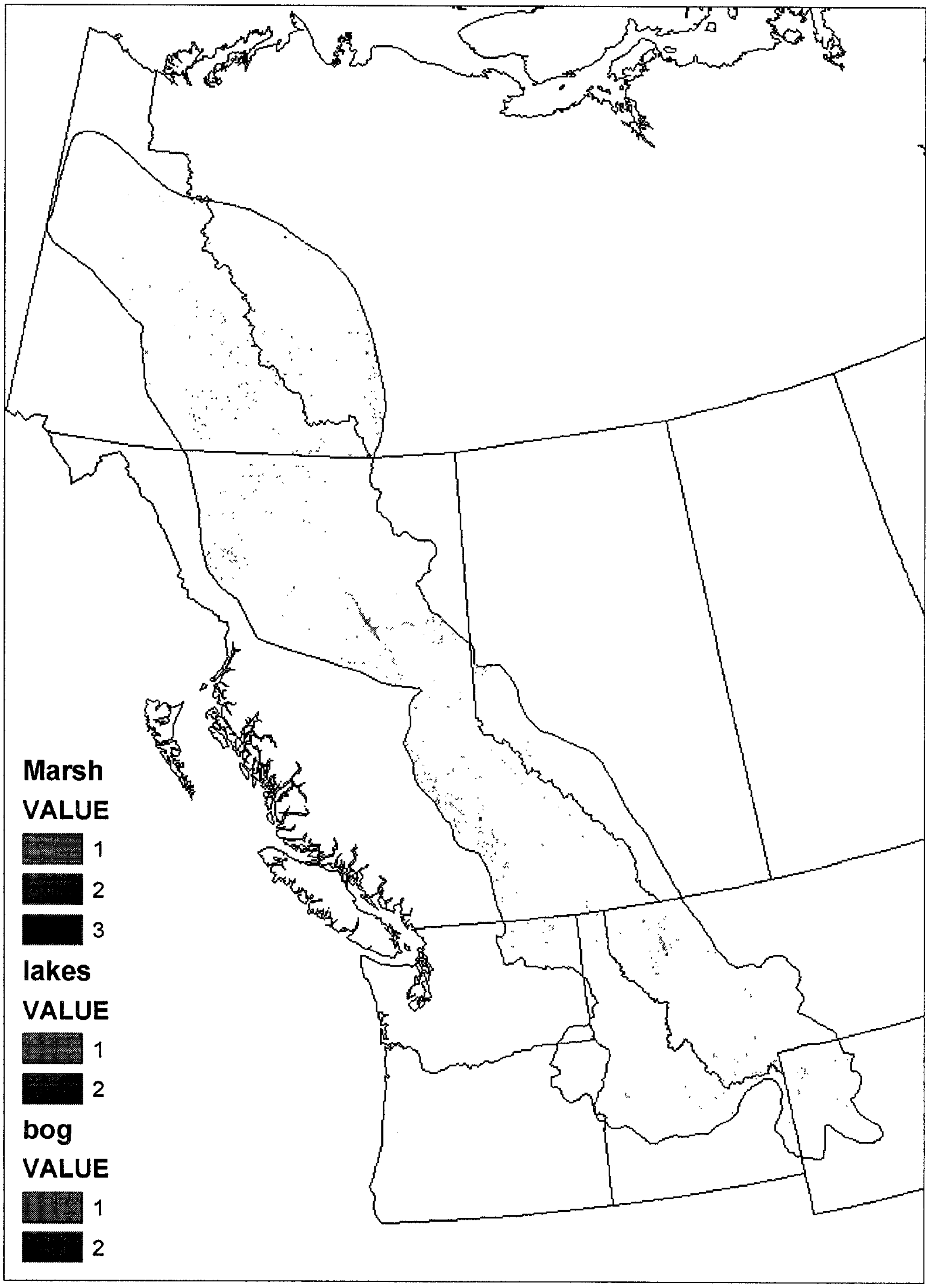
Y2Y North/South Regions used for habitat ranking



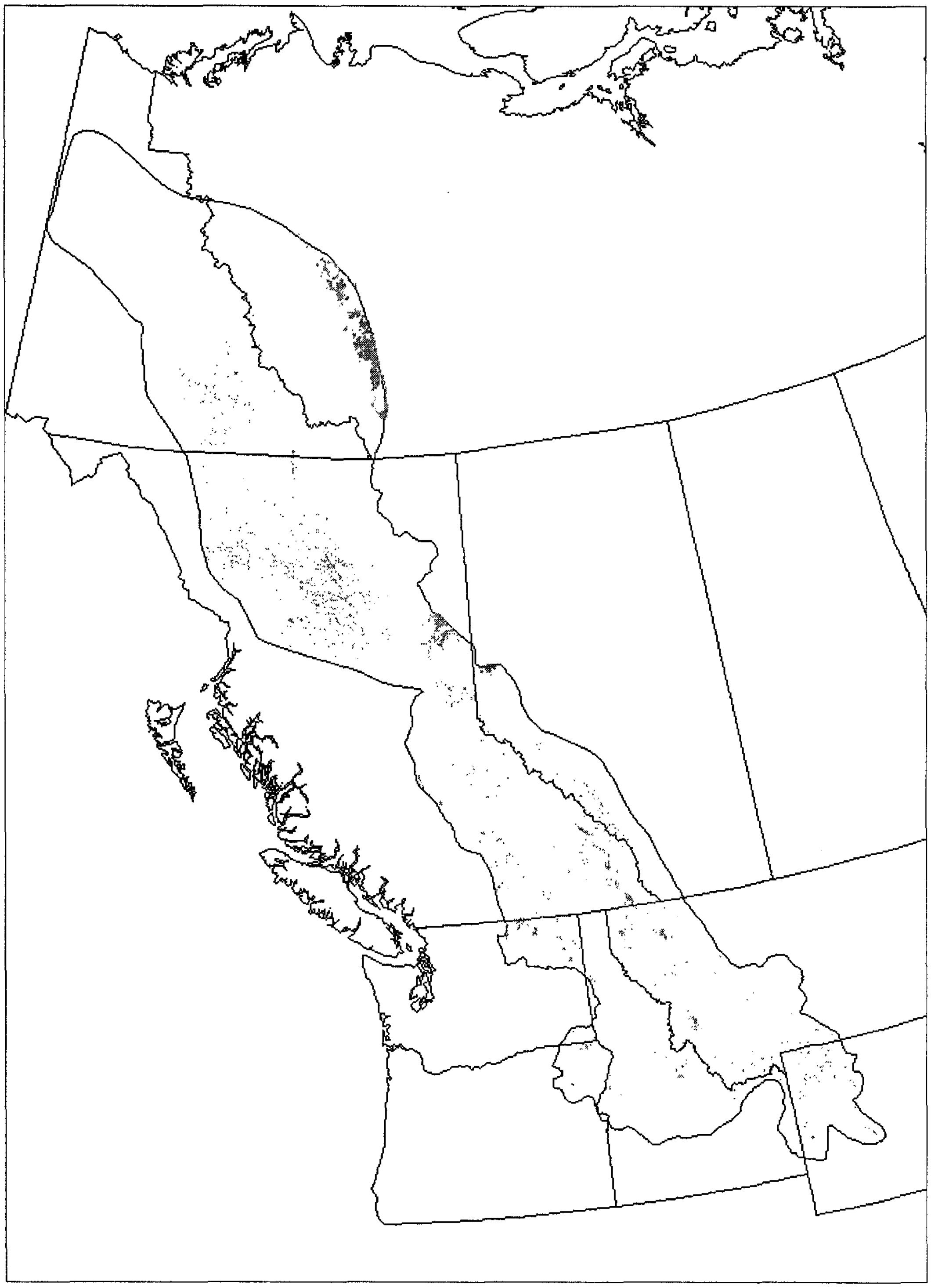
Alpine, Subalpine, Northern Shrubfields



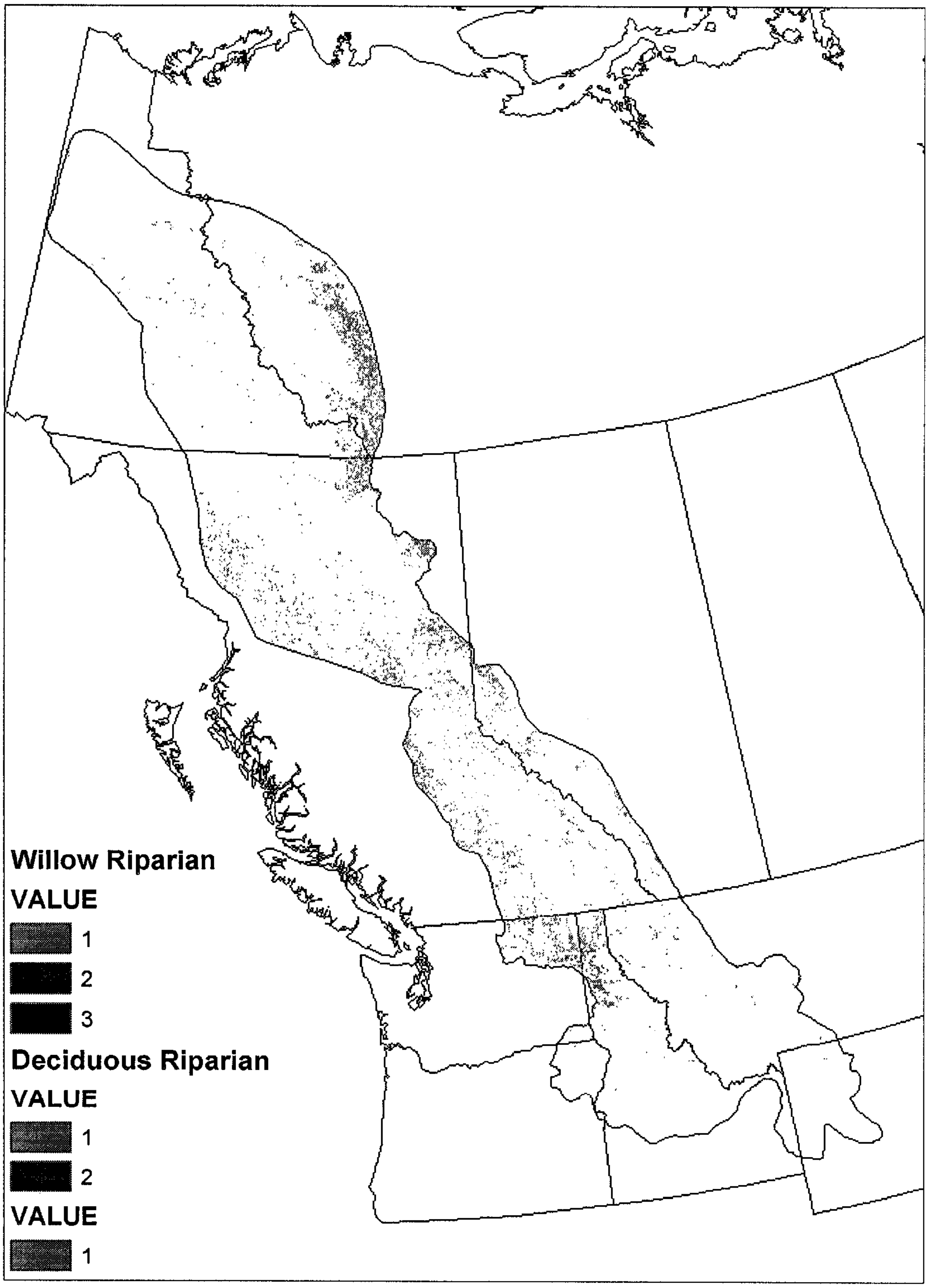
Marsh, Bog, Lakes



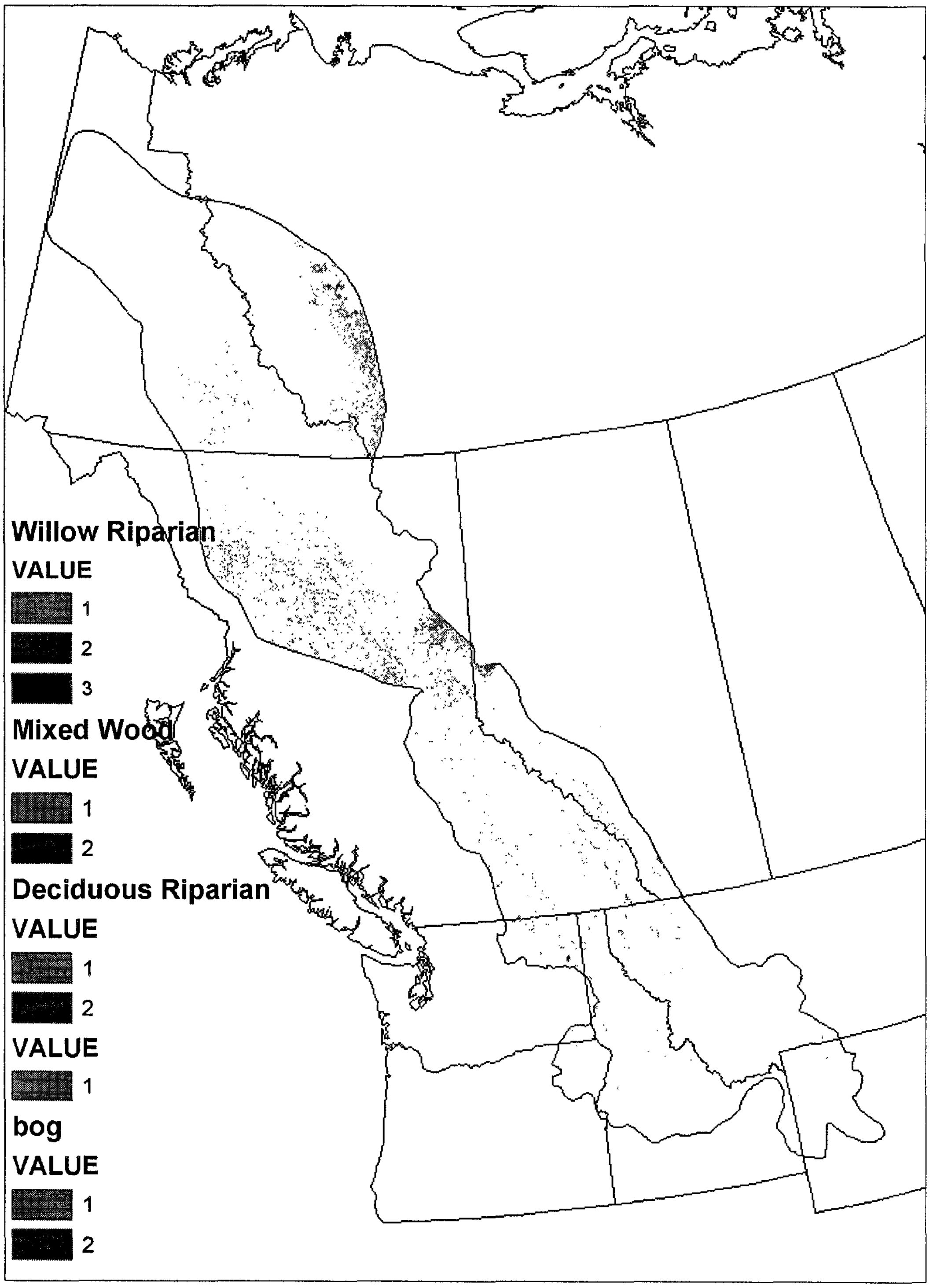
Forest Habitats (Aspen, Boreal, Mixed Wood, Ponderosa, Whitebark)



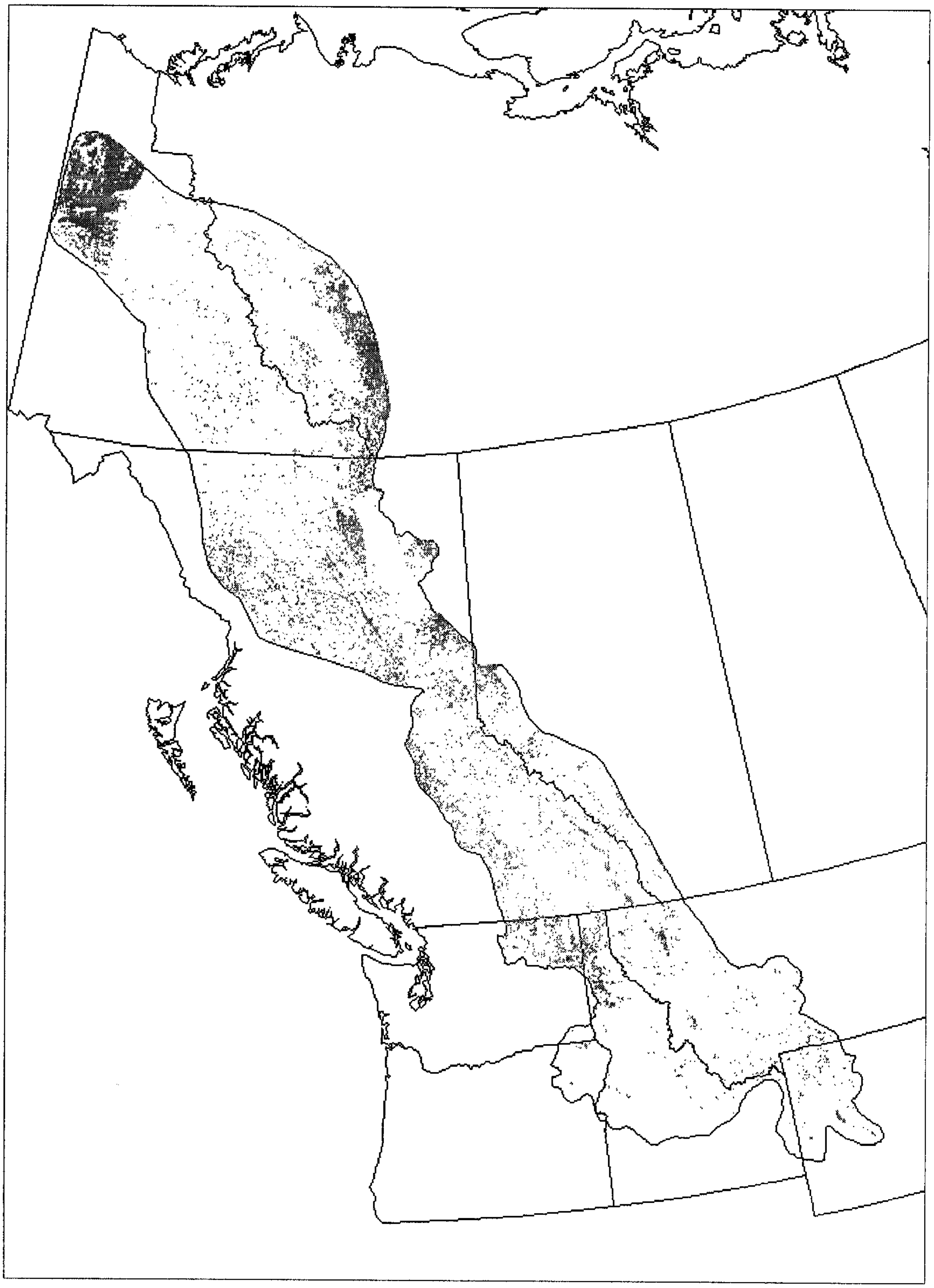
Riparian Habitats (Coniferous, Deciduous and Willow)



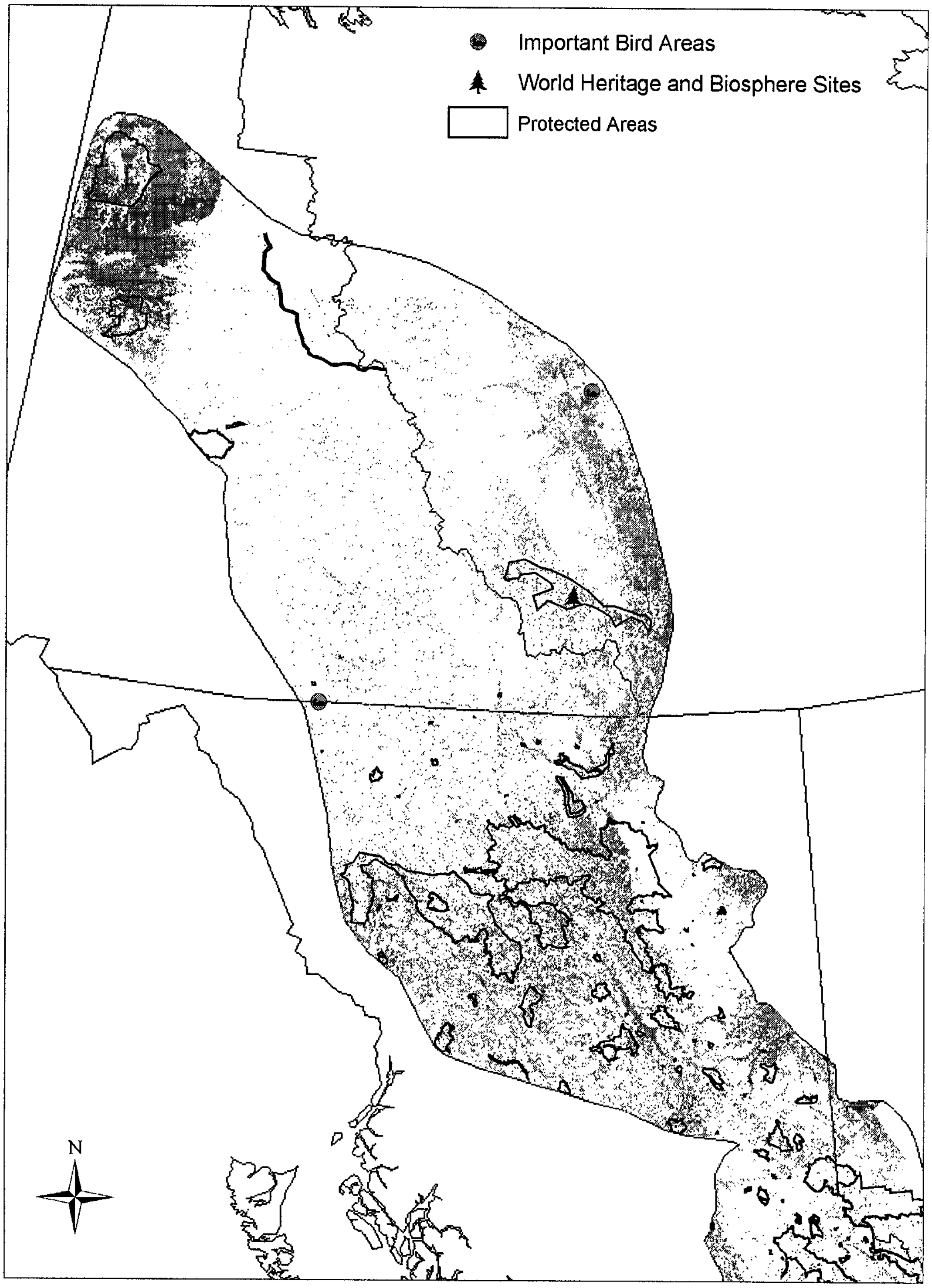
Boreal, Bog, Deciduous Riparian, Mixed Wood and Willow Riparian



All Habitats



Y2Y North high quality habitat and Protected Areas



Y2Y South high quality habitat and Protected Areas