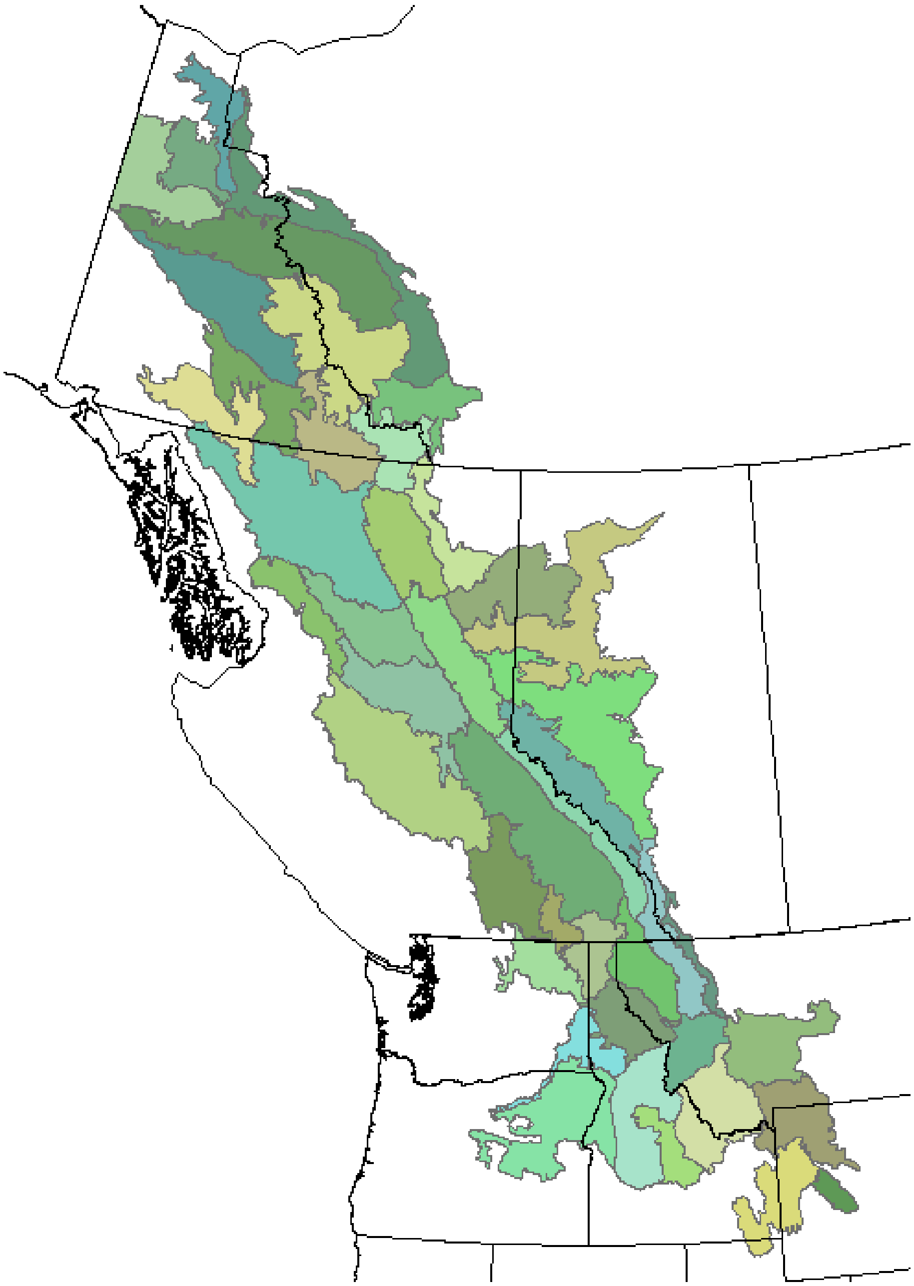
Development of Trans-boundary Ecoregions for the Yellowstone to Yukon Planning Area



Prepared for: Yellowstone to Yukon Conservation Initiative

Prepared by: Jonathan B. Haufler and Carolyn A. Mehl,
Ecosystem Management Research Institute

May 2002

EXECUTIVE SUMMARY

The objectives of this project were to develop a reconciled map of ecoregions across the Y2Y region, and to recommend a set of classifications for use within each ecoregion that would provide for description, delineation, and mapping of historical and existing ecosystems. The map of ecoregions was developed at a scale appropriate for classifying and mapping the historical and existing ecosystems within each ecoregion, and reconciled various classification systems presently being used within the Y2Y region. The recommended classification systems for use within ecoregions identified a similar level and description of historical and existing ecosystems within the Y2Y region.

Various classification systems have been developed for the identification of ecoregions. An ecoregion has been defined as an area "within which local ecosystems reoccur more or less throughout the region in a predictable pattern" (Omernik and Bailey 1997). Classification systems that were reviewed for use in this project included that of Bailey (1995), Omernik (1995), Wiken (1986), Canada's National Ecological Framework (Ecological Stratification Working Group 1996), British Columbia's Ecoregion Classification (Demarchi and Lea 1989), Alberta's Natural Region Land Classification System (www.cd.gov.ab.ca), and Hargrove and Luxmoore's Biophysical Classification (http://research.esd.ornl.gov/~hnw/esri98/). A map of ecoregions was produced through the reconciliation of maps of Bailey (1995), British Columbia's Ecoregional Classification (www.env.gov.bc.ca), and Canada's National Ecological Framework (Ecological Stratification Working Group 1996). The resulting map and descriptions (Appendix A, www.emri.org/Y2Y_ecoregions.htm, y2y data site) can be used to structure future Y2Y conservation planning projects and activities at finer scales.

Classification systems were also examined for use in describing and mapping specific ecosystems within the delineated ecoregions. Various classification systems have been proposed or are in use across the overall Y2Y region. Classification systems that were considered included: ECOMAP (Avers et al. 1993), habitat typing (Daubenmire 1968), British Columbia's Biogeoclimatic Ecosystem Classification (BEC) (www.for.gov.bc.ca), TNC's vegetation classification (Grossman et al. 1998), SAF's classification (Eyre 1980) and structural stages (O'Hara et al. 1996). We recommend two classification systems for use within the delineated ecoregions. In Canada, we recommend British Columbia's BEC at the plant association level including its description of seral stages. In the U.S. we recommend habitat typing (Wellner 1989) combined with a description of seral stages such as vegetation growth stages (Haufler et al. 1996). For each of these, we recommend some aggregation of BEC's plant associations and habitat types into groups or classes (Craighead et al. 1982, Mattson and Knight 1989, Haufler et al. 1996, Pfister and Sweet (2000), Hogg et al. 2001). However, we caution that past tendencies have been toward aggregating at too coarse a level, as certainly the habitat type series or plant alliance levels are too coarse for addressing biodiversity and ecosystem integrity objectives.

Use of these recommended ecoregions and ecosystem classification systems will provide the types and level of information needed to address Y2Y's avian and carnivore conservation objectives. While not the focus of this project, Y2Y's aquatic objectives would also benefit from the use of the ecoregion map and the identification of a similar aquatic ecosystem classification.

This project identified a number of future tasks that we think would enhance Y2Y's conservation planning and actions. These recommendations included the following:

- Analyze the BEC system for application in Yukon and Northwest Territories,
- Produce a trans-boundary classification and map of ecological sites for one or more ecoregions that cross the British Columbia- U.S. border.
- Describe and map ecological sites within all ecoregions,
- Quantify historical ecosystems and map by ecoregion,
- Map existing conditions for ecoregions using both ecological site and seral stage classifiers,
- Link ecological site and seral stages to bird species of concern,
- Develop integrated aquatic/terrestrial classifications for addressing multiple objectives within ecoregions, and
- Identify critical conservation areas based on these classifications.

INTRODUCTION

The Yellowstone to Yukon Conservation Initiative is about people working together to maintain and restore the unique natural heritage of the Yellowstone to Yukon region. Among its visions is to strive toward a day when natural resources are managed with the goals of ecosystem integrity and long-term economic prosperity in mind, and when all residents of the Yellowstone to Yukon region will take it for granted that their long-term personal, spiritual, and economic well-being is inextricably connected to the well-being of natural systems. But, what constitutes “natural systems” and “ecosystem integrity” in a region that stretches 3200 km from Wyoming to the Yukon/Alaska border? For some areas and ecosystems within the Y2Y region, this may not be difficult to answer. For other areas, the interactions of natural dynamics and anthropogenic changes are complex and far less obvious.

One way of defining “natural systems” and “ecosystem integrity” is in reference to what has occurred historically at a specific site or location. Historical in this context is typically considered a time-period of several hundred years prior to Euro-American settlement. There is a strong scientific foundation for using an historical reference for defining ecosystem integrity and biological diversity (Morgan et al. 1994, Swetnam et al. 1999, Haufler et al. 2002). It was the complex array of ecosystems and their arrangements and dynamics across the Y2Y region that supported and defined the diverse biodiversity of the region. Without an historical reference to these ecosystems and their processes, functions, compositions, and structures, defining both “natural” and “integrity” becomes problematic.

Ecosystems and habitats have and continue to be directly altered by human actions. While Native Americans interacted and influenced ecosystems for thousands of years, these influences are incorporated in an historical reference. It is the level and extent of human impacts over the last 100+ years that are of direct concern. Conversions of ecosystems to urban and suburban uses are the most obvious impacts. However, there are also less obvious, yet in some instances more pervasive, human-induced changes at the ecosystem level as well. For example, in the Rocky Mountains of the western United States and Canada, we have only recently begun to understand the implications of a century of Euro-American alterations to and interruptions of historical disturbance regimes. Yet, recent studies have shown that the suppression of historical disturbance regimes have gradually, but just as surely, changed ecosystem processes and ultimately the compositions, structures, and functions of many ecosystems. These compositional, structural and functional changes have also impacted the distribution and quality of habitat for many species. Therefore, important reference information for the identification of ecosystems or habitats in need of conservation includes a description and assessment of historical conditions as influenced by historical disturbance regimes. With such information, changes from historical conditions in amounts and distributions of ecosystems and the corresponding habitats of species can be mapped and quantified. Such information can be used to identify critical remaining areas of intact or "natural" ecosystems, highlight areas with greatest restoration potential, and describe historical habitat connectivity for selected species; helping the Y2Y Conservation Initiative meet its objective for maintaining and restoring the unique natural heritage of the Y2Y region.

The Y2Y Conservation Initiative spans not only a large geographic area, but a wide range of latitudes, elevations, geomorphologies, and climatic conditions. This range results in a corresponding range in ecosystem types, disturbance processes, and species occurrences. A challenge to conservation initiatives is in defining and addressing this range of diversity, and to accomplish this with sufficient attention to detail so that specific objectives for species habitat or ecosystem integrity are not overlooked, but for which a manageable amount of information is compiled. For an area the size of the Y2Y region, defining specific ecosystems and species habitats for the entire region is difficult because of its size and complexity. Dividing the Y2Y region up into smaller ecoregions that reduce the inherent variability and complexity of ecosystems within each ecoregion provides the ability to simplify the complexity of ecological information in an organized manner.

In order to understand and describe "natural systems" and "ecosystem integrity" using an historical reference, specific sites that differ in their processes, dynamics, functions, compositions, and structures need to be identified. Delineation of an appropriate map of ecoregions will reduce the overall complexity of ecosystems within each ecoregion of the broader Y2Y region. However, within each ecoregion, specific ecosystems must still be identified in order to address ecosystem integrity and species habitat objectives. Various classification systems have been developed for use within the overall Y2Y region. There may be some merit in developing a unique classification for the entire Y2Y region. However, the time, expense, and complexity of tackling such a task in addition to the question of need, given the past classification efforts that have already occurred, make using existing classification systems a more logical choice. Because different classification systems have been developed and are in use in different ecoregions of the Y2Y, it makes sense to conduct an analysis of these different systems and to recommend a combination of systems among the various ecoregions that will produce a similar description of sites for use in defining biodiversity, species habitats, natural systems, and ecosystem integrity.

This project was conducted to address two primary objectives. The first objective was to develop a reconciled map of ecological regions across the entire Y2Y area. This reconciled map of ecoregions was developed at a scale that will provide for an effective description and mapping of the mosaic of historical ecosystems at a finer scale within each ecoregion. The second objective of the project was to evaluate and recommend various classification systems available for use within the Y2Y region relative to their ability to describe and map historical ecosystems within the ecoregions delineated in the first objective. Because of the complicated jargon presently in use in describing classifications, scales, and mapping efforts, this report will begin with a discussion of terms and their application in this project.

Classifications, Scales, and Filters

Conservation of biological diversity can be approached through a number of different strategies (Haufler 1999). The overall strategy being used will help frame the appropriate classifications that may be needed to meet the specific objectives of the strategy. Filter refers to a type of strategy for conservation planning. Coarse filter refers to a strategy that is based on identifying the array of ecosystems that can occur and that if properly represented in the planning area will provide for the conservation of biological diversity. Fine filter refers to a strategy that is based on identifying the habitat needs of a species, groupings of species such as guilds, or categorization of species such as indicator species, keystone species, engineer species, and the like. The term filter does not address the size of the area included in the conservation effort, the resolution of the mapping used, or the level of detail in describing conditions. Scale is the term that applies to these characteristics. Scale refers to the resolution used in a mapping or classification effort. It can also refer to the size of the area being included in an assessment or planning effort, such as a broad-scale effort. In the former use of the term, mapping may be done at coarse scales (i.e., 1 km pixels), or fine scales (1 m pixels). We will not specifically address mapping resolution in this project, but will add a caution that conservation analyses based on coarse scale mapping may produce biased results by eliminating ecosystem types that only occur in small or narrow patches, and by masking the inherent heterogeneity of landscape conditions.

The Y2Y Conservation Initiative has both a coarse filter and a fine filter focus. Ecosystem integrity is a concept applied to the compositions, structures, functions, and processes of ecosystems (Haufler et al. 2002), and relates to a coarse filter approach. Developing conservation strategies for carnivores or birds are fine filter approaches to conservation planning. Y2Y is using these approaches across its broad planning area, but to be effective, it will need to consider relatively fine scale information on ecosystem types and distributions to address the habitat needs of many species.

Resolution also refers to how finely a classification describes different types of conditions, such as vegetation communities. Identification and selection of appropriate classification systems and the scale to apply these classifications for biodiversity conservation efforts are interrelated in several ways. Understanding these interrelationships is important to discussions of appropriate classifications for use at different scales.

Ecosystem and watershed are two terms commonly used in classification efforts. Definitions of both terms are generally accepted, but considerable discussion has occurred about their appropriate application in conservation planning (Omernik and Bailey 1997). Terrestrial ecosystem is a discrete area that can be characterized by its plant and animal communities as well as the associated abiotic conditions. The term ecosystem has no specific scale associated with it. A watershed is an area from which all water will flow to the same outlet. As with ecosystem, watershed has no specific scale associated with it. An ecoregion is an area “within which local ecosystems reoccur more or less throughout the region in a predictable pattern” (Omernik and Bailey 1997). A landscape is an area containing a variety of ecosystems but the boundary of the landscape may or may not have been delineated to reduce the variability within ecosystems. Neither ecoregions nor landscapes have a specific scale associated with them, but they are assumed to encompass enough area to contain a range of identifiable ecosystems. Ecoregions are designed to contain ecosystems with some degree of similarity, while landscapes may contain a range of ecosystems delineated for any number of reasons including ecological, administrative, political, or social.

Classification refers to categorizing areas into similar groupings, such that conditions within one category of a classification are more uniform than compared to conditions in other classification categories. Depending on objectives, classification systems of land areas, ecosystem conditions, administrative boundaries, or habitat variables may or may not provide the information needed to develop conservation plans under either coarse or fine filter strategies. However, as discussed in the Introduction, describing and mapping natural ecosystems at appropriate resolutions is a goal of most broad-scale conservation planning efforts.

Numerous classification systems are available for conservation planning efforts and must be carefully evaluated relative to the conservation strategy and project objectives. Different classifications have been developed for different purposes, and different classification systems have been developed for similar purposes. Some classifications are conceptual and span all areas but lack specific development for application to any one area. Other classifications have been developed for one specific area and purpose. The objective of this report is to compile, evaluate and reconcile many of these differences, and to recommend a cohesive method of using various classification systems within the Y2Y conservation effort.

CLASSIFICATION SYSTEMS

Grossman et al. (1999) provide an overview of many classification systems. Specific classification systems may emphasize terrestrial systems, riparian/wetland systems, or aquatic systems. A few attempt to integrate across these ecosystem types. One group of classification systems has been developed for delineating regions with greater similarity of ecosystems within each region than among other regions, i.e., ecoregion classifications. Other classifications are designed for more specific ecosystem classifications applicable to specific sites on the ground. Some classification systems are hierarchical while others are single level. Some classify ecological sites that may be the same in terms of the abiotic environment or potential vegetation that can occur at a site, while others classify existing vegetation or conditions regardless of the underlying abiotic conditions. Some classification systems are based on a single factor or variable while others use multiple factors for classification. Some classification systems are based on descriptions of natural ecosystems while others are designed to also accommodate anthropogenic conditions. The variability in types of classification systems is the result of classifications that are; 1) developed for different purposes or scales, 2) based on different ecological or conservation strategies, and 3) based on different assumptions or interpretation of ecological information.

Classification systems can either be hierarchical or single level. Hierarchical classifications can be nested in terms of increasing level of detail of the classification itself. For example, TNC's classification (Grossman et al. 1998) adds additional levels of detail to its description of community types. The TNC classification uses 7 levels of increasingly finer detail to more specifically define the vegetation occurring in an area. In this example, finer levels of the hierarchy provide additional information on the types of vegetation present, down to an association of species that typically occur together. Classification systems can also be hierarchical in scale in terms of defining areas of increasing homogeneity of geology, climate, and potential vegetation. Bailey's classification system (1995) nests increasingly finer delineation of areas based on similarities of geology, climate, or vegetation characteristics. Similarly, the National Classification of Ecological Units, also termed ECOMAP (Avers et al. 1993, Cleland et al. 1997) has 8 levels of hierarchy that classify increasingly specific land areas that nest within each other.

A number of ecoregion classification systems have been developed. Some are designed to function hierarchically, as discussed above, while others are designed to differentiate different regions at one specific level. Some classifications attempt to delineate regions based on watersheds, while others base delineations on climate, soils, or vegetation differences. A number of publications contrast watershed and ecoregional approaches (i.e., Omernik and Griffith 1991, Maxwell et al. 1995, Montgomery et al. 1995, Omernik and Bailey 1997).

At finer scales, classifications are used to distinguish different ecological sites, land types, vegetation conditions, etc. The purpose is to delineate specific ecosystems or vegetation types that have greater homogeneity of conditions within that ecosystem or vegetation type than in comparison to others. Two different classification approaches are those that classify different ecological sites, with a primary focus on the capability of a particular site to support similar potential vegetation, and those that classify existing vegetation. Those that classify ecological sites typically do not include a description of what is currently present at a particular site, but they do provide for the description of the successional trajectory of communities that can be supported by the abiotic conditions at that site as well as providing for the description of historical conditions. For example, habitat typing (Daubenmire 1968, Pfister and Arno 1980, Steele et al. 1981) describes the potential natural vegetation at late succession that could occur at a particular site based on the presence of indicator species. Classifications of existing vegetation provide a description of what is at a site at the present, but typically don't provide for an understanding of the successional trajectory or past disturbance regimes that apply to that site. Some existing classifications focus on dominant species (Eyre 1980) or associations of species (Grossman 1998), while others may classify stands on structural attributes (O'Hara et al. 1996).

Many classification systems base their classification on one factor, such as existing vegetation conditions. Examples of single factor classifications include habitat typing and the TNC system. Others will use multiple factors to classify sites, such as ECOMAP (Cleland et al. 1997) that uses soils, ground water proximity, and vegetation to classify a site. Biophysical classification systems, such as that of Hargrove and Luxmoore (http://research.esd.ornl.gov/~hnw/esri98/) classified sites without use of vegetation as an input variable. Hessburg et al. (2000) recently completed an analysis of regional conditions based on a combination of empirically derived information on abiotic factors and potential vegetation.

Classification systems that describe successional trajectories, potential natural vegetation, or natural ecosystem compositions or structures do not typically incorporate anthropogenic conditions particularly well. Classifications that describe existing vegetation in terms of species dominance or structural characteristics are more capable of characterizing the range of conditions that can occur with human modifications.

INTERACTIONS OF SCALE, HIERARCHIES, AND CLASSIFICATIONS

The above discussion points out the diversity of classification types that are currently available to conservation efforts. While some classifications are designed for a specific purpose, most attempt to provide a better description of the pattern of vegetation or ecosystems in an area. When using classification systems for conservation planning, consideration of the interaction of scales, hierarchies, and resolution of classifications is important.

There is a relationship between the size (relative to ecological variability) of area that a specific ecosystem classification is to be applied, the resolution of the classification system, and number of specific ecosystem units that will effectively define a coarse filter or species habitat. A major function of hierarchical classifications of ecoregions is to reduce the size of area based on factors expected to reduce the variability within finer scale ecosystems. Planning over too large and diverse an area generally results in one of two probable outcomes, either the number of ecosystems that must be addressed within the classification becomes so large as to be cumbersome or unmanageable, or the resolution of the classification system is reduced, and the classification of ecosystems may become too general for conservation purposes. For example, TNC's classification system (Grossman et al. 1998) was developed for nationwide application, and resulted in 4149 associations of terrestrial communities based on existing vegetation. This represents a relatively fine classification of plant associations, but can be difficult to apply at this level. Gap analysis (Scott et al. 1993) used the TNC classification system for planning at the scale of individual states, but only applied the classification system at the alliance level, which reduced the overall number of ecosystems to 1571. This also reduced the ability of the analysis to identify potentially important ecosystems. Maps of habitat suitability for selected species produced from these maps are very general, and allow little discrimination of high quality habitat. The broad scale used in Gap analysis required researchers to use the coarse classification level, but in doing so they sacrificed much of the detail needed to characterize important ecosystems and habitat.

Following this line of reasoning, why not conduct planning using a small-sized unit of a hierarchical classification system? For example, why not conduct assessments and planning at the landtype association level of ECOMAP (Cleland et al. 1997)? These are areas that are typically 1,000's to 10,000 acres in size. At this scale, the variability and diversity of ecosystems is greatly reduced. However, the ability to address issues such as the viability of many species as well as provide suitable representation of all successional stages for a particular type of ecological site can be compromised because of the small amount of area available for planning. In addition, the smaller the individual planning areas, the greater the difficulty of coordinating planning across this larger number of planning landscapes. In addition, many ecosystems classified within very small planning areas do not appear to differ significantly across adjacent planning areas. Landtype associations differ from other nearby landtype associations primarily in the amounts of ecosystems present, rather than in differences in the ecosystems themselves, although more research on ecosystem variability across scales of landscape classification is warranted. Thus, identification of an appropriate size of ecoregions for use in conservation planning is a very important decision that must balance attention to detail with feasibility of tracking numbers of ecosystems, number of planning landscapes, and sufficiently large areas to address complex species needs.

These examples point out several things. First, hierarchical classification of ecoregions can help to define boundaries of smaller-sized planning landscapes that can further help in maintaining sufficient resolution of lower level ecosystem classification while keeping the number of categories to a manageable number. Decisions about the correct size of the ecoregion to use in planning must consider the different types of ecosystems defined for the ecoregion, and whether these ecosystems are sufficiently uniform throughout the ecoregion. If the selected ecoregion is too large, then a specific ecosystem type defined by the classification system may differ considerably (e.g., species that are less dominant may differ significantly) from one location in the ecoregion to another. This condition could be corrected by reducing the size of the ecoregion for planning purposes, or by increasing the resolution of the classification system so that each ecosystem type is defined specifically enough that it doesn't show great variation across the ecoregion. If a smaller ecoregion were delineated instead, then the same ecosystem type could apply to both ecoregions, yet the slight but important differences in the ecosystems relative to conservation planning would be captured in the overall classification system. As long as the ecosystem was properly considered in conservation planning for each ecoregion, the overall complexity of the specific ecosystem is maintained without additional resolution of classification within an ecoregion. Conversely, if too small an ecoregion is selected, the area may not provide enough options to allow representation of all ecosystem types and their disturbance-response conditions to assure the attainment of biodiversity objectives within the planning area.

To illustrate some of these relationships, an example using ponderosa pine ecosystems can be provided. Ponderosa pine is a species with a wide distribution in the Interior West. It is an ecosystem that has adapted to short-interval understory burns that maintained large, old ponderosa pines with open understory conditions. While this is generally true throughout the range of the species, many specific ponderosa pine ecosystems can be identified throughout this range. On drier sites, ponderosa pine is the potential natural vegetation of the site. On these sites, it will be the dominant species with or without the understory fires. However, where the historical short-interval fire regime is suppressed, these sites will change in terms of the understory composition and structure, the density of ponderosa pine trees, and the types of fires that are likely to occur. Many different species are associated with this ecosystem depending upon the location, whether in Arizona, Oregon, or Idaho. Ponderosa pine ecosystems also occurred across sites with other potential natural vegetation including many Douglas fir and grand fir sites. In these areas, short-interval fire regimes favored the fire tolerant ponderosa pine, and kept the other species from occurring or dominating the sites. Thus, ponderosa pine was a fire-maintained disclimax ecosystem on these sites. However, the associated species in both the understory and often the overstory differed substantially from other nearby ponderosa pine ecosystems. In this example, if a classification system based on dominance of existing vegetation were used, it might classify large areas presently dominated by ponderosa pine as one category, and ignore the significant differences that could occur with short-interval fires in different locations. A finer classification of existing vegetation might identify more specific associations of species occurring with ponderosa pine, and divide the existing distribution of ponderosa pine into many different ecosystems, but might ignore the fact that these systems are currently very different in composition and structure than when they were influenced by short-interval fire regimes. This finer classification would further identify the ponderosa pine ecosystem according to the more fire sensitive species that have become established. Some of these sites under historical disturbance regimes were in areas that avoided the short-interval fires, and developed to the potential natural vegetation under a long-interval fire regime. Other sites were consistently subjected to short-interval fires and never established the late successional vegetation conditions. According to an existing vegetation classification system, representation of these sites for conservation purposes might be advocated, even if they may not have occurred in historical landscapes when short-interval fires maintained the ponderosa pine disclimax condition. Thus, ponderosa pine ecosystems display a wide range of conditions, and a fine-scale classification system is needed to discern the complexity of conditions that would be needed to fully address conservation objectives. Ecoregions help to divide the distribution of ponderosa pine into more manageable levels, whereby some of these complexities can be reduced or explained by the characteristics at the ecoregion level. Yet, even within an ecoregion, the classification system used may or may not discern “natural” ponderosa pine ecosystems and associated species if it does not incorporate an understanding of historical disturbances and successional trajectories.

CHARACTERISTICS OF SPECIFIC CLASSIFICATIONS WITHIN THE Y2Y AREA

A number of classifications are presently in use or available for use within the Y2Y area. A brief overview and comparison of these different classifications will be presented to provide a basis for reconciling differences and recommending specific uses. We will describe several types of classifications in use. We distinguish two separate uses of classification systems for Y2Y conservation efforts. One use is in subdividing the overall Y2Y area into smaller, more homogeneous planning areas or ecoregions for conservation planning efforts. The second use is in classification of specific ecosystems that would provide either a coarse filter or a habitat map for species of conservation concern within the various planning areas identified in the first objective.

Level I. Broad-scale Planning Area Classifications

A number of classifications are available for hierarchically subdividing and delineating planning areas for broad-scale planning efforts. These include Bailey's system (1995) and the related ECOMAP (Avers et al. 1993, Cleland et al. 1997), Omernik's classification (1995), Wiken's classification (1986), Canada's National Ecological Framework (Ecological Stratification Working Group 1996), British Columbia's Ecoregion Classification (Demarchi and Lea 1989), Alberta's Natural Region Land Classification System (www.cd.gov.ab.ca), and Hargrove and Luxmoore's Biophysical Classification (http://research.esd.ornl.gov/~hnw/esri98/). These classifications have all been used in all or part of the Y2Y area. Table 1 provides a comparison of the various levels of many of these classification systems.

Table 1. Comparison of general polygon size for primary broad-scale classifications discussed in the text.

	UNITED STATES		CANADA	
General Polygon Size	**Bailey/ECOMAP**	**Omernik**	**National Ecological Framework**	**Ecoregional Classification of British Columbia**
1,000,000s of m^2	Domain			Ecodomain
100,000s of m^2	Division		Ecozone	Ecodivision
10,000s of m^2	Province	Ecoregions	Ecoprovince	Ecoprovinces
1,000s of m^2	Section		Ecoregion	Ecoregions
10s to <1,000 m^2	Subsection		Ecodistrict	Ecosection
1,000s to 10,000 ac	Landtype Association			
100s to <1000 ac	Landtype			
<100 ac	Landtype Phase			

Bailey's Ecoregion Classification

Bailey (1980, 1983, 1995) developed a hierarchical system for delineating ecoregions at four levels: domain, division, province, and section. The objective of this system was to provide a spatial framework for ecosystem assessment, research, inventory, monitoring, and

management. It is a multi-factor approach that identifies one or more environmental variables that act as primary controls or limitations for a particular region. Different factors relating to climate and biogeography are emphasized at each particular scale. Domains are very broad climatic zones. These are subdivided into Divisions based on finer climatic criteria. Divisions are divided into Provinces based on soil orders and the dominant terrestrial potential natural vegetation, largely derived from Kuchler's (1964) potential natural vegetation map. Provinces are divided into Sections based on a finer delineation of potential natural vegetation.
The National Hierarchy of Ecological Units, also known as ECOMAP (Avers et al. 1993, Cleland et al. 1997) is a further extension of Bailey's ecoregions. This extension divides Provinces into Sections based on geomorphic process, stratigraphy, geologic origin, drainage networks, topography, and climate (Avers et al. 1993). Sections are further divided into subsections, landtype associations, landtypes, and landtype phases. Subsections are based on surficial geology, lithology, geomorphic process, soil groups, climate, and potential natural vegetation, and are usually named based on a dominant geological feature. Landtype associations are defined by general topography, geomorphic processes, soil complexes, and vegetation communities (Avers et al. 1993). They are usually named after particular geomorphic history or dominant vegetation community. Below this level, classification is dependent on specific mapping of characteristics in the field including soils, topography, rock types, and vegetation.

Bailey's ecoregion classification has been widely used in landscape planning efforts. The U.S. Forest Service has used this system, especially in the Western U.S., to help delineate planning unit boundaries. The Nature Conservancy has used Bailey's ecoregions with slight modifications or refinements at the Province level as the basis for its Ecoregional Planning initiative.

Bailey's ecoregions have been mapped throughout the Y2Y area at the Domain, Division, and Province levels. The Section level has been mapped for the U.S., but not for Canada. The subsection level is mapped for the Columbia Basin in the U.S., and landtype associations are mapped in U.S. Forest Service Region 1 and for some of the individual National Forests throughout the Columbia Basin. Landtypes and landtype phases have not received significant focus in the Western U.S. because of the past development and use of habitat typing as a site or land unit classification system.

Omernik's Classification

Omernik (1987, 1995) developed and mapped ecoregions for use by the U.S. EPA in stream categorization for water quality and quantity assessments. This approach used a holistic integration of factors as opposed to the focus on a primary controlling factor in Bailey's approach. The classification is based on geology, physiography, climate, vegetation, soils, land use, wildlife, and hydrology. It was developed primarily from a combination of information obtained from four existing maps that Omernik referred to as the component maps. His classification is a multifactor approach but has only one level; that of the 76 mapped ecoregions. It is appropriate for use in water quality assessments and comparisons at broad scales, such as regional or national assessments. It was mapped only for the U.S. A significant difference in this classification is the inclusion of human land use as a factor in mapping. This was included because of the specific purpose of this classification for evaluating water quality within the U.S., where human use was determined to be a significant criterion of water quality.

The National Ecological Framework for Canada

Canada has developed a national ecological framework, described in a report released by the Ecological Stratification Working Group (1996). This hierarchical system was built from the previous work of Wiken in delineating ecozones for Canada (Wiken 1986). The system used a holistic integration of factors and delineated 15 ecozones across Canada within which 53 ecoprovinces were delineated based on surface geomorphology, vegetation, wildlife, soils, hydrology, and climate. A third level, ecoregions identified 194 areas at a finer resolution based on climate, physiography, vegetation, soil, water, and fauna. At the finest level, 1021 ecodistricts have been mapped based on relief, landforms, geology, soil, vegetation, water bodies, and fauna.

Wiken and others (including Omernik) have continued work on this classification and have produced a map of ecological regions of North America. Presently mapped are 15 broad Level I Ecological Regions as well as 51 detailed Level II Ecological Regions (www.ccea.org/ecozones). Work is underway to complete a finer Level III mapping.

The World Wildlife Fund (Ricketts et al. 1999) used Omernik's ecoregions in the U.S. as the basis for assessment of terrestrial ecoregions. They linked Omernik's ecoregions with the map of ecoregions in Canada prepared by the Ecological Stratification Working Group (1996) to produce a trans-boundary map across the U.S. and Canada. The single level of this classification and the inability to link to boundaries of other hierarchical classifications limit the applicability of the WWF system for conservation planning at finer scales.

Ecoclimatic Regions of Canada

Environment Canada (1989) produced a map and description of ecoclimatic regions of Canada. The classification delineated 10 ecoclimatic provinces, within which 73 ecoclimatic regions were nested. This classification used climate to differentiate the provinces, and used climate and vegetation to delineate the ecoclimatic regions. Thus, it is hierarchical at two levels, and is a multi-factor classification. Its use has primarily been in interpreting changes in species distributions that might be expected with climate change.

Alberta Natural Region Land Classification System

Alberta has developed a hierarchical classification system for use in conservation planning and delineation of protected areas (www.cd.gov.ab.ca). Alberta has combined two classification systems to produce this classification. One of these systems, the Natural Regions and Subregions developed by Achuff and Wallis (1977) was designed for ecological reserve planning. The other, the Ecoregions of Alberta discussed by Strong (1992) was developed to classify regional climate and vegetation. The reconciling of these two systems has produced the classification of Natural Regions and Subregions in Alberta. Six Natural Regions have been described and mapped, with 20 subregions nested within these regions. The Y2Y boundary includes so little of Alberta that inclusion of this system in ecoregional reconciliation did not seem appropriate. However, if interpretations are desired for conditions further east of the current Y2Y boundary, then these classifications should be considered.

The Ecoregional Classification of British Columbia

British Columbia (BC) developed an ecoregional classification for the management, utilization, and conservation of the province's natural resources (www.env.gov.bc.ca). The classification is hierarchical and is based on climate and physiography (Demarchi 1992). The hierarchy is a nested system with the ecodomain as the broadest unit of climatic uniformity. Within ecodomains, ecodivisions are nested based on climatic and physiographic factors. Ecoprovinces are nested in ecodivisions as areas with consistent climatic processes and relief. Ecoregions are contained within the ecoprovinces, and are areas with major physiographic and minor macroclimatic variation. Ecosections are areas within ecoregions with minor physiographic and macroclimatic variation. The mapping has been revised several times, but presently contains 10 ecoprovinces, 46 ecoregions, and 116 ecosections.

Demarchi (1994) also described an extension and map of BC's ecoprovinces through the Western U.S. and Mexico. This produced a trans-boundary map at this level of the hierarchy, which is roughly equivalent to the ecoregional map used by TNC and the ecoregional map used by the World Wildlife Fund (Ricketts et al. 1999).

Level 2. Site Classifications

The broad-scale planning area classifications are designed to subdivide very large areas into smaller, more homogeneous areas that can better accommodate specific conservation planning. Within an appropriate subdivided area or ecoregion, information is still needed on the mix of ecosystems either currently or historically present. These ecosystems need to be classified and mapped for either coarse filter or fine filter conservation planning. Classification is needed that allows different sites or ecosystems to be categorized, described, and mapped in an appropriate manner and at a resolution to meet the conservation planning needs. As discussed in the section on Classifications, two general types of classifications have been developed for this purpose, ecological site classifications and existing condition classifications.

Ecological Site Classifications

Ecological site classifications focus on identifying areas supporting similar abiotic factors that contribute to similar plant and animal communities occurring on similar sites. These classifications may be based directly on the abiotic factors, such as the work of Hargrove and Luxmoore (http://research.esd.ornl.gov/~hnw/esri98/). Alternatively, they may be based on indicators of the abiotic factors such as the presence of specific plant species or groups of species.

ECOMAP

ECOMAP (Avers et al. 1993, Cleland et al. 1997) was discussed as a hierarchical classification system for broad-scale planning areas. At the finer levels of its hierarchy, it describes specific land units as landtypes and landtype phases. These units are nested within landtype associations, which are nested within subsections, sections, and provinces, respectively. The full range of this hierarchy allows for a detailed understanding of factors affecting ecosystems in a particular area. However, the level of nested relationships at the finer scales makes development of conservation plans difficult. In other words, landtype phases relate to landtypes that are described and mapped within landtype associations that occur within specific subsections, and so on. Landtype phases within one chain of this hierarchy would not be considered the same as similarly described landtype phases in other landtypes or landtype associations. Yet, at these fine scales, similar ecosystems occurring in adjacent landtype associations may be identical.

ECOMAP has been used in conservation planning efforts in the Lake States, but the focus has been on landtype associations rather than on specific ecosystems defined at the land unit levels. The effectiveness of planning or utilizing the classification at the landtype association level has been questioned, since each landtype association contains a wide mix of landtypes and landtype phases, let alone the seral conditions for each of these landtypes or landtype phases. Landtypes and landtype phases could be used to identify historical disturbance regimes that applied to a particular type of site.

ECOMAP has a similar hierarchy as the Land Systems Inventory as first described by Wertz and Arnold (1972). This system received considerable attention by the Forest Service in Region 1 and 4 in the 1970's-80's. It has not seen extensive use in recent planning activities.

Habitat Typing

Daubenmire (1968) and Daubenmire and Daubenmire (1968) described a system of site classification that was based on identification of potential natural vegetation for that site as indicated by both understory and overstory vegetation. Habitat typing has a series level that identifies the dominant overstory species of potential vegetation. It also has the habitat type level that is a finer delineation of late successional plant communities. Habitat types are at a similar level of classification as plant associations, but are used only to describe the late successional conditions that could occur at a site. The Series level may be useful for very broad-scale interpretations, but is too coarse for most conservation planning. The Series level is equivalent to the alliance level of plant classification, but only indicates the potential dominant species of overstory vegetation rather than the existing vegetation. The habitat type level is fairly detailed, as indicted above. For many purposes use of an intermediate level such as a subseries or habitat type group (Pfister 1991, Pfister and Sweet 2000) or habitat type classes (Haufler et al. 1996, 1999) has proven to be effective. Habitat types or habitat type classes or groups can be used to describe successional trajectories and historical disturbance regimes for sites. In fact, many studies of historical fire regimes have focused on habitat types as the basis for describing fire ecology of sites (Crane and Fischer 1986, Bradley et al. 1992, Smith and Fischer 1997).

Numerous descriptions of habitat types for specific areas have been developed as discussed by Wellner (1989). Original plans for habitat typing included the development of specific habitat typing systems for all areas of the west and the development of successional pathways for each habitat type. Much habitat type development work occurred in the 1970's-80's, but the funding for further work on the successional pathways never materialized. Some successional pathway work was conducted (e.g., Arno et al. 1985, Steele and Geier-Hayes 1987, 1989, 1992, 1993, 1994 1995), but the complete development originally envisioned did not occur. However, habitat types have been described for all of the Y2Y area within the U.S. Specific publications include: northwestern Wyoming (Cooper 1975, Reed 1976, Steele et al. 1983, Youngblood and Mueggler 1981), Idaho (Cooper et al. 1987, Daubenmire and Daubenmire 1968, Steele et al. 1981, Steele and Geier-Hayes 1987, 1989, 1992, 1993, 1994, 1995), and Montana (Arno et al. 1985, Hann 1982, Mueggler and Stewart 1980, Pfister et al. 1977, Roberts 1980).

Thus, habitat typing has been well developed in the U.S. area of Y2Y. However, it has not been mapped extensively or accurately for most areas although some of this mapping is presently being conducted. ICBEMP (Quigley et al. 1996) used habitat typing in its analysis, but at the Series level, limiting its usefulness for conservation planning. It is a classification system that is in widespread use, especially by U.S. federal agencies, and has good integration potential across disciplines. As mentioned, it not only can, but has been used to describe disturbance regimes, especially fire.

British Columbia's Biogeoclimatic Ecosystem Classification (BEC)

BC has developed a detailed system for classifying ecosystems (Pojar et al. 1987). It is designed to work separately but in parallel with the ecoregional classification system described previously. The ecoregional classification delineates areas down to the ecosection, which are still broad areas. It was developed for use in wildlife and conservation planning. The BEC system focuses on vegetation, and has several levels. Its lowest levels are very fine descriptors of specific sites. This system was developed with forestry and other resource management uses in mind. BC has mapped biogeoclimatic zones (www.for.gov.bc.ca) that are based on a generalized potential natural vegetation categorization. At a finer scale, a system of site classification is applied. The site association is the basic unit of the classification. The association "includes all ecosystems capable of developing vegetation belonging to the same plant association at the climax or near-climax stage of vegetation development" (www.for.gov.bc.ca). Thus, the site association identifies sites that will support the same collection of ecosystems indicated by plant species in the late successional stages. As such, the site association is equivalent to that of habitat types. As with habitat types, this classification could be used to describe historical disturbance regimes for different types of sites or groupings of similar sites.

The BEC system has a classification for seral conditions. Within a site association, seral plant communities are identified according to successional status and structural stages. This provides a classification of not only the site but also of the existing conditions.

Existing Vegetation Classifications

Plant Associations

A well-established vegetation classification system identifies vegetation at two levels, formation, and plant associations. Formations are determined according to the physiognomy or outer appearance of a vegetation type. An example of a formation is a category such as coastal coniferous rain forest. Within formations, plant associations (Gleason 1917) based on floristics are identified. Plant associations are "collections of all plant populations coexisting in a given habitat" (Barbour et al. 1980). Plant associations that define late successional conditions are equivalents to habitat types. However, plant associations are used to describe all ecosystems regardless of seral condition. Thus, a stand dominated by aspen would be classified as a specific aspen association based on the additional species that were present, even though the site could progress successionally to a completely different plant association, such as a subalpine fir dominated site. In habitat typing, the site would be recognized as a specific subalpine fir habitat type, even if aspen dominated the existing vegetation.

TNC has used the vegetation formation/plant association system in its classification system (Grossman et. al. 1998) introduced above. This system, based on existing vegetation, divides the formation or physiognomic classification into 5 hierarchical groups. It then uses floristics to identify two levels, the alliance and the association. The alliance is the dominant overstory species, and as such is equivalent to the series level in habitat typing, but is assessed for the existing vegetation rather than the late successional vegetation. The association is the same as the plant association discussed above. No further identification of stand maturity or successional status is included in the TNC classification. In addition, because of the focus on existing classification, the plant association classification has limited abilities for describing historical disturbance regimes or historical ecosystems.

It should be noted that in the Y2Y area, most of TNC's forested plant associations were identified using the results of previous habitat typing efforts in the northwest. In other words, the ecologists tasked to produce the plant associations for the TNC classification in the Y2Y area used the extensively developed habitat typing work and references listed above for identification of plant associations. Thus, in the northwest portion of TNC's classification, the plant alliances are generally the same as habitat type series, and the plant associations are generally the same as habitat types. A problem with the application of this information is that TNC is applying their criteria for conservation status/ranking to only the late successional or climax conditions, even if these conditions did not occur in the area under historical disturbance regimes. Further, many potentially important seral conditions are excluded from the TNC classification in the northwestern United States.

SAF, Structural Stage, and related classifications

These classifications all focus on categorizing existing stands either to dominant species, sizes, densities, or structural stages. Eyre (1980) described the system used by the Society of American Foresters. This system for forests identifies the dominant species in the overstory. Maps of the U.S. have been produced that display the existing dominant species of vegetation. This classification system does not fit well with efforts to describe historical disturbance regimes or historical ecosystems.

Structural stages, such as proposed by Oliver (1992) and O'Hara et al. (1996), categorize forest stands according to stages, such as Oliver's stand-initiation, stem-exclusion, understory-reinitiation, and old growth. They do not include species compositions, sizes of vegetation except in the most general sense, or density of vegetation. As with the SAF system, structural stages do not provide a basis for describing historical disturbance regimes or historical ecosystems that occurred at a site.

Other categorizations may assign size classes to forest stands and include such categories as seedling, sapling, pole, small-tree, medium-tree, large-tree, and giant tree (Johnson and O'Neil 2001). Forest stands may also be stratified by the density of vegetation or the canopy coverage of these stands.

Combination Classifications

Several planning efforts have combined two different classifications into one system for classifying both ecological sites and existing conditions. The BEC classification system described above does this by identifying ecological sites with their definition of site associations, and then describes existing vegetation according to seral stages. ICBEMP (Quigley et al. 1996) combined habitat typing at the series level with structural stages of O'Hara et al. (1996). They then mapped their assessment area using a 1 km pixel resolution.

Haufler et al. (1996, 1999) used habitat types that they grouped into habitat type classes (Mehl et al. 1998) based on the predominant historical disturbance regimes. Habitat type classes represented one axis of a conservation planning tool they termed an ecosystem diversity matrix for forest systems. The second axis consisted of successional stages (vegetation growth stages) and included tree size and whether the stand was single or multi-storied to identify 13 categories. Haufler et al. (1996, 1999) used this tool in Idaho to map the Southern Idaho Batholith landscape for conservation planning.

Pfister (1989) discussed the use of stages of secondary succession linked with habitat types as a way of addressing seral components within habitat typing. Pfister and Sweet (2000) described other combinations of habitat typing and size or structural classifications of vegetation, and discussed an ecosystem diversity framework that combined habitat types sizes, structures, species, and densities of species.
Craighead et al. (1982) used the ecoclass method of Daubenmire (1952) to classify alpine vegetation as grizzly bear habitat. They identified climatic zones within which they identified ecological land units and ecological landtypes. They further identified disturbed areas that resulted in seral conditions. They extended their classification into the upper elevations of forest cover. For forests, they used several groupings of habitat types to identify different sites. They identified burned areas in the forests as seral stages. Mattson and Knight (1989) combined habitat types with cover types to develop a classification system for grizzly bear habitat. Hogg et al. (2001) used methods patterned after Craighead et al. (1982) to map vegetation communities in the Salmon-Selway wilderness and surrounding areas for use in analysis of grizzly bear habitat. They aggregated habitat types into classification groupings that were then used to separately map overstory vegetation and understory vegetation.

Various other applications and combinations of the various available classification systems could be described. The examples provided highlight the capability of various classification systems to be linked together, and to allow for the consideration of both ecological site delineation as well as existing vegetation descriptions to be used together.

TRANS-BOUNDARY RECONCILIATION OF HIERARCHICAL ECOLOGICAL CLASSIFICATIONS

A primary objective of this project was to develop a trans-boundary map of recommended ecoregions for use in Y2Y conservation planning. Three existing trans-boundary maps exist: 1) TNC's refined ecoregions based on Bailey's classification and mapped at the province level, The World Wildlife Fund's (Ricketts 1999) map of ecoregions based on a combination of Omernik's and the Canadian National Ecological Framework classifications, and Demarchi's (1994) map of ecoprovinces. All three of these are at approximately the same scale. None are hierarchical in their current form, so only one level of classification is possible. All of these maps provide a method for subdividing the Y2Y area into smaller, more homogeneous areas at the province or ecoprovince level that would assist in subdividing additional levels for conservation planning. Omernik and Bailey (1997) provide convincing arguments as to why these ecoregional classifications should be used for conservation planning, rather than classifications based on watersheds or hydrological units.

All of these three existing maps are at a scale that is larger than we feel is appropriate for most aspects of conservation planning. Ecoregions defined at the Bailey's province level span relatively large areas. Based on the previous discussion concerning scale and classifications, examination of the complexity and variability in ecosystems, disturbance regimes, and successional trajectories, when conducted at the province level, is simply too large an area. The number of specific ecosystems that would need to be identified at a sufficient resolution to address conservation needs would be very large. As noted by Y2Y's bird working group, in addition to identifying an appropriate mix of ecological sites, bird populations are also strongly influenced by the successional stages distributed across the landscape. Meeting the needs of all bird species depends on maintaining a sufficient representation of the conditions that they were adapted to: i.e., the natural or historical full array of ecosystems. This information is difficult to classify, map, coordinate, and apply to a conservation plan framework at the province level. TNC is conducting its ecoregional planning at the province level, however they have chosen a supporting vegetation classification system that does not incorportate seral stages and the range of historical or natural conditions. This approach may be appropriate in provinces with simple and relatively infrequent historical disturbance regimes and with the assumption that sufficient levels of disturbance are still occurring. However, the interior mountains of the Y2Y region represent complex and often frequent disturbance regimes, which created a diverse mix of ecosystems. The birds and other species of the Y2Y region depend on the full array of naturally occurring ecosystems to assure continued habitat for all species.

For these reasons, we recommend the size of ecoregion represented by the Section level in Bailey's hierarchical classification for the U.S. portion of the Y2Y area. McNab and Avers (1994) and Nesser et al. (1997) provided a description of these areas. In certain areas, Sections may even be divided into groupings of subsections (Nesser et al. 1997) to assist in conservation planning. Bailey's sections have not been mapped in Canada, but the ecoregion level of the BC classification and the Ecoregion level of the National Ecological Framework are generally equivalent. In the Yukon, Northwest Territories and Alberta, the Ecoregion level of the National Ecological Framework provides equivalent delineations. We developed a reconciled map (Appendix A) of Bailey's sections in the U.S. (using Bailey's and TNC's refined boundaries (http://www.consci.org/ERP/EcoregionalPlansMap.cfm)) with BC's ecoregions, and the ecoregions of the National Ecological Framework for the Yukon and Alberta. This map, with associated descriptions of each ecoregion taken from the source classification is also displayed digitally (www.emri.org/Y2Y_ecoregions.htm, or at Y2Y's data site).

RECOMMENDED USE OF CLASSIFICATIONS WITHIN THE Y2Y PLANNING AREA

We recommend that within the ecoregions (Section level or equivalent) mapped as described above, that the full array of natural/historical ecosystems be classified at a relatively fine level of resolution. We support the use of site associations (BEC) in BC and habitat types in the U.S. as the base units of ecosystem classification. While other classifications of ecological site could also work, the development and use of these systems in the portions of the Y2Y region make them a desirable starting point. We have found that for conservation planning and mapping, these base units can be successfully aggregated within an ecoregion to a more manageable number of site association/habitat type groups. This level of aggregation will produce maps of sufficient resolution to serve as planning tools for either coarse filter or fine filter applications, especially when applied at this ecoregion level. Other conservation efforts have reached similar conclusions (Craighead et al. 1982, Haufler et al. 1996, Mehl et al. 1998, Pfister and Sweet 2000, Hogg et al. 2001). We caution against getting too coarse in the aggregation of types. Jumping to the habitat type series (habitat typing) or plant association alliance (BEC) appears to be too coarse a stratification, as the complexity of ecosystems within one category at this level is very great, especially for conservation planning for songbirds and other species with relatively small home ranges. Many series/alliance categories such as Douglas-fir or grand fir, often include diverse ecosystems that result from different disturbance regimes due to site level factors such as slope and aspect. For example, grand fir ecosystems that were influenced historically by frequent understory fire regimes exhibited identifiable conditions that would be important to represent in the ecoregion for maintaining ecosystem integrity for these systems and for maintaining species habitat for associated plant and animal species. At the same time, grand fir ecosystems that operated historically under infrequent, stand-replacing fire regimes need to be recognized and these conditions maintained for the same reasons. A series/alliance level categorization does not provide the ability to make these types and levels of distinctions.

Mapping of ecological sites within an ecoregion using the classification resolution discussed above would provide a powerful and effective conservation planning framework. It would provide the base information needed to describe and map the full array of historical or "natural" ecosystems upon which biological diversity for an ecoregion depended. In our experience, identifying and mapping this information at appropriate classification and mapping resolutions and accuracies should be a priority conservation activity of Y2Y.

In addition to classifying and mapping ecological sites, classification and description of existing seral conditions is important for identifying conservation status and needs. We strongly endorse an approach to conservation planning that uses a reference to historical conditions and ranges of variability (Haufler et al. 2002) as the basis for setting conservation planning goals. Under such an approach, seral conditions should be classified in response to the primary historical disturbance regimes that influenced a particular ecoregion. This is a key point for development of classification systems that would extend to existing vegetation, as classifications that do not adequately identify conditions produced by historical disturbance regimes are not likely to identify needed representation of these conditions. In ecoregions where historical fire regimes have not had as great a complexity in types and resulting ecosystems, shade tolerance of plant species may be a primary driver of succussional change. BC has a seral condition classification (www.for.gov.bc.ca) that incorporates this successional change through the full range of seral conditions.

Linking ecological site classification and seral stage classification will be important for meeting conservation objectives, particularly for birds. The BC BEC system provides for the capability of this linkage within this part of the Y2Y area. This system should apply reasonably well to the areas of Alberta included in the Y2Y. The Yukon and Northwest Territories might also extrapolate this system, although the further away from the ecoregions in BC the more likely the effectiveness of this system will begin to erode. A more detailed analysis of the suitability of the BC BEC system in the Yukon and Northwest Territories is warranted. In the U.S., Haufler et al. (1996, 1999) developed the ecosystem diversity matrix concept as a conservation planning tool to link seral conditions with ecological site classification within an identified ecoregion. An example of this applied to a predominantly fire influenced area in Idaho is presented in Figure 1. An additional example developed for a Minnesota landscape (Haufler et al. 2002) displays an ecosystem diversity matrix developed for an area where shade tolerance of species is the primary seral influence (Figure 2). Similar linked classifications of habitat types with seral conditions could be easily derived for any of the ecoregions of the Y2Y occurring in the U.S. Other methods of linkage, as explored by Pfister and Sweet (2000) could also be developed. However, we emphasize the use of a conservation planning tool that provides the ability to incorporate the role of historical disturbance regimes within an ecoregion as an important component in the development of any classification linkage of ecological sites with seral conditions.

One limitation of the emphasis on historical reference for defining functional ecosystems and species habitat requirements is that the classification of historical ecosystems may not effectively incorporate human altered ecosystems. For example, silvicultural activities in forest systems may create existing stands that have little similarity in composition, structure, or function to the ecosystems occurring on an ecological site under historical disturbances. This is a concern for mapping across areas that are managed for different objectives, and where maintaining natural ecosystems may not be a priority. This limitation does not reduce the

Figure 1. A simplified example of a conservation-planning tool termed an ecosystem diversity matrix (EDM) for forested systems of a fire dominated ecoregion (from Haufler et al. 1996). Cells of the EDM represent the probable dominant overstory tree species (covertype).

ECOSYSTEM DIVERSITY MATRIX-
IDAHO SOUTHERN BATHOLITH LANDSCAPE

VEGETATION SERAL STAGE	Habitat Type Class: Dry Ponderosa Pine/ Xeric Douglas-fir	Warm, Dry Doug-fir/ Moist Ponderosa Pine	Cool, Dry Douglas-fir	Dry Grand Fir	Warm, Dry Subalpine Fir	Warm, Moist Subalpine Fir	High Elevation Subalpine Fir
Grass/Forb/Seedling							
Shrub/ Seedling	*Pinus ponderosa*	*Pinus ponderosa* *Pinus contorta* *Populus tremuloides*	*Pinus contorta* *Populus tremuloides*	*Pinus ponderosa* *Pseudotsuga menziesii* *Populus tremuloides*	*Pseudotsuga menziesii* *Pinus contorta* *Populus tremuloides*	*Pinus contorta* *Larix occidentalis*	*Pinus albicaulis*
Sapling; shrub/seedling	*Pinus ponderosa*	*Pinus ponderosa* *Pinus contorta* *Populus tremuloides*	*Pinus contorta* *Populus tremuloides*	*Pinus ponderosa* *Pseudotsuga menziesii* *Populus tremuloides*	*Pseudotsuga menziesii* *Pinus contorta* *Populus tremuloides*	*Pinus contorta* *Larix occidentalis*	*Pinus albicaulis*
Short-interval Fire Regime	Understory Burn 5 -25 Years	Understory Burn 10-22 Years	Understory Burn 25-100 Years	Understory Burn 10-30 Years	Fire Mosaic 50-90Years	Some Understory Burn	Understory Burn 25-70 Years
Small Trees	*Pinus ponderosa*	*Pinus ponderosa* *Pinus contorta* *Populus tremuloides*	*(Pinus contorta)* *(Populus tremuloides)*	*Pinus ponderosa*	*Pseudotsuga menziesii* *Pinus contorta* *Populus tremuloides*	*Pinus contorta* *Larix occidentalis*	*Pinus albicaulis*
Medium Trees	*Pinus ponderosa*	*Pinus ponderosa* *Pinus contorta*	*Pseudotsuga menziesii* *Pinus contorta*	*Pinus ponderosa*	*Pseudotsuga menziesii* *Pinus contorta*	*Pinus contorta* *Larix occidentalis*	*Pinus albicaulis*
Large Trees	*Pinus ponderosa*	*Pinus ponderosa*	*Pseudotsuga menziesii*	*Pinus ponderosa*	*Pinus contorta*	*Larix occidentalis*	*Pinus albicaulis*
Long-interval Fire Regime	Stand Destroying Wildfire Unlikely	Stand Destroying Wildfire Unlikely	Some Stand Destroying Wildfire	Stand Destroying Wildfire Unlikely	Fire Mosaic 50-90 Years	Stand Destroying Wildfire	Stand Destroying Wildfire
Small Trees	*Pinus ponderosa* *Pseudotsuga menziesii*	*Pinus ponderosa* *Pinus contorta* *Populus tremuloides*	*Pseudotsuga menziesii* *Pinus contorta* *Populus tremuloides*	*Pinus ponderosa* *Pseudotsuga menziesii* *Abies grandis*	*Pseudotsuga menziesii* *Pinus contorta* *Populus tremuloides*	*Pseudotsuga menziesii* *Picea engelmannii* *Larix occidentalis*	*Pinus albicaulis*
Medium Trees	*Pinus ponderosa* *Pseudotsuga menziesii*	*Pinus ponderosa* *Pseudotsuga menziesii*	*Pseudotsuga menziesii* *Pinus contorta*	*Pinus ponderosa* *Pseudotsuga menziesii* *Abies grandis*	*Pseudotsuga menziesii* *Picea engelmannii* *Pinus contorta*	*Pseudotsuga menziesii* *Picea engelmannii*	*Abies lasiocarpa* *Pinus albicaulis* *Picea engelmannii*
Large Trees	*Pinus ponderosa* *Pseudotsuga menziesii*	*Pinus ponderosa* *Pseudotsuga menziesii*	*Pseudotsuga menziesii*	*Pinus ponderosa* *Pseudotsuga menziesii* *Abies grandis*	*Picea engelmannii* *Abies lasiocarpa*	*Pinus ponderosa* *Pseudotsuga menziesii* *Abies grandis*	*Abies lasiocarpa* *Pinus albicaulis* *Picea engelmannii*
Old Growth	*Pinus ponderosa* *Pseudotsuga menziesii*	*Pinus ponderosa* *Pseudotsuga menziesii*	*Pseudotsuga menziesii*	*Abies grandis*	*Abies lasiocarpa* *Picea engelmannii*	*Abies lasiocarpa* *Picea engelmannii*	*Abies lasiocarpa* *Pinus albicaulis* *Picea engelmannii*

Figure 2. This simplified example demonstrates how a conservation-planning tool termed an ecosystem diversity matrix (EDM) (from Haufler et al. 2002) can be used to describe a coarse filter and historical ranges of seral stages in a shade-dominated ecoregion.

Historical Range of Variability EDM

		HABITAT TYPE				
	VEGETATION SERAL STAGES	Moist Fir	Rich, Moist	Wet Fir/ Ash/Cedar	Wet Fir/ Cedar	Poor, Wet Spruce
	Seedling/Sapling	5-9%	5-9%	5-9%	5-8%	18-32%
Shade Intolerant Species →	Small tree	12-20%	12-20%	8-14%	12-19%	
Shade Intolerant Species →	Medium tree	7-10%	7-10%	14-18%	13-17%	
Shade Intolerant Species →	Large tree	3-5%	3-5%			
← *Shade Tolerant Species*	Small tree	1-2%	1-3%	7-9%	6-8%	15-23%
← *Shade Tolerant Species*	Medium tree	10-12%	17-18%	19-20%	17%	21-23%
← *Shade Tolerant Species*	Large tree	6%				
	Old growth	25-51%	24-29%	20-42%	19-42%	22-46%
	Total Acres	91,416	455,702	116,423	78,661	323,464

importance of an historical reference for conservation purposes. In fact, it accentuates the importance of properly classifying and describing the historical array of ecosystems so that critical ecosystems and ecosystem conditions are not obscured within a classification that does not specifically consider or define historical ecosystems. Classifications that more generally describe vegetation conditions and allow the incorporation of anthropogenic conditions may completely overlook critical ecosystems or habitats.

Both the British Columbia BEC system and habitat typing provide for the incorporation of historical disturbance regimes and successional trajectories. Both allow the classification of conditions produced by alterations of historical disturbance regimes. Both would be relatively ineffective in classifying areas that have been highly altered by human activities that have shifted stands out of any natural successional process. Such altered stands might be forced into the most similar natural stand condition, but more appropriately might be classified as human altered, and described as to its existing condition. The sites on which these altered stands occurred could still be classified by either the BEC or habitat type classifications to provide insights as to historical ecosystems that occurred there, or appropriate stand conditions if restoration of the site is desired.

Y2Y Conservation Planning for Birds, Carnivores, and Aquatics

How do these recommendations for an ecoregional classification for Y2Y and for ecosystem classification within these ecoregions apply to Y2Y's conservation efforts for birds, carnivores, and aquatics? It has a different relevance to each of these, so they will be considered separately.

Y2Y convened an avian workshop group that first met in 2000 and then again in 2001 for the purpose of helping shape a strategy for incorporating avian community needs into conservation area design. The group reviewed existing lists of species of concern, and developed a Y2Y list that was divided into various regions. It then tried to develop a conservation strategy for these species. To assist this effort, the group was provided with a map of general forest cover types for the Y2Y. The group was unable to effectively use this information because the map was too general. It was determined to lack sufficient resolution for the different ecological sites and it did not contain information on seral conditions. Birds generally respond to specific site conditions. Conservation planning, especially for a diverse list of birds, needs fairly detailed information to be effective.

The recommended classification system discussed above would provide the information needed to make effective conservation plans for avian species. The classification system would describe natural/historical conditions within each ecoregion, which would assist bird experts in tailoring habitat conservation recommendations for that particular area. In discussions, the avian group revealed that some species utilize habitat conditions differently in different parts of their range within the Y2Y area. The ecoregion approach would allow for such differences to be readily incorporated.

The classification would also allow the description and quantification of the full array of historical ecosystems. Habitat for species dependent on a specific ecosystem can then be targeted for representation within areas that supported these conditions historically. This would assist in identifying critical areas where protection or restoration efforts should be a priority. Without this level of information, conservation planning for birds cannot assure that the desired objectives will be met.

Examples of how this type of classification and consideration of historical ecosystems can be used in species modeling help to emphasize the use of such systems. Two species, Townsend's Warbler and Flammulated Owl, can provide good examples. The Townsend's Warbler is a species occurring in mature low elevation conifer forests. A primary habitat requirement is high levels of forest canopy cover (Sallabanks et al., draft manuscript). Using a classification of existing vegetation, a model of this species habitat suitability would have it widely distributed within many ecoregions in such types as western red cedar, grand fir, and Douglas fir dominated stands with high canopy cover. In contrast, the Flammulated Owl is a species that prefers stands of very large ponderosa pine, especially in a more open condition (McCallum 1994) such as occurred under historical disturbance regimes. Using a classification of existing vegetation, this species would be expected to be restricted in its distributions to dry, low elevation forests of ponderosa pine, with more marginal distributions in stands mixed with Douglas fir, grand fir, and higher densities of trees. If we desired to improve conditions for Flammulated Owls, areas supporting large ponderosa pine should be identified and maintained.

In addition, areas currently supporting Douglas fir and grand fir in combination with ponderosa pine could be restored to an historical composition and structure to favor large, more open, ponderosa pine. These actions would cause a decline in habitat for Townsend's Warblers. Is this an acceptable tradeoff? Use of classifications that allow for the description and mapping of historical ecosystems would greatly assist in this decision. Maps of historical ecosystems would reveal that Flammulated Owls were widely distributed historically, occurring in substantial areas of large ponderosa pine maintained in an open condition by understory fires. Townsend's Warblers were much more restricted in their distribution, occurring in western red cedar, and in the more moist Douglas fir and grand fir habitat types that generally did not have the frequent understory burns. These moister areas could be mapped and targeted for protection of existing conditions for Townsend's Warblers, while the drier Douglas fir and grand fir habitat types could be restored to historical conditions of ponderosa pine. While the needs of these two species could be addressed without the historical ecosystem information, what if the additional needs of 10 or 100 species were added to the prioritization process? How would the potential conflicting habitat needs be resolved without an historical reference?

Planning for carnivores is simplified by the number of species that must be considered, but complicated by their large home ranges, disrupted population continuity, and direct effects of humans on their populations. A system of protected areas can help address this last factor. However, as past work on grizzly bears has revealed, knowledge of ecological sites, seral conditions, and other habitat descriptors is important for identifying such needs as critical foraging areas. In addition, knowledge of the historical mix of ecosystems allows a better understanding of the types of habitat patterns and connectivity that these species were adapted to prior to major anthropogenic alterations. Thus, while some conservation planning for carnivores can occur with coarse classifications of ecosystems, there is no question that the classification proposed in this project would greatly enhance habitat mapping capabilities and planning.

Aquatic conservation will also be greatly enhanced by the use of an ecoregional classification. Additional classification of aquatic systems within the ecoregional framework is still needed. This project was not tasked with tackling this aspect of classification, but this type of classification work is on-going in many areas of the Y2Y area. Omernik and Bailey (1997) provide an excellent discussion of the importance of ecoregional classification for aquatic conservation planning. On-going work by the Ecosystem Management Research Institute has demonstrated that relationships exist between zones of habitat type groups and riparian/wetland and aquatic ecosystem species compositions. In addition, this type of classification provides an integrated framework that allows the incorporation of terrestrial, riparian/wetland, and aquatic ecosystems in a cohesive and related classification system. In this manner, aquatic conservation efforts could be directly tied to carnivore and avian conservation objectives.

RECOMMENDED FUTURE TASKS TO ASSIST Y2Y CONSERVATION PLANNING

The description and mapping of the ecoregions as well as the recommendations for use of classification systems within the delineated ecoregions provide Y2Y with tools that should be useful for conservation planning. These tools provide a framework within which Y2Y can develop a better understanding of historical ecosystems within the overall Y2Y region. Several additional recommendations for future tasks that should be valuable for Y2Y conservation planning can be suggested. Several of these have already been suggested in this report, while others are additional ideas.

1) Analyze the BEC system for application in Yukon and Northwest Territories

The Yukon and Northwest Territories have been mapped for ecoregions. However, they lack a specific classification system for delineating ecosystems within these ecoregions. The British Columbia BEC system should work well for this purpose, but needs to be specifically developed for this extended range. Y2Y could work with the provincial or territorial governments to accomplish this task.

2) Produce a trans-boundary classification and map of ecological sites for one or more ecoregions across the B.C.-U.S. border

A number of the delineated ecoregions recommended for use in finer scale delineation of historical and existing ecosystems cross the boundary between the U.S. and British Columbia. We have recommended using different but compatible ecosystem classifications for ecoregions on each side of the U.S./Canada border. We recommend developing a classification and map of ecosystems within one or more of these trans-boundary ecoregions. This would demonstrate the compatibility of using both BC BEC sites and habitat typing systems, and would clearly show how ecosystems transcend the international boundary.

3) Describe and map ecological sites within ecoregions

Most conservation efforts spend considerable effort and financial resources describing and mapping existing ecosystem conditions. While information on existing conditions is certainly useful, it is often less useful than information on the various ecological sites present in the planning area as well as information and maps of historical ecosystem conditions. Information on existing conditions is necessary to understand changes and threats to conservation objectives, but this information is in flux, and often out-of-date before analyses are even completed. Ecological sites are a permanent feature of ecoregions, barring such major disturbances as volcanic eruptions or similar primary disturbances. Classifying and mapping ecological sites provides a permanent conservation-planning tool. This information can then be used to describe and map historical ecosystems, another permanent conservation planning tool. These two tools provide conservation-planning efforts with important information for setting conservation goals and objectives (Haufler et al. 2002). Information on existing conditions then provides measures of progress towards the conservation objectives.

We recommend that Y2Y support, either directly or through coordinated efforts, the specific classification and mapping of ecological sites within the ecoregions comprising the Y2Y area. Mapping should have specific expectations for accuracy, with documented verification in order to maximize the effectiveness and use of these permanent layers of conservation information. While we recognize the need for maps of existing conditions, we suggest that these should receive less emphasis, command a smaller percentage of conservation funds, and have a lower acceptable level of mapping accuracy.

4) Quantify Historical Ecosystems and Map by Ecoregion

As discussed, use of the BEC system and habitat typing allows for the description and quantification of historical disturbance regimes and their resulting successional trajectories for each type of ecological site. This information can be used to describe the historical range of variability in terms of the occurrence over time of the various successional conditions produced by historical disturbances (Morgan et al. 1994, Haufler et al. 2002). The mosaic of historical ecosystems that occurred within an ecoregion can then be mapped and used as an historical reference. Such historical references can be critical for conservation planning (Haufler et al. 2002), as they provide for the definition and identification of intact or natural ecosystems as well as for the definition and quantification of biological diversity and ecosystem integrity for each ecoregion. This information is extremely useful for conservation planning using either coarse or fine filter approaches. Further, it is the basis for a coarse filter approach based on the historical range of variability (Haufler 1999). In fine filter approaches, it provides for a better understanding of species needs by providing information on what conditions supported populations of each species historically, how the habitat for each species was distributed historically, and what sites should receive conservation priorities for selected species.

5) Map existing conditions for selected ecoregions using both ecological site and seral stage classifiers

While we recommend a reduced emphasis on mapping of existing conditions, we still recognize the need to conduct comparisons of existing conditions to the historical conditions of each ecoregion. We recommend that Y2Y continue to develop descriptions, quantifications, and mapping of existing conditions. We recommend that this information be gathered using the same recommended classification systems discussed above. If an ecoregion has already been or is concurrently mapped for ecological sites, then quantification of existing conditions is simplified. Except for those areas where anthropogenic impacts have produced conditions outside of natural successional trajectories, the site maps will help provide sidebars for the range of existing conditions. Existing conditions can then be described and mapped according to information on the composition and structure of vegetation.

6) Link ecological site and seral stages to bird species of concern

Using the maps of historical ecosystems and existing conditions, present, past, and future habitat conditions for species of concern can be modeled and mapped. Two types of habitat modeling fit well with this approach. Wildlife habitat relationship models (i.e., Thomas 1979, Johnson and O'Neil 2001) use a relatively coarse resolution of habitat quality to identify areas of habitat for each species. These models identify the quality of each category of ecosystem and successional stage as habitat for each species of interest. In this way, the total amount of different habitat quality and its spatial distribution across each ecoregion can be quantified and displayed. This works fairly well for species with small home range sizes that generally occur within one stand of vegetation, and for which the quality of each type of condition for each species is known. Information from studies such as the Northern Landbird Monitoring Program (Hutto 1998) can be extremely useful in developing such wildlife habitat relationships.

Wildlife habitat relationship models do not address the specific habitat attributes needed by species, nor do they allow for the consideration of more complex habitat needs such as for species that require more than one type of condition or that have large home ranges. Habitat suitability modeling addresses some of these needs. Habitat suitability models describe and quantify the specific habitat variables that a species needs, and estimate quality of habitat based on how well any given site provides for each of these needed habitat attributes. It can incorporate needs such as proximity of different types of conditions (i.e. distance to water, cover, or food), and specifically identifies needed habitat attributes that may or may not be tracked by the classification system. For example, riparian areas and lake shores may be identified as habitat for belted kingfishers under wildlife habitat relationship models, but these areas must support not only a food base but also the presence of dirt banks for nesting sites if preferred habitat is to be present. Habitat suitability models might be used to further rate the quality of the food base for different sites and would also reveal the need to quantify the amounts of nesting sites in different areas to better define habitat quality for this species. Habitat suitability models require that habitat attributes required by species be known, and require that measures of these attributes are known for each of the ecosystems mapped within the ecoregion. While very useful for setting conservation priorities for species, this level of information may not be available for some areas of the Y2Y region at the present.

Extensions of the habitat suitability concept have been used to evaluate ecoregions based on home range sized areas for different species (Roloff and Haufler 1997), and to further quantify the number and quality of home ranges (Roloff and Haufler 2002). These later uses provide a means of assessing viability of species based on habitat quality. These methods also allow for the comparison of habitat-based species viability under historical conditions to current conditions, and allow for projection of future viability of a species based on proposed conservation actions.

7) Link Carnivore Habitat Needs to Ecosystem Classification

As mentioned, conducting an assessment of carnivore conservation needs is easier than assessing bird conservation needs because of the smaller number of species to address. However, the assessment process can become complicated by the nature of the small and dispersed populations of many of these species and their direct population impact from humans. While conservation strategies for birds can be based largely on addressing amounts and distribution of habitat, carnivores need additional planning to address their movements and direct interactions with humans. However, understanding and quantifying their specific habitat needs is also critical to their conservation planning. As past studies such as those discussed previously, or that of Hogg et al. (2001) reveal, understanding foraging, cover, and other needed habitat attributes is also critical for planning for carnivores. The classification of ecoregions and use of the recommended classification of ecosystems within these ecoregions will allow for habitat needs of carnivores to be quantified and mapped. In addition, mapping of historical ecosystems will allow for important reference information on the habitat qualities and connectivity opportunities for these species prior to recent anthropogenic impacts. Use of the recommended ecosystem classifications will greatly assist in mapping of carnivore habitat. Habitat typing and BC's BEC system will provide information on the capability of a site to produce not only certain overstory conditions, but also many understory conditions. Information on ecosystems also allows better interpretation of such characteristics as green-up times, nutrient levels of forages, and other factors that could influence habitat quality by carnivores or their prey.

8) Develop integrated aquatic/terrestrial classifications for addressing multiple objectives within ecoregions

Y2Y has focused its conservation planning on birds, carnivores, and aquatics. The ecosystem classification recommended in this report has focused on terrestrial systems. However, the identification of ecoregions is equally important for terrestrial, riparian/wetland, and aquatic systems. As Omernik and Bailey (1997) discussed, such ecoregional delineation is important for identifying areas capable of supporting similar aquatic ecosystems.

Development of classifications and coarse filter approaches has not received the same level of attention for aquatic systems as it has for terrestrial systems. However, coarse filter approaches are as equally useful and valuable for aquatic ecosystems as they are for terrestrial systems. Aquatic coarse filters will need to identify other types of indicators of ecosystem differences, such as stream sizes, gradient classes, surficial geology, or adjacent zones of terrestrial ecosystems. However, with the use of such indicators, classifications of aquatic systems can be developed and delineated. If Y2Y pursues such classifications, which we recommend, it should emphasize the importance of the development of classifications that integrate with the recommended terrestrial classifications. Conservation planning needs to become more holistic in its integration of its various goals. The use of integrated classification systems is an important way to improve on linking of aquatic and terrestrial conservation objectives.

9) Identify critical conservation areas based on these classifications

The efforts of the Y2Y avian working group highlighted the importance of understanding past and current status of ecosystems. Through the development and mapping of ecosystems within the designated ecoregions, Y2Y will be in a much better position to identify critical areas of need for either protection or restoration. Protection status alone is inadequate for addressing conservation objectives. The distribution and status of ecosystems in relation to the potential of maintaining or enhancing their contributions to conservation objectives is information that we think is critical for Y2Y to fully meet its conservation agenda. Certainly, avian conservation needs cannot advance significantly without better information on the status and distribution of ecosystems within the Y2Y region. Carnivore conservation will also be greatly enhanced by such information. Aquatic conservation will require a greater level of effort to classify and describe an effective coarse filter, but this work is important to assure provision of all aquatic biodiversity as well as to integrate aquatic efforts with actions for terrestrial objectives.

We hope that this project has provided information that can be used by Y2Y to improve the feasibility, efficiency, and effectiveness of its conservation actions. The tasks we have recommended will take additional commitment of time and efforts to complete, but the gains to Y2Y's conservation program will be significant.

ACKNOWLEDGEMENTS

This project was initiated and supported by the Yellowstone to Yukon Conservation Institute. The Ecosystem Management Research Institute (EMRI) completed the analysis and prepared this report. Information generated by this project will be used to identify core wildlife habitats and habitat connectivity necessary for the conservation of viable wildlife populations and biological diversity in the Yellowstone to Yukon region. GIS work conducted on this project has also been supported by a software grant from the Conservation Program at ESRI. For more information on the Yellowstone to Yukon Conservation Initiative, see www.y2y.net. For additional information on EMRI, see www.emri.org.

LITERATURE CITED

Achuff, P. L., and C. Wallis. 1977. A proposed policy for ecological reserves in Alberta. Alberta Energy and Natural Resources, Edmonton, Alberta, Canada.

Arno, S. F., D. G. Simmerman, and R. E. Keane. 1985. Forest succession on four habitat type in western Montana. USDA Forest Service General Technical Report INT-177. Ogden, UT.

Avers, P. E., D. T. Cleland, W. H. McNab, M. E. Jensen, R. G. Bailey, T. King, C. B. Goudney, and W. E. Russell. 1993. National hierarchial framework of ecological units. USDA Forest Service, Washington, D.C.

Bailey, R. G. 1980. Descriptions of the ecoregions of the United States. USDA Forest Service Miscellaneous Publication 1391, Washington, D. C.

Bailey, R. G. 1983. Delineation of ecosystem regions. Journal of Environmental Management 7:365-373.

Bailey, R. G. 1995. Description of the ecoregions of the United States (with separate map at a scale of 1: 7,500,000). USDA Forest Service Miscellaneous Publication 1391 (revised), Washington, D. C.

Barbour, M. G., J. H. Burk, and W. D. Pitts. 1980. Terrestrial plant ecology. The Benjamin/Cummings Publishing Company, Inc., Menlo Park, CA.

Bradley, A. F., W. C. Fischer, and N. V. Noste. 1992. Fire ecology of the forest habitat types of Eastern Idaho and Western Wyoming. USDA Forest Service General Technical Report INT-290, Ogden, UT.

Cleland, D. T., P. E. Avers, W. H. McNab, M. E. Jensen, R. G. Bailey, T. King, and W. E. Russell. 1997. National hierarchical framework of ecological units. Pages 181-200 *in:* M. S. Boyce and A. Haney, editors. Ecosystem management: applications for sustainable forest and wildlife resources. Yale University Press, New Haven, CT.

Cooper, S. V. 1975. 1975. Forest habitat types of northwestern Wyoming and contiguous portions of Montana and Idaho. Ph.D. Dissertation, Washington State University, Pullman.

Cooper, S. V., K. E. Neiman, R. Steele, and D. W. Roberts. 1987. Forest habitat types of northern Idaho: a second approximation. USDA Forest Service General Technical Report INT-236. Ogden, UT.

Craighead, J. J., J. S. Sumner, and G. B. Scaggs. 1982. A definitive system for analysis of grizzly bear habitat and other wildlife resources. Wildlife-Wildlands Institute, Monograph No. 1. University of Montana, Missoula.

Crane, M. F., and W. C. Fischer. 1986. Fire ecology of the forest habitat types of Central Idaho. USDA Forest Service General Technical Report INT-218. Ogden, UT

Daubenmire, R. F. 1952. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification. Ecological Monographs 22:301-330.

Daubenmire, R. 1968. Plant communities: a textbook of plant synecology. Harper and Row, New York, N.Y.

Daubenmire, R., and J. B. Daubenmire. 1968. Forest vegetation of eastern Washington and northern Idaho. Technical Bulletin 60, Washington Agricultural Experiment Station, Washington State University, Pullman.

Demarchi, D. 1994. Ecoprovinces of the Central North American Cordillera and adjacent plains. Pages 153-168 *in:* L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, L. J. Lyon, and W. J. Zielinski, editors. The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the Western United States. USDA Forest Service General Technical Report RM-254. Fort Collins, CO.

Demarchi, D. A. 1992. Biophysical habitat classification in British Columbia: a system for mapping mountainous ecosystems. Pages 39-46 *in:* G. B. Ingram, and M. R. moss, editors. Landscape approaches to wildlife and ecosystems management. Proceedings of the second symposium of the Canadian Society for Landscape Ecology and Management: University of British Columbia. Polyscience Publications, Inc. Morin Heights, PQ. Canada.

Demarchi, D. A., and E. C. Lea. 1989. Biophysical habitat classification in British Columbia: an interdisciplinary approach to ecosystem evaluation. Pages 275-276 *in:* D. E. Ferguson, P. Morgan, and R. D. Johnson, compilers. Proceeding- land classifications based on

vegetation: applications for resource management. USDA Forest Service, General Technical Report INT-257, Ogden, UT.
Ecological Stratification Working Group. 1996. A national ecological framework for Canada. Agriculture and Agri-Food Canada, Research Branch, Centre for Land and Biological Resources Research and Environment Canada, State of Environment Directorate, Ottawa, Ontario, Canada.
Environment Canada. 1989. Ecoclimatic regions of Canada, first approximation (with map at a scale of 1: 7,500,000). Ecological Land Classification Series No. 23, Environment Canada, Ottawa, Canada.
Eyre, F. H., editor. 1980. Forest cover types of the United States and Canada. Society of American Foresters, Washington, D.C.
Gleason, H. A. 1917. The structure and development of the plant association. Bulletin of the Torrey Botanical Club 44:463-481.
Grossman, D. H, P. Bourgeron, W. N. Busch, D. Cleland, W. Platts, G. C. Ray, C. R. Robins, and G. Roloff. 1999. Principles for ecological classification. Pages 353-393 *in:* R. C. Szaro, N. C. Johnson, W. T. Sexton, and A. J. Malk. Ecological stewardship: a common reference for ecosystem management, Volume II. Elsevier Science, Oxford, UK.
Grossman, D. H., D. Faber-Langendoen, A. S. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K. Patterson, M. Pyne, M. Reid, and L. Sneddon. 1998. Terrestrial vegetation of the United States: Volume I: the national vegetation classification system: development, status, and applications. The Nature Conservancy. Arlington, VA.
Hann, W. J. 1982. A taxonomy for classification of seral vegetation of selected habitat types in western Montana. Ph.D. Dissertation. University of Idaho, Moscow.
Haufler, J. B. 1999. Strategies for conserving terrestrial biological diversity. Pages 17-30 *in:* R. K. Baydack, H. Campa III, and J. B. Haufler, editors. Practical approaches to the conservation of biological diversity. Island Press, Washington, D.C.
Haufler, J. B., R. K. Baydack, H. Campa, III, B. J. Kernohan, L. J. O'Neil, L. Waits, and C. Miller. 2002. Performance measures for ecosystem management and ecological sustainability. The Wildlife Society Technical Review 02-01. The Wildlife Society, Bethesda, MD.
Haufler, J. B., C. A. Mehl, and G. J. Roloff. 1999. Conserving biological diversity using a coarse filter approach with a species assessment. Pages 107-16 *in:* R. K. Baydack, H. Campa, III, and J. B. Haufler, editors. Practical approaches to the conservation of biological diversity. Island Press, Washington, D.C.
Haufler, J. B., C. A. Mehl, and G. J. Roloff. 1996. Using a coarse filter approach with a species assessment for ecosystem management. Wildlife Society Bulletin 24:200-208.
Hessburg, P. F., R. B. Salter, M. B. Richmond, and B. G. Smith. 2000. Ecological subregions of the Interior Columbia Basin, USA. Applied Vegetation Science 3:163-180.
Hogg. J. T., N. S. Weaver, J. J. Craighead, B. M. Steele, M. L. Pokorny, M. H. Mahr, R. L. Redmond, and F. B. Fisher. 2001. Vegetation patterns in the Salmon-Selway ecosystem: an improved land cover classification using landsat TM imagery and wilderness botanical surveys. Craighead Wildlife-Wildlands Institute Monograph Number 2. Missoula, MT.
Hutto, R. L. 1998. Using landbirds as an indicator species group. Pages 75- 92 *in:* J. M. Marzluff and R. Sallabanks, editors. Avian conservation: Research and management. Island Press, Washington, D.C.
Johnson, D. H., and T. A. O'Neil. 2001. Wildlife-habitat relationships in Oregon and Washington. Oregon State University Press, Corvallis.
Kuchler, A. W. 1964. Manual to accompany the map- potential vegetation of the conterminous United States. American Geographers Society Special Publication 36.

Mattson, D. J., and R. R. Knight. 1989. Evaluation of grizzly gear habitat using habitat type and cover type classifications. Pages 135-143 *in:* D. E. Ferguson, P. Morgan, and R. D. Johnson, compilers. Proceeding- land classifications based on vegetation: applications for resource management. USDA Forest Service, General Technical Report INT-257, Ogden, UT.

Maxwell, J. R., C. J. Edwards, M. E. Jensen, S. J. Paustian, H. Parrot, and D. M. Hill. 1995. A hierarchical framework of aquatic ecolgocical units in North America (Nearctic zone). USDA Forest Service General Technical Report NC-176. St. Paul, MN.

McCallum, D. A. 1994. Review of technical knowledge: flammulated owls. Pages 14-46 *in:* G. D. Hayward, and J. Verner, Editors. Flammulated, boreal, and great gray owls in the United States: a technical conservation assessment. USDA Forest Service General Technical Report RM-253, Fort Collins, CO.

McNab, W. H., and P. E. Avers, editors. 1994. Ecological subregions of the United States: section descriptions. USDA Forest Service Administrative Publication WO-WSA-5, Washington, D. C.

Mehl, C. A., R. Steele, S. Warren, B. Holt, J. B. Haufler, and G. J. Roloff. 1998. The ecosystem diversity matrix for the Idaho Southern Batholith Landscape: A user's manual. Technical Report. Boise Cascade Corporation. Boise, ID.

Montgomery, D. R., G. E. Grant, and K. Sullivan. 1995. Watershed analysis as a framework for implementing ecosystem management. Water Resources Bulletin 31(3):369-386.

Morgan, P., G. H. Aplet, J. B. Haufler, H. C. Humphries, M. M. Moore, and W. D. Wilson. 1994. Historical range of variability: a useful tool for evaluating ecosystem change. Journal of Sustainable Forestry 2:87-111.

Mueggler, W. F., and W. L. Stewart. 1980. Grassland and shrubland habitat types of western Montana. USDA Forest Service General Technical Report INT-66. Ogden, UT.

Nesser, J. A., G. l. Ford, C. L. Maynard, and D. S. Page-Dumroese. 1997. Ecological units of the Northern Region: subsections. USDA Forest Service General Technical Report INT-GTR-369. Ogden, UT.

O'Hara, K. L., P. A. Latham, P. Hessburg, and B. G. Smith. 1996. A structural classification for inland northwest forest vegetation. Western Journal of Applied Forestry 11(3):97-102.

Oliver, C. D. 1992. A landscape approach: Achieving and maintaining biodiversity and economic productivity. Journal of Forestry 90 (9):20-25.

Omernik, J. M. 1987. Ecoregions of the conterminous United States. Annals of the Association of American Geographers 77:118-125.

Omernik, J. M. 1995. Ecoregions: a framework for environmental management. Pages 49-62 *in:* W. Davis, and T. Simon, editors. Biological assessment and criteria: tools for water resource planning and decision making. Lewis Publishers, Boca Raton, FL.

Omernik, J. M., and R. G. Bailey. 1997. Distinguishing between watersheds and ecoregions. Journal of the American Water Resources Association 33:935-949.

Omernik, J. M., and G. E. Griffith. 1991. Ecological regions versus hydrological units: Frameworks for managing water quality. Journal of Soil and Water Conservation 46(5):334-340..

Pfister, R. D. 1989. Basic concepts of using vegetation to build a site classification system. Pages 22-28276 *in:* D. E. Ferguson, P. Morgan, and R. D. Johnson, compilers. Proceeding- land classifications based on vegetation: applications for resource management. USDA Forest Service, General Technical Report INT-257, Ogden, UT.

Pfister, R. D. 1991. Land classification in the Western United States. Pages 9-17 *in:* D. L. Mengel and D. T. Tew, editors. Ecological land classification: Applications to identify the productive potential of southern forests. USDA Forest Service General Technical Report SE-68. Asheville, N.C.

Pfister, R. D., and S. F. Arno. 1980. Classifying forest habitat types based on potential climax vegetation. Forest Science 26:52-70.
Pfister, R. D., B. L. Kovalchik, S. F. Arno, and R. C. Presby. 1977. Forest habitat types of Montana. USDA Forest Service General Technical Report INT-34. Ogden, UT.
Pfister, R. D., and M. D. Sweet. 2000. Developing an ecosystem diversity framework for landscape assessment. Pages 91-96 *in:* H. Y. Smith, editor. The Bitterroot ecosystem management research project: what we have learned: symposium proceedings. USDA Forest Service Proceedings RMRS-P-17. Ogden, UT.
Pojar, J., K. Klinka, and J. Meidenger. 1987. Biogeoclimatic ecosystem classification in British Columbia. Forest Ecology and Management 22:119-154.
Quigley, T. M., R. W. Hayes, and R. T. Graham. 1996. Integrated scientific assessment for ecosystem management in the interior Columbia Basin. USDA Forest Service, General Technical Report PNW-382. Portland, OR.
Reed, R. M. 1976. Coniferous forest habitat types of the Wind River Mountains, Wyoming. American Midland Naturalist 95:159-173.
Ricketts, T. H., E. Dinerstein, D. M. Olson, C. J. Loucks, W. Eichbaum, D. DellaSala, K. Kavanagh, P. Hedao, P. Hurley, L, M. Carney, R. Abell, and S. Walters. 1999. Terrestrial ecoregions of North America: a conservation assessment. Islanre Press, Washington, D.C.
Roberts, D. W. 1980. Forest habitat types of the Bear’s Paw Mountains and Little Rocky Mountains, Montana. M.S. Thesis. University of Montana, Missoula.
Roloff, G. J., and J. B. Haufler. 2002. Modeling habitat-based viability from organism to population. Pages 673-686 *in:* M. J. Scott, P. J. Heglund, M. L. Morrison, J. B. Haufler, M. G. Raphael, W. A. Wall, and F. B. Samson, editors. Predicting species occurrence. Island Press, Washington, D.C.
Roloff, G. J., and J. B. Haufler. 1997. Establishing population viability planning objectives based on habitat potentials. Wildlife Society Bulletin 25:895-904.
Salabanks, R., J. B. Haufler, and C. A. Mehl. Draft manuscript. The use of the ecosystem diversity matrix to explain bird distributions in the Southern Idaho Batholith. Sustainable Ecosystems Institute, Meridian, ID.
Scott, J. M., F. W. Davis, B. Csuti, R. Noss, B. Butterfield, C. Groves, H. Anderson, S. Caicco, F. D’Erchia, T. C. Edwards, J. Ulliman, and R. G. Wright. 1993. Gap analysis: a geographic approach to protection of biological diversity. Wildlife Monographs 123:1-41.
Smith, J. K., and W. C. Fischer. 1997. Forest ecology of the forest habitat types of Northern Idaho. USDA Forest Service General Technical Report INT-GTR-363. Ogden, UT.
Steele, R., R. D. Pfister, R. A. Ryker, and J. A. Kittams. 1981. Forest habitat types of central Idaho. USDA Forest Service General Technical Report INT-114. Ogden UT.
Steele, R., S. V. Cooper, D. M. Roberts, and R. D. Pfister. 1983. Forest habitat types of eastern Idaho- western Wyoming. USDA Forest Service General Technical Report INT-144. Ogden UT.
Steele, R. and K. Geier-Hayes. 1987. The grand fir/blue huckleberry habitat type in central Idaho: succession and management. USDA Forest Service General Technical Report INT-228. Ogden, UT.
Steele, R. and K. Geier-Hayes. The Douglas-fir/ninebark habitat type in Central Idaho: succession and management. USDA Forest Service General Technical Report INT-252, Ogden, UT.
Steele, R., and K. Geier-Hayes. 1992. The grand fir/mountain maple habitat type in central Idaho: succession and management. USDA Forest Service General Technical Report INT-284. Ogden, UT.

Steele, R., and K. Geier-Hayes. 1993. The Douglas-fir/pinegrass habitat type in Central Idaho: succession and management. USDA Forest Service General Technical Report INT-298. Ogden, UT.
Steele, R., and K. Geier-Hayes. 1994. The Douglas-fir/white spirea habitat type in Central Idaho: succession and management. USDA Forest Service General Report INT-305. Ogden, UT.
Steele, R., and K. Geier-Hayes. 1995. Major Douglas-fir habitat types of central Idaho: A summary of succession and management. USDA Forest Service General Technical Report INT-331. Ogden, UT.
Strong, W. L. 1992. Ecoregions and ecodistricts of Alberta. Alberta Forestry, Lands and Wildlife Publication T/244. Edmonton, Alberta, Canada.
Swetnam, T. W., C. D. Allen, and J. L. Betancourt. 1999. Applied historical ecology: using the past to manage the future. Ecological Applications 9:1189-1206.
Thomas, J. W., editor. 1979. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. USDA Forest Service, Agricultural Handbook #533. Washington, D.C.
Wellner, C. A. 1989. Classification of habitat types in the Western United States. Pages 7-21 *in:* D. E. Ferguson, P. Morgan, and R. D. Johnson, compilers. Proceeding- land classifications based on vegetation: applications for resource management. USDA Forest Service, General Technical Report INT-257, Ogden, UT.
Wertz, W. A., and J. F. Arnold. 1972. Land system inventory. USDA Forest Service. Ogden, UT.
Wiken, E. B., compiler. 1986. Terrestrial ecozones of Canada. Ecological land classification series No. 19, Environment Canada, Lands Directorate, Ottawa, Ontario, Canada.
Youngblood, A. P., and W. F. Mueggler. 1981. Aspen community types on the Bridger-Teton National Forest in western Wyoming. USDA Forest Service Research Paper INT-242. Ogden, UT