BASIN LEVEL ECOLOGICAL REGIONS OF THE UPPER GRANDE RONDE RIVER

by

SANDRA ANNE THIELE

A RESEARCH PAPER

submitted to

THE GEOSCIENCES DEPARTMENT

in partial fulfillment of the
requirements for the
degree of

MASTER OF SCIENCE

GEOGRAPHY PROGRAM

May 1992

Directed by
Dr. Gordon E. Matzke

TABLE OF CONTENTS

Acknowledgements	i
Prologue	ii
ABSTRACT	1
INTRODUCTION	1
OBJECTIVES	4
LITERATURE REVIEW	4
The Definition and Perception of Classification	4
The Ecoregion Process - A "Top-down" Approach	6
Single Variable Regions	6
Multiple Variable Regions	7
Applications of the Ecoregion Framework	11
Setting Water Quality Standards	11
Sampling Design	11
Data Analysis	11
Predictability	12
Cumulative Effects Research; Evaluation of Best Management Practices	12
Ecosystem Restoration	13
Biodiversity Assessment; Establishment of Refugia	13
Stream Classification - The "Bottom-up" Approach	14
Evaluating the Regional Model	17
Evaluating Representational Accuracy	17
1. Using Faunal Distribution Data	18
2. Using Multiple Analyses	22
Evaluating Utility	26
MATERIALS AND METHODS	28
The Study Area	28
Materials	29
Methods	32
Scale Considerations	32
Working within the Data Layers	34
Integrating the Data Layers	42
DESCRIPTION OF THE BASIN LEVEL REGIONS	45
EVALUATION AND APPLICATIONS OF THE BASIN LEVEL REGIONS	50
SUMMARY	52
REFERENCES CITED	55

Acknowledgements

First of all, many thanks to Gordon Matzke, major professor and devil's advocate. His lectures made the traditions of geography relevant to today's problems, while pointing out the need to question comfortable paradigms.

Thanks to Sharon Clarke, for suggesting that I take part in the Grande Ronde project, for being "the other half of the brain", and for making lively debate a part of true collaboration.

It was a pleasure to work with Jim Omernik and others involved in ecoregions research. They have laid the foundations for work which is continuing to evolve and is being applied nationwide.

Bob Hughes offered suggestions for revision of the draft paper. His willingness to interrupt his work for discussion is much appreciated.

Thanks to Denis White for serving as an ecoregional authority on the committee and for allowing access to his extensive library of regional articles.

Sue Pierson provided a good measure of patient assistance in the transition to a new Geographic Information System.

And, last but not least, I owe my family a debt of gratitude for keeping the household intact for an absentee wife and parent.

Much of our disagreement about the proper role and function of regions, models and other generalizations probably should be attributed to basic and inherent differences between humans and their need for order, in which case it cannot be resolved by rational discussion. Most of us are probably somewhere on a continuum between two polar extremes. At one extreme are those tidy-minded souls whose instincts tell them that the world should move with all the precision of a finely tuned watch,... that our inability to detect regularity and order merely reflects our own weak analytical skills rather than the possibility that it may not exist. At the other extreme are those rambunctious types who perceive the world as a massive stochastic process, who glory in its disorder, chaos, and complexity, and who revel in the thought that every leaf on every tree is different. This battered old planet has quite enough evidence to keep both extremes happily convinced that they are right.

-----John Fraser Hart, 1982

BASIN LEVEL ECOLOGICAL REGIONS OF THE UPPER GRANDE RONDE RIVER

ABSTRACT: Ecological regionalization is a form of spatial classification, where boundaries are drawn around areas relatively homogeneous in landscape characteristics. In the delineation of ecological regions, or ecoregions, the process includes the analysis of ecosystem structure and function. Ecoregions have been developed at national and state scales for research and resource management. Stream classification is another method to order the variability of aquatic habitats, that spans spatial scales from microhabitat to valley segment. In this study, ecoregions are developed at the scale of a large watershed (3000 square kilometers), the upper Grande Ronde River basin in northeastern Oregon. The ecoregion framework presented here is proposed to bridge the gap between stream and ecoregions classification. The classification at this scale is meant to address issues of management at local scales: to aid in sample design, extrapolation of the results of site-specific studies and the development of best management practices that are predictive of ecosystem response.

INTRODUCTION

It is only human to take the complexity of the natural environment, incomprehensible in its variety, and try to make it ordered and simple. Classification is one human attempt to create order out of apparent chaos. Through classification, objects are divided into groups according to similarities, relationships or hierarchies (Warren, 1979; Platts, 1980). Working within a tested classification system, researchers can generalize, extrapolate and predict with greater confidence.

Ecological regionalization is a form of spatial classification. It is the process by which boundaries are drawn around relatively homogeneous areas where within-region variability among landscape characteristics has been minimized. In the delineation of ecological regions, or ecoregions, the process includes the analysis of ecosystem structure and function (Omernik, 1987; Bailey, 1988). Because the process of regionalization creates discrete areas out of a continuum, the resulting region boundaries are approximations.

Several ecoregional schemes developed in the United States and Canada have a terrestrial focus (Wiken, 1982; Bailey and others, 1985). Other systems attempt to integrate terrestrial and aquatic systems (Lotspeich and Platts, 1982; Omernik, 1987). The rationale for such an integration is that streams are a reflection of the watersheds which they drain. The climate, geology and soils of an area determine the substrate, seasonal discharge, channel morphology and chemical properties of the water. The vegetation type and its extent also influence water quantity as well as its temperature and clarity. The grouping of basins having similar geology, topography, soil and vegetation allows a comparison of streams of similar size across a relatively homogeneous area.
The usefulness of regionalization to land managers lies in the assumption that a subpopulation of streams within a relatively homogeneous region will respond similarly to a specific type of management. This gives a predictive capacity to management decisions and aids in the development of best management

practices. Water resource managers must also be familiar with the potential capabilities of streams in particular classes. The best management practices that they develop should reflect stream response to the impacts of land use practices (Warren, 1979). Knowing the potential capability of an area enables managers to derive management practices that allow the ecosystem to retain a measure of its original productivity.

Federal and state agencies have used ecoregions to plan monitoring and restoration programs, to sort proportional impacts in nonpoint source studies, and to assess biodiversity. The US Environmental Protection Agency in cooperation with various state agencies presently utilize Omernik's ecoregions (Omernik, 1987) at a national, regional and state level to assess the quality of aquatic resources and to set water quality standards.

It has been suggested that for some areas it may be appropriate to further subdivide ecoregions until they reach the scale of local management decisions (Science Advisory Board Report, 1991). Perhaps in so doing a link will be created with "bottom up" stream classification schemes, which classify on the basis of site specific characteristics such as stream channel morphology or valley segment geomorphologic structure. The purpose of this study is to bridge the gap between the stream and ecoregional classifications by extending the ecoregional classification scheme to a finer, basin-level resolution.

OBJECTIVES

The objectives of this study were to:

1) review the literature on ecoregional classification and stream classification; determine the feasibility of taking the ecoregion methodology, which has been used at national and state levels, to a finer scale, basin-level resolution.

2) create basin-level ecological regions for the Upper Grande Ronde River watershed (3000 square km) in the Blue Mountains of northeastern Oregon.

3) outline the utility of ecoregions at this scale to land managers.

4) propose methods of evaluating the representational accuracy of the regions.

LITERATURE REVIEW
THE DEFINITION AND PERCEPTION OF CLASSIFICATION

Classification is the ordering of objects into groups on the basis of their similarities or relationships (Platts, 1980). While there may be general agreement on the definition of classification, there are mixed expectations of the resulting classification systems. Classifications may be regarded as hypotheses that are either true or false, or they may alternatively be seen as tools, to be judged by their ability to accomplish particular tasks (Warren, 1979). In reality, a good classification incorporates both elements; it is a model created to meet predetermined objectives.

The two kinds of classification, true/false hypothesis or tool, have been described in terms of mathematical set theory (Gale and Atkinson, 1979). In one, the members are classified strictly and may belong to only one set (Boolean set theory); the result is a clearly defined unit. In the other, described in terms of the theory of "fuzzy sets", the territorial boundaries are indeterminant and context dependent. The membership conditions are "subjective estimates of belongingness" (Gale and Atkinson, 1979). Ecological regions, then, may be seen as a "fuzzy set"; they are discrete areas created out of an ecological continuum.

If an ecosystem is defined as the organisms in any given area interacting with their physical environment, then ecoregional boundaries indicate where significant ecological changes are taking place. The line on the map is an approximation representing a transition area of varying width. The ecoregions are models of reality, and, as such, they should not be judged strictly by some criterion of truth or falsity, but by their ability to meet predetermined objectives and by their explanatory power.

THE ECOREGION PROCESS
A "Top-down" Approach

The very size, complexity and variability of land management units preclude the creation of ecoregions by extrapolation of site-specific information. Available data is project-specific, not spatially distributed, with different methodologies used for data collection and analysis. Extrapolation is not possible until it is determined that a site is representative of a group of sites. By using a "top-down" approach, the process is reversed; available landscape data provides a continuous fabric of information to illustrate landscape patterns. Knowledge gained from specific projects may then be organized within this regional framework.

Single Variable Regions

There are early examples of national regional frameworks built upon a single variable, such as climate, physiography or vegetation patterns: the Climates of North America (Thornthwaite, 1931), the Physical Divisions of the United States (Fenneman, 1946), and National Potential Natural Vegetation (Kuchler, 1964). Such single variable regions have a specific use built upon their themes.

Other single variable land classifications are data driven; that is, they are derived inductively, building a general hypothesis from a body of specific data. Fish faunal regions have been developed for the states of Arkansas (Hughes and others, in press) and Kansas (Hawkes and others, 1986) using ordination techniques to cluster sampling sites into homogeneous regions according to similarities in fish assemblages. There are those who would object to this method in principle, on the premise that it inverts the scientific process; they claim that theory should be the starting point, not facts and data. Rowe and Sheard (1981) declare that land classifications do not generate theories about the land's structural organization, but that they result from the application of theory, whether climatic, geomorphic or ecological.

Multiple Variable Regions

Ecological regions are built through the use of multiple variables, such as climate, geology, vegetation, soil, and topography. Because they are constructed through the integration of many data layers, ecoregions do not have a specific theme and thus have the potential for a more general application. While they may not explain the response of any single element, such as a particular species distribution, they represent an area of integrated ecosystem potential.

Ecoregional schemes differ in the ways that the multiple component variables are applied to various scales. The process of regionalization normally follows one of two conceptual pathways. In one the region delineated at a particular scale is a result of a primary controlling factor, such as climate or geology. A dominant controlling factor is chosen for each level of resolution. The other method of regionalization assesses the influence of all the landscape characteristics at each level of resolution.

Bailey developed a hierarchical regionalization scheme using the controlling factor concept. He created macroecoregions according to climatic regime, and more local ecoregions by basal landforms. He hypothesized that regions delineated in this way would be formed by relatively stable, unchanging elements; they would then be independent of the changes wrought by present landuse practices (Bailey, 1983; Figure 1). Lotspeich and Platts (1982) ascribed to a similar approach, classifying land units as a hierarchy according to climate and geology, with first order watersheds serving as the basic organizing unit.

The other regionalization approach uses a collection of landscape and ecological information at each level of resolution. This multivariate method of regionalization involves the integration of several layers of mapped information, as well as the interpretation of the relationships between the mapped layers and information from written material. Using multiple layers compensates for gaps in the data as well as for differences in data quality. For example, climate data may be available at a continental or regional scale, but it is rarely available at more local scales. Weather station data is often used, but it is spatially biased toward lower elevations and settled areas.

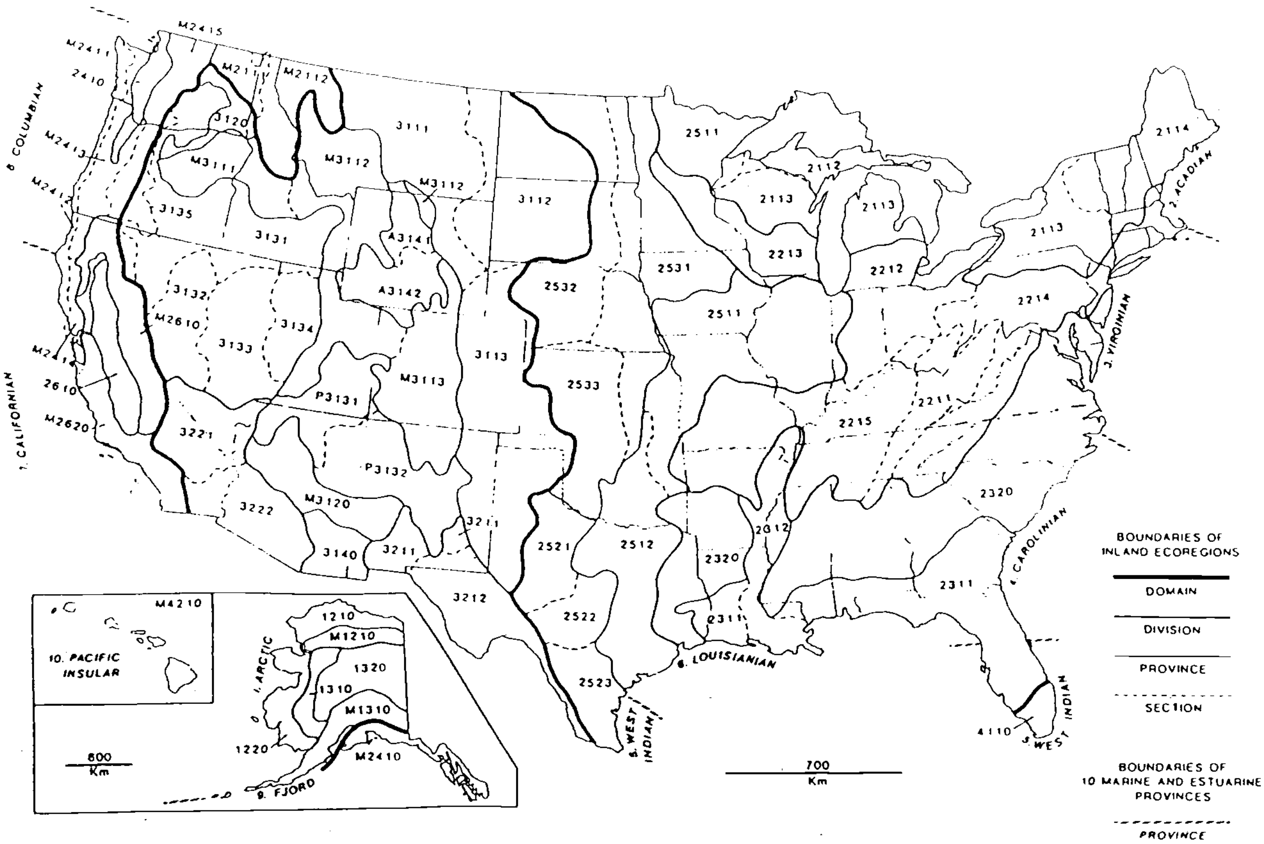
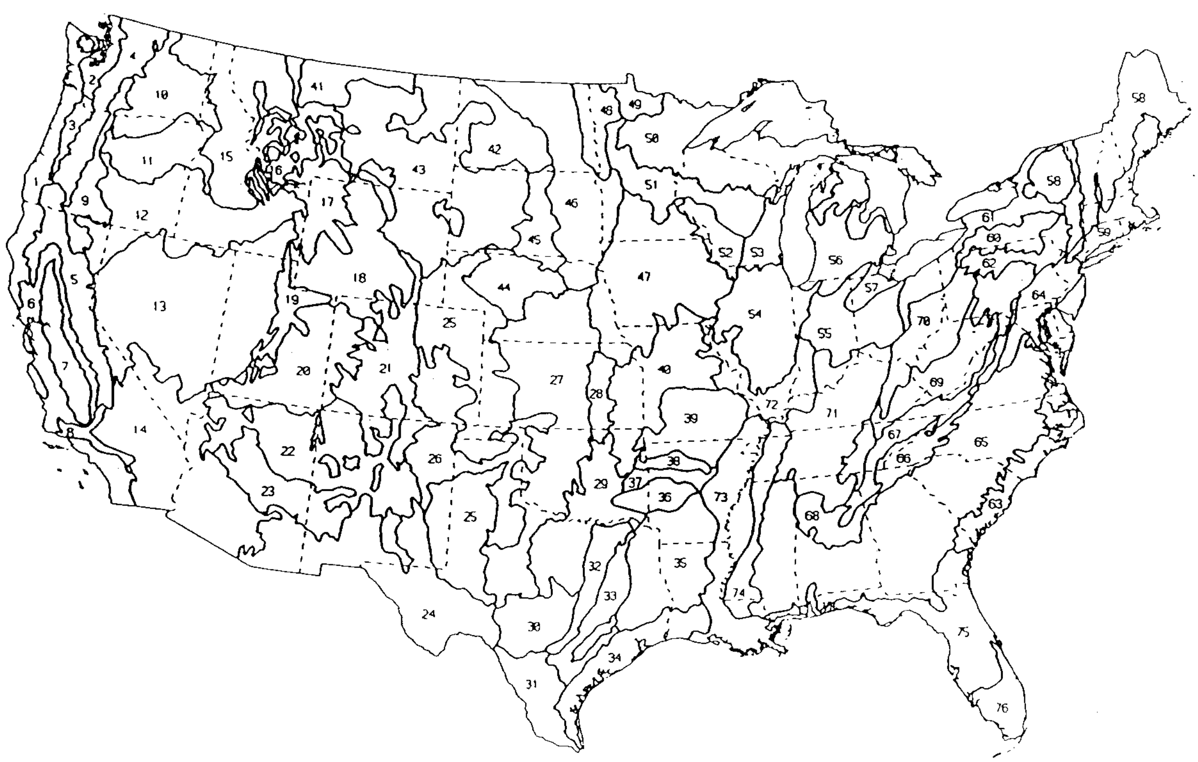


Figure 1. Bailey's Ecoregion Map of the United States.

Figure 2. Omernik's Ecoregion Map of the United States.



This classification method was used in the early 1980's by researchers at the Canadian Lands Directorate. Their seven hierarchical regional levels range from the broad ecozone, fifteen across Canada, to the detailed ecosite and ecoelement. The component variables interact at each level to describe the distinctive character of the region (Wiken, 1982). In the U.S., Omernik (1987) used a similar approach to create ecological regions for water quality management at a national scale (Figure 2). Omernik's ecoregions were compiled at a scale of 1:7,500,000. At this scale, the regions are appropriate for regional or national assessments. In areas of high heterogeneity, differences in water quality may be better explained by reducing the variability even more, that is, by further subdividing ecoregions into subregions. Subregionalization has been done for the states of Colorado (Gallant and others, 1989), Alabama and Mississippi (Griffith and Omernik, 1991), and Oregon (Clarke and others, 1991).

APPLICATIONS OF THE ECOREGION FRAMEWORK

Setting Water Quality Standards

Omernik's ecoregional framework has been used by several states to meet the requirements of EPA's Water Quality Standards Regulation in the development of biological criteria. Delineating areas of regionally varying water quality allows a more explicit definition of attainability and aquatic life uses than does a single statewide standard. The ecoregions also provide a framework for locating representative, relatively unimpaired waterbodies to serve as reference sites. The numbers and kinds of organisms found in the less impaired habitats are then compared with what is present in the degraded habitats to give a relative measure of impact.

Sampling Design

In order to plan a monitoring program, it may be necessary to group similar sites together to form a population from which a representative sample may be chosen. The size and heterogeneity of a region indicates the appropriate number of sites required to adequately represent an area. Regions aid in determining the density of the sampling frame to ensure that important areas are not missed.

Data Analysis

The stratification of sites and sampling information into relatively homogeneous groups reduces apparent variability and increases precision in data analysis. It means that sites within a region will be comparable, and that site-specific results may be extrapolated to a defensible area.

Predictability

The usefulness of regionalization to land managers lies in the assumption that a subpopulation of streams or terrestrial sites within a relatively homogeneous region will respond similarly to a specific type of management. This gives a predictive capacity to management decisions and aids in the development of best management practices.

Cumulative Effects Research; Evaluation of Best Management Practices

Ecoregions are built according to ecosystem potential; that is, they are constructed on the basis of the most stable and unchanging attributes. Land managers should be familiar with the potential capabilities of the terrestrial and aquatic resources in their care. They need to be aware of how far ecosystems undergoing human impacts have departed from their initial natural state. Best management practices, in order to approach true sustainability of resources, should reflect not only how much can be extracted from a system, but how capable the system is of returning to some semblance of its original state.

Reference sites, representative of streams within the ecoregion, serve as a model for potential attainability. Best management practices may be evaluated by sampling a random collection of sites of varying impacts and comparing their current condition with that of the reference sites. The results may be extrapolated regionally to estimate cumulative effects over time (Gallant and others, 1989).

Ecosystem Restoration

Rehabilitation of disturbed waterways can proceed most effectively if there is a measurable goal for the cleanup effort (Hughes and others, 1990). As mentioned above, reference sites provide such a measure by serving as a model of attainable conditions for an entire population of streams. Relating condition and attainability to the underlying capability of the system contributes to the search for the probable causes of condition. Once probable causes are known, priorities can be set for cost effective restoration of waterbodies.

Biodiversity Assessment; Establishment of Refugia

The historical method for preserving biodiversity has tended toward an expensive, last ditch effort to save single species. Recently, biodiversity assessment has taken more of a systems approach, identifying species rich areas and comparing these with protected areas, to determine whether preserves are protecting the maximum number of species (Scott and others, 1987).

Depending upon the scale of the effort, ecoregions as they exist now, or reconfigured with specific biodiversity objectives, could be used to organize the species distribution and preserve information to determine whether major ecosystems are adequately represented. In addition, redundancy is important in establishing preserves or refugia as source areas for recolonization following disturbance. A regional framework can aid in predicting the number and location of preserves needed per ecoregion to compensate for disease and natural disasters.

Examining major stressors by region would help prioritize preservation efforts in rapidly changing, high impact areas. Regions built on ecosystem potential, rather than present day information, would also be important if areas must be restored before they could support a population of interest.

STREAM CLASSIFICATION
The "Bottom-up" Approach

Stream biologists, working with a small number of sites, face issues of sampling and monitoring similar to those at national and state levels, but at a different scale. One of their major problems has been simply defining the boundaries of the system. The sample area may include a square meter of riffle, a pool-riffle sequence, a reach, segment or entire drainage. This has caused problems in determining how comparable sampling sites should be selected or how to extrapolate information from a particular pool or riffle to a watershed or other geographical area (Minshall, 1988).

Water resource managers face a wider problem of applying the results of site-specific studies to broad scale resource planning and management. In order to respond to losses in biodiversity, they need to understand the relationships between stream habitat diversity and the changing populations of stream organisms. They would like to know how much structural diversity can be lost before significant degradation occurs in aquatic communities (Schlosser, 1991; Sedell and others, 1990).

A variety of stream habitat classifications have been developed to respond to these issues. Most of these classifications place stream habitat features in a broader scale geomorphic context, recognizing that processes operating at broad scales over time effect stream ecosystem structure and function. Lithology and channel geomorphology shape biological community structure (both instream and riparian) by influencing habitat structure, water quantity and chemistry, and the transport and availability of nutrients (Brussock and others, 1985; Gregory and others, 1991; Frissell and others, 1986). Platts (1974) recognized this terrestrial/aquatic connection when he classified streams in Idaho using channel characteristics and bank conditions as well as geomorphic types. In a later project, he attempted to merge the US Forest Service's terrestrial-based landtype classification with a system designed for aquatic resources. The classification was based on the premise that similar land units contain similar stream environments and thus similar fisheries (Platts, 1978).

Frissell and associates (1986) developed a hierarchical framework which included five scales of stream habitat systems from microhabitat to watershed. Their intent was to place the stream habitat in its geographical context and to eventually connect the stream classification to a broad scale biogeoclimatic land classification system as suggested by Warren (1979). While Frissell's classification attempts to span multiple spatial and temporal scales, other classifications concentrate on a particular level of detail. Rosgen (1985) categorized stream channels on the basis of measurable stream channel features such as stream gradient, sinuosity, and width/depth ratio. He illustrated channel elements and their accompanying valley type for fishery habitat interpretation and for feature recognition in the field. Cupp, on the other hand, emphasized the valley segment, preferring to use relatively persistent features outside the stream channel, for his classification of forested stream habitats in the state of Washington (Cupp, 1988).

As illustrated in these last sections, the classification of aquatic resources is proceeding at two very different scales. The two classification approaches, the top-down ecoregion approach and the bottom-up stream classification method, are on a generally convergent pathway. Yet a gap remains between the ecological subregions that have been developed for state-level applications and the stream habitat classifications which encompass the scale of small watersheds. The basin level ecoregion framework presented in this paper is intended to bridge the gap between the two classification methods.

EVALUATING THE REGIONAL MODEL

An ecoregional classification should be tested to show that it has ecological significance (Rowe and Sheard, 1981; Bailey, 1987). However, as discussed earlier, expectations for classification schemes may vary between reviewers. Ecoregion boundaries may be regarded by some as hypotheses that are either true or false, or they may be seen as tools, to be judged by their ability to accomplish particular tasks. As a hypothesis or model, the regional framework ought to have some measure of representational accuracy; as a tool it ought to have utility (Warren, 1979). Any evaluation of a regional model should incorporate both elements.

Evaluating Representational Accuracy

To test the representational accuracy of a regional classification system, researchers require spatially distributed data, such as fish distribution, physical habitat, or water quality. Unfortunately, available information of this nature is often limited and spotty in its distribution for any particular region. The ideal situation is to design a sampling program to collect sufficient spatially distributed data. Several examples follow of projects undertaken by state water quality agencies with the cooperation of the U.S. Environmental Protection Agency specifically to evaluate Omernik's ecoregional framework.

1. Using Faunal Distribution Data

Because fish are the main focus of attention in stream ecosystems, fish distribution and relative abundance data are often used to evaluate the accuracy of regional frameworks. Also, fish data may be the only spatially distributed information that is available. In Oregon, researchers used cluster and detrended correspondence analysis (DCA) on a historic fish collection database to analyze regional distribution patterns of 68 native fish species. The multivariate analysis resulted in seven distinct fish faunal regions (ichthyogeographic regions) (Hughes and others, 1987). These fish faunal regions compared favorably with four of the eight Omernik ecoregions, two out of the ten physiographic provinces and five of eighteen river basins within the state. The fish data used in the Oregon study was rather coarse in its resolution. Regional distinctions may have been masked by the fact that the sampled streams often were not entirely within one ecoregion.

Sampling sites for a later study were located on forty-nine small, representative, relatively unimpacted streams wholly within ecoregion boundaries. Again, consistent regional patterns were sought in fish (and macroinvertebrate) species distribution data. Clear differences between montane and nonmontane regions were shown from detrended correspondence analysis of these data, as well as distinctions between three of the nonmontane areas, the Willamette Valley, Columbia Basin and High Desert (Whittier and others, 1988; Figure 3). Differences in fish assemblages between ecoregions were also apparent in similar studies in Ohio and Arkansas (Larsen and others, 1986; Rohm and others, 1987). For example, in Ohio, in the intensively farmed Huron/Erie Lake Plain, fish species richness was low and assemblages were dominated by those tolerant of sedimentation and turbidity. In the forested Western Allegheny Plateau, fish species richness was higher and fish there were intolerant of sedimentation and turbidity. The remaining three ecoregions of Ohio, where land cover is a mosaic of farm and forest, were intermediate in their species composition (Larsen and others, 1986)

In other areas of the country, correspondence between fish assemblages and Omernik's ecoregions is not as conclusive. Hawkes' fish faunal regions of Kansas, developed through Principal Components Analysis of fish presence/absence data at 410 stream sites, do not coincide with Omernik's ecoregions

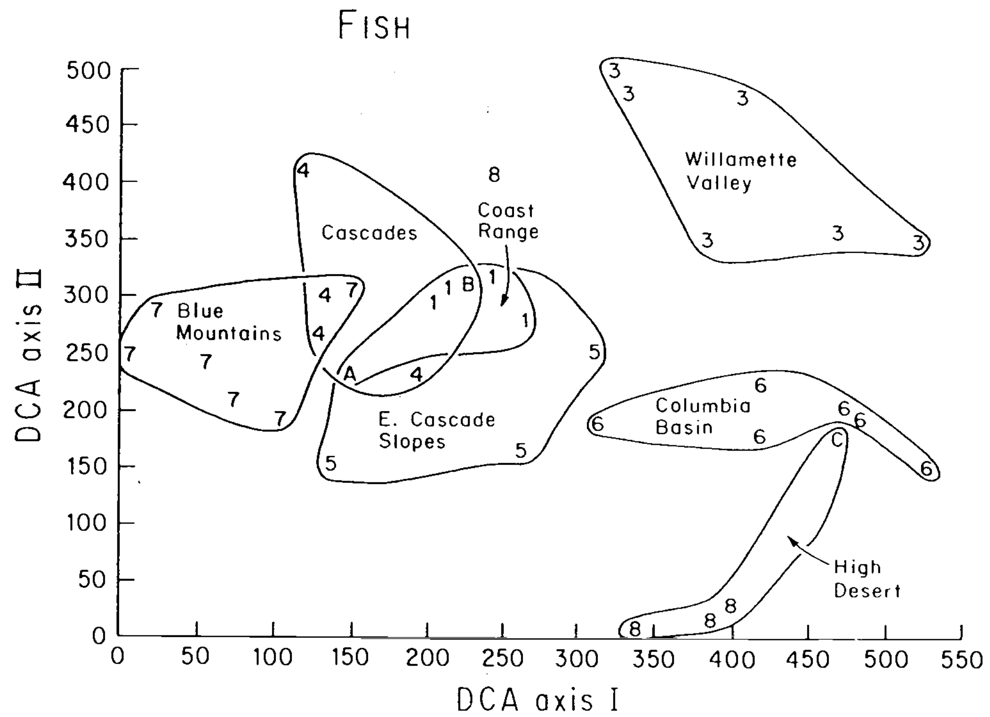


Figure 3. Regional patterns in fish assemblages shown by DCA ordination of 49 sites in Oregon. Sites were located on small, regionally representative, relatively unimpacted streams (Whittier and others, 1988).

(Hawkes and others, 1986). Lyons also used multivariate techniques to evaluate Omernik's ecoregions for the state of Wisconsin; he found good correspondence for larger streams and rivers, but little for small brooks and creeks (Lyons, 1989). He concluded that these results were consistent with the small scale at which ecoregions were delineated.

The mixed results of evaluating ecoregions using fish assemblage information may result from several factors. First, there are problems connected with using available databases, such as uneven spatial distribution of sites, inconsistent sampling techniques, unrecorded nongame species, or taxonomic difficulties. Second, the data may not match the scale of the ecoregions, as noted in the Wisconsin example above. Perhaps a better correspondence will be achieved between the fish assemblage data and the ecoregions in Wisconsin if subregions of the state are developed. Subregions partition the variability of landscape characteristics at a higher resolution to create more detailed ecoregions. In Oregon, there was good correspondence between fish species and ecoregions at a subregional level in a sample of seventeen sites on the Calapooia River. Fish species assemblages matched changes in the terrestrial features of the watershed between the Western Cascades, the Willamette Valley Foothills and the Willamette Valley, three of the ecological subregions of Oregon (Omernik and Griffith, 1991).

In summary, one should be cautious when using a single parameter to test a system built through the use of multiple variables. We can't expect distribution information from a single biotic assemblage to explain the representational accuracy of an ecoregional framework. We are evaluating ecological regions, not fish regions; fish assemblage information is only one element of a complex interrelated system. Fish sampled within a region are not only responding to habitat suitability, but also to sampling gear, stocking and management pressures, predation and competitive interactions. Also, the distribution patterns from present-day samples are an expression of the present status of the system, not its capability.

2. Using Multiple Analyses

A thorough evaluation should be based on more than one type of analysis. The redundancy and overlap found in a full range of analyses lends corroborating evidence to any regional patterns in the data. In the evaluation studies done in Oregon, Ohio, and Arkansas, results from fish faunal distributions were combined with additional analyses of abiotic factors, such as physical habitat and water quality (Whittier and others, 1988; Larsen and others, 1986; Rohm and others, 1987). Patterns in the data were sought using mapped distributions of individual variables, boxplots, and multivariate analyses:

A. Mapped Distributions. Dot maps display spatial patterns for single values at particular sites. For example, individual water chemistry or physical habitat values may be divided into classes, with a sequence of colors assigned to the classes. The values are then mapped for the area of interest. The example shown in Figure 4 is a map of total phosphorus values for Ohio streams (Larsen and others, 1988).

B. Boxplots. Boxplots are used to display groups of values. They can be constructed to show medians, minimum and maximum values, interquartile ranges, outliers, etc. Including boxplots for each region within the same figure allows direct comparisons across the regions. Figure 5 gives examples of boxplots for water quality measures in Ohio (Larsen and others, 1988).

C. Multivariate Analysis. In these studies, multivariate analyses, particularly ordination techniques, were used with the water chemistry, physical habitat and biological data. As illustrated earlier, detrended correspondence analysis (DCA), used with the biological data, showed relationships among sites based on species composition (see Fig. 3). For the physical habitat and water chemistry data, principal components analysis (PCA) was used. PCA reduces a set of correlated variables to several that explain the bulk of the variability. In the Ohio study, water quality variables were

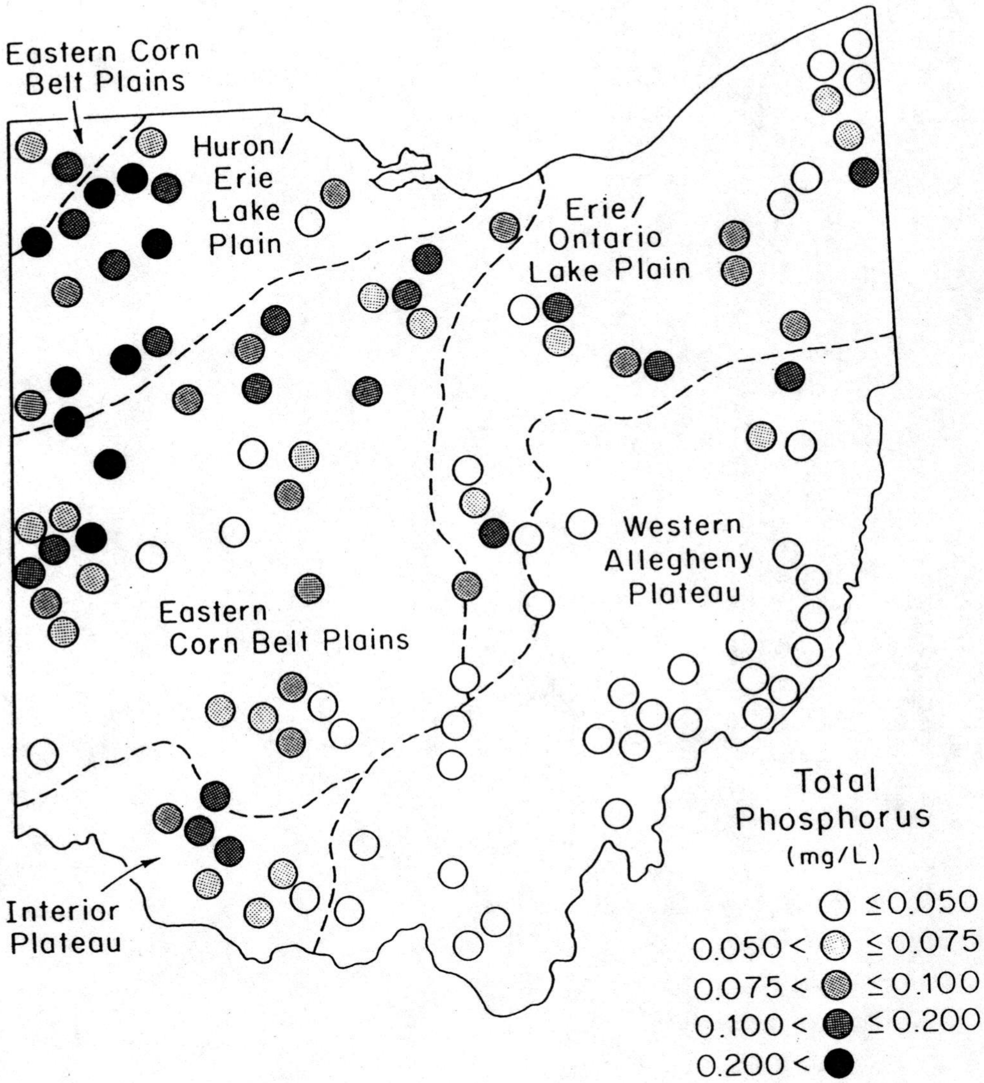


Figure 4. Mapped distribution of total phosphorus values for Ohio streams (Larsen and others, 1988).

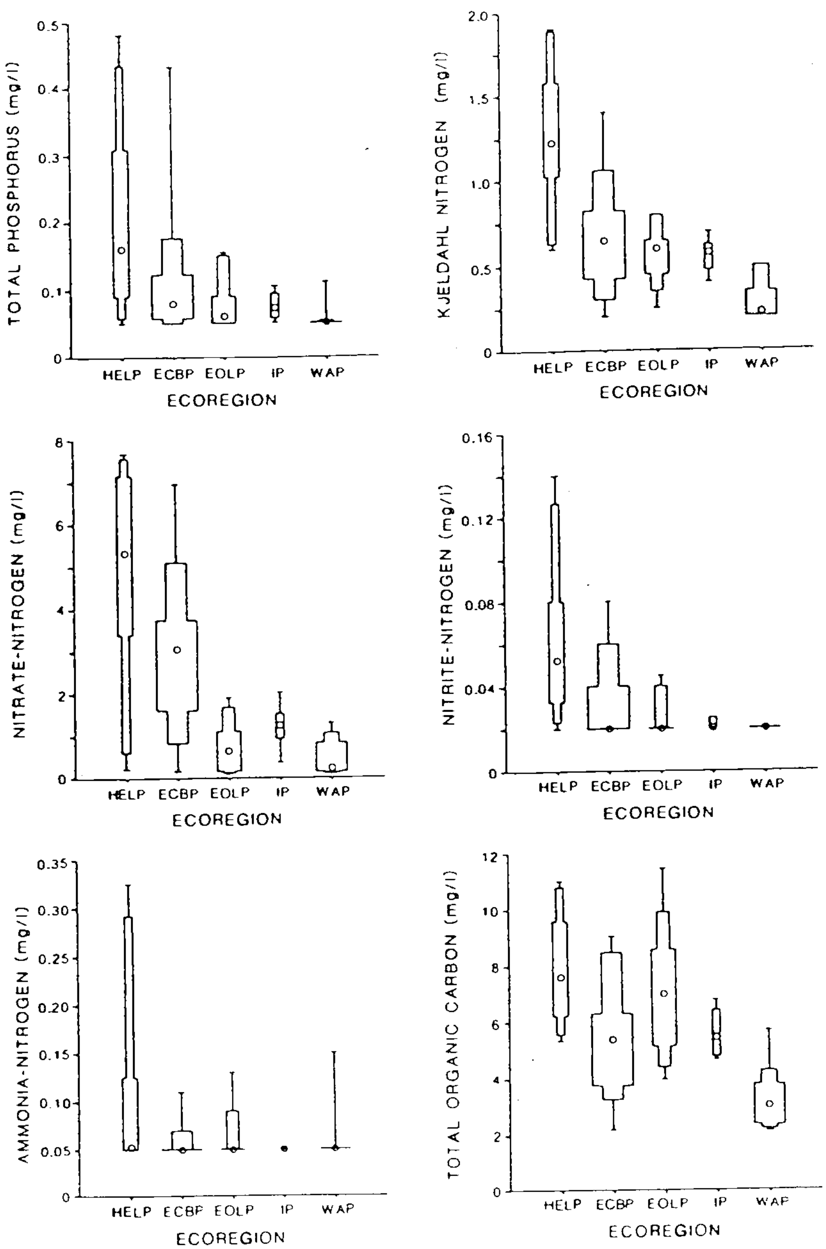


Figure 5. Boxplots of nutrient richness variables, comparing values across ecoregions of Ohio. HELP=Huron/Erie Lake Plain; ECBP=Eastern Corn Belt Plains; EOLP=Erie/Ontario Lake Plain; IP=Interior Plateau; WAP=Western Allegheny Plateau (Larsen and others, 1988).

divided into two groups, those associated with nutrient richness and those representing ionic strength. The results of PCA on this data are shown in Figure 6.

In summary, careful site selection tailored to the scale of the regions, plus a complete analysis of biotic, physical habitat and water quality data provide a more robust evaluation and illuminate relationships at varying scales. Time and budget constraints often preclude such a complete, customized evaluation of a regional model; however, if available data must be used to evaluate a regional framework, its limitations should be recognized from the outset.

Evaluating Utility

The ultimate test of a regional classification is in its application and usefulness (Warren, 1979, J. Omernik, personal communication). The basic question then becomes: have the objectives for classification been met? An ecoregional classification should

1. lead to better understanding of the system; explain and order the natural variability
2. provide a framework for sampling and management
3. allow the extrapolation of site specific information
4. lend a measure of predictability of ecosystem response to land use practices (Warren, 1979; Gallant and others, 1989; Clarke and others, 1991).

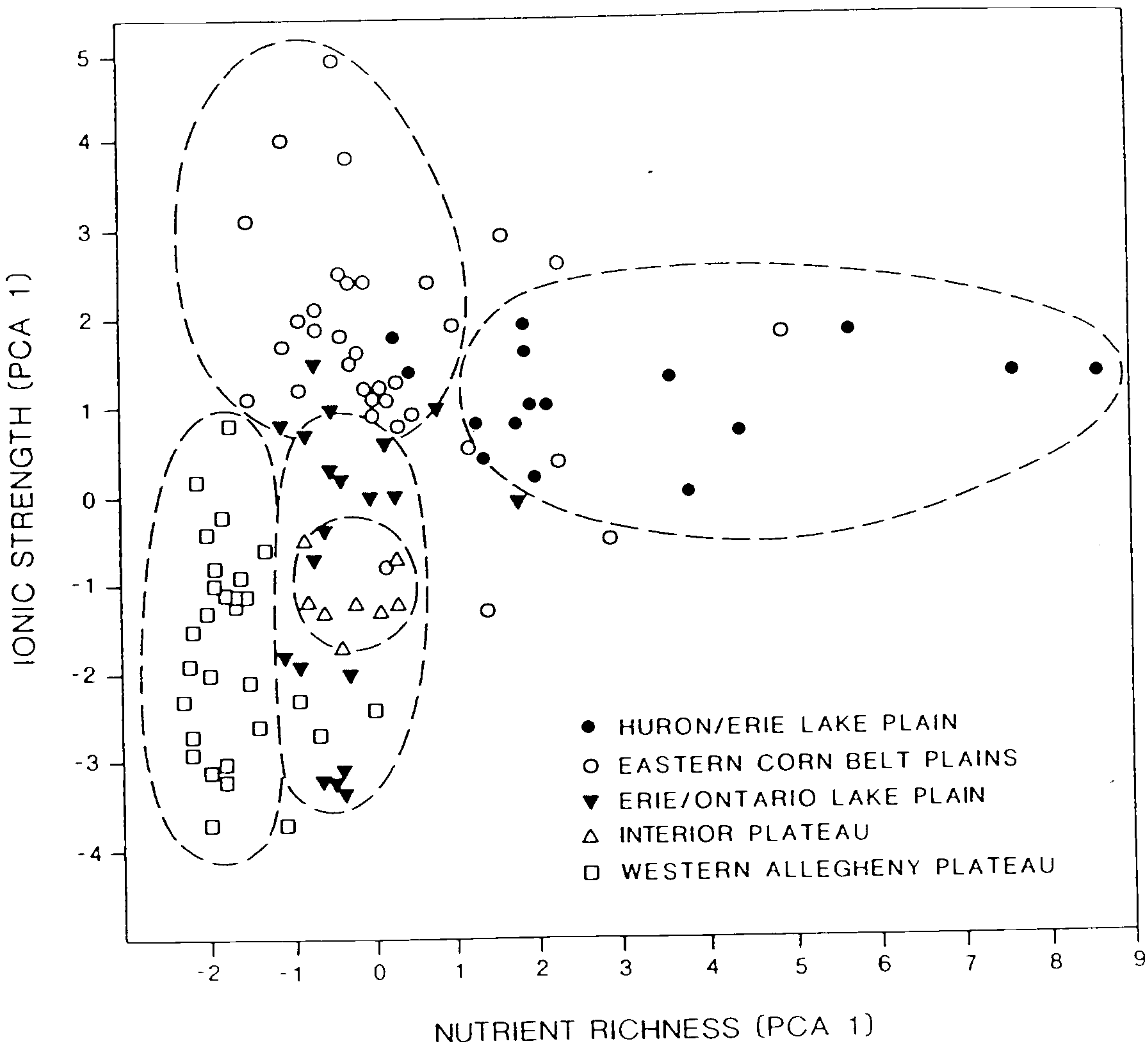


Figure 6. Ecoregion patterns in nutrient richness and ionic strength variables indicated by principal component axis score I for each. Areas enclosed, coded to correspond to ecoregions, indicate hypothesized attainable water quality for each region (Larsen and others, 1988).

If several classification systems existed, another test of utility would be to compare them to judge which best meet the stated objectives. However, if only one system exists, if the methods of its construction seem reasonable, and if it meets the stated objectives, it should be used until a better system is developed.

MATERIALS AND METHODS

The Study Area

The upper Grande Ronde River lies in the northern Blue Mountains of northeastern Oregon between 45° and 46° N. latitude, 117° 45′ and 119° 45′ W. longitude. This area is at the southern edge of the Columbia Plateau which was submerged during the Miocene epoch, beginning 15 million years ago, by massive basalt flows (Baldwin, 1976). Since then, the region has undergone vertical faulting and uplift as the Blue Mountains developed into their present form. The climate of the region is continental and temperate with hot, dry summers and cold winters. Precipitation is between 33 and 80 cm. (13-32 in.), with upper elevations receiving greater amounts, much of it as snow. (Barrash and others, 1980).

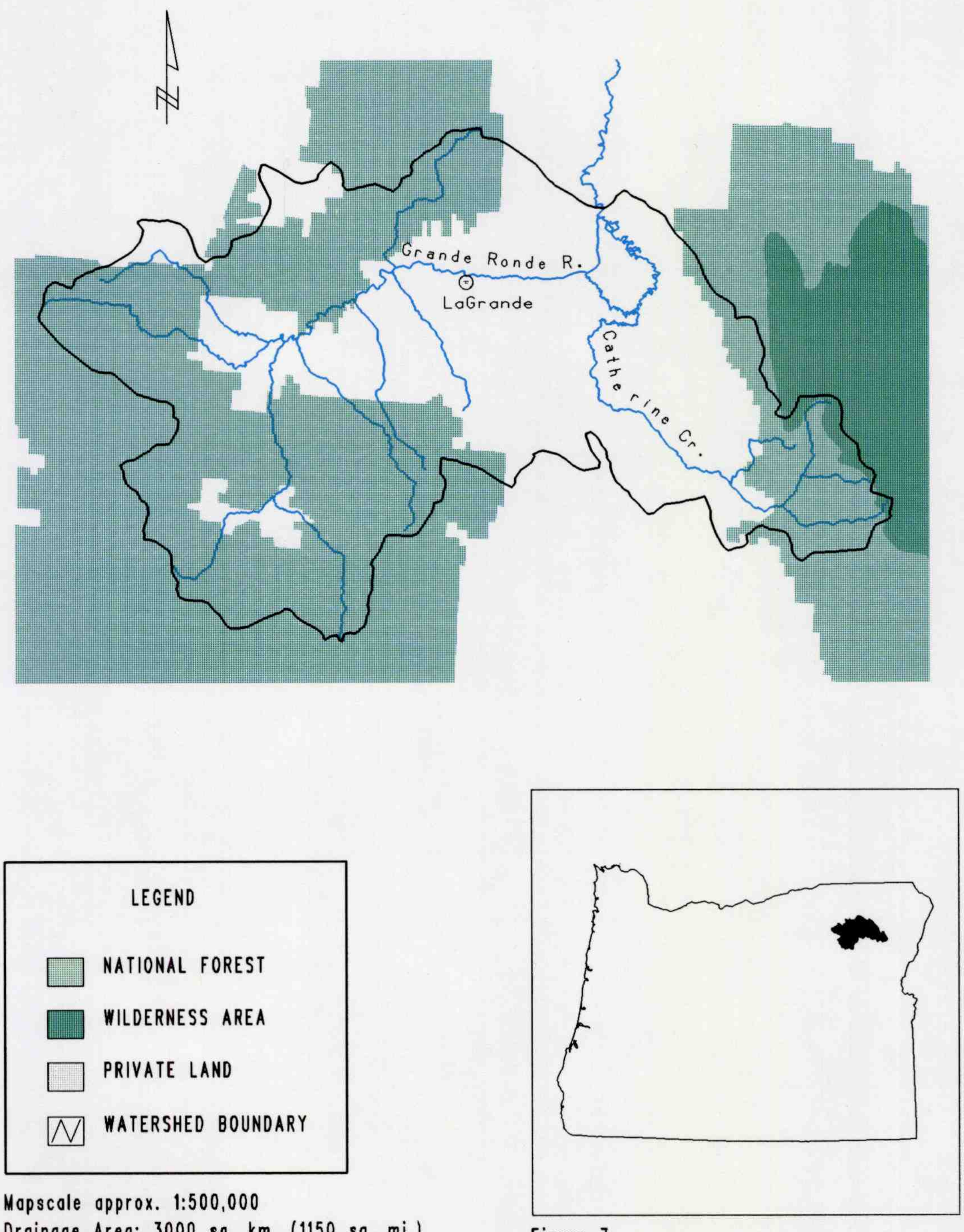
The study area includes the headwaters of the Grande Ronde River and its tributaries as well as the watershed of Catherine Creek to the southeast. The upper elevations of both watersheds are managed by the US Forest Service. Both streams flow from elevations of 2000 meters (6600′) down to the broad agricultural Grande Ronde valley near La Grande, Oregon. The watershed area is approximately 3000 sq. km. (1150 sq. mi.) measured upstream from the vicinity of Imbler, Oregon (see map, Figure 7).

Materials

Many data sources were used in the regionalization process. As a first step, component maps and data were assembled. Maps included geology, topography, soil, potential and existing vegetation, precipitation, land use and other relevant geographic information. Additional information, such as historical documents, a LANDSAT image, aerial photos, and pertinent published articles contributed to the refinement and evaluation of regional boundaries.

The major map layers used for the regionalization of the Upper Grande Ronde River basin were soil, potential and present-day vegetation, geology, topography, and landuse/landcover. Draft maps at 1:250,000 scale from a new series of soils maps (STATSGO) were acquired from the the Soil Conservation Service. These were supplemented by existing county level 1:24,000 scale soil maps and text (USDA Soil Conservation Service, 1985). A present-day vegetation map of Oregon sponsored by the US Fish and Wildlife Service was also available in preliminary draft form from the Idaho Department of Water Resources. This map, combined with an historic

UPPER GRANDE RONDE RIVER BASIN



Mapscale approx. 1:500,000
Drainage Area: 3000 sq. km. (1150 sq. mi.)

Figure 7.

forest type map (Andrews and Cowlin, 1936), a national scale potential natural vegetation map (Kuchler, 1970) and literature about the vegetation communities of the Blue Mountains made up the vegetation layer. A new 1:500,000 scale geology map (Walker, in press) of the state of Oregon was not completed in time to use in this study. An older 1:500,000 geology map of eastern Oregon (Walker, 1977) and a report on the geology of the La Grande area (Barrash and others, 1980) were used instead. Land use maps were available in digital form. However, the source materials for these maps were dated from the 1970's. To augment this information, aerial photographs of the upper Grande Ronde basin and the Catherine Creek area from 1937, 1956-57, 1970 and 1984 were used as a cross-reference to the land use maps. Finally, USGS topographic maps, at 1:250,000 and 1:100,000, were indispensable to the interpretation of land surface form, drainage pattern, contour intervals, gradient, aspect and elevation. The ecoregion boundaries were delineated using the topographic maps as base maps at both 1:250,000 and 1:100,000 scales, but the 1:100,000 scale maps were used for the final digitized regions. Topographic maps serve as a reality check for the other data layers.

The general methodology of regionalization has been outlined elsewhere. In this project the process is brought to another level of resolution, that is, from state level subregions to basin level regions. Work at each level of resolution requires decisions as to the level of detail that is appropriate to the major issues and management needs of the area. The scale of the component data layers, the scale of the final product and the size range of the areas to be delineated must all be considered before the actual mechanics of the regionalization process begin. The following sections will deal with these scale issues, as well as working with the data layers and drawing region boundaries. The steps leading to the actual boundary decisions at this level are illustrated with examples from work within individual data layers, vegetation and soil, in this case, and then from integrating the various layers to create the final regions.

Methods

Scale Considerations

Scale is one of the more pervasive issues in scientific research, even though it often goes unrecognized. Disagreements between the results of very similar studies can arise because of a different treatment of scale. In ecological studies, for example, the scale chosen for the area of investigation, whether it is a square meter quadrat, a patch of habitat or an entire landscape, is based on an anthropocentric perception of nature. What seems appropriate to the investigator may not be significant to the population being studied. Results may be very different depending upon whether the scale of measurement fits that of the organisms' response (Wiens, 1989).

The scale of effort for ecological regionalization is predetermined by a range of issues of a state, a region of the country or, in this case, a particular river basin. The process of regionalization within this prescribed area requires different criteria and resolution of data depending upon the nature of the terrain and the nature of the question (Meentemeyer and Box, 1987). Once the appropriate range of scales for the mapped and written information has been settled upon, the next task is to determine how much of the data at this range of scales will be available for all the component layers, i.e., geology, vegetation, soils, etc. The level of detail of the regions to be delineated cannot exceed that of the available reference maps and data (Gallant and others, 1989). Working down to ever smaller areas of concern increases the level of detail as well as the volume of data to be assimilated (Meentemeyer and Box, 1987).

Once the resolution of the project has been determined, the remaining issues of scale concern work within the area of interest. Each level of resolution has its own set of questions. How does one integrate information gathered at different scales so that it makes sense at the scale of interest? What is the lower size limit for a region at each scale or level of resolution? There are no rules for the proper size of regional elements (Hart, 1982). What does a region of any size mean to biota, habitat or water quality? An area may be distinctive and fit some anthropocentric rationale, but it may not have ecological significance. The resolution of all of these questions requires a measure of expert judgment and qualitative reasoning. How some of these questions were resolved for this particular project will be discussed in the following sections on working within each data layer and finally integrating the data layers.

Working Within the Data Layers

Vegetation

The vegetation layer posed particular problems in the classification process. Ecological regions are created on the basis of potential natural vegetation because potential provides the yardstick against which attainability is measured. The regional description and the associated reference sites provide the model for restoration efforts even if heavy human impact precludes returning to a pristine condition (Hughes and others, 1990). However, potential natural vegetation maps are rarely available at a higher resolution than national scale. As a result, it was necessary to trace the history of vegetation change within the Grande Ronde basin.

Timber cutting, fire suppression, and land clearing for cattle grazing have occurred in the Grande Ronde basin since the turn of the century. These activities have blurred the boundaries between tree associations. Selective cutting and later clearcutting of ponderosa pine (Pinus ponderosa) and grand fir (Abies grandis), with accompanying soil disturbance and fire suppression, allowed the advance of Douglas fir (Psuedotsuga menziesii), grand fir and Englemann spruce (Picea englemannii) beyond their normal range into lower elevation, drier sites (Skovlin, 1991). Thickets of second growth Douglas fir, larch (Larix occidentalis), lodgepole pine (Pinus contorta) and grand fir create a different forest community than the one mapped by the National Forest Service in 1936 (Andrews and Cowlin, 1936). The new community spans an area between the former higher elevation forest of true fir and lodgepole pine and the open ponderosa pine forest at lower elevations (Hall, 1973; Franklin and Dyrness, 1973). Insect pests devastated fir thickets throughout the 1980's (Skovlin, 1991). Salvage logging will most likely change the forest character yet again. Thus, to reflect the natural pattern of forest types, the classes comprising the vegetation layer were created using the 1936 forest type map as a guide, in addition to distribution information from plant community texts (Hall, 1973).

In general, forest types are distributed elevationally, elevation being an indicator of moisture and temperature limitations. Aspect, soil type and slope also determine species distributions. For example, although grand fir (Abies grandis) is listed as being found above 1500 m (4950′), it may be found as low as 725 m (2400′) on a north-facing slope. Lodgepole pine (Pinus contorta), a seral species, prefers areas of soil derived from volcanic ash, on slopes of 20% or less, at elevations of 1200 to 2300m (4000-7500′). In the Blue Mountains of northeastern Oregon, the ash layer has often eroded from south-facing slopes, meaning lodgepole pine will be more often found on north-facing slopes and flat ridgetops with ash derived soil (Hall, 1973; Franklin and Dyrness, 1973). Where applicable, aspect and soil preferences were taken into account when determining vegetation layer and region boundaries.

Soil

The 1:250,000 scale Soil Conservation Service soil maps (STATSGO series) provided the basis for the soils work. Each coded map unit on a STATSGO map represents a soil association, with individual soils listed in the legend as a percentage. Patterns were sought in the data by creating a soils table, listing the relevant characteristics of the major soils found in each map unit (Table 1). The STATSGO soil interpretation record as well as the county soils handbook provided the

Table I. Upper Grande Ronde River Watershed Soils

Code	Major %s	Texture	Elev. (ft.)	Comments
125	100			Rock outcrop
163	25% Helter	Silt loam	4500-5500	Formed in volcanic ash over basalt. Englemann spruce, subalpine fir, grand fir, larch; deep
	10% Klicker	Stony, silt loam	3000-4800	Formed in loess and basalt Ponderosa pine, doug fir Water erosion high on slopes
	10% Brickel	Stony loam	3600-5700	Formed from granite with mantle of volcanic ash
	8% Angelpeak	Gravelly silt loam	6200-8500	Deep; Lodgepole pine, larch, subalpine fir, grand fir
161	31% Klicker	as above		
	37% Tolo	silt loam	3000-4200	Deep; Formed in loess and ash over basalt; Doug fir and larch, ponderosa pine; even paths and trails erode easily
171	45% Catherine	Black silt loam	2200-4000	Formed in mixed alluvium on floodplains. Poorly drained. Cultivated.
	31% La Grande	Black silt loam	2200-4000	Alluvial fans and low stream terraces; Mainly from basalt. Cropland.
	10% Veazie	Loam	1200-4000	Ponderosa pine, cottonwood
172	47% Hot Lake	Silt loam	2600-2800	Old lake basin; cultivated valley floor; poorly drained
	19% Conley	silty, clay loam	2600-3500	Cultivated valley floor
	12% Umapine		2600-3500	Mixed alluvium; high water table; hay, pasture

Code	Major %s	Texture	Elev. (ft.)	Comments
125	100			Rock outcrop
173	45% Gwinly	Cobbly silt loam	2300-4600	Ridgetops from basalt; Shallow, well drained; Grasses, range
	11% Anatone	Stony loam	3500-5000	Derived from basalt; extremely stony, shallow; No trees, grasses, sagebrush
	10% Starkey	Very stony	2800-4000	Range
168	24% Watama	silt loam	1800-3400	Formed in aeolian materials on ridgetops; Biscuit scabland, range
	20% Ramo	black, silty clay loam	2800-3800	Concave foot slopes and alluvial fans derived from basalt; bunchgrass, perennial shrubs
	14% Gwinly	Cobbly silt loam	2300-4600	Ridgetops from basalt; Grasses, range
169	37% Ruckles	Stony clay loam	2000-3800	Colluvium, derived from basalt; Fescue, bluegrass
	34% Rucklick	Cobbly silt loam	2000-3800	Colluvium; Grasses, sagebrush
	12% Lookout	Very stony silt loam	2800-3600	Derived from basalt; Range
170	32% Imbler	Coarse sandy loam	2600-2800	Deep, aeolian material, derived from basalt; Cropland; High wind erosion potential
	29% Palouse	Silt loam	2800-3500	Formed in loess; Crops, except steep areas
	29% Alicel	Loam	2600-3000	Mixed aeolian material from basalt on valley terraces; Cultivated

information for the table. Several of the STATSGO soil map units were aggregated and color coded to create the 1:250,000 scale soil layer (Figure 8). The basic divisions are upper and lower elevation forest soils; thin, stony range soils that do not support trees; and alluvial and valley bottom soils with agricultural capability.

Initial work with the STATSGO maps prompted the delineation of several disjunct areas, the Range River Bottom region, from the alluvial areas, based on the soils information as well as their capability for agricultural use. The 1:250,000 scale STATSGO soils maps (Soil Conservation Service, in progress) emphasized these alluvial areas by over-generalizing them at this scale. Later cross-checking with larger scale county soils maps at 1:24,000 revealed that the actual size of the alluvial areas was limited to a narrow strip at the bottom of each drainage. In Figure 9, the width of the alluvial soil is measured at a point on Rock Creek one-half mile from the confluence of the Grande Ronde River. The width of this area on the STATSGO map is approximately one-half mile, while the width of the area on the county soils map is approximately .05 mile, an order of magnitude difference. Even though the alluvial areas were reduced in size, they were retained as viable regions, because of the influence they exert on the stream ecosystem in terms of productivity as well as human impact.

UPPER GRANDE RONDE BASIN SOILS

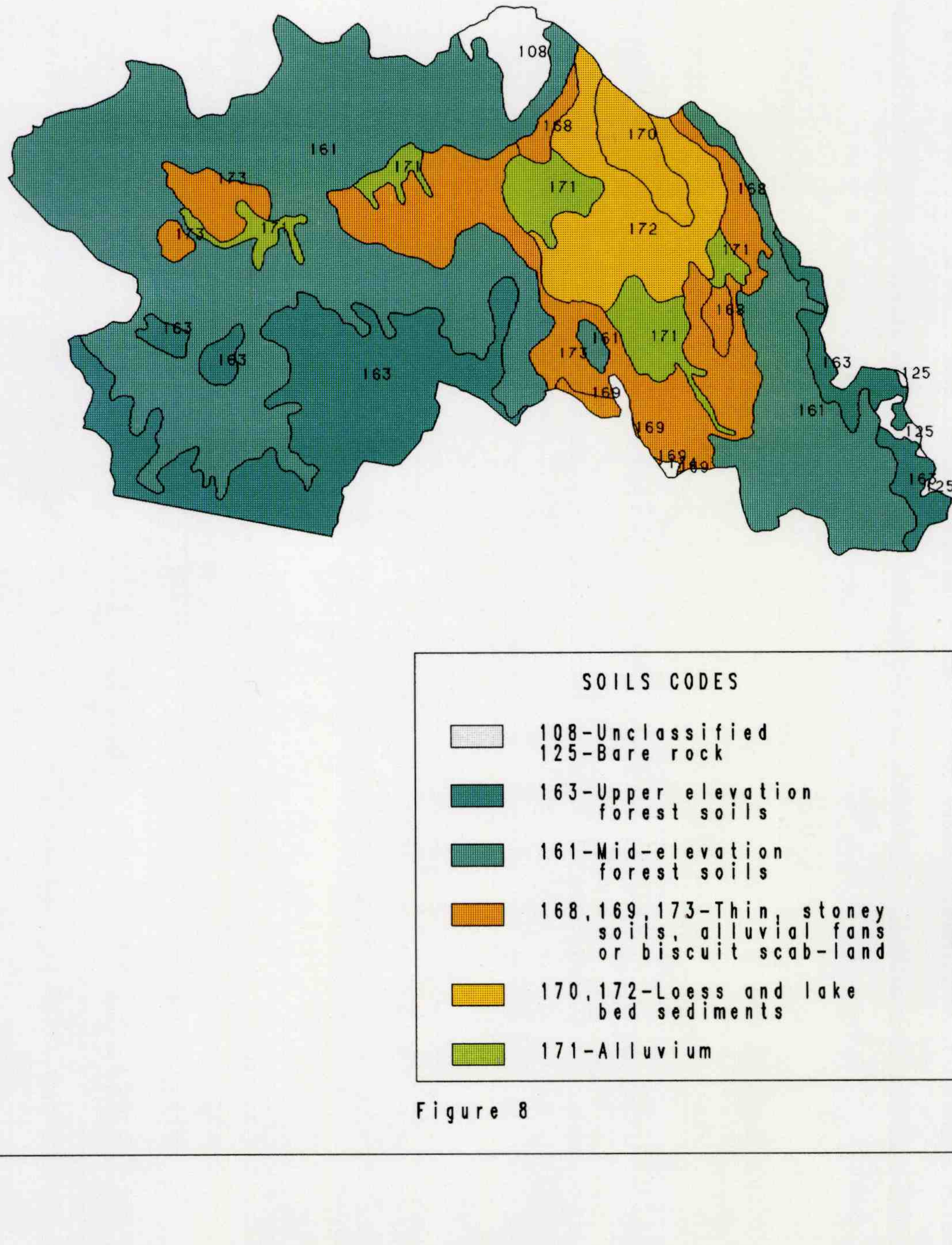
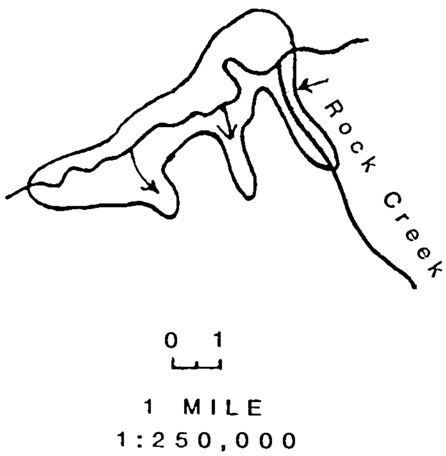


Figure 8



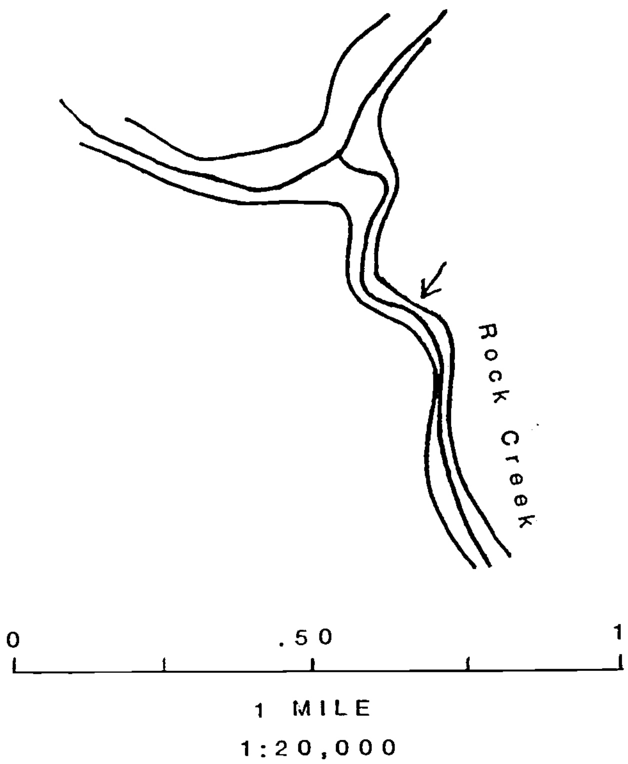


Figure 9. Comparing the width of valley bottom alluvial soil depicted on Soil Conservation Service STATSGO map (1:250,000) and larger scale county soil map (1:20,000). At arrow on Rock Creek, one-half mile from the confluence with the Grande Ronde River, the width of the alluvial soil on the STATSGO map is approximately one-half mile. The width on the county soil map, interpreted from aerial photos, is approximately .05 mile, an order of magnitude difference.

The recent development of computerized Geographic Information Systems makes the mechanical overlay of layers of information physically possible. However, as this example has shown, this could produce misleading results. Each data layer, particularly if it is interpreted, should be cross-checked with others to ensure that false assumptions are not being made. If the process is over-automated, it means that the application of knowledge of pertinent ecological processes and dominant factors, which are prerequisites for the delineation of any region line, will be lacking.

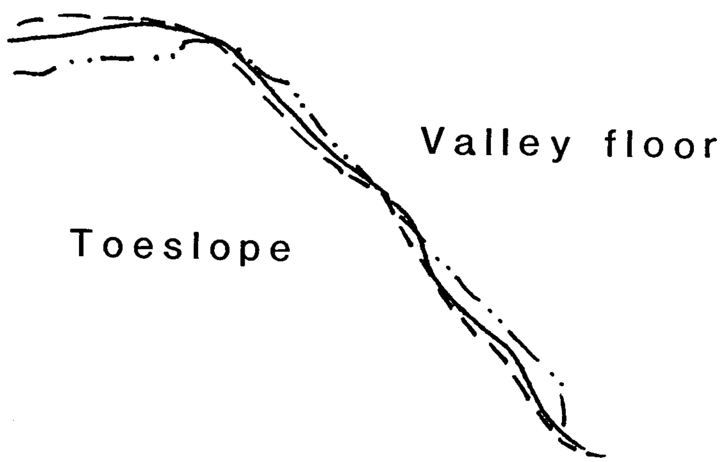
Integrating the Data Layers

Once the mapped layers and ancillary written information were studied and assimilated, the data layers, geology, soils, potential natural vegetation, etc., were combined or overlaid to draw the region lines, creating the basin level regions of the upper Grande Ronde River (see map, Fig. 11). During the regionalization process, breaks between distinctive heterogeneous areas were obvious. Other boundaries were not so readily apparent, but their delineation had an underlying rationale which was the result of integrating various source materials or relating pattern and process. These less apparent boundaries represent transition areas of varying widths. A line in such an area can only be an approximation, the limits of the "fuzzy set" discussed earlier. A solution to this problem is the use of "fuzzy boundaries" with a scale indicating the width of the boundary in kilometers (Clarke and others, 1991). Sites near region boundaries, especially in transition areas, will have characteristics of both regions. Field visits will be required to determine which regional characteristics are dominant.

Figure 10 provides an example of a clear boundary drawn between distinctive areas: the geology, soil and vegetation type lines are nearly coincident at 1:250,000 scale. This line was drawn at the transition between the rangeland of the talus slope and the flat agricultural valley south of La Grande, Oregon (see map, Figure 11). The thin soils on the large broken blocks of basalt (2. in map legend) do not support trees, while the deeper alluvial soils on the valley bottom support irrigated agriculture (1. in map legend).

Not all boundary decisions were this clear cut. The line between the upper elevation forest and open forest (areas 5 and 6 on map, Figure 11) was difficult to determine because of land use practices and the general immaturity of the forest. The boundary had to be reconstructed from a 1936 forest type map, vegetation texts, soil, elevation, precipitation and aspect information. As a result, the line not only marks a transition zone, but it is an expression of an historical situation which no longer exists.

Figure 10. Boundary delineation. This area at the south end of the Grande Ronde valley marks the abrupt end of the basalt toeslope where it meets the alluvial valley floor. The geology, soil and vegetation type lines are nearly coincident at 1:250,000 scale.



	Legend	
Vegetation	—··—··—	Forest edge
Soil	— — — —	Forest soil-Thin,cobbly soil boundary
Geology	———	Upper edge of talus slope, fault scarp

DESCRIPTION OF THE BASIN LEVEL REGIONS

The basin level regions are illustrated in Figure 11. The numbers following each region name in the text correspond to the numbers in the map legend.

Grande Ronde Valley (1)

The Grande Ronde valley near La Grande, Oregon, is a broad, flat valley at approximately 785-850 meters (2600-2800'). The climate is semi-arid, with precipitation amounts from 32.5-60 cm (13-24"). Most areas in the valley support irrigated agriculture, winter wheat, alfalfa, peas, bluegrass seed and pasture. The historic meandering drainage pattern of the Grande Ronde River has been changed by extensive channelization. Ditching has diverted many tributary streams.

The valley lies in a down-faulted graben which once was a lakebed. The valley soils are a patchwork of alluvium, loess and lacustrine deposits. Vegetation in areas not cultivated consists of bunchgrasses and annual forbs.

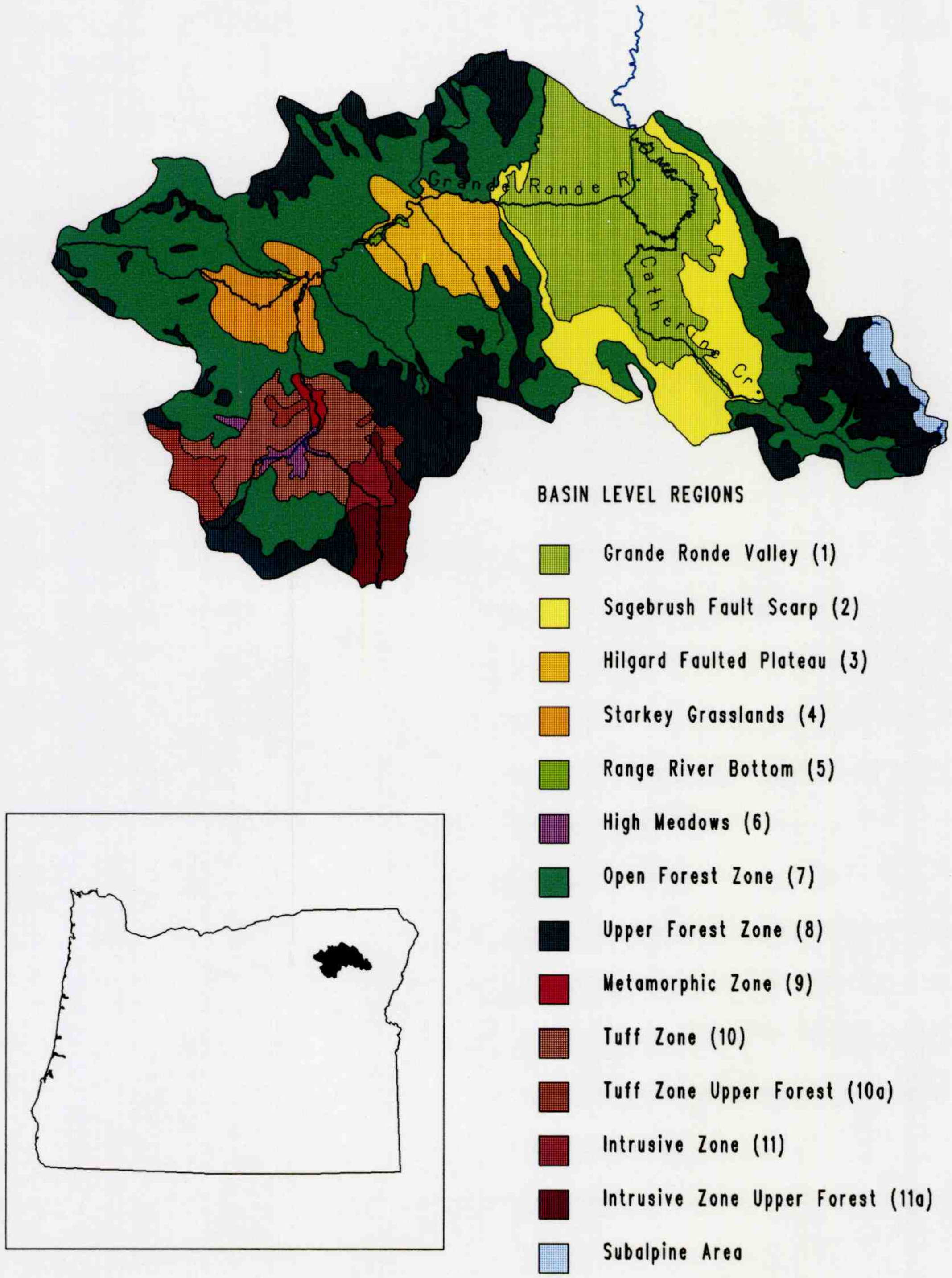
Sagebrush Fault Scarp (2)

The sagebrush fault scarp region occurs on basalt talus and blocks which have broken off subsequent to vertical faulting and formation of the valley graben. The soils, formed in loess, volcanic ash and colluvium on slopes of 5-40%, are too thin and stony for cultivation. The thin soils also do not support trees. Wheatgrass, fescue and sagebrush make this area suitable for grazing or wildlife habitat. Soils, substrate and vegetation are similar for this region and the next two regions; however, the distinguishing feature here is gradient.

Hilgard Faulted Plateau (3)

The faulted plateau is a block of uplands dissected by numerous northwest trending vertical faults. It is created by slightly northwesterly dipping basalt flows south of the Grande Ronde River meeting southeasterly sloping flows on the north side of the river. Elevations range from 700-1500 meters (2300-5000'). The thin, stony soils are derived from bedrock and support mainly grasses such as wheatgrass and fescue. As a result, the predominant landuse is grazing. Trees, mostly ponderosa pine below 1200-1360 meters (4000-4500'), follow the drainages or occur on pockets of forest soil.

BASIN-LEVEL ECOREGIONS OF THE UPPER GRANDE RONDE RIVER



Starkey Grasslands (4)

The Starkey grasslands are rolling uplands at an elevation of 1050-1250 meters (3500-4125'). The region has been used heavily by livestock since the 1840's (Skovlin, 1991). This area has soils and patterns of tree growth similar to the previous region, the grassy faulted plateau. The difference lies in the absence of vertical faulting in the basalt substrate which gives a more random, rolling quality to the landscape. The substrate differences result in distinctive drainage patterns for the Hilgard faulted plateau and the Starkey grasslands (see figure 12). The stream channels of the faulted plateau, following the fault lines, are more incised than those of the Starkey grasslands. The trees following the incised drainages grow in a confined area, creating a more shaded streambed, and thus, the potential for cooler water temperatures (Bruce McIntosh, pers. comm.).

Range River Bottom (5)

Two disjunct areas form the range river bottom, the alluvial flats of the Grande Ronde River, where it flows through regions 3 and 4 listed above. Though the river bottom areas are not large, they influence the river ecosystem in terms of productivity and human impact. The soil is suitable for cultivated crops, though in the Starkey grasslands the river bottom is used mainly for grazing.

High Meadows (6)

The Sheep Creek and Fly Creek meadows are high elevation alluvial flats which have a high water table. The altitude and year round moisture make these areas unsuitable for cultivation, but they are prime grazing areas for cattle.

Open Forest Zone (7)

The open forest corresponds roughly to the Ponderosa pine zone, areas where creeping ground fires kept forests open and free of shrubs until the era of extensive timber cutting and fire suppression. The topography is rolling to steep (slopes 3-60%), at elevations of 900-1500 meters (3000-5000'). Soils are silt loams formed in loess and volcanic ash over basalt; they are 30-150 cm (12-60") deep and erode easily. The major landuse is grazing and timber harvest.

Upper Forest Zone (8)

The upper forest is a mesic area found at elevations of 1350-2000 meters (4500-6500'), where precipitation levels increase

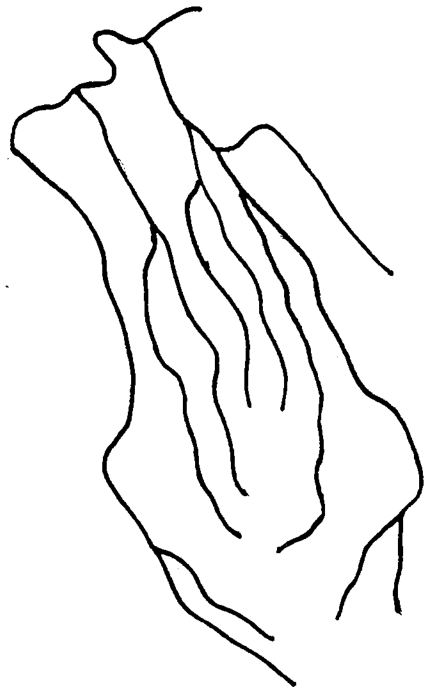
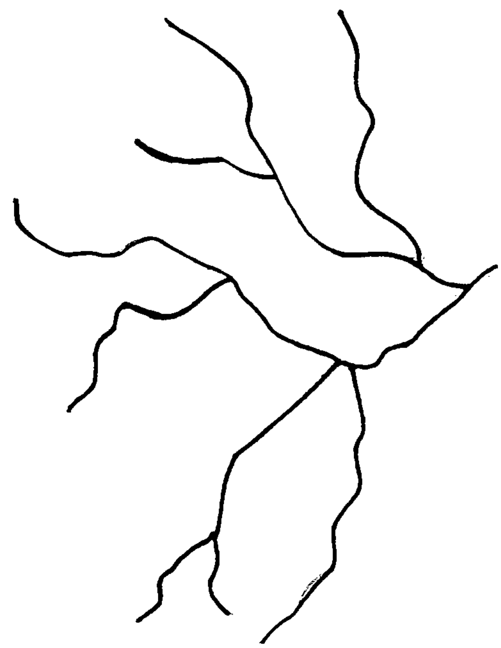


Figure 12. The drainage pattern within the Grassy Faulted Plateau (top), dissected by northwest trending faults, compared to that within the Starkey Grasslands (bottom).



to 62.5-87.5 cm (25-35") and moisture stress is minimal. Grand fir (Abies grandis) stands are interspersed with lodgepole pine (Pinus contorta) and Western larch (Larix occidentalis), which generally repopulate burned areas. Fires at these elevations were more likely to be conflagration fires (Skovlin, 1991), unlike the cooler, creeping fires of the Ponderosa pine forest. This zone extends into lower elevations near springs or on cooler north facing slopes, particularly in stream canyons. The boundary between this region and the open forest zone has been blurred by large areas of larch and Douglas fir (Psuedotsuga menziesii) thickets invading dryer areas, a result of logging and fire suppression practices over the last 100 years.

Metamorphic Zone (9)

The metamorphic zone, as its name implies, has geology as the dominant factor. The Grande Ronde River and its tributaries are highly constrained in this area with tributary junctions at right angles to the river. The region is quite small; only after an evaluation of the regions through sampling will it become clear whether the area is large enough to have an effect on the biota.

Tuff Zone (10), Intrusive Zone (11)

Geology is also the dominant factor in these regions. In an area that is composed almost entirely of basalt, changes in substrate can be significant in terms of stream physical habitat, as well as geomorphology and vegetation type.

The confidence in each region's ecological significance may vary. There will be regions that are delineated because they are distinctive, but there will be no corroborating evidence or data. Or, as shown by the two rangeland areas with different drainage patterns (Figure 12), regions that at first glance appear very similar, could, on further investigation, prove to have real differences in stream physical habitat or productivity. It is better to highlight distinctive areas, to err on the side of "too many" regions. As areas are evaluated and become better known through field work, it will become clear whether they are ecologically significant or not. Time and interdisciplinary effort are required to evaluate the usefulness of a regional framework.

EVALUATION AND APPLICATIONS OF THE BASIN LEVEL REGIONS OF THE UPPER GRANDE RONDE RIVER

A full evaluation of the regional framework proposed here is beyond the scope of this paper. The ideal approach would be to plan a sampling program to collect a full range of measurements of water chemistry, physical habitat, fish and macroinvertebrates. However, working in a new spatial scale may require rethinking some of the measures and their analysis. For example, macroinvertebrate data may not be useful at this scale. In previous studies, the changes in macroinvertebrate assemblages seem to occur at coarse scales. Macroinvertebrate taxonomy is also often a problem; in studies over broad areas, classification may be taken only to genus or family levels (Bahls and others, in prep; Whittier and others, 1987). Without complete identifications, distinctions between assemblages at a finer basin scale might be lost. Similarly, if fish data is used for evaluation, it should be at the appropriate scale. The statewide fish assemblage information, used in examples earlier, is too coarse. Fish data should be taken from streams that are wholly within region boundaries. For the basin level focus of this study, it may be appropriate to use population data for fish, such as size, age class, habitat use, and spawning areas. Once the data is at the proper scale, the same range of analyses could be applied to the data as outlined in the literature review.

Adapting the ecoregional classification to larger scales is a new exercise. As ecoregions are developed at finer levels of resolution, they may be applied to new uses. The predominant use for ecological regions at the state level is to establish attainability goals, biocriteria standards and reference sites for water quality regulation. Regions at the basin level, that is, at the scale of one to several watersheds, will continue to fulfill water quality monitoring needs. However, they also have potential as a land management tool for planning, resource management, cumulative effects studies, restoration efforts and biodiversity assessment.

Evaluations of basin level regions ought to reflect management concerns. How are management practices affecting the water quality and physical habitat of streams in different areas? The ability of the regions to explain historical changes in physical habitat features, such as the number of pools or turbidity or embeddedness, should be tested. Historical stream survey data would be most useful in this regard to document spatial changes in active channel widths, bank conditions, or pools/kilometer. Relating changes in physical habitat measures with land use practices by ecoregion, illuminates correlations to probable causes of poor condition, and suggests how changes in management practices may place the system closer to its potential.

SUMMARY

Classification is the ordering of objects into groups according to their similarities or relationships. Ecological regionalization is a form of spatial classification where boundaries are drawn around areas of similar landscape characteristics. Ecological regions, or ecoregions, are created in an attempt to relate landscape pattern to ecosystem structure and function.

Ecoregions are delineated through a "top-down" approach. That is, the regions are built through the integration of multiple landscape characteristics, such as climate, geology, vegetation, soil, and topography. The landscape data provides a continuous fabric of information to illustrate landscape patterns. Stream classification, on the other hand, is done rather inductively, moving from the particular to the general. Stream physical habitat elements at various scales are catalogued and fit into the geomorphic structure of the surrounding valley types. While stream and ecoregion classification are on a generally convergent pathway, a gap remains between valley segment classifications and state-level ecological subregions. The object of this study is to bridge the gap between the two frameworks by extending Omernik's ecoregion methodology to larger scales, beyond state level applications to a scale of more localized land management decisions.

Basin-level ecoregions were created for the upper Grande Ronde River watershed in northeast Oregon. The methodology of boundary delineation was described and methods were proposed for evaluating the representational accuracy of the regions. A sampling program tailored to the scale of the regions, plus a complete analysis of biotic, physical habitat and water quality data would provide a thorough evaluation. Time and budget constraints often preclude such a complete, customized evaluation of a regional model, however. The proposed classification may initially be evaluated by its applications and utility. To meet its objectives, the basin level regional framework should:

1. Lead to better understanding of the system; explain and order the natural variability.

2. Provide a framework for sampling;

   a. help plan sampling and monitoring programs: stratify sampling area, array sample sites at the proper density, prioritize field work and make it more cost effective,

   b. ensure that masses of inventory data can be put to use; that is, by allowing extrapolation of site specific data within an area of similar ecological characteristics.

3. Provide a framework for management;

   a. develop water quality management approaches that are consistent with the potential attainability of each region,

   b. provide a yardstick of potential attainability for cumulative effects studies and restoration efforts,

   c. aid in the search for causes of poor condition by relating present status to underlying strengths, resiliencies or vulnerabilities of a system.

4. Prompt the creation of appropriate Best Management Practices;

   a. judge existing best management practices by what extent they preserve the potential capability of the ecosystem,

   b. create new best management plans that are appropriate to regional ecological characteristics and predictive of ecosystem response to particular land use practices.

By organizing the complexity of the natural world, a regional framework can prove to be a powerful management tool. It can help to preserve or restore ecosystems and conserve the limited time and fiscal resources of managers.

REFERENCES CITED

Andrews, H.J., and R.W. Cowlin. 1936. Forest type map of Oregon: Northeast quadrant. Pacific Northwest Forest Experiment Station, USDA Forest Service, Portland, Oregon. Scale 1:253,440.

Bahls, L., R. Bukantis, S. Tralles and R.W. Wisseman. 1991 (in prep). Benchmark biology of Montana reference streams. Water Quality Bureau, Montana Dept. of Health and Environmental Sciences, Helena, Montana.

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

Bailey, Robt. G., S.C. Zoltai, E.B. Wiken. 1985. Ecological regionalization in Canada and the United States. Geoforum 16:265-275.

Bailey, Robt. G. 1985. The factor of scale in ecosystem mapping. Environmental Management 9:271-276.

Bailey, Robt. G. 1987. Suggested hierarchy of criteria for multiscale ecosystem mapping. Landscape and Urban Planning 14:313-319.

Bailey, Robt. G. 1988. Ecogeographic analysis: a guide to the ecological subdivision of land for resource management. Misc. Publ. 1465. USDA Forest Service, Washington, D.C.

Baldwin, Ewart M. 1976. Geology of Oregon. Kendall/Hunt Publishing Co., Dubuque, Iowa. 170 pp.

Barrash, Warren, John G. Bond, John D. Kauffman, Ramesh Venkatakrishnan. 1980. Geology of the La Grande area, Oregon. Special Paper 6, State of Oregon, Department of Geology and Mineral Industries, Portland, Oregon.

Brussock, P.B., A.V. Brown, and J.C. Dixon. 1985. Channel form and stream ecosystem models. Water Resources Bulletin 21(5):859-866.

Clarke, Sharon E., Denis White, and Andrew L. Schaedel. 1991. Oregon, USA, ecological regions and subregions for water quality management. Environmental Management 15(6):847-856.

Cupp, C. Edward. 1988. Valley segment type classification for forested lands of Washington. Timber, Fish and Wildlife Ambient Monitoring Program Report. Olympia, Washington.

Franklin, Jerry F., and C.T. Dyrness. 1973. Natural Vegetation of Oregon and Washington. Oregon State University Press. 452 pp.

Frissell, C.A., W.J. Liss, C.E. Warren, and M.D. Hurley. 1986. A hierarchical framework for stream habitat classification: Viewing streams in a watershed context. Environmental Management 10:199-214.

Gale, Stephen, Michael Atkinson. 1979. On the set theoretic foundations of the regionalization problem. Philosophy in Geography. S. Gale and G. Olsson (eds.). D. Reidel Publishing Co., Dordrecht, Holland.

Gallant, Alisa L., T.R. Whittier, D.P. Larsen, J.M. Omernik, R.M. Hughes. 1989. Regionalization as a tool for managing environmental resources. EPA/600/3-89/060.

Gregory, S.V., F.J. Swanson, W.A. McKee, and K.W. Cummins. 1991. An ecosystem perspective of riparian zones. Bioscience 41(8):540-551.

Griffith, Glenn E., and James M. Omernik. 1991. Alabama/Mississippi project: Geographic research component - Ecoregion/subregion delineation. Interim report.

Hall, Frederick C. 1973. Plant communities of the Blue Mountains of eastern Oregon and southeastern Washington. USDA Forest Service, Pacific Northwest Region, R6 Area Guide 3-1.

Hart, John Fraser. 1982. The highest form of the geographer's art. Annals of the Association of American Geographers 72:1-29.

Hawkes, C.L., D.L. Miller, and W.G. Layher. Fish ecoregions of Kansas: Stream fish assemblage patterns and associated environmental correlates. Environmental Biology of Fishes 17(4):267-279.

Hughes, R.M., E. Rexstad, and C.E. Bond. 1987. The relationship of aquatic ecoregions, river basins, and physiographic provinces to the ichthyogeographic regions of Oregon. Copeia 1987(2):423-432.

Hughes, R.M., T.R. Whittier, C.M. Rohm, and D.P. Larsen. 1990. A regional framework for establishing recovery criteria. Environmental Management 14(5):673-683.

Hughes, R.M., S.A. Heiskary, W.J. Matthews, and C.O. Yoder. In Press. Use of ecoregions in biological monitoring. In: S.L. Loeb (ed.), Biological Monitoring of Freshwater Ecosystems. Chapman and Hall, New York.

James, Preston E. 1952. Toward a further understanding of the regional concept. Annals of the Association of American Geographers 42:195-222.

Kuchler, A.W. 1970. Potential natural vegetation map. Scale 1:7,500,000. In: The national atlas of the United States of America, pp. 89-91. Washington, D.C. U.S. Geological Survey.

Larsen, D.P., D.R. Dudley, and R.M. Hughes. 1988. A regional approach for assessing attainable surface water quality: An Ohio case study. Journal of Soil and Water Conservation 43(2):171-176.

Larsen, D.P., J.M. Omernik, R.M. Hughes, C.M. Rohm, T.R. Whittier, A.J. Kinney, A.L. Gallant, and D.R. Dudley. 1986. Correspondence between spatial patterns in fish assemblages in Ohio streams and aquatic ecoregions. Environmental Management 10(6):815-828.

Lotspeich, F.B. 1980. Watersheds as the basic ecosystem: This conceptual framework provides a basis for a natural classification system. Water Resources Bulletin 16:581-586.

Lotspeich, F.B., W.S. Platts. 1982. An integrated land-aquatic classification system. North American Journal of Fisheries Management 2:138-149.

Meentemeyer, V., E.O. Box. 1987. Scale effects in landscape studies. In: Ecological Studies, vol. 64, Monica G. Turner (ed.), Landscape heterogeneity and disturbance. Springer-Verlag, N.Y.

Meentemeyer, V. 1989. Geographical perspectives of space, time and scale. Landscape Ecology 3:163-173.

Minshall, G.W. 1988. Stream ecosystem theory: a global perspective. Journal of the North American Benthological Society 7(4):263-288.

Omernik, James M. 1987. Ecoregions of the conterminous United States. Annals of the Association of American Geographers. Text and map supplement. 77(1):118-125.

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

Platts, William S. 1974. Geomorphic and aquatic conditions influencing salmonids and stream classification - with application to ecosystem classification. USDA Forest Service, Intermountain Forest and Range Experiment Station, Boise, Idaho. 200 pp.

Platts, William S. 1978. Method for including the fishery in land use planning. USDA Forest Service, Intermountain Forest and Range Experiment Station, Boise, Idaho. 76 pp.

Platts, William S. 1980. A plea for fishery habitat classification. Fisheries 5:2-6.

Rohm, C.M., J.W. Giese, and C.C. Bennett. 1987. Evaluation of an aquatic ecoregion classification of streams in Arkansas. Journal of Freshwater Ecology 4(1):127-140.

Rosgen, David L. 1985. A stream classification system. In: Riparian ecosystems and their management: Reconciling conflicting uses, R.R. Johnson, C. D. Ziebell, D.R.Palton, P.F. Ffolliott, and R.H. Hamre, editors. First North American Riparian Conference, Tucson, Arizona.

Rowe, J.S., and J.W. Sheard. 1981. Ecological land classification: A survey approach. Environmental Management 5(5):451-464.

Schlosser, Issac J. 1991. Stream fish ecology: A landscape perspective. Bioscience 41(10):704-712.

Science Advisory Board Report. 1991. Report of the ecoregions subcommittee of the ecological processes and effects committee: Evaluation of the ecoregions concept. US Environmental Protection Agency, EPA-SAB-EPEC-91-003, Washington D.C.

Scott, J.M., B. Csuti, J.D. Jacobi, and J.E. Estes. 1987. Species richness: a geographic approach to protecting future biological diversity. BioScience 37(11):782-788.

Sedell, J.R., G.H. Reeves, F.R. Hauer, J.A. Stanford, C.P. Hawkins. 1990. Role of refugia in recovery from disturbances: Modern fragmented and disconnected river systems. Environmental Management 14(5):711-724.

Skovlin, Jon M. 1991. Fifty years of research progress: A historical document on the Starkey Experimental Forest and Range. USDA Forest Service, General Technical Report, PNW-GTR-266. Pacific Northwest Research Station. Portland, Oregon. 58 pp.

Thornthwaite, C.W. 1931. The climates of North America according to a new classification. Geographical Review 21:633-655.

Turner, M.G. 1989. The effect of pattern on process. Annual Rev. Ecol. Syst. 20:171-197.

United States Department of Agriculture, Soil Conservation Service. 1985. Soil Survey of Union County area, Oregon.

United States Geological Survey. 1972-1976. Land use and land cover, Pendleton, Oregon; Washington. Land Use Series, Map L-193. Scale 1:250,000. Digital coverage.

United States Geological Survey. 1978-1980. Land use and land cover, Grangeville, Oregon; Idaho. Land Use Series, Open File 81-866-1. Scale 1:250,000. Digital coverage.

Walker, George W. 1973. Reconnaissance geologic map of the Pendleton Quadrangle, Oregon and Washington. United States Geological Survey, Denver, Colorado. Scale 1:250,000.

Walker, George W. 1977. Geology map of Oregon east of the 121st Meridian. Miscellaneous Investigations Series Map I-902. US Department of the Interior, United States Geological Survey, prepared in cooperation with Oregon Department of Geology and Mineral Industries. Scale 1:500,000.

Walker, George W. 1979. Reconnaissance geologic map of the Grangeville Quadrangle, Baker, Union, Umatilla and Wallowa Counties, Oregon. United States Geological Survey, Denver, Colorado. Scale 1:250,000.

Warren, Charles E., 1979. Toward classification and rationale for watershed management and stream protection. EPA-600/3-79-059. U.S. Environmental Protection Agency, Corvallis, Oregon. 143 pp.

Whittier, T.R., D.P. Larsen, R.M. Hughes, C.M. Rohm, A.L. Gallant, J.M. Omernik. 1987. The Ohio stream regionalization project: a compendium of results. EPA/600/3-87/025.

Whittier, T.R., R.M. Hughes, and D.P. Larsen. 1988. Correspondence between ecoregions and spatial patterns in stream ecosystems in Oregon. Canadian Journal of Fisheries and Aquatic Sciences 45(7):1264-1278.

Wiens, J. A., 1989. Spatial scaling in ecology. Functional Ecology 3:385-397.

Wiken, E.B. 1982. Ecozones of Canada. Environment Canada, Lands Directorate, Ottawa, Ontario.