Chapter 6: Developing a Decision-Support Model for Assessing Condition and Prioritizing the Restoration of Aquatic Habitat in the Interior Columbia Basin

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Abstract

The INLAS Aquatic Module is part of the larger Interior Northwest Landscape Analysis System (INLAS)—a multidisciplinary effort to develop midscale analytical tools to project succession and disturbance dynamics across landscapes in the interior Northwest. These tools are intended to be used to examine change in ecological and socio-economic systems under various policy or management options (Barbour et al. Chapter 1). For the Aquatics Module, we are developing tools to assess midscale aquatic habitat in the context of the biophysical characteristics of streams and watersheds and landscape-scale processes, including natural disturbances such as fire, and alternative management scenarios. We will apply these analytical tools to a demonstration area (the Upper Grande Ronde River subbasin), where we will assess factors influencing conditions of aquatic habitat and water quality and evaluate the potential cumulative effects of alternative management scenarios on aquatic habitat, hydrology, and erosion. The tools we are developing are intended to help natural resource specialists and managers define the types of management most likely to be compatible with guidelines for aquatic species and their habitat and management objectives for other resources.

Keywords: Decision-support models, aquatic habitat, water quality, salmon, steelhead, bull trout, alternative management scenarios.

Introduction

Chinook salmon (*Oncorhynchus tshawytscha* (Walbaum)), steelhead (*O. mykiss* [formerly *Salmo gairdneri* Richardson]), and bull trout (*Salvelinus confluentus* (Suckley)) have been eliminated from much of their historical range and are now listed as threat-
ened or endangered within most of the interior Columbia River basin (USDA and USDI 2000). Other native fishes also have declined (Lee et al. 1997). Many factors have contributed to declines, including (1) overharvest; (2) blocked access and increased mortality of migrating fish from dams; (3) interactions between wild fish and hatchery stocks, which appear to impair fitness of wild stocks; and (4) degradation of spawning and rearing habitat (Federal Caucus 2000). Degraded water quality is closely linked to issues surrounding degraded spawning and rearing habitat. Thousands of miles of streams throughout the Columbia River basin, including the Upper Grande Ronde subbasin (Grande Ronde Water Quality Committee 2000), have been listed as impaired by the states under section 303d of the Clean Water Act for failing to meet water quality standards (Lee et al. 1997). Streams in USDA Forest Service (USDA FS) ownership are most commonly listed for failure to meet standards for sediment/siltation/turbidity, water temperature, and flow (Lee et al. 1997).

The USDA FS and other federal agencies, including National Marine and Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USF&WS), and USDI Bureau of Land Management (BLM) have been developing broad-scale approaches to address aquatic and other land management issues within the region (FCRPS Biological Opinion 2000, Federal Caucus 2000, USDA and USDI 2000). These broad-scale plans recognize the importance of maintaining existing high-quality habitat in tributaries of the Columbia basin and restoring habitat that is currently degraded.

The success of broad-scale management depends on the ability of natural resource specialists to convert broad-scale management direction into mid- and fine-scale management practices. To do this, natural resource specialists, managers, and planners must be informed as to the nature and extent of potential impacts resulting from current management practices and proposed changes in those practices (Rieman et al. 2001). Specifically, natural resource specialists need to be able to assess (1) the ability of a stream (or watershed) to support species of interest and other desired resource values, (2) the current condition, and (3) the potential impacts of management decisions on future conditions. Managers and planners must be able to use this information to determine the type and location of management activities most likely to meet desired objectives and to prioritize these activities on the basis of multiple and sometimes conflicting objectives.

Management actions occur in systems with high natural variability and that have been altered by a number of historical and current land and water management practices. Thus, predictions of the potential effects of management actions are fraught with uncertainty associated with the ecological responses and the complexity of multiple management objectives and strategies under consideration (Rieman et al. 2001). To aid evaluations, land managers in the inland Northwest need tools that formalize these complex relationships into a common framework that describes aquatic habitat in the context of landscape processes and conditions, potential effects of management actions, and sources of uncertainty. There are currently no analytical tools available that provide managers the ability to assess conditions of aquatic habitats at mid to fine scales (i.e., 4th to 6th hydrologic unit codes or HUCs) in a landscape context and to analyze potential cumulative effects of management decisions, including forest harvest, fuels reduction, herbivory, and riparian management, on aquatic species and their habitats.

The goal of the proposed research is to develop a decision-support tool to help inform management decisions at midscales. The proposed research is guided by four primary questions:
- How have changes in landscape processes, such as fire, over the last 100 to 150 years affected aquatic habitat and populations of aquatic species?
- What and where are the principal opportunities to maintain and restore aquatic species and water quality?
- What are the cumulative effects of alternative management approaches on aquatic habitat and water quality?
- How can stream restoration opportunities be better integrated with management for other resources?

A variety of modeling approaches are available to address the questions we pose above. Below, we briefly review these modeling approaches and evaluate their suitability for this project.

Existing tools are unable to adequately address the questions listed above for various reasons. First, many models are narrowly focused and thus do not include other factors that are likely to influence aquatic and riparian habitat. For example, the Stream Segment Temperature Model (SSTemp) (USGS 1999) is typical of reach-scale temperature models that calculate shading/sun exposure to the stream surface and use temperature and volume of water flowing into a reach to estimate a new temperature at the bottom of a reach. These models reliably predict the effect of site-scale modifications on stream temperatures within relatively short stream reaches. However, they are not designed to analyze temperature changes within entire stream networks. Secondly, most existing models have been designed to answer questions at different scales. For example, the aquatic-effects analysis model developed for the interior Columbia basin (Rieman et al. 2001) operates at too coarse a scale, whereas models such as SSTemp work at too fine a scale for subbasin planning. Thirdly, most mechanistic models are too complex, requiring extensive data and a high degree of expertise to run and analyze, both of which are frequently not available. Examples of these models include network-scale stream-temperature models such as SNTemp (USGS 2000) or distributed hydrology models, such as the Distributed Hydrology Soil Vegetation Model (DHSVM) (Wigmosta et al. 1994). The DHSVM, e.g., is designed to predict event-based stream discharges and annual water yield at watershed scales but requires detailed inputs of soil and topographic characteristics and is driven by spatially distributed energy and precipitation budgets. The DHSVM would need to be calibrated to match observed hydrographs and then validated by predicting hydrographs for a different series of storms or a different watershed. However, it would usually be difficult to obtain local calibration data, and the calibrated model will not be readily transferable to other watersheds. Fourthly, most existing models lack followup support for technology transfer to agency management units to help natural resource specialists parameterize the models to local conditions and then run the models. Finally, only a few empirical models have been developed for the interior West that relate landscape variables and processes to aquatic habitat or species because the empirical basis for these relationships is limited. All these factors limit the use of complex, mechanistic models as planning tools that can be applied to subbasins across the entire Columbia River basin.

Each of the models described above offers some utility toward analyzing a specific problem related to land management practices and their effect on aquatic habitat. None of these models, however, attempts to link landscape processes and the range of land
management practices to cumulative effects on either habitat capacity or water quality. We do not know of a linked series of models that would enable a user to simultaneously examine multiple, midscale land management issues and their effect on aquatic habitat capacity and water quality.

Recently, several models (for example, the Ecosystem Diagnosis and Treatment [EDT] Method, the Plan for Analyzing and Testing Hypotheses [PATH], and the Cumulative Risk Initiative [CRI]) have been developed to help inform decisions related to salmon management in the Columbia River basin. The EDT model (Mobrand Biometrics 1999) was designed to compare effects of alternative strategies for managing hatcheries, hydropower, and harvest. The EDT model was designed to be a comprehensive model, accounting for spatial and temporal interactions between habitat conditions, competition, and predation, and projecting cumulative effects (ISAB 2001). Consequently, the model is relatively complex, requiring qualitative and quantitative habitat information about species, which are represented as a set of rules relating survival to habitat conditions. The model is fine scale, utilizing habitat information at the 6th HUC (HUC6 level) and some 40 habitat parameters (ISAB 2001). The EDT model will be required in future subbasin assessments in the Columbia River basin, and work is currently underway to integrate EDT into a broader assessment framework to evaluate fish and wildlife species across aquatic, riparian, and terrestrial environments (Marcot et al. 2002). Although EDT is a habitat-based model, it was not designed to link instream features to processes occurring in upland areas—processes such as fire and other natural disturbances or land management activities such as harvest or grazing. Also, EDT does not directly assess uncertainty in predicted outcomes, and because the model is complex, it is difficult to ground-truth all input data and to review or edit rules linking habitat to the survival of fish species (ISAB 2001). These factors would make EDT difficult to use in INLAS.

The PATH and CRI models are statistical modeling approaches focused on population dynamics of anadromous salmonids. The PATH model (Marmorek et al. 1998) was designed to examine Snake River listed salmon and steelhead and to evaluate management options for these species as affected by survival in specific life stages. The model’s main focus is the survival of fish migrating through the mainstem river corridor and the influence of variations in the management and operation of the hydropower system on fish survival. The CRI model statistically examines the survival of fish in freshwater habitats as one generalized component of the overall extinction risk for all listed anadromous salmonids in the Columbia River basin (CRI 2000). However, CRI does not link survival to specific habitat attributes nor does it consider how habitat might change under different management scenarios. These factors make PATH and CRI unsuitable for use in INLAS.

Decision-support models (DSMs) are based on decision analysis and provide possible alternatives to the more traditional modeling approaches described above. Decision analysis can be broadly divided into two components: (1) risk analysis and (2) risk management. Risk analysis is the process of identifying the results of alternative decisions. Thus, risk analysis can help natural resource specialists examine the expected effects of different management strategies (Varis and Kuikka 1999). Further, because risk analysis uses explicit, quantitative methods to examine uncertainty (Clemen 1996), risk analysis can be used to assess the influence of various sources of uncertainty (e.g., variability) on the probability of achieving specific outcomes given a particular decision. Additionally, risk analysis can be used to estimate the value of additional information (e.g., monitoring, watershed analysis). Risk analysis, however, cannot choose the “best”
management strategy. Risk management is the process of assessing the value of possible outcomes. A formal risk management plan requires that decisionmakers (i.e., managers) define their attitudes about risks and assign quantifiable values (e.g., an economic cost or a societal benefit) to each possible outcome identified in the risk analysis.

The use of DSMs to conduct risk analysis for the INLAS aquatic module offers several specific advantages that meet our modeling needs. The DSMs can:

- Provide a quantitative framework to describe the current understanding of the complex interrelationships between landscape properties and aquatic habitat, to explicitly define these relationships within the model structure, and then to test the influence of each variable on expected outcomes.
- Use outputs from other models (e.g., the projected changes in vegetation, fire severity and extent, management activities, and other variables from other INLAS modules) to project changes in aquatic habitat units at selected points in time.
- Use expert opinion to parameterize input variables when empirical data are lacking. Additionally, the influence of those opinions and the underlying assumptions are explicit and consistent within the model. The model is transparent in that key assumptions and the values of all variables, including those based on expert opinion, are displayed.
- Incorporate empirical data, mechanistic models, meta-analyses, and subjective probabilities from experts into a single model, integrate information from several disciplines, and use that information to analyze alternative management scenarios.
- Be used to test effects of alternative assumptions on outcomes.
- Determine the relative contribution of each variable to model outcomes through sensitivity analysis of model variables.

At least two DSMs have been developed and are currently in use in the Pacific Northwest and interior Columbia basin. The Ecosystem Management Decision Support System (EMDS) (Reynolds 1999, Reynolds et al. 2000), developed by the Pacific Northwest Research Station, is a fuzzy logic rule-based model providing decision-support tools for landscape analysis and restoration priority setting. However, the aquatic applications to date have primarily focused on disturbance from landslides and debris flows, rather than fire, in basins west of the Cascade Range. Further, current applications of EMDS are driven primarily by inchannel variables, such as large wood and pools, rather than upland characteristics and management activities. Aquatic applications also have not been integrated with other resource areas (e.g., vegetation management, terrestrial species).

A Bayesian belief network (BBN) model was developed for the aquatic effects analysis of management alternatives proposed in the environmental impact statement for the interior Columbia basin (Rieman et al. 2001). This model has been used to evaluate broad-scale effects of federal land management alternatives on aquatic habitat and species for the interior Columbia basin. However, the model is designed for broad-scale analyses of Interior Columbia Basin Ecosystem Management Project (ICBEMP) management alternatives. Also, the model does not directly examine the effects of specific management practices. Rather it uses measures of management activity, such as road density, to
project habitat condition over large spatial scales. Although neither the existing versions of EMDS nor the ICBEMP BBN model are sufficient to meet our objectives, they are examples of the types of DSMs most likely to meet the modeling needs identified above.

**Modeling Approach**

We will develop a DSM to evaluate the effects of alternative land-management scenarios on salmonid habitat at the subbasin scale within the interior Columbia basin. The work described here is focused on risk analysis. Objectives include:

- Develop midscale analytic tools to:
  - Assess aquatic habitat condition in the context of the biophysical characteristics of streams and watersheds and landscape-scale processes.
  - Compare potential cumulative effects of alternative management scenarios on aquatic habitat.
  - Help define where and what types of land and water management treatments may be most compatible with aquatic habitat considerations (e.g., key habitats and limitations of species, sensitive soils, existing roads).
  - Develop analytic tools that can incorporate new information to resolve key uncertainties in an adaptive management framework.
  - Develop analytic tools that are spatially explicit (i.e., can analyze and report information at various fine and mid scales).
  - Develop analytic tools that are sufficiently flexible to accommodate a variety of available data and that facilitate widespread application,
  - Complement other existing midscale aquatic analytic tools (EDT and EMDS).

**Objectives**

**Methods**

The initial phase of decision-model development will be to identify the decision context(s), responses to be modeled and management alternatives. Decision models will then be structured specifically to address each decision situation and to link with other INLAS modules. Conditional dependencies will be parameterized by using the existing data from the region and data gathered from published studies via meta-analysis (Gelman et al. 1995). Where empirical data or other model output are lacking, expert opinion will be solicited from a panel of species and habitat experts and used to parameterize variables included in the models (Morgan and Henrion 1990). To explicitly incorporate uncertainty, relationships between environmental variables and habitat capacity will be modeled as conditional dependencies (probabilities), combined in a BBN (influence diagram) (Haas 2001), dynamic optimization model (Williams 1996), or similar decision-model form. Sensitivity analysis will then be performed on these models.

**Links to Other INLAS Modules**

Although the streams make up only a tiny percentage of the total land base of the Upper Grande Ronde watershed, they can be impacted by land use activities occurring anywhere within the watershed. Thus, the decision-support tool developed for the INLAS Aquatic Module needs to be linked directly to many other INLAS modules. Potential direct linkages between the vegetation, disturbance, riparian, wood utilization, herbivory, recreation, and economic modules are illustrated (fig. 13). We will use inputs from these INLAS modules to characterize watershed attributes that directly or indirectly influence the aquatic system and then analyze those projected landscapes to evaluate likely habitat capacity and water quality effects for short-term (e.g., 5- to 10-year) and long-term (e.g., 100-year) timeframes that would result from specific management scenarios. Aquatic habitat capacity potential also is affected by physical attributes of the subbasin, attributes such as slope steepness, soil types, and valley floor widths, which are fixed.
physical attributes and insensitive to management-caused changes. Many of the other INLAS modules require similar descriptive information. Spatially explicit databases will be compiled for the INLAS project and available to all INLAS modules so that effects of specific management scenarios will be based on identical watersheds.

**Expected Outputs**

We will develop DSMs and provide detailed documentation of those models including methods used to incorporate data into the decision models, the sensitivity analysis, and evaluation of the relative value (cost benefit) of collecting additional data to better parameterize model variables. The latter also will be used to make recommendations regarding future studies or monitoring efforts.

We also will develop a user-friendly electronic version of the DSMs for use by Forest Service biologists.

The DSMs will be applied to the Upper Grande Ronde subbasin to evaluate the influence of alternative management scenarios developed to address aquatic and other resource issues.

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**Figure 13**—Example of possible linkages between physical conditions, land management practices, and aquatic habitat capacity to be used for decision analysis (The actual decision analysis framework will be developed with the use of expert panels during the project). Potential links to other Interior Northwest Landscape Analysis System modules are illustrated (bold text in boxes).
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Methods for Integrated Modeling of Landscape Change: Interior Northwest Landscape Analysis System
Methods for Integrated Modeling of Landscape Change:

Interior Northwest Landscape Analysis System

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The Interior Northwest Landscape Analysis System (INLAS) links a number of resource, disturbance, and landscape simulations models to examine the interactions of vegetative succession, management, and disturbance with policy goals. The effects of natural disturbance like wildfire, herbivory, forest insects and diseases, as well as specific management actions are included. The outputs from simulations illustrate potential changes in aquatic conditions and terrestrial habitat, potential for wood utilization, and socio-economic opportunities. The 14 chapters of this document outline the current state of knowledge in each of the areas covered by the INLAS project and describe the objectives and organization of the project. The project explores ways to integrate the effects of natural disturbances and management into planning and policy analyses; illustrate potential conflicts among current policies, natural disturbances, and management activities; and explore the policy, economics, and ecological constraints associated with the application of effective fuel treatments on midscale landscapes in the interior Northwest.

Keywords: Forest simulation analysis, midscale, vegetation succession, disturbance, management.
The concept of a process for evaluating policy direction and management options for subbasin-size landscapes in the interior West evolved from the Pacific Northwest Research Station's Research Initiative for Improving Forest Ecosystem Health and Productivity in Eastern Oregon and Washington. The Interior Northwest Landscape Analysis System (INLAS) project was initiated to explore this concept and began with meetings of resource managers and scientists from various disciplines and institutions. This group suggested ways to build an integrated set of tools and methods for addressing resource management questions on large, multiowner landscapes. The papers in this volume are the outcome of these meetings and document our initial approach to developing an integrated landscape analysis framework. Collectively, the papers illustrate the diversity of methods for modeling different resources and reflect the inherent complexity of linking models to create a functional framework for integrated resource analysis. We are still a long way from a perfect tool, the linkages among the chapters are not always apparent, and integration issues have not been consistently addressed. We cannot yet address the interrelationships between many key natural and anthropomorphic processes on large landscapes. We also found that integration forced scientists to generalize relationships and to summarize detailed research findings in order to incorporate their disciplines at the landscape scale of the INLAS framework. With a growing interest in integrated natural resource modeling, we concluded that, despite the fact that we have not solved all the problems associated with integrating information from different scientific disciplines, creating this document will provide a valuable resource for future researchers who want to understand how groups of scientists organize themselves for a project like INLAS. There are few examples of case studies of similar work in other regions, and to our knowledge, none that document such early stages of these projects’ organization. The reader can learn from both the continuity and lack thereof among the chapters, and perhaps use this publication to learn new ways to deal with the dilemma of how to hybridize long-term research lineages into coherent ways of thinking about integrated natural resource management.

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Contents

1 Chapter 1: A Framework for the Development and Application of INLAS: the Interior Northwest Landscape Analysis System
   R. James Barbour, Alan A. Ager, and Jane L. Hayes

17 Chapter 2: A State and Transition Approach for Integrating Landscape Models
   Miles Hemstrom, Alan A. Ager, Martin Vavra, Barbara C. Wales, and Michael J. Wisdom

33 Chapter 3: Application of the Forest Vegetation Simulator and Related Tools for Integrated Modeling of Forest Landscapes
   Alan A. Ager

41 Chapter 4: The SafeD Forest Landscape Planning Model
   Pete Bettinger, David Graetz, Alan A. Ager, and John Sessions

64 Chapter 5: Assessment Techniques for Terrestrial Vertebrates of Conservation Concern
   Barbara C. Wales and Lowell H. Suring

73 Chapter 6: Developing a Decision-Support Model for Assessing Condition and Prioritizing the Restoration of Aquatic Habitat in the Interior Columbia Basin
   Steven M. Wondzell and Philip J. Howell

82 Chapter 7: Modeling the Effects of Large Herbivores
   Martin Vavra, Alan A. Ager, Bruce Johnson, Michael J. Wisdom, Miles A. Hemstrom, and Robert Riggs

104 Chapter 8: Simulating Mortality From Forest Insects and Diseases
   Alan A. Ager, Jane L. Hayes, and Craig L. Schmitt

117 Chapter 9: Landscape Fire Simulation and Fuel Treatment Optimization
   Mark A. Finney

132 Chapter 10: Connection to Local Communities
   Gary J. Lettman and Jeffrey D. Kline

137 Chapter 11: Conflicts and Opportunities in Natural Resource Management: Concepts, Tools, and Information for Assessing Values and Places Important to People
   Roger N. Clark

153 Chapter 12: Analysis and Modeling of Forest-Land Development at the Wildland/Urban Interface
   Jeffrey D. Kline

161 Chapter 13: Evaluating Forest Products as Part of Landscape Planning
   R. James Barbour, Douglas Maguire, and Ryan Singleton

171 Chapter 14: Bibliography
   Marti Aitken and Alan A. Ager