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The complexity of forest management has increased with the scope of resources of concern and the level of scrutiny from stakeholders. The design and use of specialized computer software, often referred to as “decision support systems” (DSS), is one method for helping managers deal with this complexity. DSS have proven helpful in a wide range of fields, including business planning, medical diagnosis, and transportation. In the forestry sector, they have been used intensively for timber supply modeling, but their application to the more diverse and nebulous goals of ecosystem management and sustainable forestry has not been as straightforward. This study investigates the availability and utility of such DSS in relation to questions about forest biodiversity.

Part one of this research was based on a written survey of the capabilities of existing decision support systems relevant to forest biodiversity issues (FBDSS). The primary objectives of the survey were to (1) help potential FBDSS users find systems which meet their needs and (2) help FBDSS designers and funders identify unmet needs. Thirty systems met the screening criteria from a pool of over 100 tools generated from previous reviews and other sources. These systems were reviewed against three themes: (1) classes of forest biodiversity indicators used, (2) major forest influences addressed, and (3) abilities to tackle complex political decisions. The results show only one system appears to address the full suite of biodiversity indicator classes based on the Montreal Process Criteria and Indicators. While there are a

number of forest modeling tools that evaluate the influences of fire and biological threats on forest ecosystems, these systems do not generally deal with related biodiversity effects, and only one system was found which attempts to integrate the influence of climate change. Very few FBDSS appear to have capabilities explicitly designed to address the often value-based, political nature of forest biodiversity decisions.

Part two comprises four in depth case studies on how FBDSS were actually used in different problem solving situations. Participant interviews and available documentation were reviewed using a four-part, qualitative framework. First, participants' were asked how they judged success of the efforts (success measures) and what factors contributed the most to the outcome (success factors). Contrary to the analytical view of FBDSS, social measures of "stakeholder evaluations" and "contribution to consensus building" were found to be the most popular measures of success. The second part of the framework compared and contrasted the applicability of success factors taken from existing analytical and social theories on these cases. Three analytical factors were drawn from information systems theory (system quality, information quality, and service quality), and four social factors were taken from the environmental assessment literature (participation, communication, translation, and mediation). These factors covered participants' explanations well and helped reveal additional aspects of the cases not directly expressed. Third, the cases were examined for a "mutual and recursive" pattern of analysis and deliberation. The least successful case also had the most difficulty in realizing this pattern. Fourth, it was hypothesized that participants in less conflicted situations would use fewer social indicators of success, and that as social complexity increased, simpler tools would be more successful. Neither of these expectations were supported by this group of cases.

Part three of the study brought together information from the written survey, four in depth case studies, ten more cursory cases, and the literature to construct a framework help practicioners think about the "why, when, what, how, and who" of adoption and use of FBDSS. Important threads through these considerations include the question(s) of interest, the decision context, and the available capacity and time. The social and political uses of FBDSS should be explicitly considered because, as shown in the Part II case studies, these uses can be as important as the more traditionally recognized analytical benefits. A number of authors have suggested guidelines for choosing decision making methods (e.g. computation, expert judgment, stakeholder negotiation, integrated deliberation) best suited to different types of decision contexts. Lack of value agreement on and a dearth of knowledge about biodiversity means that these guidelines will rarely recommend a purely analytical approach. Therefore, I argue that if a DSS is used, it should be explicitly structured to serve the more preferred decision method. Reviewing the cases in this study has also provided some more specific suggestions on DSS use, such as understanding the (not necessarily scientific) information credibility demands of decision makers, the importance of incorporating local information, and how DSS can help structure group work and accumulate results. Finally, further research is suggested in the taxonomy of biodiversity decisions, the ability of DSS to address the more unique aspects of ecosystem management, and ways to gauge compatibility between different analytic and deliberative methods.

Decision support systems for forest biodiversity management:
A review of tools and an analytical-deliberative framework
for understanding their successful application

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I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

Sean N. Gordon, Author

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CHAPTER 1 – INTRODUCTION

During the 20th century forest management in the U.S. has undergone a number of paradigm shifts, from sustained timber yield to multiple use to the current suite of sustainable forestry, ecosystem management, and adaptive management approaches (Davis et al. 2001; Kohm and Franklin 1997; Gordon 1994; Sample 1993; Cortner and Moote 1999). This transition entails a number of consequences related to the planning and management of our forests:

- Consideration of many more decision factors besides market economics and wood production (e.g. ecological and social impacts);
- Greater concern about longer times and larger areas (e.g. landscape assessments);
- Continual refinement of plans due to the realization that there are no stable solutions to dynamic biological and social complexity ("adaptive management");
- More complex political negotiations because these additional factors, larger scales, and more frequent revisions of plans bring in a greater number and diversity of stakeholders.

Legal requirements for this increased scope and participation have been codified in national legislation, including the Multiple Use and Sustained Yield Act (1960), National Environmental Protection Act (1969), Endangered Species Act (1973), and National Forest Management Act (NFMA 1976). Many forest management organizations are now adding further voluntary requirements through sustainable forestry certification initiatives (e.g. Sustainable Forestry Initiative, Forest Stewardship Council, American Tree Farm System). Together these factors create a central problem: how to manage within this environment of increased complexity.

In response to the complex planning requirements brought on by NFMA, Cortner and Schweitzer (1983) contend that the adoption of quantitative, computerized procedures was inevitable. From 1979 to 1996, the U.S. Forest Service required the use of FORPLAN, a computerized decision support system based on linear programming techniques. Barber and Rodman (1990) note that such systems had been successful in the military and had helped put a man on the moon, but their application to forest planning proved considerably more problematic. Cortner and Schweitzer (1983 p. 494) argued that these difficulties stemmed from the fact that public planning "…allocates benefits to some and imposes costs on others, it is inherently political."

Allen and Gould (1986) echoed this argument that the crisis in public forest planning was due to assuming the problem is a complex one, but solvable with increased technical analysis. Rather, they said, the nature of the problem was of a qualitatively different sort. It shared the following characteristics of many public planning problems, for which Rittel and Weber (1972) coined the term "wicked" problems:

- no definitive formulation
- no definitive solution
- each is unique

They suggest that planning methods that successfully interface politics, science, and analysis cannot be standardized, and only very simple models will be employable in this context.

Healy and Ascher (1995 p. 17) also studied the role NFMA-initiated analysis played in decision making and concluded:

> New information may shift power away from non-expert actors, undermine rights arguments, polarize debates over appropriate resource use, and delay timely decision making. Although new information may change policy outcomes, often for the better, there is little reason for believing that it will make the decision making process itself either shorter or smoother.

These forestry studies are consistent with a variety of established and emerging theories of organizational decision making, planning and policymaking which emphasize the importance of communicative rather than instrumental rationality (Fischer and Forester 1993). Instrumental rationality, which Shannon (1999) argues has been the dominant normative model in public and private resource planning over the last 50 years, is focused on finding efficient means to defined ends, assuming that ends are first clearly identified and then means are formulated in separate steps. In contrast, communicative rationality assumes that formulation of ends and means are inseparable and that decision making is primarily advanced through social argumentation, advocacy and learning. This tension between analytical and communicative strategies has been especially prominent in the field of environmental risk assessment. Panels commissioned by the U.S. National Research Council have argued for more emphasis on and research into methods to integrate analysis and social deliberation (NRC 1996, 2005). In their review, "Tools to Aid Environmental Decision Making," Dale and English (1999 p. 323) note a shift from authoritative/analytical decision styles to more conflict management and collaborative learning. They close with two questions:

> Can currently available information-gathering and analytic tools also be used in the conflict-management and collaborative-learning modes of decision making, or will they need to be modified?
>
> Will completely new tools be required as various organizations address the hard environmental questions that are arising in a society that is changing, with environmental issues becoming more pressing and complex?

Previous reviews have described the technical capabilities of a considerable number of computerized tools related to national forest planning (Schuster et al. 1993), ecosystem management (Mowrer 1997) and biodiversity planning (Johnson and Lachman 2001). However, except for a few reflections on the use of the FORPLAN system, there does not appear to be any research on the use of these tools in real-world decision-making situations, which could begin to answer the questions posed by Dale and English (1999) and the broader issue of the uses of instrumental versus communicative rationality in forest planning and management.

The question this study attempts to answer is, "How can decision participants find the tools that best meet their needs and use them effectively, given the wide range of technical needs and social contexts associated with forest decisions?"

This research focuses on decision support systems used to address forest biodiversity issues. Biodiversity is one of the most visible and contentious of the issues comprising sustainable forestry and ecosystem management. Decision support systems are an accessible and important type of tool to study because they have been formally codified and are usually intended for repeated application.

The study is broken into three parts. Part I surveys what decision support systems are available for forest biodiversity analysis and planning, and it compares their capabilities to a generalized set of decision making needs. Part II employs a case study approach to examine the use of such tools in four real-world applications. It addresses questions of why and how these systems are used in decision making, and what factors appear to influence their success. Part III brings together the two previous sections and the broader literature to provide a practical framework for thinking about when and how to use decision support systems to address forest biodiversity issues.

PART I : THE CAPABILITIES OF FOREST BIODIVERSITY DECISION SUPPORT SYSTEMS

CHAPTER 2 – LITERATURE REVIEW

Computer-based decision support systems (DSS) have been used in forest planning since the mid-1970s (Iverson and Alston 1986). The first formal, comparative survey of such systems appears to have been published in 1993, and it found a surprising 250 tools (Schuster et al. 1993). A variety of surveys and reviews have been done since and are discussed below. This chapter begins with a brief review of how decision support systems are defined, then discusses past reviews of DSS for natural resource management, and concludes with a discussion of the substantive issue for the current review, biodiversity and forest management decision making.

Decision Support Systems

"Decision support system" is a phrase with multiple meanings. Specialists in the field of information systems use it to describe a genre of computer-based software applications, but in more general usage it could refer to any system for supporting decisions (whether involving computers or not). This study uses the term in the former, more disciplinary sense. However, as discussed below and further studied in Part II of this research, a computer-based DSS always sits within (and is sometimes even defined by) a larger decision-making framework

In spite of the precision often expected of computer-related concepts, current DSS textbooks acknowledge that the definition of what qualifies as a "decision support system" is quite nebulous (Marakas 1999). Turban and Aronson (2001 p.13) go so far as to call it a "content-free expression" (but still use it as their book title). In what has been cited as the first paper on DSS, Little (1970) provided a succinct definition: "a model-based set of procedures for processing data and judgments to assist a manager in his decision making." This definition suggests at least three functional components are typically present in a DSS: 1) a subsystem for storing and retrieving data, 2) one or more models that provide techniques to analyze the data, and 3) a user interface that facilitates control over the system as a whole.

In contrast to "management information systems," Laudon and Laudon (2000) characterized DSS as more focused on a particular problem and end user, more reliant on models and assumptions, and more frequently refined with the definition of the problem. Gorry and Scott Morton (1989) provide an oft-cited alternative method of classifying information systems based not on the systems components but on the types of problems they address. They created a matrix using Simon's (1976) classification of decisions by level of structure with Anthony's (1965) division by level of decision making. Their emphasis was that DSS are systems developed for semi-structured problems (see Table 1).

Table 1. DSS in the Context of Other Information Systems

	Level of Decision Making			Appropriate Technologies
Level of Structure ↓	Operational	Tactical	Strategic	
Structured	inventory control	short-term forecasting	warehouse location	*management information systems; transaction processing; operations research*
Semi-structured	production scheduling	project scheduling	new product planning	***decision support systems*** *knowledge management*
Unstructured	selecting artwork for ad	recruiting	new technology development	*executive support systems; problem structuring methods*

Source: Adapted from Gorry and Scott-Morton (1989), Marakas (1999), Turban and Aronson (2001)

Past Reviews of DSS Related to Natural Resource Management

While there do not appear to be any previous reviews of DSS specifically focused on forest biodiversity decisions, there are a number of studies which address closely related themes. Table 2 lists the most relevant of these studies. In this section I group these studies into three types, based on their general approaches, and then discuss their methodologies and results.

Table 2. Past reviews of DSS for Natural Resource Management

Type	Authors	Title	# DSS reviewed
1	Schuster et al. (1993)	A Guide to Computer-Based Analytical Tools for Implementing National Forest Plans	250
1	Mowrer 1997	Decision support systems for ecosystem management: an evaluation of existing systems	24
1	Johnson and Lachman 2001	Rapid scan of decision support system tools for land-use related decision making	50
1	Barrett 2001	Models of vegetation change for landscape planning	4
1	Lee et al. 2003	An evaluation of landscape dynamic simulation models	3
2	Dale and English 1999	Tools to aid environmental decision making	NA
2	Oliver and Twery 2000	Decision support systems: Models and analyses	NA
2	Reynolds et al. 2000	Decision Support for Ecosystem Management	18
2	Gustafson et al. 2002	Evolving approaches and technologies to enhance the role of ecological modeling in decision-making	NA
3	Lexer et al. 2000	The use of forest models for biodiversity assessments at the stand level	NA
3	Monserud 2003	Evaluating forest models in a sustainable forest management context	NA
3	Robinson and Monserud 2003	Criteria for comparing the adaptability of forest growth models	NA
3	Rauscher 1999	Ecosystem management decision support for federal forests in the United States: a review	30

Key: NA = not applicable (many reviews discussed general types of systems rather than specific systems)

Type 1: DSS Operational Specifics

The first type of approach is one which focuses on the operational specifics of systems available. These studies describe each system using a common set of criteria or questions designed to reflect specific user needs (e.g. geographic scale of application). They appear oriented towards technical specialists interested in choosing a system to support a particular type of analysis. In addition, they also probably serve as an information exchange mechanism among DSS designers.

All the Type 1 studies developed a standard template to describe each system. Although they do not document their theoretical origins, these frameworks (see Table 3) clearly draw on issues from the substantive domain (forest, ecosystem, biodiversity management) and information systems (modeling techniques, hardware/software needs, user support). The categories covered have many similarities. Barrett (2001) and Lee et al. (2003) are somewhat different, in that they focus on a specific type of system (landscape simulators), thus spend more time on capabilities specific to this genre.

The studies used a variety of data gathering methods. Schuster et al. (1993) and Mowrer (1997) employed written surveys sent to the system designers. Schuster identified a large number of systems via a snowball sampling inquiry, while Mowrer limited their review to 24 multi-functional tools identified by their 15 member panel. Johnson and Lachman (2001) also used a snowball sample to identify tools, but they filled in their template themselves from the internet, literature, and interviews. Barrett (2001) reviewed the documentation and tools herself, while Lee et al. (2003) organized a small workshop where three outside experts reviewed the tools and interviewed their designers.

Analysis centered on applying the standard template to each individual tool and summarizing the results. Mowrer (1997) summarized this information in a series of four checkbox matrices. In some cases it was difficult to make a definitive true/false call, and, in particular, Mowrer (1997) employs a "dependent on user" category. Schuster et al. (1993) constructed matrices between their various criteria (e.g. Purpose by Resources/Functions) and calculated descriptive statistics (counts and percentages) about the numbers of tools in each cell. Johnson and Lachman's (2001) summarization was less detailed; they only created lists of tools by main application areas (e.g. water management) and functionality (e.g. simulation).

The conclusions of these reviews identified some more problem-specific needs. Schuster et al. (1993) found tools for analyzing resource effects were most numerous (with 41% of these focused on timber, 10% on wildlife). At the same time, they commented that few tools were available for emerging implementation needs, such as monitoring, cumulative effects estimation, spatial analysis, or legal documentation. They recommended three areas for further research: 1) evaluate tool strengths, weaknesses, and functional gaps; 2) expand scope of tools beyond national forest plans; and 3) study technology transfer issues, like actual use and barriers to use. Mowrer (1997) found the greatest gaps to be the abilities to 1) integrate social, economic and biophysical issues, 2) transform between spatial scales, and 3) help build consensus. Johnson and Lachman (2001) found little emphasis on biodiversity issues in their sample, and they recommended a number of success factors (see Appendix A).

Table 3. Summary of FBDSS Type 1 Review Frameworks

Schuster et al. (1993)	Mowrer (1997)	Johnson and Lachman (2001)	Barrett (2001)	Lee et al. (2003)
1. Brief description 2. Geographical scope addressed 3. Purpose of analysis 4. Resources applied to 5. Software type 6. Modeling technique 7. Hardware/software needed 8. User support 9. Contact details	1. Scope and Capabilities 2. Spatial Issues 3. Basic Development and Status 4. Inputs/Outputs 5. User Support 6. Performance 7. Computational Methods 8. Contact details	1. Description of the Tool 2. Use of the Tool 3. Environmental Considerations 4. Logistical Information About the Tool 5. Lessons learned and the Significance of the Tool 6. Technical DSS Functions & Characteristics 7. Contact details	1. model formulation 2. data structure 3. capabilities 4. potential applications	1. state space (resolution in space & time) 2. memory (of landscape history, adjacent locations) 3. approach to landscape dynamics (coarse/fine, stochastic/deterministic, sensitivity analysis) 4. approach to spatial characteristics and relationships

Type 2: DSS General Principles

A second type of review uses only selective DSS examples in order to describe what general capabilities are available for managers or analysts interested in learning about new techniques. Relevant examples in this category include a book edited by Dale and English (1999), which provides chapters on different decision support methodologies (not necessarily computer-based systems), and a book chapter by Gustafson et al. (2002) focusing more specifically on ecological models. Two other articles of this type also appear in a large compendium on ecosystem management (Reynolds et al. 2000; Oliver and Twery 2000).

These Type 2 studies are designed to be illustrative rather than exhaustive. They do not use any formal methodology for selecting the systems discussed, rather they rely on the authors existing knowledge. Three of the studies, however, use the common organizational framework of a stepwise rational decision-making process (Dale and English 1999, Oliver and Twery 2000, Reynolds et al. 2000). Oliver and Twery (2000) focus more on factors contributing to each step, such as “It is important to separate the roles of suggesting alternatives, combining alternatives, and analyzing the consequences of various alternatives” (p. 667). Reynolds et al. (2000) offer some more synthetic thoughts on barriers and promising possibilities, especially the need for interconnectivity among systems to enable more complete support of the ecosystem management approach. Dale and English (1999) provide an explicit list of success factors (see Appendix A). It is interesting to note that many of these recommendations address how the system is used, rather than simply the capabilities of the system itself. Gustafson et al. (2002) identify a communication gap between modelers and managers, and also note the trend towards greater participation in decision making means models will need to be more transparent and better documented. Also related to social use, Dale and English (1999) and Oliver and Twery (2000) discuss alternative decision-making styles, such as “bounded rationality,” “expert/intuitive,” and “crisis”. They do not, however, get specific as to how these approaches affect DSS use or success.

Type 3: DSS Theory

Type 3 studies focus more on the abilities of individual models to meet the needs derived from specific theoretical frameworks. Although they discuss individual models, their conclusions are based more on broader model types or approaches. For example, Lexer et al. (2000) compare the capabilities of forest growth models to address the composition, structure, and function aspects of biodiversity. They find that distance-dependent, individual tree models to be more suited to forest biodiversity uses than distance-independent or whole stand models. Monserud's (2003) review focuses on biological factors, specifically those affecting net primary productivity such as carbon and nutrient cycling, moisture regimes, and climate. He finds hybrid (process/empirical) forest models to be the most promising for sustainable forestry uses. Rauscher (1999) evaluates DSS on their abilities to address steps in the adaptive management process (Plan-Act-Monitor-Evaluate), with particular emphasis on four planning stages (problem identification, alternative development, alternative selection, authorization) adapted from Mintzberg et al. (1976). The diverse requirements of this process led him to emphasize the need for integration of systems with different capabilities, and he also identified a critical lack of systems to that could help facilitate social negotiation processes.

Forest Biodiversity Management

The evaluation frameworks used in previous DSS reviews all were build on an understanding of decision makers' needs in the area addressed. To develop such a framework for the current study, the following sections discuss definitions of forest biodiversity and past research relevant to assessing decision makers' needs.

Defining Forest Biodiversity

Biological diversity has been defined as "…the variety and variability among living organisms and the ecological complexes in which they occur" (OTA 1987). Most definitions recognize three levels of diversity: "…the diversity of ecosystems, the diversity between species, and genetic diversity in species" (WRI et al. 1992).

Franklin (1986) chose to define it in terms of "composition, structure, function," which emphasizes that it is more than a simple species count

Biodiversity conservation has become a major theme in forest management and is the first criterion in the internationally-recognized set of Montreal Protocol Criteria and Indicators for the sustainable management of temperate and boreal forests (Montreal Process 1998). It has affected both public and private forest management in the United States, primarily through the Endangered Species Act treatment of individual species, and more recently through voluntary forest certification standards. Managing for biodiversity conservation presents a complex challenge for forest managers, from policymakers to field foresters, due to its broad scope and lack of a widely accepted operational definition.

Although sometimes considered as a singular issue, biodiversity has increasingly been viewed as part of a broader list of forest management concerns described by the concepts of "ecosystem management" or "sustainable forestry". Ecosystem management has mainly been used in reference to public forests, being adopted as the official approach of the U.S. Forest Service in 1992, while sustainable forestry has had more currency with regards to private lands, as evidenced by its use in certification initiatives (SFI 2004, FSC 2004). Similar to biodiversity, there is also debate whether "ecosystem management" is simply procedural (Overbay 1992) or whether it defines an expected end state (Grumbine 1994).

. Beyond the technical definitions, it should not be missed that biodiversity is also a social construct. Takacs (1996) interviewed 23 of the best known biodiversity experts in the U.S., and, using a social studies of science approach to question their underlying assumptions and motivations, came to the following conclusion:

> "The term biodiversity is a tool for a zealous defense of a particular social construction of nature that recognizes, analyzes, and rues this furious destruction of life on Earth. When they deploy the term, biologists aim to change science, conservation, cultural habits, human values, our ideas about nature, and, ultimately, nature itself." (p. 1)

Forest Biodiversity Decision-making Needs

For the current study, understanding the adequacy of DSS in addressing forest biodiversity decisions begs the question, "What are the decision makers' needs?" Individual decisions about forest biodiversity have been studied using a number of disciplinary approaches, including economic (Kline et al. 2000), psychological (Miller 1999), and the science-policy interface (Noon and McKelvey 1996). Other approaches to studying biodiversity decision making have focused on the roles of various disciplines (Montgomery and Pollack 1996; Nyhus et al. 2002; Simberloff 1999) and actors (Kelly and Hodge 1996). Unfortunately there is little in the literature which attempts to describe the breadth of types of forest biodiversity decisions being made and the different decision makers' needs.

Smythe et al. (1996) present one study which did attempt to empirically describe decision makers' biodiversity information needs. They used interviews and meetings to elicit the needs of 100+ governmental and nongovernmental decision makers. They identified six priority areas for research:

1. Characterization of biodiversity
2. Environmental valuation
3. Management for sustainability
4. Information management strategies
5. Governance issues
6. Communication and outreach

While the needs encountered by Smythe et al. (1996) appear useful for guiding research priorities, I felt for the most part they were too broad to usefully categorize the functions of specific forest decision support systems. Ideally, a survey of managers' needs would be conducted, however, that was beyond the scope of this study. A more specific and readily available source of decision-making needs can be deduced from what experts choose to emphasize in their forest biodiversity management texts. The next sections highlight some common themes which emerge from three texts (Hunter 1990, Patton 1997, Lindenmayer and Franklin 2002) and the journal literature.

Characterization of Biodiversity

Hunter (1990) devotes an early chapter in his book to considering the many ways in which biodiversity may be characterized. Despite considerable congruency in the high-level concepts, on-the-ground operational definitions of biodiversity remain both difficult and contentious. For example, debate has been rekindled about revisions to the species viability clauses in national forest regulations, and whether to measure diversity using "coarse filter" (habitat-based) or "fine-filter" (species-based) indicators ("Wildlife Rule Change Challenged," Oregonian, 10/27/2004, p. A8).

Influences on Forest Habitats

Since forest managers principally manipulate forest structures, not individual wildlife species, texts on the management of forest biodiversity tend to focus on processes which influence these structures (Hunter 1990; Patton 1997; Lindenmayer and Franklin 2002). While the literature has traditionally focused on forest harvesting and its effects, the scope is now broadening to include other influences, such as fire (NCSSF 2003), urbanization (Diamond and Noonan 1996), invasive species (Carey 2002), and climate change (Kappelle et al. 1999).

Scale, Integration, and Negotiation

Three of the six research needs (valuation, governance, communication) from Smythe et al. (1996) have more to do with human values and behavior than with biological science, reflecting the political nature of biodiversity decision making. On the issues of valuation and communication, people hold quite different values for biodiversity, creating the need for mechanisms to communicate and negotiate around these value conflicts. Valuation is also a method to integrate biodiversity with other forest values, such as wood products or recreation; it implies the integration of different information types, ecological, economic, and social commonly thought of as the core of sustainability discussions. Governance issues address who has decision making responsibilities. Forest structures at the landscape, stand, and within stand levels have all been identified as critical to biodiversity, leading experts to recommend a "multiscaled approach" to forest management (Lindenmayer and Franklin 2002). Similarly, political decision making occurs at a variety of scales, from local to global, and the coordination of these decisions is a major issue (Yaffee 1997; Cortner and Moote 1999).

Summary

Even when used as a technical term from the computer sciences, there is no unambiguous definition of what constitutes a "decision support system." Some general defining principles are available, but to some extent every DSS study must negotiate its own definition. A number of reviews of DSS related to natural resource management have been conducted, and a few different design formulas were identifiable. The substantive focus of past reviews has generally been quite broad, e.g. national forest planning, ecosystem management, landscape modeling. Forest biodiversity is a component of these themes, but relevant DSS capabilities have not been covered in any depth. A number of more specific decision making needs were identified in the literature, including how to characterize biodiversity, the effects of habitat influences, and needs to integrate information, scales, and value systems.

CHAPTER 3 – METHODS

The objectives for the current review are twofold: 1) to provide managers with a list of existing DSS which might meet their needs, and 2) identify gaps where the existing suite of DSS does not appear to meet decision-making needs well. Meeting these objectives requires developing an inventory of available systems and their capabilities, a framework of decision-making needs, and a method for comparing the two.

Study Focus

Rather than a specific place, time, or organization, this research focuses on a certain type of tool: DSS used in decision making related to forest biodiversity. There is a general geographical focus on the United States, but cases outside this scope are considered if they appear to have exceptional instructive value. Both public and private forests are considered. The context of forest biodiversity decision making has already been described in the literature review, but what is still needed are clarifications on how biodiversity and decision support systems were defined in this study.

Biodiversity

As discussed earlier, biodiversity is commonly measured at three levels: genetic, species, and ecosystems. For this study, systems addressing any of these levels were included. For some researchers, a tool that only looks at the habitat or population of one species is not truly examining diversity. However, such single-species systems were included here, based on the reasoning that each species is a component of biodiversity and individual species are often used as broader indicators.

Decision Support Systems

In the literature, the boundaries of what qualifies as a DSS vary considerably. Most of the literature focuses on computer-based systems, although a number of authors acknowledge a broader definition in principle. This study is restricted to computer-based tools, more specifically, those tools which are intended for or used in decision processes about forest biodiversity and which have the three basic DSS components (data, model, user interface). For example, models designed and used purely for research were not included, nor were biodiversity-related databases and geographic information systems, unless they were associated with a process or assessment model. Some of the examples included are actually suites of loosely linked models united under a common project. I did extend the usual expectations of what constitutes data and models from the biophysical/analytical to the communicative (e.g. a model could be a model for communication like an online discussion forum with the data consisting of individual postings).

Research Design

Robson (2002) provides a framework for thinking about research designs by classifying research approaches into two broad classes, *fixed* versus *flexible*, and research objectives into three broad categories, *exploratory*, *descriptive*, and *explanatory*. Past DSS reviews of types 1 and 3 used fixed designs; they constructed a survey or evaluation template and applied it to all the systems reviewed. The type 2 reviews are more difficult to classify. The majority used a framework of decision phases as a fixed organizing principle, but the discussion of systems within each phase was more free-form. The research objectives of these past studies contained both descriptive and explanatory elements. They were descriptive in the sense of cataloging the capabilities of various systems, and were explanatory to the degree that they drew conclusions on the adequacy of existing systems in meeting certain objectives (e.g. ecosystem management, sustainable forestry).

The goals for the current study include both a descriptive element (what systems are available and what do they do?) and an explanatory angle (to what extent do they meet decision-making needs?). A fixed survey approach incorporating questions reflecting forest biodiversity decision needs appeared to be the best design for both documenting and making comparable a potentially large number of systems.

Survey Design

Following the methodology of previous reviews (Schuster et al. 1993; Mowrer 1997; Johnson and Lachman 2001), I developed a standardized descriptive template to be filled out for each system (see Appendix B). Many of the questions were based on basic descriptive and operational attributes from the past surveys, such as a general description, hardware/software needs, and developer contact information.

The core of the template, however, was specifically designed to address forest biodiversity decision-making needs. Ideally, an empirical study of forest managers' needs would be conducted; however, the indefinite population and large variety of such decision makers would make this a complex undertaking. It was decided the time required for such a survey was infeasible given the commitment to the second goal of studying actual DSS use in Part II. A secondary strategy of interviewing forest biodiversity experts was attempted. Six experts were interviewed and asked the question, "What are the most important forest biodiversity decision-making needs?" The interviews were analyzed for common themes, but little concurrence was found. Ultimately, the results of the literature review on forest biodiversity decision making were used as the basis of the core questions on the survey.

The questionaire was organized around three themes: (1) methods to characterize biodiversity, (2) influences on forest biodiversity, and (3) the complex and political nature of decisions related to forest biodiversity conservation (see Table 4). Theme 1 was operationalized by generalizing the nine Montreal Process biodiversity indicators into 8 indicator classes (MPCI 1998). The indicators for theme 2, forest habitat influences, were derived directly from the literature. Theme 3 was characterized by adapting three areas identified as important for ecosystem management in the previous DSS review by Mowrer (1997): the integration of information from different research disciplines; the support of decision makers at multiple spatial scales; and the facilitation of social negotiation.

Data Collection and Management

Since the subjects of previous DSS reviews (Table 2) overlap significantly with the theme of forest biodiversity, the initial list of systems was compiled from these reviews. This initial list was supplemented with the personal knowledge of a small team of experts assembled for an associated grant project (Gordon et al. 2004) and searches of the world-wide web. Over 100 systems were identified.

The resulting list of systems was screened into five categories according to information that was readily available on their purposes, capabilities, and applications: (1) DSS which appeared to include both forest and biodiversity modeling capabilities, (2) systems focusing on wildlife and biodiversity, (3) systems focusing on forestry, (4) general-purpose DSS with known applications to forest biodiversity issues, (5) systems without an explicit link to forest or biodiversity modeling. Only categories one through four were selected for further review, a total of 30 systems.

Past reviews have used two different strategies to gather information on chosen DSS: written surveys filled out by the DSS developers, and descriptive templates filled out by the researchers themselves using multiple information sources. The former generally requires less effort on the part of the researchers and may provide more in-depth and up-to-date information on the systems, but, at the same time, the reviews may be more favorably biased by designers wishing to cast their systems in a positive light. The latter approach is likely to involve more researcher time, but also has the potential to gather information from third party (user) interviews and publications. I used a hybrid approach, filling out the descriptive template as far as possible, based on available information, and then e-mailing this draft to the system designer with a standard message inviting them to review and comment. I reviewed the feedback for appropriateness and credibility and, in some cases, followed up by e-mail or telephone to resolve remaining questions.

The questionnaire was implemented as a Microsoft Word form. It used form fields to pass data back and forth with a Microsoft Access database, which was used as the overall data repository.

Data Analysis

To generate some synthetic observations about whether available systems were meeting decision-making needs, a matrix similar to Mowrer (1997) was used to display the capabilities of each system with regards to the core decision needs criteria (Table 4). If a system has functionality which specifically addresses an indicator, it was given an "X" in the matrix. This "specific functionality" requirement was especially restrictive with regards to criterion theme 3. For example, any system might be used as part of a negotiation process, but to receive an "X" in this column the developer had to point out one or more features specifically designed to support negotiation.

"L" was used to indicate a system that can address an indicator via specific design links to another system. An "a" was used if the system does not provide any special help in addressing an issue, but it has been applied to the issue by users (many systems provide a general analytical framework, like optimization, which users can adapt to various substantive issues). Patterns in the matrix were analyzed to identify strengths and gaps in the abilities of current systems to address important forest biodiversity issues.

Table 4. Core DSS Review Criteria and Indicators

I. Methods to characterize biodiversity

1. Forest area by type
2. Forest area by age / successional stage
3. Forest area by management class
4. Fragmentation of forest types
5. Species diversity measures
6. Species viability measures
7. Species distribution measures
8. Species abundance measures

II. Major influences on forest biodiversity

1. Silviculture
2. Land use change
3. Climate change
4. Biological threats
5. Fire

III. Abilities to address the often complex political nature of forest biodiversity decisions

1. Interdisciplinary information integration
2. Decision support at multiple spatial scales
3. Facilitation of social negotiation

CHAPTER 4 – RESULTS AND DISCUSSION

Results

Out of 114 systems amassed for the initial inventory, 32 systems clearly met the initial screening criteria and were surveyed (see Table 5). Of the 32 reviewed, only six DSS appear to integrate capabilities for both forest and biodiversity modeling. Ten systems focus on wildlife and biodiversity modeling, 12 on forest modeling, and four are general purpose DSS.

Forest Biodiversity Indicators

I found a split between the forest modeling systems, which tend to focus on indicator classes 1-3 (forest structure and management), and the wildlife/biodiversity systems which focus more on classes 5-8 (species-based measures). Fragmentation (4), a forest structure indicator, is rare in the forest systems but common in the wildlife DSS. The combined forest-biodiversity systems tend to cover a fuller range of indicator classes, but only one addresses species distribution and abundance measures. This system, the Willamette Basin Futures Analysis (WBAFA; see Table 6 below for system abbreviations and references), and the LANDIS forest modeling system stood out in that they have established explicit links between forest growth and wildlife population modeling systems (PATCH and RAMAS, respectively).

Forest Biodiversity Influences

While many of the combined forest-biodiversity systems model the effects of silviculture and land use change, none of these systems nor the biodiversity systems include tools to address the influences of fire, biological threats (pest, pathogens, invasive species) or climate change on biodiversity. The forest modeling systems frequently consider silviculture, fire, and biological threats, but they generally do not include mechanisms to address the impacts of these disturbances on non-tree organisms. LANDIS appears to be the only system with some designed capacity to model climate change effects.

Forest Biodiversity Decision Processes

All forest-biodiversity systems perform some integration of biophysical, social, and economic information, most often predicting the impact of (social/economic) land use changes on biophysical attributes. Forest modeling systems also generally predict the impacts of management actions on the forest resource, and a few of the more generic DSS enable integration of socio-economic goals or constraints. The most frequent integration of information performed by the wildlife/biodiversity systems is combining land-use costs with biophysical information in designing reserve networks.

Virtually all of the DSS manage data at at least two scales, a minimum modeling unit (stand, polygon, cell) and the aggregate of such units at the level of the full analysis (forest, landscape, etc.). Because of this ubiquity, I chose to distinguish only systems which also provide disaggregation (landscape goals to stand level results) or that simultaneously try to address the needs of managers at two or more scales. Two of the combined systems clearly produce results for decision makers at different scales. MRLAM is designed to produce results relevant to individual landowners as well as for the larger region as a whole, while CLAMS provides results relevant to both watershed councils and regional policymakers. Multiscale evaluations were generally not evident in the biodiversity systems, except for the Restore model that assists with site-level allocation of restoration alternatives and watershed-level evaluation of cumulative restoration impacts. Two of the forestry systems (RELM, Woodstock) had specific design features to help bring strategic management goals (e.g. harvest levels) down to the operational level by spatially placing them according to constraints using GIS. In the generic DSS category, EMDS is a system specifically designed to nest resource evaluations over two or more spatial scales.

Only two systems stood out for their abilities to facilitate social negotiation: EZ-IMPACT for its ability to integrate individual values in group decision processes and the Willamette Basin Futures Analysis for its extensive use of stakeholder groups in setting up model assumptions and extensive visualization techniques in presenting model results.

Table 5. Comparison of Available DSS to Forest Biodiversity Decision Making Needs

Category	System Name	user defined	forest type	forest age	mgmt class	fragmentation	species diversity	species viability	species distribution	species abundance	silviculture	land use change	climate change	biological threats	fire	information integration	multiple scales	social negotiation
	Decision-making Needs ►	Biodiversity Indicators Supported									Forest Influences Supported					Complexity		
For & Bio	CLAMS		X	X	X	X	X	X			X	X				X	X	
For & Bio	Harvest		X	X	X	X					X						X	
For & Bio	LUCAS		X	X	X	X	X	X			X	X				X		
For & Bio	MRLAM		X	X	X	X		X			X					X	X	
For & Bio	NED		X	X	X		X				X					X		
For & Bio	WBAFA		X	X	X	X	X	X	X	X	X	X				X		X
Biodiversity	BMAS		X					X										
Biodiversity	CAPS		X	X	X	X	X					X						
Biodiversity	C-Plan	X																
Biodiversity	MARXAN / SPEXAN	X			X	X	X									X		
Biodiversity	PATCH					X		X	X	X								
Biodiversity	RAMAS		L	L		X	X	X	X	X								
Biodiversity	Refuge GAP					X	X		X							X		
Biodiversity	ResNet & Surrogacy						X	X										
Biodiversity	Restore											X				X	X	
Biodiversity	Sites	X			X		X	X								X		
Biodiversity	Vista	X	X	X	X	X	X	X	X		X	X		X	X	X	X	X
Forestry	FVS		X	X							X			X	X			
Forestry	Habplan	X									X						X	
Forestry	LANDIS		X	X		L	L	L	L	L	X		X	X	X			
Forestry	LANDSUM		X	X	X						X			X	X			
Forestry	LMS		X	X	X						X				X			
Forestry	RELM	X									X						X	
Forestry	RMLANDS		X	X	X	X					X			X	X			
Forestry	SIMPPLLE		X	X							X			X	X			
Forestry	Spectrum	X	X	X	X		a	a			X				X	X		
Forestry	VDDT / TELSA		X	X	X						X			X	X			
Forestry	Woodstock	X	X	X	X	a	a	a			X		a		X	X	X	X
General	DEFINITE	X														X		
General	EMDS	X														X	X	
General	EZ-IMPACT	X									a	a			a	X		X
General	MAGIS	X	X	X	X						X						X	

Key for Table 5

Biodiversity Indicators Supported

- User defined: indicators can be defined by the user
- Forest types: DSS tracks areas of forest different forest types
- Forest age classes or successional stages: tracks habitat age classes and/or successional stages
- Mgmt class: tracks habitat by different management classes (e.g. protected areas)
- Fragmentation: calculates the degree of fragmentation of habitat by type and/or successional stages
- Species diversity: calculates species diversity measures
- Species viability: calculates species viability measures
- Species distribution: calculates species distribution measures
- Species abundance: calculates species abundance measures

Forest Influences Supported

- Silviculture: the DSS handles basic human forest management activities, such as harvesting and planting.
- Land use change: conversions of land use between forest and other non-forest types
- Climate change: effects of changing climatic conditions on forests
- Biological threats: tree pests and pathogens, such as insects and fungi
- Fire: modeling of fire behavior and effects

Complexity

- Information integration: DSS evaluates interactions between different basic information types (biophysical, economic, social) - beyond the common management - biophysical interactions. For example, NED helps set value-based objectives, simulate growth & evaluate habitat, and calculate financial returns.
- Multiple scales: DSS produces coordinated results for decision makers operating at different spatial scales - Can the system produce and integrate analyses occurring simultaneously at several scales (e.g. the Restore model provides site specific restoration recommendations and a landscape-level analysis of their cumulative impacts)?
- Social negotiation: DSS facilitates social negotiation either by design (e.g EZ-IMPACT is specifically designed to integrate judgments or values from multiple individuals) or by its demonstrated effect on a social process.

Body of Table

(shaded)	Gaps Identified in DSS Capabilities	L	Links to another system with this function
X	System includes specific support for this function	a	Documented application of system to this function

Table 6. DSS Abbreviations and References

Category	*System*	*Full Name*	*Website or Reference*
For & Bio	CLAMS	Coastal Landscape Analysis and Modeling System	http://www.fsl.orst.edu/clams/
For & Bio	Harvest	Harvest	http://www.ncrs.fs.fed.us/4153/harvest/harvhome.asp
For & Bio	LUCAS	Land-Use Change and Analysis System	http://www.cs.utk.edu/~lucas/
For & Bio	MRLAM	Multi-Resource Land Allocation Model	http://www.or.blm.gov/umpqua/
For & Bio	NED	NED	http://www.fs.fed.us/ne/burlington/ned
For & Bio	WBAFA	Willamette Basin Alternative Futures Analysis	http://oregonstate.edu/Dept/pnw-erc/
Biodiversity	BMAS	Biodiversity Management Area Selection	Fischer, D. and Church, R. 2003. Clustering and compactness in reserve site selection: an extension of the Biodiversity Management Area Selection model. Forest Science 49(4): 555-565.
Biodiversity	CAPS	Conservation Assessment and Prioritization System	http://www.umass.edu/landeco/research/caps/caps.html
Biodiversity	C-Plan	C-Plan	http://www.uq.edu.au/~uqmwatts/cplan.html
Biodiversity	MARXAN / SPEXAN	MARXAN / SPEXAN	http://www.ecology.uq.edu.au/marxan.htm
Biodiversity	PATCH	Program to Assist in Tracking Critical Habitat	http://www.epa.gov/wed/pages/models/patch/patchmain.htm
Biodiversity	RAMAS	RAMAS	http://www.ramas.com
Biodiversity	Refuge GAP	Refuge GAP	http://www.sdvc.uwyo.edu/wbn/refuge/
Biodiversity	ResNet & Surrogacy	ResNet & Surrogacy	http://uts.cc.utexas.edu/~consbio/Cons/Labframeset.html
Biodiversity	Restore	Restore	http://biosys.bre.orst.edu/restore/
Biodiversity	Sites	Sites/Site Selection Module	http://www.biogeog.ucsb.edu/projects/tnc/toolbox.html
Biodiversity	Vista	NatureServe Vista	http://www.natureserve.org/Vista

Table 6. DSS Abbreviations and References (continued)

Category	*System*	*Full Name*	*Website or Reference*
Forestry	FVS	Forest Vegetation Simulator	http://www.fs.fed.us/fmsc/fvs/
Forestry	Habplan	Habplan	http://ncasi.uml.edu/projects/habplan/
Forestry	LANDIS	LANDIS	http://landscape.forest.wisc.edu/projects/landis.htm
Forestry	LANDSUM	Landscape Successional Model	http://www.landfire.gov/Products_3_Models.html
Forestry	LMS	Landscape Management System	http://lms.cfr.washington.edu/
Forestry	RELM	Regional Ecosystem and Land Management Decision Support System	http://www.fs.fed.us/institute/planning_center/plan_relm.html
Forestry	RMLANDS	Rocky Mountain Landscape Simulator	http://www.umass.edu/landeco/research/rmlands/rmlands.html
Forestry	SIMPPLLE	Simulating Patterns and Processes at Landscape Scales	http://www.fs.fed.us/rm/missoula/4151/SIMPPLLE/
Forestry	Spectrum	Spectrum	http://www.fs.fed.us/institute/planning_center/plan_spectrum.html
Forestry	TELSA	Tool for Exploratory Landscape Scenario Analyses	http://www.essa.com/downloads/telsa/
Forestry	VDDT	Vegetation Dynamic Development Tool	http://www.essa.com/downloads/vddt/
Forestry	Woodstock	Woodstock, Spatial Woodstock & Stanley	http://www.remsoft.com
General	DEFINITE	DEFINITE	http://www-old.vu.nl/ivm/research/defenite.htm
General	EMDS	Ecosystem Management Decision Support	http://www.fsl.orst.edu/emds/
General	EZ-IMPACT	EZ-IMPACT	Bonnicksen, T.M. 1996. Reaching consensus on environmental issues: the use of throwaway computer models. Politics and the Life Sciences 15(1): 23-34.
General	MAGIS	Multiple-resource Analysis and Geographic Information System	http://www.fs.fed.us/rm/econ/magis

Discussion

The review of indicator classes used by DSS revealed a split between the capabilties of the forest-focused and the biodiversity-focused systems. There appears to be potential for more formal linkages between these types of systems, as has already occurred with LANDIS and RAMAS. Forest models could provide the temporally dynamic habitat information to move wildlife systems beyond a one-shot reserve selection problem. However, in many cases, additional details of habitat structure are needed beyond those that have been traditionally supplied by forest growth and yield models (Lexer, Lexer and Hasenauer 2000).

Although forest growth and management DSS have the capacity to predict the impacts of many major forest influences, such as forest management, fire and biological threats, they do not include capabilities for extending these impacts to wildlife species. Forest DSS results often appear to be run through habitat suitability indices designed for particular planning exercises, but there appears to be little work on encapsulating these indices into DSS itself, so they could be more easily shared with others. NED, FVS and LMS are exceptions in that they contain some linkages to wildlife habitat information. NED incorporates simple habitat-species matrices to give landowners an idea of the types of species their forest might support. A few "post-processors" available for FVS deal with wildlife, including one for California Spotted Owl Wildlife Habitat Relationships and another for Multistory Elk Hiding Cover. LMS includes the ability to derive a variety of stand structure classifications often used in biodiversity analysis, such as those derived from Oliver and Larson (1996). Change in land use is addressed by the regional modeling efforts, but tools at a more localized level are likely to be needed as new housing continues to be developed in forested areas. More tools are clearly needed to help managers cope with the potentially largeimpacts of climate change over the long term.

Integration of biophysical, economic, and social information is possible in a number of the systems but is only actively supported in a few. NED and Restore both enable users to input their relative values for biophysical, economic and social goals and evaluate results accordingly. Similarly, many of the systems can be used at different scales but few provide coordinated products for decision makers at multiple scales. Previous surveys identified communication and consensus building as top needs, but a majority of tools still appear to be designed for use in the context of a single organization or set of values. EZ-IMPACT provided a methodology for integrating values, but it has not found the support needed to upgrade it for use with the latest computer operating systems. Regional assessments (WBAFA, CLAMS, LUCAS) have attempted to facilitate social negotiation to different degrees, but they tend to be one-shot applications that lack an enduring institutional basis to continue such work over the long-term.

A prime rationale for decision support systems is to faciliate a diffusion of decision support capacity, for example domain-specific knowledge (such as in forest growth simulators) or decision-aiding techniques (such as optimization). However, four of the only six systems in the survey that include both forest and biodiversity modeling capabilities are large, regional-scale assessment efforts. As such, they are more prototypes than systems that could be easily transferred to others. In the same vein, the LANDIS system, whose capabilities stood out in a few of the review categories, has been designed more as a research tool rather than a system ready for adoption by managers.

Conclusions

The management and evaluation of forest biodiversity appears to be in a pre-paradigm state, in the sense that there are no widely accepted standards. Some agreement on methods to characterize biodiversity in the U.S. is emerging through the Montreal Process Criteria and Indicators and the various forest management certification standards (SFI 2004; FSC 2006; ATFS 2006). For the most part, however, these standards lack specifics on how their elements are to be evaluated (Reynolds, Johnson and Gordon 2004). SFI's adoption of the NatureServe global rank and viability system may be a major step in the direction of standardization. The inherent geographic variability in the types and needs of forest-dependent species, as well as the human values regarding them, may mean that DSS will be most successful if they provide flexibility for local decision makers to fine tune their own analytical frameworks.

PART II: THE USE OF FOREST BIODIVERSITY DECISION SUPPORT SYSTEMS

CHAPTER 5 – LITERATURE REVIEW

> *The fault, dear Brutus, lies not in our stars [or models], but in ourselves.*
>
> (Shakespeare's Julius Cesar 1599, modified by Barber and Rodman 1990)

As discussed in the Introduction, the utility of analytical tools in addressing complex social problems, including forest planning, has been called into question (Rittel and Weber 1972; Cortner and Schweitzer 1983; Allen and Gould 1986; Healy and Ascher 1995; Shannon 1999). Many of these critics argue that how these tools are used in the social decision-making context is as important as their technical capabilities. Even a recent DSS textbook opens with a similar point:

> The study of decision support systems (DSSs, for short) is not about computers. Although they play an integral role in the DSS world, computers are just one part of the picture. The study of DSSs is really about people--about how people think and make decisions, as well as how they act on and react to those decisions." (Marakas 1999 p. 3)

Although the field of information systems research has been criticized for focusing on the means (technologies) more than the ends (results of technology use) (Galliers 1992), it contains a considerable body of research into information system use. The applicability of this research to forest and biodiversity DSS may be limited, however, for a few reasons elaborated below. These shortcomings are partially addressed by another much more diffuse set of literature on technical analysis in decision making that can be derived from studies of planning, policy analysis, and environmental assessments. Only a few studies exist that specifically review the use of DSS related to either forest or biodiversity issues. These accounts are of the use of the FORPLAN system and are summarized in the final section.

Information Systems

Why are information systems used?

Major IS and DSS textbooks have surprisingly little to say about why systems are adopted. The importance of analytical complexity has primarily been emphasized in the information systems literature, where DSS are commonly proposed as a method for dealing with such complexity (Marakas 1999). The DSS texts reviewed provide short, general lists of DSS benefits (e.g. extend decision maker's processing power and speed) and some of their case vignettes mention reasons companies embarked on DSS projects. However, they do not provide any summarized analysis of these reasons (Turban and Aronson 2001; Marakas 1999). Nor does Laudon and Laudon's (2000) text on MIS discuss any empirical analyses of system adoption, although they do provide some general reasons (Table 7), as well as discussing two normative approaches to systems needs diagnosis: enterprise analysis and critical success factors.

Table 7. Information Systems Adoption Factors

External environment
▪ globalization
▪ shift from industrial to information economy
▪ changes in the structure of organizations
Internal
▪ values that encourage any kind of innovation
▪ ambitions of various groups within the company
Goals
▪ automation
▪ rationalization
▪ business reengineering
▪ paradigm shift

Source: Summarized from Laudon and Laudon (2000 p. 84-85)

A commonly used perspective on the adoption of technologies, such as DSS, relies on theories of innovation diffusion. Rogers (2003) text on innovation diffusion theory states that adoption rates depend on five attributes of innovations: relative advantage, compatibility, complexity, triability and observability. Relative advantage is the degree to which an innovation surpasses the idea it supersedes; compatibility is the degree to which the innovation is compatible with the values, needs and norms of the population; complexity is the extent to which the innovation is perceived as difficult to understand or use; triability measures the ease with which people can try out the innovation, while observability is the degree to which others can observe the innovation.

Fichman (1992) reviewed the application of innovation diffusion theory in information technology research and found little support for hypotheses based on classical diffusion variables. He makes the point that traditional innovation diffusion theory has been built largely upon studying decisions made at the individual level about technologies that are relatively simple to adopt. In contrast, many information technologies are complex and involve decisions at the organizational level. Using a framework based on these differences (see Table 8), he recommends additional independent variables for studying complex, organizational technologies. Additionally, he concludes that a replicated case study approach may be more appropriate than traditional survey methods for achieving the depth necessary to further our understanding of the adoption of such technologies.

Table 8. Diffusion Factors for Information Systems

Class of Technology	**Type 1** (low knowledge burden, low user interdependencies)	**1** ▪ Classical diffusion variables: ▪ Perceived Innovation Characteristics ▪ Adopter Characteristics ▪ Information Sources and Communication Channels ▪ Change Agents and Opinion Leaders ▪ Managerial influences	**2** ▪ Classical diffusion variables ▪ Organizational characteristics ▪ Organizational decision processes ▪ Stage of implementation ▪ Competitive effects (adopter industry) ▪ Supply side factors ▪ Economic factors (price) ▪ IT group characteristics
	Type 2 (high knowledge burden or high user interdependencies)	**3** ▪ Classical diffusion variables ▪ Managerial influences ▪ Critical mass ▪ Absorptive capacity ▪ Implementation characteristics ▪ Institutions for lowering knowledge barriers	**4** ▪ Cell 2 and 3 variables
		Individual	**Organization**
	Locus of Adoption		

Source: Information technology diffusion: a review of empirical research, R.G. Fichman. ©1992 by R.G. Fichman. Reproduced with permission.

Rai and Bajwa (1997) conducted a written survey which affirmed a number of such organizational and contextual factors. Information systems department size, level of technical support available, top management support, and business environment uncertainty were all found to be significant determinants of DSS use (organization size was not however).

What determines success?

Marakas (1999) provides a broad overview of frameworks which have been developed to measure DSS success. He groups these frameworks into four categories. First, some focus on general *software quality*: Is it reliable, efficient, user friendly, etc.? A second approach focuses on more *operational specifications*: Does it meet the system requirements specified in the project? Third, actual *use and user attitudes* can be measured. The fourth category is *organizational measures of success*: To what extent does it meet organizational needs and expectations (possibly measured in a cost/benefit framework)?

Marakas' (1999) categories appear quite similar to those used by one of the most popular success models in the broader field of information systems (DeLone and McLean 1992, 2003). DeLone's construct consists of three levels. The first level includes the following three measures:

- system quality (analogous to Marakas' "software quality"),
- information quality (Marakas' "operational specs"), and
- service quality (i.e. availability of support mechanisms).

These factors influence the following three measures on the second level (similar to Marakas' use and user attitudes):

- intention to use,
- actual use, and
- user satisfaction.

These second level factors are seen to influence a third level of success measures, which consist of "net benefits" such as "individual and organizational impacts" (Marakas' "organizational measures"). DeLone and McLean (2003) state that "net benefits" are the most important success measures, but that they are frequently difficult to gauge, subject to different viewpoints, and cannot be understood without analyzing system and information quality variables as well.

In contrast, most of the IS literature does not focus on defining success, but rather starts with a given definition of success and investigates factors which contribute to this success. This literature is voluminous and presents a wide spectrum of success factors. Turban and Aronson's (2001) DSS textbook *summarizes* the literature into 14 *categories* of factors. A slightly more recent review article by Larsen (2003) found 83 focal factors, which he grouped into 12 categories. Udo and Guimaraes (1994) provide one specific example. They summarized past research into eight benefit measures and four categories of explanatory factors (Table 9). In a survey of 200 businesses they found all these factors, save user age to be significantly correlated with at least some of their eight measures of success.

Table 9. Expected DSS Benefits and Factors

Success Measures	Success Factors
▪ decision quality ▪ competitive edge ▪ improved communication ▪ cost reduction ▪ increased productivity ▪ time savings ▪ overall satisfaction ▪ overall cost-effectiveness ▪ total benefits	▪ industry: strategic position, degree of competition ▪ organization: size, task structuredness, frequency of use, quality of training, organization support, vendor support ▪ DSS: timeliness of output, completeness of output, accuracy, relevance, flexibility, range of alternatives, user-friendliness ▪ DSS user: age, experience w/DSS, experience on job, education level, attitude, expectations

Source: Summarized from Udo and Guimaraes (1994)

Interpretive IS Studies

The "positivist" nature of much of IS research has been criticized (Orlikowski and Baroudi 1991; Galliers 1992, preface). Success measures and factors are usually limited to those pre-specified by the researcher, and interactions between different factors are not considered, greatly reducing the real complexity of situations. Then the simplified relationships found are assumed to be fixed across different organizations and times.

An "interpretive" branch of IS research has been developed in response to these perceived shortcomings. "Interpretivism" (sometimes used synonymously with "constructivism" or "naturalism") is a branch of social theory and an epistemology which postulates that our knowledge of reality is socially constructed (Robson 2002). No objective understanding of reality is possible, so the goal of research is to understand the multiple "realities" generated by individuals and groups. Instead of looking for general laws of cause and effect, interpretive studies look for deeper understanding of individual cases, which can then provide insights into others.

Checkland's work on "soft systems methodology" (Checkland 1981; Checkland and Holwell 1998) was pioneering in this field. He promoted moving from technology-focused to people-focused design methods. Rather than assuming goals could be precisely defined and fixed over time, he recognized their problematic and shifting nature within organizations. He also challenged the overall paradigm that human behavior is goal-seeking and instead argued it is more oriented towards maintaining relationships.

In three case studies, Walsham (1993) developed an interpretive approach which focused on the context and processes of IS implementation using a social theory called "structuration." Structuration theory (Giddens 1984) concentrates attention on how IS influence everyday behavior that in turn reinforces or changes more enduring social structures of meaning, power, and legitimacy. This type of process approach focused more on describing how certain mechanisms (both social and technological) influenced outcomes, rather than the more traditional static correlations between factors and results.

Fincham (2002) provided a parsimonious summary of how different research perspectives (e.g. paradigms) define the connections between study objects (relating to organizational behavior), methods, and definitions of success (Table 10). He demonstrated how a narrative/interpretive approach can capture success or failure as identified by the people involved, rather than by an outside researcher.

Table 10. Research perspectives and success definitions

Perspective	*Form of organizational behavior and action*	*Methodological focus*	*Success and failure seen as*
Rationalist	Organizational goals; managerial and organizational structures	Simple cause and effect	Objective and polarized states
Socio-technical	Organizational and socio-political processes	Socio-technical interaction	Outcomes of organizational processes
Narrative	Organizational and socio-political processes; symbolic action; themes, plots, stories	Interpretation and sense-making; rhetoric and persuasion	social constructs; paradigms

Source: Narratives of success and failure in systems development, R. Fincham. ©2002 Blackwell Publishing. Reprinted by permission.

Limitations of IS Theories

There are a number of reasons why IS methodologies may not be a good fit for studying forest biodiversity DSS. First, IS research has typically studied situations in which the users have direct interaction with the technology, such as a new word processor or e-mail program. In contrast, my experience with FBDSS leads me to believe that these systems are normally operated by specialists, who then communicate the results to a wider audience of information users (sometimes referred to as "mediated" use). Second, much of the previous research on IS success has used measures of success based on the objectives of a single organization. This unitary view is problematic in the study of forest biodiversity decisions, which frequently involve multiple parties. This multi-party situation emphasizes a third difference, IS studies often assume instrumental, non-political use of the systems. As will be discussed later in this review, even the few FBDSS studies available point clearly to quite politicized uses.

Technical Analysis in Decision-making

Looking more broadly for relevant lines of research, decision support systems can be seen as a form of technical analysis oriented towards decision making. The use of technical analysis in decision making has been studied on a variety of levels and associated disciplines, including individual (psychology), organizational (organizational studies), and inter-organizational (primarily policy sciences). The fact that biodiversity concerns often cross organizational boundaries, along with its regulation as a public good, has led me to emphasize theories of public planning and policy analysis.

Instrumental versus Interpretive

Perhaps the most fundamental issue concerning technical analysis for decision making, which I broached in the Introduction, is whether it is viewed as an instrumental or interpretive process. In fact, this has been considered a central question of decision making itself (March 1994). In the instrumental view, analysis plays the primary role, while under the interpretive paradigm communication is paramount.

A number of studies of seemingly technical processes have revealed the importance of interpretive aspects. In their account of water resource management, Rayner et al. (2001) found that

> "the decision processes…were more reminiscent of negotiating than instrumental decision making as described by classical decision analysis. Interviewees described a normative consensus building process, not a single choice, or even an orderly sequence of choices, made by isolated decision-makers." (p. 48)

Cash and Clark (2001) studied a number of environmental assessment processes and view the assessments as

> "…distributed information and decision support systems embedded in a network of institutions…In this view, assessment is still seen as a communication process. While formal outputs such as reports, models, or forecasts can still play an important role in such systems, the continuous and iterated communication of policy relevant technical information across different levels of the system is emphasized." (p. 6)

Feldman (1989) found that the direct transfer of technical analysis from government analysts to decision makers was not typical. Instead, analysts' reports were typically "watered down" through extensive "sign-off" processes between different groups. Decision makers favored this "interpreted" information, even though it rarely provided clear guidance. Often the end result of analysis was general information distribution, rather than a direct effect on decision making.

Susskind et al.'s (2001) categorization of policy analysis methods recognizes three aspects, which also follow an analytical/communicative split: "analytical," "rhetorical" (with a focus on mass communication), and "procedural" (focus on small group interaction). Kraemer et al. (1987), studying the use of economic models in federal policymaking, identified two "ideologies" of model use: managerial (instrumental) and "political" (interpretive).

Rein and Schön (1993) argue that policy analysis and planning continue to be dominated by the ideas of objectivity and instrumental rationality, especially in their teaching, but that these are poor foundations for the task. Rather, they make the case that 'argumentation' should be their central concept. In their compendium on this topic, Fischer and Forester (1993) lay out how understanding analysis and planning as an argumentative process emphasizes the importance of six aspects:

1. Problem framing
2. Rhetoric and performance as well as content of analysis
3. The complex exercise of agenda setting power
4. Organizational networking, boundary spanning, relationship building, and ritualized bargaining that analysts must do
5. Problems can be represented in many languages, discourses, and frames;
6. Its potentially pedagogic functions.

The following sections do not mirror this list, rather they have been derived more holistically from the literature. Nevertheless, many of the themes are similar.

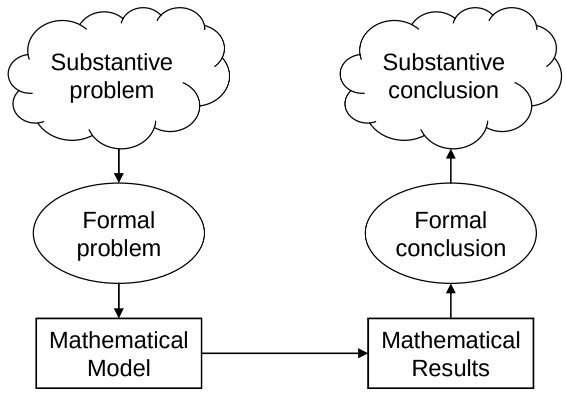
<u>Problem Framing</u>

From the perspective of technical analysis, problem framing occurs at two levels: the first is the frames brought by the various participants in an issue; the second level concerns framing the technical analysis itself.

Rein and Schön (1993 p. 146) describe a frame as "…a perspective from which an amorphous, ill-defined, problematic situation can be made sense of and acted upon." Because frames integrate facts, values, theories and interests, it is impossible to separate facts from values. They distinguish between "policy disagreements," which arise in a common frame and can be settled by established rules, from "policy controversies," which cannot be resolved by facts or any type of evidence. The only solution, they argue, is via "frame-critical policy analysis," which seeks to uncover the frames and their sources (histories, rules, institutional contexts, interests). Such discourse holds the possibility for translating, restructuring, integrating, converting, or choosing between different frames.

Framing has also been described as it relates directly to technical analysis. Strauch (1975) notes how the subjects of policy analyses are typically "squishy problems," in other words lacking well-defined formulations, but that a formal definition must be arrived at before quantitative methods can be applied. Figure 3 depicts this process of problem framing and interpretation of results. He argues that attention tends to focus on the technical adequacy of the bottom model to results link, when in fact the translation links are more important. This translation can take two forms. The model can be used as a "surrogate" for the problem: that is, the model captures enough of the problem that its results are directly applicable. Scientific and technical training tend to reinforce this view. Squishy problems are not so easily captured, however, so he argues a more appropriate approach is recognizing models as a "perspective" on the problem.

Figure 1. Problem Formalization and Solution Translation



Source: Squishy problems and quantitative methods, R. Strauch. ©1975 Springer Publishing. Reprinted with kind permission of Springer Science and Business Media.

Ordinary versus Constitutive Decision Making

Changes in problem framing can also change not only the topic of discussion but also the decision-making process itself: who participates, their relative power, and what types of evidence are used. This is a central theme in Healy and Ascher's (1995) work, one which they reference back to Lasswell's (1971) distinction between ordinary and "constitutive" policymaking. They discuss how the analytical mandates changed the nature of how decisions were to be made and by implication, who should be involved. While some participants were edged out, many industry and environmental groups developed their own counter-expertise.

Fischer (2000) found this demand for expertise to apply broadly to environmental concerns. "Whereas social problems typically draw much of their rhetorical power from moral discourse (e.g. Should women get the same pay as men? Should the homeless sleep in the park?), environmental problems turn much more on arguments about 'facts'". In consequence, environmental policy making has given rise to a "new model of regulation…[where]…scientific and technological determinations have become the primary standards by which substantive regulatory decisions affecting environmental quality are reached." (p. 91)

Fischer (2000) dwells on another related consideration, which is the tension between the use of expertise and broad participation. He traces this theme back to John Dewey (1927), who recognized the difficulty of maintaining public participation in policymaking given social differentiation, advancement of technology, and knowledge specialization. Fischer discussed the limitations of policymaking as now dominated by technocratic "policy communities," and advocates for more public involvement to enable the integration of scientific with local knowledge.

Power, Conflict, and Cooperation

As described by Allen and Gould (1986) and Healy and Ascher (1995), calls for more "science" or "analysis" often assume that these strategies will help resolve conflict. Similar to these authors, but more broadly stated, Fischer (2000) concludes that "[s]cience has very often only intensified the very politics that those who turned to it sought to circumvent" (p. 92). Increased conflict may be either an unintentional byproduct of analysis or an intentional outcome of the actors. In the unintentional category, modeling strives for explicitness while policy consensus may more often be aided by ambiguity (Greenberger et al. 1976).

Power-seeking Strategies

King and Kraemer (1993) found conflict to be a key factor in why economic DSS were used much more in the USA than in Germany. Political conflict has been much more institutionalized in the US than in Germany, and "[p]ut simply, the models were used because they were effective weapons in ideological, partisan, and bureaucratic warfare over fundamental issues of public policy" (p. 354).

Power-seeking strategies may also be more subtle than outright partisan warfare. Feldman and March (1981) studied why organizations seem to gather more information than they can actually use in decision making and concluded that such information gathering is often displayed as a "symbol" of sound decision making (even if it is not actually used) and a "signal" to others of the organization's turf.

Power-sharing Strategies

Other scholars have seen the potential for technical analysis to be integrated with social deliberation in order to mediate disputes. This approach has been particularly prevalent in the literature on environmental assessment. This concept of science-policy integration traces back to a body of scholarship on "boundary work," which has primarily focused on studies of the ways in which science is demarcated from other types of work and knowledge (Gieryn 1983; Gieryn 1995). Attention by some scholars to how these boundaries are established and maintained led to interest by others in how they are crossed. Jasanoff's (1990) investigation of how scientific advisory panels constituted by federal regulatory agencies helped bridge the science-policy divide is perhaps the best-known work in this area. She concluded that "proceedings founded on the separatist principle frequently generate more conflict than those which seek, however imperfectly, to integrate scientific and political decision making." Along the same lines, a 1996 report on risk assessment methods by the National Research Council stated:

> The analytic-deliberative process should be mutual and recursive. Analysis and deliberation are complementary and must be integrated throughout the process leading to risk characterization: deliberation frames analysis, analysis informs deliberation, and the process benefits from feedback between the two. (NRC 1996 p. 163)

More recently, a program of research on "assessing assessments" has related their success to the ability of the assessments (and the models used in them) to serve as a "boundary object" that contributes to bringing different groups together in a planning process (Cash et al. 2003).

<u>Success</u>

As noted above, technical analysis can have a wide variety of impacts on different actors, making an assessment of success and contributing factors problematic. However, a few studies have attempted it, often using a combination of instrumental and interpretive criteria.

After coining the term “wicked” problems, Rittel (1984) later argued that strategies for solving wicked problems must be based on three elements of communication:

1. Participation of as many and as different people (i.e. experts and citizens) as possible has to be assured. They all should be guaranteed equal rights in the participation process.
2. Since there is no objectivity in assessments and judgments, it is important to be able and willing to explain one’s own assessments to others.
3. Argumentation has to be the basic mechanism of the process.

In a book titled “The Electronic Oracle” Meadows and Robinson (1985) analyzed nine case studies of social policy models. They noted that there are inevitably more goals than just those that are officially stated, and they used four types in their model evaluation framework: stated goals, personal or institutional goals, wild hopes and fears, and life goals. They recognized that uncovering these unstated goals (a highly interpretive task) ranges from difficult to impossible, but that such goals are no less important because of it. In addition to looking at model-specific goals, they hypothesized more generally that models could, given the right implementation, increase decision rigor, comprehensiveness, logic, accessibility, and testability. They failed to find any universal static factors driving success, such as level of documentation, institutional home, model complexity, modeling technique, budget, type of client, or timing. Rather, they provided a synthetic list of 22 procedural factors related to model use success (see Appendix A).

Kraemer et al. (1987) studied the roles of models in federal policymaking through case studies of two economic policy modeling environments, each involving multiple federal agencies. They defined success as model use for any of three purposes: policy use, political use, and institutionalization of model use. They attempted a comprehensive review of social and technical success factors, divided into four categories: environmental conditions, organizational attributes, technology features, and transfer policies.

Rouwette et al. (2002) reviewed 107 documented applications of system dynamics models. Irregular reporting among the studies limited their conclusions and led them to propose a more standardized framework to guide future research. They formulated success measures at four levels (Table 11) and suggested a large number of specific potential success factors. Some general categories for these factors included initial expectations, who participated when, modeling procedures used, and meeting characteristics

Table 11. Success Measures at Four Levels

Individual Level	Group	Organization	Method
▪ positive/negative ▪ insight ▪ commitment ▪ behavior	▪ communication ▪ consensus ▪ shared language ▪	▪ system changes ▪ positive results	▪ further use ▪ efficiency vs alternatives

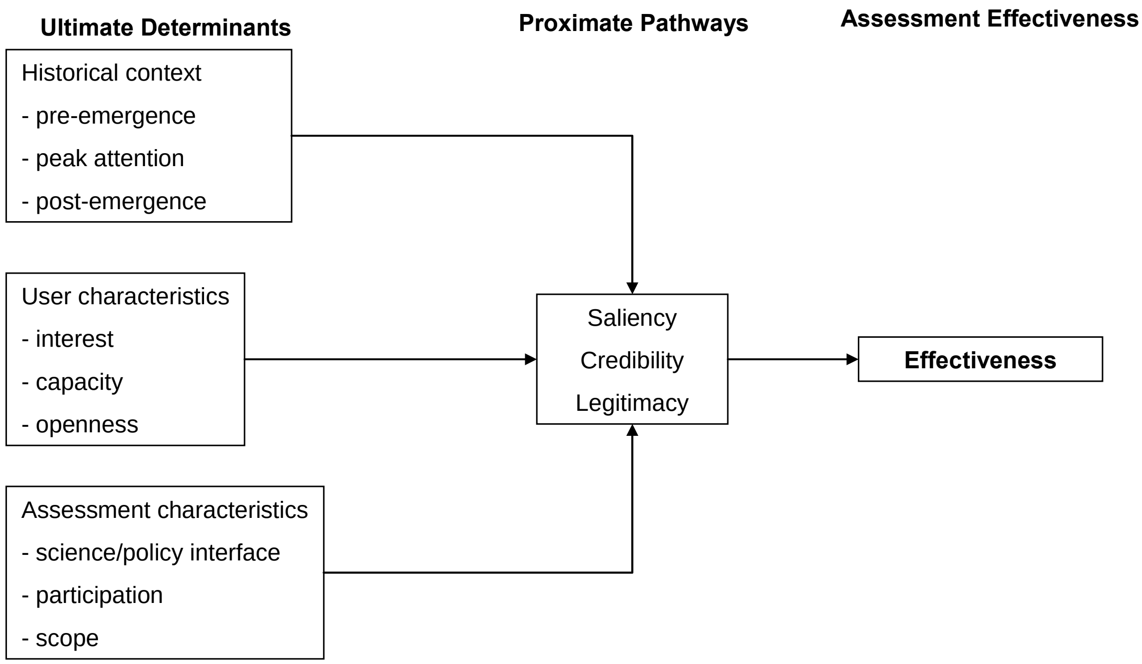
Source: Group model building effectiveness: a review of assessment studies, E.A.J.A. Rouwette et al. ©2002 John Wiley & Sons Limited. Reproduced with permission.

As discussed above, Cash & Clark's (2001) work on the effectiveness of environmental assessments emphasizes the importance of communicative processes. They did not propose one specific way to measure success, but rather suggested looking for effects on a variety of factors:

- the strategies and behavior of key actors
- the pool of management options
- issue framing and agenda setting
- identification of needed knowledge
- the building of scientific communities, the creation and maintenance of issue networks, and professional advancement.
- the natural resources being managed.

They proposed an abstracted success model which would apply widely. Their three antecedents of success are: scientific credibility, saliency to decision makers, and legitimacy to all stakeholders (Figure 2). Based on a number of case studies of environmental assessments, Cash et al. (2003) recommend core strategies of "communication", "translation", and "mediation" (see Table 12).

Figure 2. Assessment Effectiveness Model



Source: science to policy: Assessing the assessment process, D. Cash and W. Clark. ©2001 D. Cash. Reprinted with permission.

Table 12. Keys to Assessment Success

Communication

- two-way
- frequent and continuous
- stakeholders see themselves as included in dialogs

Translation

- problem deeper than disagreements about the facts, goes to failures to understand the other side's knowledge claims or criteria of credibility

Mediation

- increasing transparency
- bringing all perspectives to the table
- providing rules of conduct
- establishing criteria for decision making

Source: Summarized from Cash et al. (2003)

Considering the frequently interdisciplinary nature of forest biodiversity management issues, one more applicable list of success factors was supplied by Nicolson et al. (2002). They provide ten "heuristics" for interdisciplinary modeling, derived from their own experiences, which are listed in Appendix A.

Social Context

With similar objectives to the procedural "success factors" literature, a number of authors have proposed heuristics for thinking about context: What kinds of decision making mechanisms are best suited to different types of situations? While this search for "covering laws" may be positivistic, ideas about the influences of different social contexts are also quite important from an interpretivist viewpoint.

Thompson and Tuden (1959) recommend different decision-making strategies based on levels of agreement on two dimensions of decision context, "agreement about causation" and "agreement about outcomes" (see Figure 3). They concluded the total disagreement box, required inspirational leadership. Lee (1993) built on this work but is skeptical that such leadership is possible in today's climate, and suggests that problems must be moved out of this box by either planning or settling. Chess et al. (1998) and Shannon (2003) present two similar matrices, except more focused on the type of participation needed. Chess et al. (1998) used "level of knowledge" and "level of value agreement," and Shannon (2003) bases her recommendations on the levels of organization of the actors versus the problems and interests. They appear to agree that when agreement, knowledge, and organization are low, a type of "integrated deliberation" or "communicative action" is needed. Such participation integrates scientists and stakeholders, and it recognizes that further work on defining the problems and interests is needed before proceeding towards a solution. Salwasser (2004) uses a model based on the same two dimensions but comes to a different interpretation about best strategies: no conflict situations are simple problems and do not require analysis, conflict only over solutions (means) are complex problems amenable to decision analysis, and any conflict over problem definition is wicked, requiring a coping strategy (authoritative, competitive, or collaborative) in addition to analysis.

Figure 3. Preferred Decision Structures

	1. Agreement on Outcomes		
	2. Agreement on Values		
	3. Definition of Problems		
1. Agreement about Causation / 2. State of Knowledge / 3. Organization of the Actors	High	Low	
High	Bureaucratic Computation	Representative Bargaining	1
	Oversight Deliberation	Stakeholder Deliberation	2
	Representative Structure	Collaborative Structure	3
Low	Collegial Judgment	Inspirational Leadership	1
	Scientist Deliberation	Integrated Deliberation	2
	Collaborative Structure	Communicative Action	3

Key: Numbers 1-3 refer to sources below.

Source: Adapted from 1. Thompson and Tuden (1959), 2. Chess et al. (1998), 3. Shannon (2003)

Rouwette et al. (2002) used another framework for gauging analytical and social complexity, which was defined by the Bradford series of decision studies (Hickson et al. 1986 - Hickson's categories were actually "complexity of problems" and "politicality of interests").

Complexity of Problems

- rarity or uniqueness of the situation
- radicality, seriousness, diffusion, and endurance of consequences
- precursiveness (to what extent does a decision set parameters for subsequent decisions)
- number and diversity of interests involved
- openness to alternatives (has a decision already been made)

Politicality of Interests

- pressure of influence (how much influence was exerted)
- intervention (how much external influence was exerted)
- imbalance (to what extent was the pressure uneven between units)
- contention of objectives

Forest and Biodiversity-related DSS Use

Only one decision support system applied to forest or biodiversity analysis seems to have risen to a level of prominence that stimulated public reflection on social aspects of its use. This system was the FORPLAN model, which the US Forest Service required for use in national forest planning between 1979 and 1996. The literature comprises a number of journal articles as well as the proceedings from two symposia (Hoekstra et al. 1987, Bailey 1986). The system's principle author summarized the reasons that FORPLAN was adopted as follows (Johnson 1987 p. 45):

1. It was available at the right time and deals with the two major themes: scheduling of timber with constraints and pursuit of cost-effectiveness
2. It helped break the hold of professional omnipotence on national forest management planning
3. It helped shield the Forest Service from attacks by its critics

Critiques of the system's use likewise reflected a range of instrumental to interpretive rationales. Authors brought up many of the concepts discussed above under information systems and technical analysis in policy.

On the instrumental side, McQuillan (1989) noted a number functional limitations (i.e. system quality). The linear programming methodology used in FORPLAN makes a number of mathematical assumptions about resource value inputs which are not necessarily accurate (e.g. proportionality, additivity, divisibility, and certainty). In addition, computer processing power restricted planners' ability to represent their forest with a sufficient degree of resolution and the system could not adequately handle spatial relationships. As a linear programming system, FORPLAN was most commonly used to find an optimum (maximized) to a set of goals. In order to do this, the goals (whether forest products or wildlife) must be represented in a common metric, in this case an economic measure of "net present value". Both Cortner and Schweitzer (1983) and McQuillan (1989) note the technical difficulties in translating all concerns into such a common, quantitative format.

A lack of technical capacity was also seen as a major problem. Few national forests had specialists adept enough at linear programming techniques to comfortably handle the construction of FORPLAN models. Documentation of and training for the system were inadequate, especially initially (support quality). Even after training was provided, the complexity of the modeling process and planning time constraints often meant that it was only applied mechanically, without any real understanding or questioning of the results (information quality) (Johnson 1987). Nor was it clear to planners what the overall role of FORPLAN in forest planning was supposed to be (Kent et al. 1991).

McQuillan (1989) argues that in fact the Forest Service framed the whole problem incorrectly. He states that the National Forest Management Act (1976) was written primarily to help restore public trust in the Forest Service planning, and such trust could only come from a transparent, comprehensible and accessible process. Instead the Forest Service interpreted the Act as mandate to use their expertise and economic techniques to maximize a technically-derived measure of net public benefits, and they adopted an inaccessible "black box" approach to doing so.

In the application of FORPLAN, Barber and Rodman (1990) saw an intentional power-seeking strategy. They argued that most of FORPLAN's short-comings were not technical, but rather abuse of the tool to meet unrealistic management expectations, such as:

- the model would confirm that Forest Service policies were "right";
- specialists, planners and analysts:
  knew what needed to be done,
  had the data to analyze the problem,
  would provide unbiased analysis;
- forest plans developed using FORPLAN could be implemented.

So was FORPLAN successful? It received many critiques related to system, information, and support quality. Yet at the same time, it incorporated more functionality, especially in regards to multiple resource evaluation, than any of its predecessors. By simple measures of usage, it is certainly one of the most successful forest-related DSS. In terms of user satisfaction, some users at the conferences expressed their satisfaction with the tool, while others did not. One study on the planning process reported many negative mentions of the tool (Bradley 1986). What about "net impacts"? In summarizing one of the FORPLAN symposia, Sedjo (1987) saw two major goals expressed: reducing conflict and improving decision making. He saw some support for the conclusion that FORPLAN had helped reduce conflict or at least make it more focused. Evidence for improving decision making was more negative. The tool had taxed the capacity of forest planners and come to dominate the planning process, to the exclusion of other valid techniques and information.

Summary

Research in the fields of forest management, environmental assessment, policy analysis, and information systems all are experiencing debate as to the importance of instrumental versus interpretive views and analytical versus communicative decision-making strategies. The NRC (1996) has concluded that successful risk assessment depends on effectively combining both analytical and social strategies. Information systems research has developed theory about analytical aspects and to a lesser extent about social processes, but it lacks experience with inter-organizational processes. Research in the fields of policy analysis and planning provides such a multi-party perspective. There have been a small number of studies on the use of information systems and models in the policy process, including some reflections on forest planning, but the research and its results have been eclectic. A recent, concerted program of research into environmental assessments has provided a more concrete yet general theoretical framework for the effectiveness of technical analysis in decision making. Some common threads are apparent across a number of these studies, including participation, communication, translation, and mediation.

CHAPTER 6 -- METHODS

Part II of this dissertation addresses the second half of the research question posed in the Introduction: "How can decision makers use DSS effectively, given the wide range of technical needs and social contexts associated with forest decisions?"

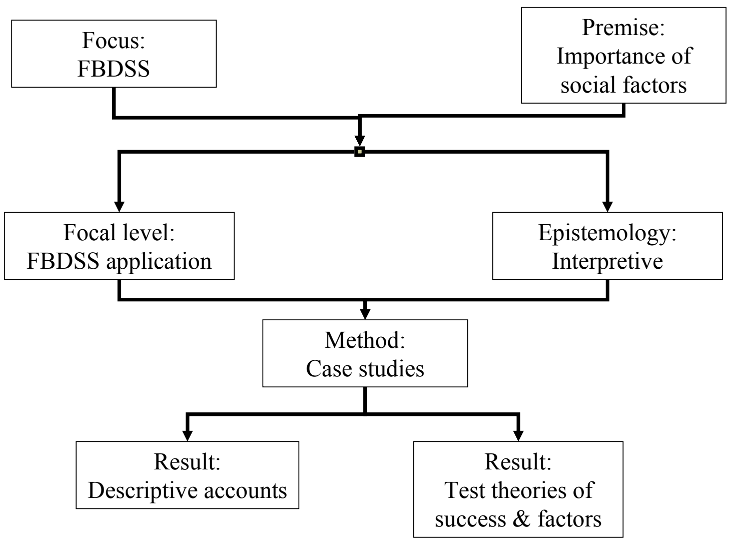
Research Approach

Past studies indicate that the successful use of technical tools, such as FBDSS, depends on social as well as technical factors. Given the social focus, the logical unit of analysis is the application of a DSS in a particular social situation, in contrast to the Phase I focus on the DSS themselves, independent of context. The focus on "cases" in which a particular system is applied leads naturally to a case study research strategy. This research also fits the other tenets for choosing a case study approach: it asks "how" and "why" questions about contemporary phenomena over which the researcher has little control (Yin 2003). Many of the studies on the use of computer models in decision making described in the previous chapter have used a case study approach (Greenberger et al. 1976; Kraemer et al. 1987; Meadows and Robinson 1985; Walsham 1993; Costanza et al. 2001; Van Den Belt 2004).

Previous research and theory development has described numerous reasons for DSS use, as well as success factors and measures. However, the complexity of real-world decision making and the subjective nature of "success" make assuming or limiting the study to fixed concepts problematic. Instead of a fixed survey based on such pre-defined factors, I adopted a more flexible, interpretive approach, which attempts to uncover the participants' understandings of events and results through interviews.

The expected results from these case studies are a set of descriptive accounts of why and how FBDSS are used, as well as a comparison of selected elements against those emphasized in existing theories. Figure 4 presents an outline of the general research approach.

Figure 4. Research Approach



Theoretical Framework

Theories discussed in the previous chapter were used to construct a framework for organizing the data gathering and analysis.

The first element of the framework is to allow participants in the case to express ideas of success and contributing factors freely, without any constraints or prompting based on past research. Success is in the eye of the beholder. In the information systems field, Fincham (2002) argued that criteria for the assessment of success are socially constructed in each situation, rather than a fixed formula, and therefore understanding success is best done through the use of participant narratives.

While this research assumes that each situation is unique and that measures of success are socially constructed, this does not preclude that patterns that can be seen across situations. Previous research has suggested a number of success factors based on attributes of the tools, users, processes, and contexts. The second element of the theoretical framework for this study compares the case study evidence collected against a few of these existing theories.

From the tools perspective, DeLone and McLean’s (2003) theory of information systems success appears to be one of the most widely used. Although all of its elements are portrayed as success *measures*, some lead to others, so in this way can be considered success *factors*. This study focuses on their three most primary measures, which are also those most concerned with the tool and an analytic/instrumental view: system quality, information quality, and service quality. Because DeLone and McLean were discussing measures and not factors, their framework does not include the fundamental factor of "user capacity," which is typical to most information systems usage studies. Preliminary information on the FBDSS milieu suggests that much DSS use is "mediated" through specialist operators, rather than direct use by decision makers, so I included the concept of "modeling capacity" under the Service Quality category. Table 13 summarizes more specific indicators comprising these factors.

Table 13. Summary of Analytical/Instrumental Factors

System quality
Ease of use, functionality, reliability, flexibility, data quality, portability, integration
Information Quality
Information product accuracy, meaningfulness, timeliness, completeness, relevance, consistency
Service Quality
Reliability, responsiveness, assurance, empathy, modeling capacity

Source: Compiled from DeLone and McLean (2003)

Theories regarding social and interpretive process factors were far less unified, but some common elements appeared across a diverse set of literature: participation, communication, translation, and negotiation (Rittel 1984; Cash et al 2003; Rouwette et al. 2002). These factors are used as the basis of the social/interpretive evaluation framework for this study. Table 14 summarizes the recommendations related to these factors from the literature reviewed.

Table 14. Summary of Social/Interpretive Factors

Participation

Important aspects of participation include identifying and including all stakeholders and having numerous and varied opportunities for input through the decision-making process. Providing opportunities early in the problem framing stage is important, rather than only after specific alternatives have been analyzed.

Communication

Communicating with stakeholders throughout the process in an iterative, two-way manner is recommended.

Translation

Two areas where translation is commonly needed are 1) between people with different levels and types of knowledge (e.g. scientists, policymakers, and the public), and 2) between different interest groups and people with different worldviews.

Mediation

Successful mediation has been linked to some of the concepts already discussed, such as participation of the affected parties and understanding (translation) of the process and terms. Other aspects of mediation include providing rules of conduct and establishing criteria for decision making.

The third piece of the theoretical framework addresses the importance of the interaction between analytical and deliberative elements. NRC (1996) recommended that this interaction be “mutual and recursive,” in other words, analysis should inform deliberation and vice-versa, and there should be some iteration in the process to allow multiple opportunities for refining this interaction.

Fourth, in terms of context, a number of authors have proposed “contingency” theories, in which appropriate decision strategies vary according to the attributes of the situation (Thompson and Tuden 1959; Lee 1999; Rouwette et al. 2002; Salwasser

2004; Chess et al. 1998, Shannon 2003). A simple, common theme can be seen in these theories that is relevant to the current study: *as problems become more socially complex, social/interpretive factors become more important.*

A second theme also came out strongly from the modeling literature: *as problems become more socially complex, analytical strategies should become simpler* (Allen & Gould 1986; Sterman 1991; Nicolson et al. 2002).

Rouwette et al. (2002) had already defined measures of social and analytical complexity. However, in testing these measures the social measures were found to be too focused on clear-cut decisions (which, somewhat counter intuitively, do not always exist in the application of a DSS) and the analytical measures not representative of information systems aspects. Consequently, a simpler description of social complexity was used, based only on the diversity of, and contention between, involved interests (similar to other "contingency" theories). Analytical complexity was judged on a relative scale using a qualitative combination of factors, such as the number and level of biodiversity indicators used, the number of forest influences considered, and the extent and detail of analyses in time and space.

Table 15. Summary of Theoretical Framework

1. Document success measures and factors as expressed by decision participants
2. Compare to success factors from the literature
   a. Analytical: system quality, information quality, service quality
   b. Social: participation, communication, translation, mediation
3. Look for a "mutual and recursive" relationship between analysis and social deliberation
4. Test hypothesized effects of social and analytical complexity:
   a. As problems become more socially complex, social/interpretive factors become more important
   b. As problems become more socially complex, analytical strategies should become simpler

Sampling Strategy

<u>Case Definition</u>

In Part II of this study, the research focus is on a type of event: the use of a decision support system in a forest biodiversity decision-making process. The definitions for the terms "biodiversity" and "decision support system" remain the same as in Part I. As with the other two terms, definitions of "decision" also vary considerably. Mintzberg et al. (1976) describe a "decision" as a "specific commitment to action (usually a commitment of resources)" and a "decision process" as "a set of actions and dynamic factors that begins with the identification of a stimulus for action and ends with the specific commitment to action." As noted in the review of technical analysis in decision making, such analyses are often not tied to a specific decision. Since the focus of this study is more on the use of tools in decision-making processes than on the decisions themselves, a more open-ended definition akin to what is sometimes referred to as "problem solving" is used (March 1994).

Case Identification and Selection

A number of potential cases were identified as part of the Phase I research survey of DSS designers and other key informants. These cases were then filtered and organized. First, only cases occurring in the United States were kept, both to ensure a somewhat similar policy environment and to limit the scope of the task. Second, only cases active in the past five years were considered because computer technologies change rapidly and interviewees' recollection of events is likely to fade with time. Third, the remaining cases were sorted into categories by the type of implementing organization. Organizations from a variety of sectors and levels make decisions affecting biodiversity, including federal, state and local governments, private industry, and individual landowners. In addition, responsibilities at these levels are generally split between landowners and regulators.

A short list of applications to investigate further was finalized by selecting one or two cases for each of the organizational categories based on accessibility of information (documentation and contacts) and geographic diversity. This short list is presented in Table 16. Note that for a few categories, no suitable cases were found (indicated in parentheses).

Table 16. List of Potential Case Studies

Case #	Decision-making Sector*	Case Name	Type of Decision
1	mixed	Willamette Basin Futures Analysis	regional futures assessment
2	mixed	Sandy Basin Anchor Habitats	aquatic habitat restoration priorities
3	federal-mgt	NW Forest Plan Watershed Condition	regional assessment
4	federal-mgt	Boise-Payette National Forest Plan	national forest mgt plan
5	federal-reg	FWS red-cockaded woodpecker	federal species recovery planning
6	fed-state-mgt	FSP Spatial Analysis Project	landowner assistance planning
7	state-mgt	Chesapeake Forest	state forest mgt plan
8	state-mgt	Oregon Harvest & Habitat Model	state forest mgt plan
9	state-reg	WA state water typing model	state forest practice rules
10	state-reg	TNC WA state ecoregional planning	setting priorities for conservation
11	local gov-mgt	Baltimore watershed plan	city watershed mgt plan
	local gov-reg	(zoning board)	(local zoning regulations)
12	industry-mgt	Intl Paper habitat modeling	industrial forest mgt planning
	industry-reg	(forest management certification)	(industry self-regulation)
13	nipf-mgt	Consulting foresters	small landowner mgt plans
	nipf-reg	(state forest practices system)	(state forest practices regulations)

*Key: * mgt = land management process; reg = regulatory process; nipf = non-industrial private forest owner*

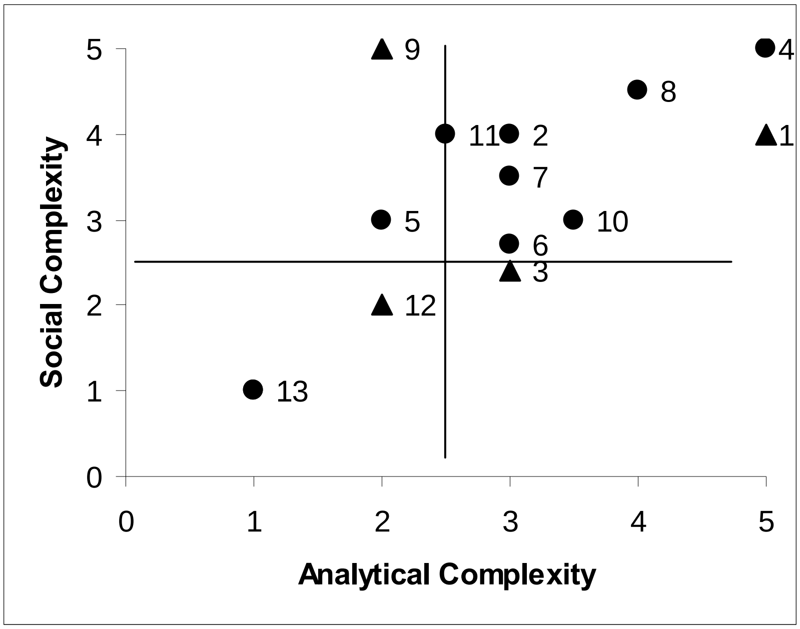
The next criterion was based on the theoretical construct of social and analytical complexity. The aim was to test the effect of the different combinations by studying one case from each quadrant of a matrix formed by these dimensions. Characterizing each case required some preliminary data collection and analysis, resulting in the case briefs contained in Appendix C. This preliminary information was used to derive a relative score for each of the cases using the system described in Table 17. Note that this scoring was done rapidly and qualitatively in order to avoid devoting too many resources to the screening process (Yin 2003).

Table 17. Summary of Analytical and Social Complexity Measures

Description	Score
Analytical Complexity	
small geographic and short temporal extent, simple biodiversity and forest measures	1
↓ (gradient of increasing complexity in these factors) ↓	↓
large geographic and long temporal extent, complex biodiversity and forest measures	5
Social Complexity	
Single decision maker	1
Multiple decision makers within one organization	2
Decision shared between two organizations (e.g. regulator and regulated)	3
Open stakeholder process with no immediate allocation of resources	4
Open stakeholder process involving direct allocation of resources	5

The results are presented in Figure 5. What is most striking about these results is the general correlation found between analytical and social complexity. Few cases were found where high social complexity was associated with low analytical complexity or vice-versa.

Figure 5. Analytical and Social Complexity of Potential Case Studies



Key: ▲ *= cases selected,* ● *= other cases; numbered labels correspond to Table 16.*

Because this study was intended to explore the breadth of DSS applications, the final cases were chosen to represent a wide variety of decision-making sectors, as described in Table 16. The following cases were selected for in-depth study: (#12) International Paper's Forest Patterns system, and (#3) the Northwest Forest Plan watershed assessment, (#9) the Washington state water typing model, and (#1) the Willamette Basin alternative futures analysis,. A brief discussion of the rationale for each selection follows.

International Paper's Forest Patterns system (#12) was a clear choice to represent the low analytical / low social complexity quadrant. The other obvious possibility, the "consulting foresters" case (#13), was simpler in both aspects, but initial screening information revealed that the consulting foresters were not using the biodiversity-related aspects of the DSS. The Forest Patterns case provides an important private industrial perspective.

The only case in (or at least on the edge of) the high analytical / low social complexity quadrant was the Northwest Forest Plan watershed assessment (#3). In terms of decision-making sectors, it represents a federal land management perspective. The case is also interesting because the Northwest Forest Plan is one of the first large-scale attempts at ecosystem management within the U.S.

The Washington state water typing model (#9) was the clearest representative of a high social/low analytical complexity case. Although its geographic extent was large (the whole state of Washington), other analytical complexity factors were low: it was only to represent one snapshot in time, it concerned only one biodiversity indicator (fish presence/absence), and did not consider any forest habitat effects. In terms of sectors, it represents a state-level regulatory process, which is important because forest regulations in the U.S. are the responsibility of state governments. Washington has been a national leader in incorporating stakeholders into the forest rule-making process.

The most choices were available in the high analytical / high social complexity quadrant. The Willamette Basin Alternative Futures Analysis (#1) was chosen because it was one of the most extreme cases in this quadrant. The Boise-Payette-Sawtooth National Forest Plan (#4) would have been more extreme in social complexity, but another case the already represented federal management perspective and national forest planning has received considerable study already. The Willamette case brought a "mixed" sectoral perspective, along with a different and intensive process for citizen involvement in modeling.

Data Collection

Case studies are generally built from multiple sources of information. This study relied on two sources: interviews and documents (in addition, for the Northwest Forest Plan case, the author was a participating analyst). Table 18 shows the interview outline was developed to cover the main topics of interest. The outline was purposefully kept general to minimize the researcher’s framing of answers and to allow for flexibility in pursuing topics most pertinent to each case.

Table 18. Outline of Interview Topics

1. Decision support system (DSS) used and issue applied to
2. Key players and relationships
3. DSS selection process
4. Defining objectives for the DSS
5. Describing how the system was operated
6. Communication between modelers and others
7. Overall usefulness of the DSS and key factors

Interviews were targeted at the individuals most knowledgeable about the role of modeling in each case, and in most cases began with the principle analyst or modeler. A total of twenty-two interviews were conducted to build the case briefs used for selecting the four core cases. Two to three additional interviews were conducted and additional documents reviewed to further develop each of the core cases. A description of these interviewees for the core cases is presented below (Table 19), as well as a full list of documents consulted (Table 20). Considering the broad range of people involved in each case, interviews with a broader cross-section of participants would have been helpful. However, the time-intensive nature of interview analysis and the broad range of cases covered in the preliminary assessment limited the time available. Instead of aiming for a saturation of perspectives in each case, the data gathering process was conducted to collect sufficient information to complete the case description framework (explained below) and address the theoretical questions posed.

Table 19. Description of Case Study Interviewees

Case	Interviewee Descriptions	Total
International Paper's Forest Patterns system	Wildlife biologist, regional operations forester, GIS support forester	3
Northwest Forest Plan watershed assessment	Monitoring team leader, principle analyst, regional decision maker, environmental advocate	4
Washington State Water Typing Model	Scientist representatives from 4 organizations: Dept. Natural Resources, Dept. Fish & Wildlife, industry group, conservation caucus	4
Willamette Basin Alternative Futures Analysis	Project principle investigators (2) Stakeholder participant (1)	3

Table 20. List of Case Study Documents Reviewed

<u>International Paper Forest Patterns</u>

DeGraaf, R.M., M. Yamasaki, W. Leak, and J. W. Lanier. 1992. New England Wildlife: Management of Forested Habitats. Gen. Tech. Rep. NE-144. USDA, Forest Service, Northeast Forest Experiment Station, Radnor, Pennsylvania. 271 p.

Donovan, G. 2005. Forest Patterns™ : A landscape management tool. Presentation to the SFI Conference, Portland ME, Sept. 20, 2005.

IP 2002. Northeast Area Sustainable Forestry Policy. International Paper internal document dated 9/5/2002.

<u>Northwest Forest Plan Watershed Assessment</u>

Gallo, K.; Lanigan, S.H.; Eldred, P.; Gordon, S.N.; Moyer, C. 2005. Northwest Forest Plan—the first 10 years (1994–2003): preliminary assessment of the condition of watersheds. General Technical Report PNW-GTR-647. Portland, OR : USDA Forest Service, Pacific Northwest Research Station.

Reeves, G.H.; Hohler, D.B.; Larsen, D.P.; Busch, D.E.; Kratz, K.; Reynolds, K.; Stein, K.F.; Atzet, T.; Hays, P.; Tehan, M. 2003. Aquatic and Riparian Effectiveness Monitoring Plan for the Northwest Forest Plan. General Technical Report PNW-GTR-577. Portland, OR : USDA Forest Service, Pacific Northwest Research Station.

Reynolds, K.M.; Rodriguez, S.; Bevans, K. 2002. Ecosystem management decision support 3.0 user guide. Corvallis, OR : USDA Forest Service, Pacific Northwest Research Station. [http://www.fsl.orst.edu/emds/]

RIEC. 2004-2005. Meeting notes of the Regional Interagency Executive Committee. Oct 18, 2005. [http://www.reo.gov/library/riec/]

Table 20. List of Case Study Documents Reviewed (continued)

Washington State Water Typing Model

Bakke, B. 1997. Washington Trout finds lost salmon habitat. NW Fishletter #48. [http://www.newsdata.com/enernet/fishletter/fishltr48.html]

CMER. 2000-2005. Minutes of the Cooperative Monitoring, Evaluation, and Research Committee. [http://www.dnr.wa.gov/forestpractices/adaptivemanagement/cmer/meetings/]

Conrad, R. H.; Fransen, B.; Duke, S.: Liermann, N.; Needham, S. 2003. The development and assessment of the preliminary model for identifying fish habitat in western Washington

Cupp, E. 2004. Water typing model field performance assessment. Washington Forest Practices Adaptive Management Science Conference. April 5, 2005. Olympia WA.

FPB. 2000-2005. Minutes of the Washington Forest Practices Board. [http://www.stage.dnr.wa.gov/forestpractices/board/meetings/minutes/]

Fransen, B. R., S. Needham, G. McWethy, and V. Kim. 1997. Development of a process to delineate potential fish habitat based on physical characteristics measured at the upper extent of known fish distribution. Unprocessed report to the Timber, Fish, and Wildlife Water Typing Committee.

Kepkay, M. 2003. Complexity and adaptive management in Washington state forest policy, 1987-2001. Master Thesis, Simon Fraser University, BC. Canada.

McClure, R. 2001. Forest-Fish Plan: Was it Too Political? Seattle Post-Intelligencer, January 29.

WAC-222-16-030. Washington Administrative Code Title 222 (Forest Practices Board), Chapter 16 (Definitions), Section 030 (Water typing system).

WDNR. 2000. Forest and Fish Report. Washington Department of Natural Resources. Olympia, WA.

WDNR. 2001-2005. Washington forest practices board manual (sections 13 and 22). Washington Forest Practices Board. Olympia, WA. [http://www.stage.dnr.wa.gov/forestpractices/board/manual/]

Willamette Basin Alternative Futures Analysis

Baker, J. P., D. H. Landers, H. Lee, II, P. L. Ringold, R. R. Sumner, P. J. Wigington, Jr., R. S. Bennett, E. M. Preston, W. F. Frick, A. C. Sigleo, D. T. Specht, and D. R. Young. 1995. Ecosystem management research in the Pacific Northwest: five-year research strategy. U. S. Environmental Protection Agency, Office of Research and Development, Washington, D.C., USA. EPA/600/R-95/069.

Baker, J.; Hulse, D.; Gregory, S.; White, D.; van Sickle, J.; Berger, P.A.; Dole, D.; Schumaker, N.H. 2004. Alternative futures for the Willamette River Basin, Oregon. Ecological Applications 14(2): 313-324.

Table 20. List of Case Study Documents Reviewed (continued)

Hulse, D.; Gregory, S.; Baker, J. 2002. Willamette River Basin Planning Atlas: Trajectories of Environmental and Ecological Change. Corvallis, OR : Oregon State University Press. 192p.
Hulse, D.W.; Branscomb, A.; Payne, S.G. 2004. Envisioning alternatives: using citizen guidance to map spatially explicit assumptions about future land and water use. Ecological Applications 14(2): 325-341. [http://www.fsl.orst.edu/pnwerc/wrb/Atlas_web_compressed/PDFtoc.html]
INR 2005. Willamette Basin Conservation Project Final Report. Corvallis, OR : Institute for Natural Resources [http://hdl.handle.net/1957/469]
INR 2006. About INR. Corvallis, OR : Institute for Natural Resources. Retreived March 6, 2006 [http://inr.oregonstate.edu/about_index.html]
WVLF. 2001a. The Willamette chronicle. Newspaper insert. [http://www.lcog.org/wvlf/chronicle.html]
WVLF. 2001b. Willamette Valley: Choices for the Future. Proceeding of a conference held April 26, 2001. Willamette Valley Livability Forum [http://www.lcog.org/wvlf/pdf/wvlfconfpro.pdf]

Data Analysis

The research approach outlined above has both descriptive and explanatory goals. A standard descriptive framework was used to organize the case descriptions in a common manner to help in comprehension and comparison. The more explanatory objective was accomplished by comparing the theoretical framework above with the data from interviews and documents.

Coding

Miles and Huberman (1994) note that, at the macro level, both qualitative and quantitative data analysis involve data reduction, data display, conclusion drawing, and verification. The data reduction strategy used in this study was based on "coding," which entails the selection, categorization, and linking of specific portions of the raw data (interview transcripts and documents). Codes were created to track information relevant to both the descriptive framework and the theoretical analysis. The Atlas-ti software was used to code the interview transcripts and core documents available electronically; it facilitates assigning specific passages to user-defined themes and creating flexible queries to extract them for analysis. Additional information from ancillary documents was handled by manual highlighting and notes.

Descriptive Coding

Studies from the major bodies of theory reviewed in Chapter 5 have used explicit process models to organize their description and theory building. Rogers (2003) developed a five-step innovation decision model; Rauscher (1999) set his analysis within an adaptive management model of “plan-act-monitor-evaluate”; DeLone and McLean (2002) used a simple model of “IS adoption-use-impacts”; and decision theory includes many variations on the “phase” model of decision making, with perhaps the best known example being (Simon 1960) “intelligence-design-choice-review”. While the actual existence and orderly progression of such steps have been questioned, they appear to at least have some heuristic value for description and theory development. The descriptive framework used for each case in this study is analogous to Simon’s stages, but with a few differences to accommodate theories reviewed in the previous chapter. “Intelligence” is broadened to “problem framing” to reflect a more policy-oriented perspective. “Design” and “review” were simply renamed “analysis” and “evaluation” to be more understandable to a lay audience. “Resolution” was preferred to “choice,” since problem solving situations do not always result in a clear choice decision.

Theoretical Coding

The theoretical coding followed the theoretical framework presented above. First, the case materials were reviewed and coded to indicate success factors and measures identified by the interviewee or document author. Factors and measures could be expressed in positive or negative terms, so this was also indicated. Second, the information was reviewed again and aspects related to the themes for analysis and deliberation were coded. For example, the statement, “The system was not successful because of its complex user interface” would be coded with “factor”, “negative”, and “system quality”. Table 21 summarizes the principle codes used.

Table 21. Summary of Codes Used to Categorize Case Study Information

Descriptive	Theoretical		
	Success	Analysis	Deliberation
Problem framing Problem analysis Problem resolution Problem evaluation	Factor Measure Positive Negative	System quality Information quality Support quality	Participation Communication Translation Negotiation

Case Description

Case descriptions were assembled by extracting and integrating the relevant coded information from across the different information sources available. Direct quotes were used whenever possible to give the reader the most unfiltered access to the evidence possible. These descriptions were then sent back to the interviewees for review and their suggestions were incorporated.

Theoretical Analysis

Information related to each theoretical code was then extracted and summarized in separate sections. As these codes represented broad concepts, more specific mechanisms were identified wherever possible. These summaries provide a gauge of how important each factor was for the system's overall success. Factors identified by the case information but not related to any of the theoretical factors used were also noted as limitations to this framework. The hypothesized importance of interactions between analytic and deliberative elements was considered in more holistic manner for each case, and the extent to which the interactions were "mutual and recursive" was described.

Following analysis of the individual cases, a cross-case analysis was performed to compare and contrast the findings. For each hypothesized factor, the results from each case were displayed in a four-square table mirroring the quadrants of social and analytical complexity used in Figure 5. These tables were used to note patterns in the factors across cases. The two hypotheses related to levels of complexity were addressed, and a combined view of analytical-deliberative interactions was synthesized.

Validity

The trustworthiness of quantitative data analysis is based on a set of widely-accepted practices, including random sampling, well defined variables, and control of confounding variables or competing explanations. In contrast, opinions about qualitative data analysis are much more varied, ranging from mimicking quantitative methods to rejecting the possibility of such objective measures in an inherently subjective world. Both Yin's (2003) case study methods and Robson's (2002) more general methodology discussions recommend attending to the concepts developed for more traditional quantitative studies by creating specific methods more appropriate to qualitative data. Yin (2003) outlines four types of validity: construct, internal, external, and reliability.

Reliability refers to the repeatability of the study. Following Yin's (2003) advice, I used an explicit case study protocol. An explicit descriptive framework was applied to each case. Documents reviewed were referenced and recorded in the bibliography. Interviews were conducted using a common set of themes (Table 18), but because of the exploratory nature of the research, a strict, standard set of questions was not used. This flexibility and the inherent variability of interview data (people may not answer the same question the same way twice) do decrease reliability. However, interviews were recorded and transcribed, so the same database could be used by other researchers. An explicit theoretical framework was also applied to each case, and the central concepts were further defined (Table 13, Table 14) to help standardize their identification.

Construct validity is a measure of how accurately the desired concepts are represented in the study. Central constructs in this study include the idea of "success", "success factors", the distinctions between analytical and social factors, and the definitions of analytical and social complexity. Success was explicitly viewed as a subjective concept, and descriptions were built based on the case data (interviews, documents). As discussed above, the theoretical success factors were further defined and applied to the case data in an explicit manner ("coding"). Other researchers might disagree with what constitutes "participation," but at least a chain of evidence is available to demonstrate my definition. Finally, the case descriptions were reviewed for accuracy by key informants (usually the interviewees).

Internal validity is a measure of causality between variables in the study. Overall, a broad pattern-matching approach was used; case success was expected to be associated with certain expressions of success factors, the analytic-deliberative process, and levels of social and analytical complexity. Patterns consistent with expectations were seen across three successful cases as well as one less successful case (a negative case test). "Explanation building" was another strategy used. Factors were not simply listed as affecting success, but rather each factor was discussed and an explanation built on how its effects occurred. These explanations were bolstered by the ability to compare between multiple interviewees and document sources.

External validity is the extent to which the study findings can be generalized. Obviously, case studies are not designed to provide the same type of statistical generalization as typically expected from quantitative survey data. Instead they are more often viewed as single experiments testing a path of theoretical development. The success factors tested here have been tested before in similar fields (information systems and environmental assessments), so the validity of this study is bolstered by these previous findings. A key difference with laboratory experiments, however, is that they carefully control context and confounding variables. The case study researcher does not control the environment and must use other strategies. One method used by this study was the deliberate selection of cases to represent as broad a range of analytical and social complexity as possible. Results from these cases could be generalized to others to the extent that these aspects influence case findings. A second method for determining external validity used here relies on detailed description of the case environment. This strategy places more responsibility on the reader/user of this research to determine how closely their own situation matches the one found in the case.

CHAPTER 7 – CASE STUDY : INTERNATIONAL PAPER'S FOREST PATTERNS™ SYSTEM

Sources

This case study was developed from interviews with three people who have used the system since its introduction: 1) the wildlife biologist primarily responsible for developing the Forest Patterns system, 2) an operations forester/coordinator, who managed 125,000 acres of land and now coordinates the work of multiple foresters, and 3) a GIS forester, who provides analytical support to the operations foresters. I also was given access to the relevant sections of International Paper's (IP) Sustainable Forestry Policy, which was used to obtain third-party forest management certification under the Sustainable Forestry Initiative (IP 2002) and a PowerPoint presentation given at an SFI conference in 2005 (Donovan 2005). I also reviewed the IP website (http://www.internationalpaper.com). One of the interviewees reviewed the initial case study draft, and his comments were incorporated into the final version.

To help establish a chain of evidence for assertions in the theoretical analysis below, quotes from case materials have been numbered and these numbers are referenced in brackets (e.g. [3] refers to quote 3).

Case Description

Background

In the early 1990s the forest industry in the upper northeastern United States was facing considerable public concern spurred by above average clearcutting rates instituted as a response to a large scale (cyclical) spruce budworm outbreak. In 1994, Champion International decided to create a system to help it provide information to assure the public about the sustainability of its forest management practices. They hired a former state wildlife director, who led the design of a GIS-based land classification system which links to a database of management guidelines for each land type. At this time the idea of sustainable forest management certification was just developing, and so was integrated into the process. International Paper (IP) acquired

Champion in 2000, named the process "Forest Patterns," and has been expanding its use to other regions.

Problem Framing

As one interviewee put it, Champion International initiated the DSS development with

> (1) …an eye toward certification and also trying to change public opinion about forest practices…Champion at the time was actively pursuing developing a program that they could be third-party certified under. That was also a time when the Sustainable Forestry Initiative and FSC came into being. So my task when I came aboard with Champion was to help them develop a program that would address water quality, biodiversity, and protecting rare features.

Another issue identified as important was the currency of the data. At the time, Champion was just making the transition from paper-based mapping to computer-based geographic information systems (GIS). The new wildlife director saw the opportunity to take advantage of this new technology to insert wildlife and other non-timber information into the management process. An interviewee defined the need for a process as much as a tool.

> (2) One of the things that my experience with Maine Fish and Wildlife and working with the forest industry over the years, it became really apparent to me that we needed to have a system that was map-based, data-linked, and something that foresters, who were really busy individuals with a lot of responsibilities, would use. If we were to be effective in designing some sort of effective on the ground management concept, it would have to be something that was updated periodically, something that they could get an idea of what were the concerns at a glance, and that would be a GIS generated map.

Problem Analysis

Champion International setup a lead team of higher level managers to oversee development of the certification and public information system. They in turn created six or seven teams to come up with proposals related to different aspects of sustainable forestry. One of these teams focused on water quality and wildlife. Its six members were chosen to represent the organization both vertically, from managers to operations foresters, and horizontally, across the four northeastern states. The team leader was also empowered to enlist outside participation, and so he included a Forest Service researcher on the team and had the team's draft products reviewed by a number of academics, agency personnel, and water and wildlife consultants. The team met in person four or five times, with interim e-mail and phone discussions, over a three month period and came up with a detailed proposal on harvesting guidelines at the landscape scale and for different types of sensitive areas. Input from both outside reviewers and the field foresters was seen as critical.

> (3) There were several iterations of that, where we got those folks' [external reviewers] input on our recommendations. What I found is that it was a constructive process because some of the recommendations, some of the help we got from the operations people in the field helped us come up with a better product that had relevance in commercial forest management. It allowed us to go ahead and identify those particular features that, because of one thing or another, were not practical. They supported the outcome of water quality or wildlife habitat management, but there were certain elements of the proposal that, because of the way that they apply management in their particular geographic area, may or may not have relevance. So by having their input we covered all the bases.

The proposal was accepted by upper management and a wildlife consulting group was hired to draft habitat identification protocols and locate sources for the necessary information. The wildlife manager oversaw this effort. He then marked up hardcopy maps to reflect the management guidelines as applied to the water and wildlife information obtained, and these maps were digitized by Champion's GIS specialists.

The computer-based part of the Forest Patterns process was developed as a GIS-based land classification system with links to a database of management guidelines associated with each land class. One interviewee described its use like this:

> (4) It's really the backbone of how we manage the land, the land classification program that puts each parcel of land into a certain class, so a forester knows how to manage that certain parcel of land, dependent on how it's classed.

It is a hierarchical system, with three categories at the top level: High Conservation Value Areas, Primary Production Areas, and Non-Forest Areas. High Conservation Value Areas are identified first to avoid conflicts with timber production. The Conservation Areas class is further divided into Riparian Areas and Habitat Management Areas, where timber harvest is limited to the extent compatible with non-timber values, and a third subclass of Protected Areas, including rare ecologic, geologic, cultural and historic features, where no harvesting generally takes place. Production areas are also important for wildlife and are divided into natural forest management and plantation management. The wildlife manager works directly with counterparts in the state agencies to get the information used to define the conservation areas, recently through the direct exchange of GIS layers. He reconnects on an annual basis to update the information with any changes.

A principle objective of Forest Patterns was not only to identify conservation features, but also to help manage for biodiversity on a landscape scale. To operationalize this level of management, the wildlife biologist used the concept of Diversity Units, building upon existing research.

> (5) If you've got the appropriate habitat, you're likely to have the species that are supposed to be there. I found that it was timely, the folks at the Forest Service, Yamasaki and DeGraaf, had already done a lot of thinking in this area and had a model that was applicable to new England, so I didn't hesitate to use it.

Before the specific zoning is carried out, the wildlife biologist works with the foresters to divide each forest operations unit, typically 100 to 150 thousand acres, into Diversity Units. Following the guidance of well-known wildlife biologists in the northeast (Hunter 1995, 1996; DeGraaf et al. 1992), the size of each of these units is 25 to 50 thousand acres or more, and corresponds to what is called beta (landscape) diversity in scientific terms.

Conservation targets are set for each diversity unit, and the Forest Patterns system is used to evaluate the extent to which each unit meets these targets. In the northeast case, Forest Patterns drew on guidelines for landscape structure needed to sustain the

338 inland vertebrate species that are found across New England (DeGraaf 1992). An example is presented Table 1.

Table 22. Example of Landscape Targets in Forest Patterns

Size-class distribution combining all forest types on a Diversity Unit	
Regeneration	5-15 %* (< 1" DBH)
Sapling-pole	30-40 % (1.0-3.9", 4.0-8.9" DBH)
Sawtimber	40-50 % (>9.0 DBH sftwd, >12.0 DBH hdwd)
Large sawtimber	< 10 % (>20.0 DBH sftwd, >24.0 DBH hdwd)
Cover-type distribution on a Diversity Unit	
Deciduous (not hard mast species)	
Shade Intolerant (aspen/birch)	10-25%
Shade Tolerant (northern and swamp hardwoods)	15-30%
Hard mast (beech, oak)	1-5 %
Coniferous	35-60%

Source: DeGraaf et al. (1992 p. 21)

To make the system more relevant, the wildlife biologist went beyond just including the basic water and wildlife information:

> (6) I worked with each one of the groups of foresters [from each state] to get their input as to what kinds of information needed to be applied to these maps in addition to the information that I was primarily concerned about. That's a little trick to just to make these maps that much more important to these folks.

One of the interviewees described how these guidelines were further refined, vetted, and integrated into silvicultural prescriptions:

> (7) a management group would get together, and that would be forest managers, procurement folks, everyone involved in the business kind of laid out what those guidelines were. As long as everyone was on board with it, it would meet our business objectives and our environmental objectives. That's how we came to those compromises or decisions.

When Champion was bought by IP, Forest Patterns was again put through a formal review process. The wildlife team included specialists in wildlife, silviculture, harvesting, and now IP's existing environmental management system. It was decided that the two companies systems complemented each other, and so they were merged, first in the Northeast and then companywide over an approximately three year period. Donovan (2005) notes how a variety of people have contributed to the concept over time, from cross sectional IP teams and forest ecology consultants involved in the initial development to reviews by state/federal agencies and academic experts, and ongoing suggestions from regular third party audits.

Problem Resolution

The Forest Patterns software is used in decision making at both the tactical and operational levels. In relation to biodiversity, Forest Patterns uses the Diversity Unit goals to drive planning at the tactical level.

> (8) You can query your system and find out, say, where am I today versus where I want to go with my targets. You might want to say that you want to have 20% of your land base in high yield management for plantations. You can use the system to immediately query and can say I'm at 10% right now and I want to get to 20%, so I'm going to have to convert more acres over time. So for long-range planning tool it is excellent because it is all GIS driven and you can instantly know what percentages you have by town.

At the operations level, foresters use the system on a day to day basis to plan their activities:

> (9) It was used whenever a forester would plan a harvest area. We have a harvest planning checklist, in other words, things we need to go through to make sure that we are doing everything that we're supposed to do to plan properly for this harvest. One of the first things on the checklist is a Forest Patterns map check.

The interviewees all mentioned that foresters in different regions can (and do) add other types of information to the system that are useful to them.

Problem Evaluation

Success Measures

When asked how they evaluate the success of the system, the interviewees mentioned the use of and support for the system by foresters (quotes 10-12), the prevention of errors and conflict (13-14), conferring of credibility (15), and compliance with certification standards (16):

(10) When IP bought Champion the foresters basically made the transition to the new company, and they pretty much insisted that the new company continue with using this tool because it was so important to them and it was such an efficiency of time to be able to look on one map that was updated as new information became available, rather than leave the burden to them to track it all themselves.

(11) Once the people have been exposed to it, once that they know that they are part of the development of this tool, I've found that wherever it's applied, they take ownership in it and it becomes important for their day-to-day operations.

(12) To be able to have the end-user conceptualize over the whole forest, what is the plan here, what is the trend, what are my objectives for the next three to five years, and use this for setting their day-to-day logging jobs. That's critical, if that's not happening, you can make all the maps you want and all the presentations you want, but if it's not being done on the ground, to me you're not getting return on investment.

(13) The other thing that happens is that conflicts with these other resource values are a rarity rather than a common occurrence.

(14) I think it's successful if it's being used, if it is preventing environmental mistakes, hazards, it’s certainly successful.

(15) It lends credibility to everything we do. We use it with all kinds of agencies. We present at any time we have a tour of the lands with outside parties that's one of the major selling points, that we basically know what we're doing, here’s a prime case of excellent management. We can show people visually that we’re using this system, that it works.

(16) It's important from a certification standpoint and from a state agency reporting standpoint. Every year we are asked to report how many acres we harvested in what towns. That's the cost of doing business within the state of Maine. Also for SFI certification, using our GIS

> and the harvest plan database we can accumulate an annual volume and acres of what forest patterns we harvested in that year.

Success Factors

The interviewees also identified a number of reasons why they thought Forest Patterns had been successful (i.e. success factors) and, more generally, the pros and cons of using the system. The support of management was seen to be fundamental:

> (17) First of all you got to have the hearts and minds of the management. They have to be committed to this right at the very top of the relevant organization that you're working with for either a state or a multi-state area. Even right up through division level management, they've got to be aware of it and have got to be supportive of it and recognize the values. That's first and foremost, if you don't have that, you're not going to get very far.

Keeping the system up to date was named as another success factor. Since the costs of maintaining such a system are substantial, it is linked to management support.

> (18) …probably the minus is that it does take a lot of time to maintain. It is certainly worthwhile in the long run, but you have to dedicate resources to the maintenance of it. If you don't, it will not be updated in a timely manner and the information just becomes useless. You have got to dedicate the GIS specialist's time and foresters' time to maintain the system. If it is not properly maintained, it's not going to be any good to you.

As mentioned in the Analysis section above, one interviewee said that contacting the state agencies directly on a regular basis way key to getting the best information and keeping it current. Another interviewee mentioned how the use of hand-held global positioning system (GPS) units is enabling the field foresters to do more of the data maintenance. The third interviewee stated that updating is encouraged internally by integrating of system maintenance tasks into personnel evaluations.

But mandating maintenance seemed to be the second half of the equation with regard to the operations foresters. The first half was to build a tool that was flexible and relevant enough to be useful in their daily operations. Since FP is built on top of a standard GIS package, it easily integrates with the foresters' other mapping and data management activities. As explained by one participant:

(19) The tool that was available to operations foresters had to be relevant to them. If it wasn't relevant to them they wouldn't use it, that's just human nature. If you're going to do anything like a paper push to them, something extra that they would have to tend to as part of their day-to-day operations, chances are it would fall by the wayside. So what it should do is design a tool that had the flexibility and relevant information that they could use on a day-to-day basis.

In addition to flexibility, one of the interviewees mentioned training and the

(20) customization of platform to make it easier and basically cookbook what they need to do.

In other words, simplifying and focusing the software interface on the tasks the foresters need to perform. Two of the interviewees also emphasized the visual nature of a map-based system as a success factor both for external communications (10) as well as for internal users:

(21) I think the critical thing is getting it in the hands of the end-user and being able to visualize it, some kind of map or on-screen display.

(22) Most foresters are visual to begin with, and when they can see these zones in the colors of the legends that show what a piece of land is, it sort of brings it all out.

Summary of Key Points

- Top management support was critical
- A diverse internal group and external reviewers were involved in the system design
- It took a large commitment to keep data up to date
- Part of the system involves regular, direct contact with state agency personnel for updating data
- A flexible framework that can be adapted to the needs of different regions encouraged local adoption and use
- Providing training, a simple software interface, and management incentives facilitated use of the system by the foresters making decisions on the ground

Theoretical Analysis

The following sections analyze the case information using the four-part framework presented in Table 15.

Part 1. Participant Definitions of Success and Contributing Factors

Table 23 below summarizes the success measures and factors contributing to success identified from the case information.

Table 23. IPFP Case Participant-defined Success Measures and Factors

	Analytical	*Social*
Success Measures	+ use of system by operations foresters + prevention of forest operations errors	+ response of users and experts + increases public credibility + reduces conflict with public + meets certification requirements
Success Factors	+ keeping data current + ease of use + flexibility to add custom data + visualization	+ top management support + cross-sectional design teams + data maintenance officially recognized in job duties

Part 2. Assessment of Predefined Analytical and Social Factors

Analytical Factors

The following sections analyze the case information using the framework of the three social/interpretive factors presented in Table 13.

System Quality

Interviewees put considerable emphasis on aspects of system quality, including maintenance of the underlying data, ease of use of the system [customized “cookbook” software interface – quote 20], and flexibility to incorporate locally-relevant information.

Information Quality

Information quality also came out as an important factor. Since the underlying data are kept current, the system provides timely and relevant data to the field foresters. The flexibility of the system has enabled the production of outputs that are more locally-relevant, and the visual nature of map-based information helped to make its outputs more easily understood.

Service Quality / Modeling Capacity

One interviewee identified support and training as important factors in Forest Patterns success, since it was intended for use by field foresters, some of whom had no experience with computers or GIS. He characterized getting all the foresters to use the system as difficult initially ("through blood, sweat, and tears"), but the process was helped along by having the commitment of upper management. Another of the interviewees mentioned training, but said that, "It was not a real high level of difficulty or anything, just getting familiar with the system and how to use it." The difference appears to be between the initial transition to the system (difficult) and subsequent training for new personnel (easier).

Other Analytical Factors

No factors that did not fit into the framework above were noted.

Table 24. IPFP Case Summary of Analytical Factors

System Quality
+ keeping data current
+ flexibility to customize for local conditions/priorities
+ ease of use
Information Quality
+ information up to date
+ visualization via maps
+ customization for local relevance
Service Quality / Modeling Capacity
+ training supported/required by upper management

Key: "+" = positive factor; '-' = negative factor; '▪' = undetermined effect (factor in parentheses indicates identified by researcher, not directly mentioned by participants)

Social Factors

The following sections analyze the case information using the framework of the four social/interpretive factors presented in Table 14.

Participation

Before the implementation of Forest Patterns, land management decisions were primarily made by local forest managers. The system's development appeared to lead to more formal involvement of a wide variety of people from inside and outside the organization. The design teams included expertise from a variety of the company's functions and geographic areas, and a number of outside experts were used to develop and review the land classification and management procedures. The system is also the subject of regular review and feedback as part of third party management certification processes.

While the decision authority of the operations foresters has been reduced given the wider input, they were seen as the critical users by the interviewees. Their participation and use of the system is the link to management prescriptions on the ground and key to keeping the system up to date.

Communication

The cross-sectional teams used in the original development and subsequent review of Forest Patterns increased communication between different specialists within the organization and also with outside experts. As recommended in the literature, this communication appeared to be iterative and two-way, in that the design teams met numerous times and the input of all members seemed to be valued. The system also went through an iterative review process with outside experts.

Now in day-to-day operations the system serves to communicate a common definition of ecological features to all IP personnel in a management unit. Forest Patterns also helps IP communicate with the regulatory agencies by providing a framework in which to share data. Both these internal and external users of the system provide ongoing feedback on how it can better meet their needs.

Translation

IPFP uses simple land management categories and visual mapped outputs to translate more abstract knowledge of ecological features into specific management guidance for the field foresters. The most basic, top-level categories are shared across the organization, but the subcategories of these land classifications are allowed flexibility to best meet local needs. This arrangement serves to translate knowledge across geographies. Interviewees also stated that maps of these management categories have been very useful in the translation of IP's management strategy to regulators and the public [15].

Mediation

While there was no mention of using the system to help resolve particular conflicts, one of the interviewees said that the system helps avoid conflicts in the first place [13]. However, this appears to be more a measure of the system's success than a factor contributing to a successful design. Within the organization the system clearly provides rules of conduct (management guidelines) and establishes criteria for decision making (land classifications).

Other Social Factors

Support from top management was a factor emphasized in one of the interviews (and appears in the literature) but which did not fit well under any of the four categories above.

Table 25. IPFP Case Summary of Social Factors

Participation
+ cross-sectional teams, outside experts helped to set management guidelines
+ participation of end users (field foresters) in system design
Communication
+ iterative, two-way communication in cross-departmental teams
+ iterative reviews by outside experts, regulators
+ ongoing feedback from internal and external users
Translation
+ a simple set of common land use categories with underlying flexibility
+ maps make IP's management strategy explicit for the public
Mediation
+ helps avoid conflicts with conservation interests
+ provides rules of conduct (management guidelines)
+ establishes criteria for decision making (land classifications)
Other
+ support from top management

Key: "+" = positive factor; '-' = negative factor; '▪' = undetermined effect (factor in parentheses indicates identified by researcher, not directly mentioned by participants)

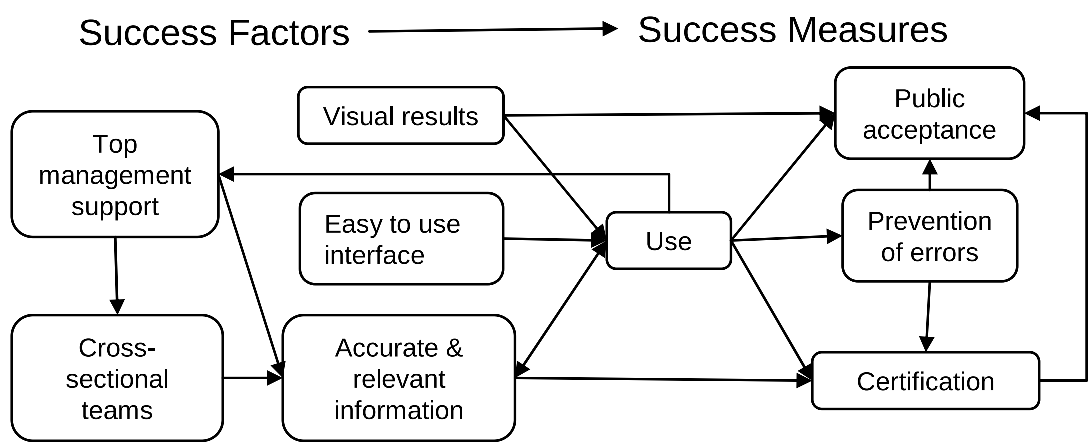
Part 3. Analytical - Deliberative Interactions

In this case the work of the design and review teams clearly demonstrates a "mutual and recursive" process. Cross-cutting teams were assigned to deliberate on specific aspects, such as wildlife. They performed research and analysis to come up with specific management guidelines, which were then sent to outside reviewers (further deliberation), and, as [3] describes, this process was repeated a few times.

Conclusions

Figure 6 summarizes the basic relationships between the success factors and measures identified in the case. Development of the Forest Patterns system began with a commitment from the top management at Champion International. This support was seen by interviewees as fundamental to the successful development and ongoing use of the system. Management organized and provided the resources for the work of cross-sectional teams in developing the product. Management also continues to provide incentives for the maintenance of the database. The mix of functional and geographic expertise on the teams (*participation* and *communication*) helped create a product that was relevant to the company's overall goals, as well as the needs of field foresters in the various states (*information quality*). Along with this relevance, an easy to use software interface (*system quality*) and the visual nature of the GIS-based software (*information quality*) facilitated its use in forest operations and presentations to the public. In turn, the use by field foresters mean that the data are kept current (*system quality*). By the time IP acquired Champion, the foresters had come to rely on the system, which helped win support from the new management (feedback arrow). System use is also what leads to the ultimate success measures identified. By providing standardized and spatially explicit guidance, the system helps prevent inappropriate cutting. This prevention of errors, along with the ability to track, summarize and explain its practices, helps the company with direct public outreach as well as management certification.

Figure 6. IPFP Case Key Relationships between Success Factors and Measures



CHAPTER 8 – CASE STUDY : NORTHWEST FOREST PLAN WATERSHED CONDITION ASSESSMENT

Sources

Four individuals were interviewed for this case: 1) the lead analyst/facilitator, 2) the monitoring program team leader, 3) a member of the Regional Interagency Executive Committee (which oversees the Northwest Forest Plan), and 4) a representative of an environmental advocacy organization. I also reflected on my own personal experience of providing modeling and meeting facilitation support to the process as a half-time research assistant, and I reviewed the literature cited below. I circulated a draft write-up to the informants and the monitoring program design leader (not interviewed), and their feedback from three of these informants was integrated into the final draft.

Case Description

Background

One of the earliest and largest applications of ecosystem management principles in the U.S. has been in the Northwest Forest Plan (NWFP), a coordinated set of guidelines for 24 million acres of federal lands in the home range of the Northern Spotted Owl in Washington, Oregon and Northern California (FEMAT 1993, USDA and USDI 1994). The NFWP calls for monitoring the status and trends in a number of areas, one of which is aquatic and riparian ecosystems. The Aquatic and Riparian Effectiveness Monitoring Program (AREMP) is using the Ecosystem Management Decision Support System (EMDS; Reynolds et al. 2002) software to aggregate numerous watershed indicators into an overall condition assessment score for each watershed.

Problem Framing

The AREMP monitoring plan (Reeves et al. 2003) framed the problem to be addressed and the use of the DSS. The development of this document turned out to be the most contentious and difficult part in the entire DSS application. There was little debate on the proposal to use the DSS (which came relatively late in the process), rather the agencies involved had very different ideas about how the monitoring should be structured and what parameters were to be included and how they would be measured. It took three separate efforts over four years to finalize a plan.

Since some of the monitoring plan authors had direct experience with the modeling approach, they were not only able to describe the program mission but also the objectives of the DSS fairly precisely:

> (1) The condition of sixth-field watersheds in the region of the Forest Plan will be evaluated by using a DSM based on the NetWeaver fuzzy logic knowledge base software (p. 20)… The strength of the model developed for AREMP is that it uses an explicit process for assessing watershed condition and documents the data and relations assumed in the interpretation. This allows everyone to understand and track how a particular result was obtained. (p. 21)

The monitoring team members considered the problem relatively well-defined from the outset. As one interviewee put it, "the objectives are to consistently aggregate indicators of watershed condition across time and space." A few definitional questions did emerge during the workshops, which the AREMP team answered in consultation with the monitoring plan's lead scientist.

Although the use of the DSS was well-defined, it was also recognized that the resulting models would change over time. As expressed by one interviewee, "We realize that it's essentially an iterative process, things will change as our knowledge changes, but I still feel pretty good about the overall model."

Problem Analysis

The first model of watershed condition was developed internally by the AREMP project team. None had prior experience with the software, but using the software's tutorial (which conveniently focused on watershed assessment), they were able to draft a model in one week. More time was needed to refine and check the inputs, including the individual indicators and how each would be evaluated on a common scale.

The initial watershed condition model was quite useful as a proof of concept and practice run for the monitoring team. However, the Aquatic Monitoring Plan recognized that a variety of experts would need to be engaged to build a suite of models which could address the physiographic variety over the large Plan area. The AREMP team used their personal knowledge and official contacts to generate a list of 10-20 experts for each of the seven physiographic provinces contained by the NWFP. These experts were largely internal to the land management agencies. Although regulatory agencies also participate in the NWFP management team, the decision was made not to involve them at this point because such regulatory consultations often are contentious and this was not an assessment of proposed activities (like an environmental impact statement) but rather a post-hoc assessment of general conditions. One interviewee felt the expertise represented was good, but could also have been broader:

> (2) I think we got them for fisheries and hydrology but I'm not convinced at this point that we did as good a job as we could have reaching out to other disciplines, such as soils, geology, some of the folks associated more with a blend and riparian processes. The invitation was there, but sometimes you have to do more than just invite people.

Four expert workshops were held to develop models for the seven regions (adjacent regions often had overlapping expertise, so were scheduled together). Before each workshop, the AREMP team sent out a package describing the process. The team had spent considerable effort to craft these materials, including developing terms to describe the modeling process which they felt were easier to understand than those used in the model documentation. Each workshop took between 2-3 days and consisted primarily of working out a model structure, including what indicators to use, how to evaluate each one, and how to combine them into an overall watershed score. This work was facilitated by a team member using a white board to sketch the proposed model structures and relationships, while another team member recorded these results. Although the modeling software was not used during the workshops (in order not to slow down the interaction process), it seemed to provide a structure which helped focus the group work. As one interviewee put it,

> (3) "I thought people went away, I don't know if I'd use consensus, but generally everyone thought, yeah this is a pretty good product."

The actual computer models were built after the initial workshops. Each model also required additional GIS analysis to create the requested inputs. A graduate student of the software developer worked with the team half-time to implement the models. Structuring and testing each model was fairly rapid, on the order of a day or two. The GIS work to prepare the data was more time consuming, maybe one week per workshop. Linking the model to the data proved to be unexpectedly time consuming, since the names and formats of the many variables in the DSS model had to match those in the data structures exactly, and the DSS modeler, GIS analyst, and in-stream data manager were all different people using different types of software. When asked about the DSS software, one interviewee said,

> (4) My biggest complaint is that Netweaver is so hard to use, [connecting] the DBF files and making sure everything matches and chasing all that junk down, which I guess you'd have to do with any model.

It was two additional factors, however, which stretched the analysis process out from a matter of weeks to a year. First, a number of parameter decisions in each workshop had been postponed pending further analysis and consultation, which often took months to realize. Second, the vegetation GIS data was being developed by another monitoring module at the same time, and was updated numerous times, each requiring rerunning the AREMP GIS routines and processing these results through the models. One of the interviewees started out with a much different expectation:

> (5) I thought it would be pretty easy to dump our data in there with both the spatial and the attribute data, and that day we'd have the answer. Maybe we're closer to that now, but it sure seemed like that to get an output in the beginning was more like weeks than days or even hours. Crimity, it's just putting data in and hitting a button!

One the results were finally available, they were sent out to the workshop participants for review. Creating a format to communicate how the model arrived at the overall score from numerous sub-scores was an unexpected challenge, but the result also helped the team more quickly diagnose problems. Some comments were received by e-mail, but most of the review of the models was done in a second round of workshops.

Problem Resolution

The most direct choice that resulted from this DSS application was the confirmation of how watershed conditions would be evaluated (i.e. the final model structures), which occurred mainly at and after the second round of expert workshops.

This direct result might not be recognized as a decision in the sense of a commitment to allocate resources or change behaviors. Responsibilities for these types of decisions rest with the Regional Interagency Executive Team, which sets policies for the Northwest Forest Plan. AREMP's results, along with those from the other monitoring programs, were communicated to this group in 2005 mainly via a public conference and a combined report. This group is still deliberating on actions to take, but have already noted some hurdles to using this information in decision making:

> (6) Lack of specific targets made monitoring interpretations difficult; 10 years is not adequate to see significant changes, and what new questions need to be asked? Suggested implications: Revisit the monitoring questions; to address next decade issues, establish more specific goals and benchmarks, and seek better balance among costs, benefits, and expectations. [RIEC 2005]

One of the interviewees pointed out that, although specific targets have not been set, a general upward trend was expected by the Plan and confirmed by the data:

> (7) The goal of the ACS was to improve the condition of watersheds across the NWFP area. While it was never specified what the rate of change in the distribution of watershed distribution scores should be, they were expected to increase over time.

To reach out to others who might find this information useful, AREMP has established a website which provides access to detailed data, but one interviewee remarked that even more must be done:

> (8) We also of course post everything on the web site, it's all in the GTR, and I think those are good efforts and necessary but until you really sit down with people I don't think it really sinks in. Everybody just has too much going on to read everything that's thrown at them.

AREMP staff are now making time to help others who are interested in using their DSS approach, including fish assessments by the Forest Service in Alaska and NOAA Fisheries in Oregon, and watershed restoration in the Siuslaw National Forest.

Problem Evaluation

Interviewees evaluated the success of the modeling effort in both analytical and social terms, as exemplified by the following quote:

> (9) I think it's [the DSS] very useful. It's very easy to explain to people and it does what we needed to do: consistently assess the condition of watersheds across time and space in an integrative way.

On the analytical side, the tool's flexibility was also identified as important,

> (10) You can incorporate as much complexity as you want into it. That is another good benefit of it.

The fact that the overall analytical results made sense also contributed to the credibility of the tool:

> (11) I guess as a gut check what we ultimately concluded, as far as the success of the Northwest Forest plan, was that it made sense. We didn't see a lot of changes, but where we did see changes, it just intuitively made sense to us.

The participants also identified some analytical weaknesses. Data for barriers to fish passage and biological metrics (e.g. fish counts) were not available, yet were important to decision makers.

> (12) "A lot of people, especially as you move up the hierarchy of the organization, their simple question is, 'How are the fish doing?'

The two analysts also commented that software interface for the model-building part of the program was difficult to comprehend at first. Linking data to the model was difficult, and some of the data changed frequently. On the positive side, help was readily provided by the developers of the two main software components.

On the social side of success measures and factors, another interviewee also emphasized the importance of transparency in how the tool operated:

> (13) It's a great tool for that and everyone sees right there on paper but this is how you did it. Whereas some of the other models that I'm aware of, you go into a black box approach and you don't really know what happened with the data but it just spits out a number in the end.

The interviewee also identified the usefulness of the tool for increasing participation and assisting in the negotiation surrounding the modeling process:

> (14) Another strength was it really brought a lot of the local knowledge together, and at least from a federal perspective, we really did bring a lot of good people in…And I thought people went away, I don't know if I'd use consensus, but generally everyone thought, yeah this is a pretty good product.

Two of the interviewees mentioned that they did not see any obvious impacts of the modeling results on decision makers,

> (15) I also felt we have the problem of a decision protocol that says, 'okay if you're not meeting certain watershed condition indicators, what does that mean for management.' There is no decision protocol in the Northwest Forest plan that is all that clear.

However, one supported the quantitative approach as "putting some teeth" into otherwise vague objectives, and the other thought that the model results were useful, even if no specific decision standards or thresholds had been set:

> (16) Whether we get the conventional number down to the nth degree isn't as important as being able to demonstrate that you're on a positive trend for all the factors that feed into your ranking. So one of the things that I thought was pretty powerful is that we could say based on the data we've got, we're either on a stable or improving trend in the vast majority of watersheds…so what was done with AREMP I think is the best thing I've seen.

On the other side s/he noted some apparent cross-scale disconnects. At the plan-wide scale watershed assessment and the use of a decision support model have been given a high priority, yet most of the decisions are actually being made on individual national forests or BLM districts. For these local units, the region-wide watershed sample is not specific enough, and they have been reluctant to adopt this type of modeling approach themselves. It appears the problem frame (or at least emphasis) may be shifting from plan-wide to more local, creating tension with the original AREMP design and DSS objectives.

Summary of Key Points

- Framing the original problem (on which the DSS was used) was the most challenging aspect
- Focusing participation on experts from agencies with similar mandates (land management) likely facilitated more rapid development of the models.
- Engaging experts in an iterative process, alternating short, intensive interaction in workshops with extended, intermittent e-mail contact appeared to be an effective strategy.
- Relatively simple, expert judgment-based models sufficed to represent a quite complex set of ecological processes.
- While the roads and vegetation data used seemed simple, their compilation and correction was the most time consuming part of the modeling
- The problem frame has continued to evolve, causing a potential disconnect between the plan-wide modeling process and a newer emphasis on locally-relevant assessments.

Theoretical Analysis

The following sections analyze the case information using the four-part framework presented in Table 15.

Part 1. Participant Definitions of Success and Contributing Factors

The participants defined success in both analytical and social terms. On the analytical side they identified integration of different indicators, flexibility of the modeling tool, and results which matched their expectations. On the social side they pointed to the transparency of the approach, its ability help to integrate information from numerous experts and to help structure their debate so as to achieve agreement. Table 26 summarizes the success measures and factors from the case description above. Note that "use in decision making" was not mentioned.

Table 26. AREMP Case Participant-defined Success Measures and Factors

	Analytical	*Social*
Success Measures	+ consistency of evaluations + quantitative results + results consistent with expectations	+ helped bring local knowledge into process + (helped to structure discussion) + participants gave positive reviews
Success Factors	+ ability to integrate different indicators + flexibility of the modeling tool + use of gradients instead of absolute measures	+ transparency of the approach

Key: "+" = positive factor; '-' = negative factor; '▪' = undetermined effect (factor in parentheses indicates identified by researcher, not directly mentioned by participants)

Part 2. Assessment of Predefined Analytical and Social Factors

Analytical Factors

The following sections analyze the case information using the framework of the three social/interpretive factors presented in Table 13.

System Quality

Interviewees made positive comments about the system's flexibility [quote 10] and integrative capacity:

(17) I really like the approach of being able to integrate a variety of indicators or attributes. I think the decision support model does that well.

On the other hand, they complained about ease of use related to the system's interface, particularly in regards to connecting to data sources [4]. Although not mentioned by the interviewees, the fact that generation of the data to feed the model was the most time-intensive activity suggests data quality as an important success factor.

Information Quality

Watershed assessment is a complex objective, which was undertaken in a relatively information poor environment. Nevertheless, there were no complaints by the interviewees concerning information quality, rather they seemed to be quite satisfied with the tool outputs. Two of the interviewees remarked on the system's transparency and consistency [9, 12]. Although the system's concepts appeared readily understandable, the analysts did feel the need to put considerable effort into translating the raw models and outputs into more accessible formats. One of the interviewees also mentioned the fact that the system used gradients to evaluate indicators, instead of abrupt boundaries, helped the experts parameterize the model.

Service Quality / Modeling Capacity

The DSS, although quirky in some interface aspects, was relatively easy to use. Without prior experience, the AREMP team had draft models working within a week. One of the interviewees mentioned going to the software designer whenever there was a hard problem, indicating some importance for support quality. Modeling capacity was not mentioned in the interviews, but the AREMP program and software designer did devote significant resources to the modeling effort, in the form of supporting a half-time graduate student to assist with the modeling.

Table 27. AREMP Case Summary of Analytical Factors

System Quality
+ flexibility of the modeling tool + ability to integrate diverse indicators - some difficulties with model interface
+ (considerable investment in generating data)
Information Quality
+ transparency and consistency of evaluations
+ use of gradients for parameters
+ (additional effort given to formatting outputs)
Service Quality / Modeling Capacity
+ (good support from system developers available)
Other
▪ none

Key: "+" = positive factor; '-' = negative factor; '▪' = undetermined effect (factor in parentheses indicates identified by researcher, not directly mentioned by participants)

Social Factors

The following sections analyze the case information using the framework of the four social/interpretive factors presented in Table 14.

Participation

One of the interviewees identified the fact that the approach enabled integration of local expertise as one of the key attributes of the efforts success [10]. An initial decision to focus participation on land management agency employees, although later reversed, meant that few regulatory agency representatives participated. Given the generally difficult nature of negotiating decisions between these two perspectives, this limitation on participation appeared important for producing a timely product. One interviewee also expressed regrets that a wider variety of technical experts were not involved in the modeling workshops.

Communication

Two primary sorts of communication were described by the interviewees: 1) communication with the experts about the model-building process, and 2) communication of results to other audiences. Communication with the experts was two-way (experts structured the models), and iterative. It consisted of two rounds including both intense, in-person elements (workshops), as well as an extended, remote phase (between workshop and post workshop model refinement via e-mail).

Communication with other audiences was more one-time and one-way. The team gave a number of ad hoc presentations to interested groups, but the main, formal avenue of communication was through the preparation of the watershed assessment section of the 10-year report on the Northwest Forest Plan and the associated symposium.

Translation

An immediate translation challenge was encountered between the modeling team and the experts they engaged. The AREMP team spent considerable effort on translating descriptions of the modeling process for the workshop participants. The team developed a vocabulary for model description that they felt was easier to understand than the language in the original model documentation. They prepared a two-page brochure and a Powerpoint presentation using this vocabulary, which were sent to workshop invitees. Interim model results were exported to Excel spreadsheets, and considerable effort was also expended in formatting these to make them accessible to the workshop participants. These appeared sufficient to make the experts comfortable with the methodology and results.

The AREMP team believed that the DSS provided a consistent and transparent tool. This analysis did not get into how understandable the results were to outside audiences, however, the basic model structure and watershed evaluation results, as presented at a public conference marking a 10-year review of the plan, appeared comprehensible to a wide audience.

Mediation

Although the participants in the model-building workshops were a relatively homogeneous group, it is still not uncommon that serious disagreements can occur between members of the same profession. Only one interviewee appeared to bring up this topic. S/he went from discussing the transparency of the modeling process to how it integrated a lot of local knowledge to mention of "consensus" and how workshop attendees went away in considerable agreement [3].

Table 28. AREMP Case Summary of Social Factors

Participation
+ engaged regional expert groups
+ limited to land management agencies
Communication
+ (engaged experts through extended, iterative process)
+ (ad hoc presentations within the agencies involved)
▪ (limited, more one-way communication with other audiences (report, symposium))
Translation
+ transparency of the modeling approach
+ (effort made by analysts to translate model descriptions and outputs)
Mediation
+ helped to structure experts' debate so as to achieve consensus
+ (expert groups homogeneous)
Other
▪ none

Key: "+" = positive factor; '-' = negative factor; '▪' = undetermined effect (factor in parentheses indicates identified by researcher, not directly mentioned by participants)

Part 3. Analytical - Deliberative Interactions

Table 29 displays an outline of the major activities undertaken during the project, along with the corresponding uses made of the DSS. What is evident in the DSS uses is an alternating pattern of analytical and communicative actions. In the project planning stage, the DSS helped to convey an analytical strategy which could be agreed upon by the project design group. The project implementation team then applied the DSS internally to come up with some initial, analytical results. In order to bolster the credibility of results, the AREMP team then convened a series of expert workshops, where the DSS provided a structure which helped to capture and combine the experts' input. A second set of models were built and run using this input (analytical), and the models and results were again taken to the expert groups for comment (communicative). Final revisions were made, the models run (analytical), and the results presented to various audiences (communicative).

Table 29. AREMP Case Analytical-Deliberative Interactions

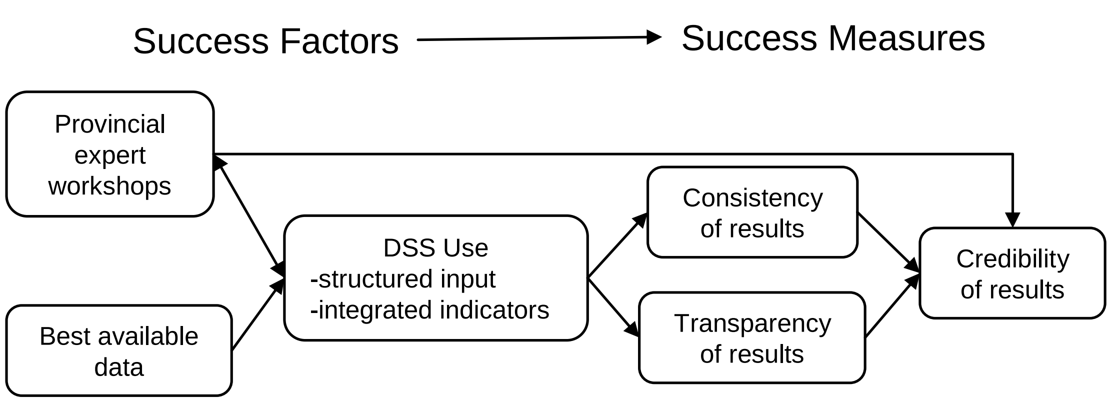
Outline of Activities	*DSS Uses*
▪ interagency science team outlines monitoring process, including use of EMDS tool	▪ helps get agreement on process to use (communicative)
▪ staff uses literature to draft and pilot test EMDS-based evaluation	▪ DSS as calculation mechanism (analytical)
▪ regional expert workshops convened to create models	▪ DSS provides structure for group input (communicative)
▪ data assembled, models built and run	▪ DSS as calculation mechanism (analytical)
▪ results reviewed in 2nd round of expert workshops	▪ GIS used as data visualization tool ▪ DSS provides structure for group input (communicative)
▪ models and data refined and models rerun	▪ DSS as calculation mechanism (analytical)
▪ results presented in conference and as published report	▪ DSS as visualization tool (communicative)

Conclusions

Figure 7 attempts to capture some of the key relationships between success factors and measures in the case. Interestingly, the participants did not mention “use in decision making” as a measure of success. Instead they focused simply on the credibility of the assessment. The DSS was used in a knowledge-poor environment, where statistical relationships between ecosystem attributes and fish responses have not been well established, especially considering the range of biophysical conditions across the area of the Northwest Forest Plan. The use of expert opinion has been the standard method to bridge this information gap, and the use of provincial expert teams in building the AREMP models appeared to be a key success factor (related to participation). Expert opinion often suffers from a lack of consistency and transparency, and the AREMP architects saw how EMDS could provide these analytical aspects. Fundamentally, an analytical DSS was used to focus and enhance the credibility of a social deliberation process.

Less obvious from the outset was the DSS role in structuring the input of the expert groups (a mediating function). Previous watershed evaluation frameworks often examined individual indicators one at a time using sharp thresholds, and if any one indicator failed the test the overall watershed condition might be considered poor. The DSS provided new possibilities, where indicators could be evaluated on gradients and related in compensatory or non-compensatory ways in a hierarchical structure. Although it was a more complex system, interviewees did not see any problems in understanding it and thought that the structuring it provided helped the groups come to consensus. The theory on social deliberation would suggest that the iterative, two-way communication between the modelers and experts also contributed to the effort's success.

Figure 7. AREMP Case Key Relationships between Success Factors and Measures



CHAPTER 9 – CASE STUDY : WASHINGTON STATE WATER TYPING MODEL

Sources

This case study is based upon interviews with four scientists from different stakeholder groups on the Cooperative Monitoring, Evaluation, and Research Committee. These individuals were closely involved with the modeling process and its presentation to policy makers and the public, as well as a review of public notes from the Washington Forest Practices Board (2001-2005) and Cooperative Monitoring, Evaluation and Research Committee (2001-2005), and other related documents (see references cited). A draft of the case study was circulated to the interviewees, and comments were received from two informants and incorporated into the final version.

Case Description

Background

"Water typing" in this case refers to the process by which segments of streams are assigned to different levels of state forest management regulation. The principal characteristic used has been whether the segment provides habitat for fish species, with wider reduced-harvest zones ("riparian management areas") required for fish-bearing streams. The use of water typing in Washington began with state regulations adopted in 1976. In 1988 the rules were updated based on the Timber Fish Wildlife ("TFW") agreement, a stakeholder driven negotiation process. In 1996, stakeholders convened another major process to agree on further state rules needed to address tightening federal regulations, including fish species being added to the Endangered Species List and water quality problems identified under the Clean Water Act (WDNR 2000).

At that time, new data surfaced which showed that the existing water typing system was up to 70% inaccurate, mainly in underestimating the actual extent of fish presence (Conrad et al. 2003). In response the Forest Practices Board passed an interim rule. Two of the interviewees mentioned how this interim rule shifted the burden of proof:

> (1) The biggest thing that happened with the interim rule is that it shifted the burden of proof from the environment to the landowner, to essentially prove absence [of fish] regardless of what the map said.

The interim rule stated that streams were assumed to be fish-bearing if they were greater than two feet wide with less than a 20% slope, criteria which greatly expanded the earlier habitat estimates. Throughout this time, parties disagreeing with the classifications could test streams for fish using electrofishing techniques, but at their own expense, and, since electrofishing has the potential to harm fish, it had become more difficult to get the required permits.

Problem Framing

Policy makers found themselves in a difficult situation: one with great uncertainty about fish distributions and high stakes involved with either under- or over-protecting streams. On top of this, the tool used for determining fish distributions (electrofishing) was itself seen as a threat that had to be eliminated. One interviewee described how the scientists involved saw an opportunity to help:

> (2) At the time of the negotiations a group of scientists came together and said 'we can develop a model for you that will be better balanced in terms of errors, over-estimation and under-estimation errors.' [The TFW] Policy [Committee] said 'great, we will proceed with the negotiations under the assumption that, as soon as we get done with the negotiations, we will develop a habitat-based model for predicting the distribution of fish.'

A modeling approach was seen as the best hope, since there were no other alternatives proposed that would result in improved maps, shared risk between public resources and landowner impacts, and regulatory certainty. An ad hoc water typing committee was established under the Forest Practices Board and two technical working groups were formed. One group, dubbed the "tweakers" looked at improvements based on the current electrofishing data, while the other, called "geomorphs" investigated methods based on geomorphic (stream channel) measurements.

Both groups came up with models based on geomorphic indicators. The tweakers model made a better link to existing fish data, which made it more convincing to the stakeholders, especially landowners who desired proof that economic sacrifices would directly contribute to fish recovery. It was tested on a basin that had been completely surveyed using electrofishing, and the model was found to have considerably less error than the previous maps.

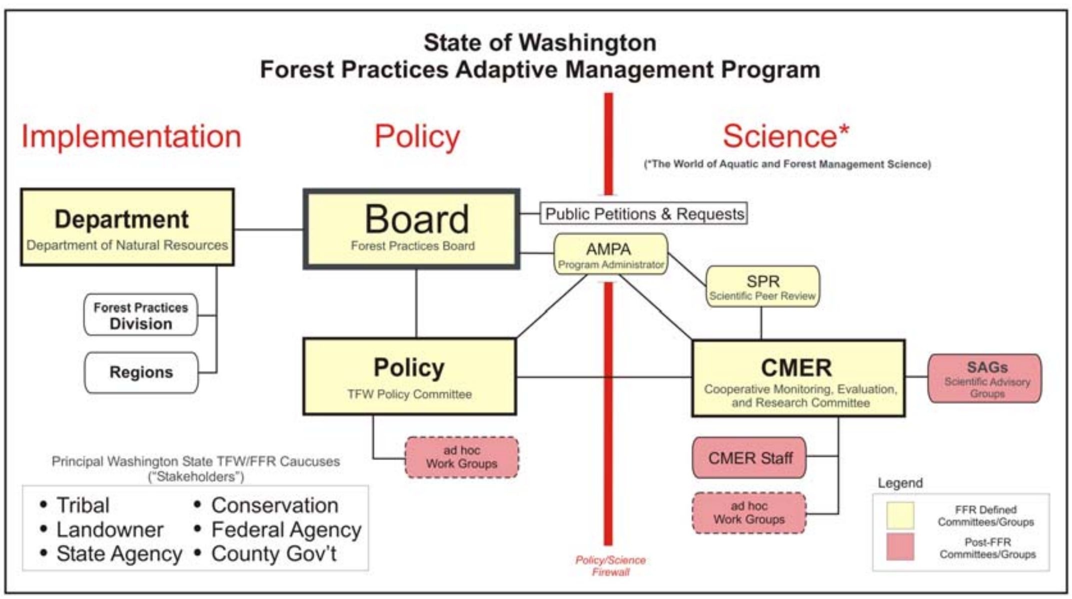
> (3) The information that we brought forward from the water typing committee on the fish habitat model got the attention of the negotiators, met their desire to get rid of electrofishing as a tool for stream typing. It was agreed to, during those negotiations, that this would be the preferred approach to stream typing from that point forward. It was unclear from within the negotiations exactly what the performance targets of this tool had to be. It was expected that a new model would have to be developed with data from a wide range of different stakeholders, and then tested across western Washington before being adopted.

Environmental groups dropped out of the negotiations in 1998. This action did not seem primarily due to water typing, since that methodology was still in development, but rather more related to the riparian rules that would apply to streams once they were typed (e.g. buffer widths; McClure 2001). This second major round of TFW negotiations wrapped up in 1999, and summarized the understandings in what is called the "Forests and Fish Report". The state forest practice rules were subsequently revised based on these recommendations. The rules stated (and still state) that stream types will be based on a "multi-parameter, field verified geographic information system (GIS) logistic regression model…using geomorphic parameters." The burden of proof is to be balanced, "the demarcation of fish and nonfish habitat waters shall be equally likely to over and underestimate the presence of fish habitat," and a level of accuracy established, "the modeling process shall be designed to achieve a level of statistical accuracy of 95% in separating fish habitat streams and nonfish habitat streams." However, the rules also state that until this model is ready, the previous interim rule is to remain in effect (WAC-222-16-030). The modeling team was further encouraged to implement a model quickly using existing data because of "concerns about impacts to fish from continued electro-fishing surveys and possible 'take' of ESA listed species" (Conrad et al. 2003 p. 7).

Problem Analysis

Further development of the model has been led by the In-stream Scientific Advisory Group (ISAG) under the Cooperative Monitoring, Evaluation, and Research Committee (CMER). CMER and its subcommittees were established by the TFW process to provide scientific oversight for the adaptive management program, and it reports to both the Forests and Fish Policy Group (the successor to the TFW Policy Committee) and the Forest Practices Board (FPB or the Board (see Figure 8).

Figure 8. WWT Case Organizational Environment



Source: Washington State Forest Practice Manual Chapter 22. ©2005 by A. Pleus. Reproduced with permission.

Work on the official model began in 2000 with acquiring and reviewing available datasets for western Washington (where substantial electrofishing data were available) and consideration of a data collection design for eastern Washington (where few data were available). Since a 'proof-of-concept' model had already been demonstrated during the Forests and Fish (FF) negotiation process (Fransen et. al. 1997), CMER originally expected to be able to expand and implement full water typing models for western/eastern Washington by June 2002/2003, respectively (CMER 2001-06-05; FPB 2001-08-08). Some technical difficulties arose in late 2001, including errors in the testing dataset and, more significantly, delays in the state's transition to a new, more accurate GIS layer for streams. Since the streams in the typing model were generated using a different system than the state's GIS layer, a method was needed to translate one to the other. The delivery date was revised to June 2003 (FPB 2001-11-14).

On the policy side, the FF stakeholders could not come to consensus on whether electrofishing to determine fish presence was allowed under the interim rule (FPB 2001-03-09). On a narrowly split vote, the Board clarified that electrofishing could be used while the conservative interim rule remained in effect, but the belief was that electrofishing would be phased out once the typing model was operational. Some early political opposition was voiced by the Washington Farm Forestry Association, representing small landowners. They testified to the FPB three times in 2002 that the electrofishing option should not be eliminated because they did not believe the model could accurately reflect the lower elevation, flatter lands owned by their constituents, since most of the model data had been collected on mostly higher elevation industry, state and tribal lands (FPB 2002-02-12, 2002-05-08, 2002-06-19).

The technical team (ISAG) spent 2002-2003 collating the available data and developing a model. They also made plans for collecting broader samples of data to develop a model for eastern Washington and to validate the western model. In September 2003 the western model was completed (Conrad et al. 2003). The Washington Department of Natural Resources (WDNR) transferred the results to their stream layer to create a draft western water type map. The Board chair urged a rapid implementation of the map to avoid another season of electrofishing, but one of the more environmentally-oriented Board members said he could not support the model use because, without the broader validation, there was no way to tell if it met the 95% accuracy level specified in the regulations (FPB 2003-12-02).

Problem Resolution

The first decision on whether to switch from the interim rule to the model was made in early 2004. The Board took a field trip to examine water typing issues on the ground, and at their subsequent meeting, agency staffers recommended delaying implementation of the new, model-based maps another year. They had reviewed the maps and process with stakeholders and decided that the maps were not accurate enough for all areas, and that it would be confusing to the public to release them now, only to revise them in a year, when the broader validation data were incorporated. Concerns had also been raised that the model should not override existing electrofishing survey data, so the delay would allow these data to be incorporated into the final map. The Board concurred on delaying the release of the draft maps until July and the target implementation date to March 2005 (FPB 2004-02-10).

An updated map was released for public review in July 2004, and the water typing manager at the Department of Natural Resources (WDNR) worked with communications specialists from the stakeholder groups to devise a communications plan. The new data were integrated into the Forest Practices Application and Review System interactive mapping website (itself an impressive forest information system worth review; see FPARS in References) and provisions made for requesting hardcopy maps. The manager attended and made presentations at a number of regional stakeholder meetings, and instituted an informal e-mail update, which is sent to stakeholder representatives and regional WDNR staff, and then forwarded by them, in "snowball" fashion, to their contacts.

The public feedback received was chiefly about over-estimation of habitat in certain circumstances and the perceived lack of mechanisms for landowners to correct these mistakes with their local survey data. Testimony from industry, environmental, and small landowner groups at a special February 2, 2005 Board session was almost unanimous against implementing the model. The groups were concerned about the accuracy of the model (especially in the northwestern area), losing the right to electrofish, and increasing the rule complexity above the interim rule's simple guidelines (FPB 2005-02-02).

WDNR presented a number of options for moving forward at the February 2, 2005 session. The options included implementing the model-based map as regulation in 2005, continuing with the interim rule, or a "hybrid" alternative. The hybrid consisted of using the new, more accurate streams layer, adding the modeling results, but then overwriting these results with those of electrofishing surveys where they are available. The modeled results would only be informational though, with the interim rule remaining as the legal standard. Public testimony was overwhelmingly in favor of the hybrid option, and the FPB backed its implementation at their next meeting (FPB 2005-02-16). In April, the FF Policy Group decided to delay the field validation study for a year because contracting issues and a fear that a drought year could invalidate the results. This was reported to the Board at their May meeting (FPB 2005-05-11).

The technical specialists working with CMER continue to investigate aspects of the model and look for other relevant sources of information, but even they appear to be questioning whether additional testing of the model will have any influence on its acceptance:

> (4) McDonald said that it was apparent within the ISAG group there is growing support to ask two key questions: how will the model be used and if the map will not be rule, then why is the model being evaluated. (CMER 2005-10-25)

A debate continues over the definition of habitat and to what extent this differs from fish presence.

> (5) In fact we're working on the protocol to define fish habitat. I think that is one of the biggest problems we did have, we don't have a biological definition for fish habitat. We have a legal definition for

> fish habitat, but it doesn't help us when we are out in the field and fish biologists have to identify habitat on a consistent basis. Take 10 biologists out in the field to define fish habitat and you'll get 10 different locations of where the end of fish habitat is, even though they went to the same schools.

Because the interim rule remains in place, electrofishing is still frequently used. One interviewee identified this policy trade-off as the core issue:

> (6) [landowners] are still out there electro-fishing virtually every stream. The landowners are definitely finding that it's to their advantage to use the electro-fishing opportunity because it will bring the presumed fish streams way downstream from where the default criteria would set them.
>
> (7) It is not a technical question to decide how that will be allocated, it is a policy decision on how much shocking is tolerable versus how much error can they live with. Until that gets resolved it is pretty difficult for the technical people to come to consensus on any use of the model.

Problem Evaluation

Two of the interviewees thought that one of the key benefits of the modeling approach is that it allowed the original Forests and Fish negotiations to move on. As one interviewee described it:

> (8) Without them [models] I fear we would have been absolutely deadlocked in minutia that we would never have been able to get out of. So in that sense, we often called it the parking lot. Items went in to the parking lot that we could get our arms around using models, so in that regard I think it was critical to help get us through a very tough and complex negotiation.

All of the interviewees identified one of the main problems with model implementation as defining and meeting the 95% accuracy level called for in the regulations. The rationale for 95% (instead of simple improvement on the previous and interim rules) seems to be that all the stakeholders are quite intolerant of modeling error given the high stakes and the availability of a more certain alternative (electrofishing).

(9) Initial discussions to determine what 95% accuracy meant produced four different perspectives, and the scientists have presented a fifth interpretation…the meaning of 95% remains unidentified. (FPB 2005-05-11)

(10) …many of the policymakers that sit on the board and so forth are stuck on this 5% [error rate], and we've had a very difficult time undoing what that meant to them and trying to retrain them on how to think about the model outputs. But again, I think if we hadn't come up with 5%, I'm not sure we'd be talking about the success of the Forests and Fish program right now. Because for them it was like 'Okay, you guys are going to develop a model and it's going to be a darn good one, so let's move on to next issue.'

(11) …people are recognizing that a little electroshocking is better than accepting this error.

Three of the interviewees commented on the different view of the modeling process from the policy arena and how the uncertainties in the scientific modeling approach led to difficulties in interpreting and using model results:

(12) Policy has this conception that you just ask a question of GIS and it spits out the answer.

(13) I think it's [lack of understanding] a tremendous problem. I think that a great deal of the problems in getting consensus in the use of the model is in a lack of understanding of what it is, a fear of the unknown…And policy people get an earful from a variety of people with different agendas and don't know who to believe, they get conflicting information. It is all kind of resulted in a lack of movement in any direction for the last several years.

(14) I think what we have struggled with a little bit is not so much that it is complex, [rather] that for policymakers it is difficult to understand some of the trade-offs with modeling. Getting them on the same page as the scientists has been a little bit difficult to do. That sort of backs up what I was telling you about how do they measure accuracy, how do you make them understand what the model output means and whether it's good enough to really answer the question.

Three of the interviewees pointed to the coarseness of the data as the underlying problem; its resolution was simply not detailed enough to map streams accurately and identify critical habitat attributes in some landscapes. The interviewees seem to believe that the modeling approach has merit and could reach the 95% accuracy threshold given more accurate data:

> (15) the Forests and Fish model we didn't think was very complex, at least conceptually. As it turns out, almost without fail, there is way more complexity than we had ever envisioned…we've come to realize that the model is not as good as we had hoped. It is not that it is a bad modeling approach, it's because we're using very coarse scale habitat descriptors, like DEMs [digital elevation models] and so forth, and because of that the errors are larger than we had hoped for.

> (16) the 10m DEM is probably the biggest limitation to that model. Had they used LIDAR or similar technology, it would have done a much better job. The 10m DEM just does not operate at a fine enough resolution to pick up some of these channel features that either proved to be or didn't prove to be blockages to fish habitat.

> (17) If we had finer resolution and a more complete hydrography data layer, I think we probably could have reached the vision of 95% accuracy in the model. So how good the information you have in the system is very critical.

Three of the interviewees also noted that some experts had voiced accuracy concerns at the time the modeling solution was being considered, but that these issues had not been investigated then because of the push to finish the negotiations.

> (18) What you may hear is that in 1999 when they developed this, it was a hurry up deal. Someone laid this as an option on the table, and it sounded so favorable that they latched onto it and said let's just do this so we can move on to other issues. Probably should have done a little bit more evaluation and listening to other folks at the beginning. I've heard that there were some GIS people that pushed hard not to accept this decision to use the model...

> (19) So I hope it changes people's perceptions about when you develop a model of any type, you need to think ahead and consult with people that have done the type of work at the model is supposed to replace. In this case it would be the people out typing streams. That is one thing they failed to do. Had they gone out or even sent a questionnaire to people who had been stream typing for years, I hope they would have given it a second thought. Because of when you talk to people who do that, tribes or industry biologists, in my mind they all come down to the same thing you can't substitute on the groundwork with a model of this type.

On the positive side, even though the technical details of the model have kept it from being applied as envisioned, one of the interviewees saw the explicit nature of the model as a benefit rather than a burden:

> (20) Models make a lot of our notions, thoughts and ideas much more explicit. Models require specific inputs and so forth, and I think it has helped structure our thinking a lot. One of the things that happens in these negotiations, where you have all levels of expertise, is that people bring their preconceptions, their biases to these forums. I think in the process of having to be explicit about models, we've been able to expose those and get very explicit about what it is we are all after. To me it has been the thing that has made it easier to communicate among different levels of training and different objectives and value sets. To me it is one of the most important things that we can do…now, four years later, we are sort of struggling over some of the intent of the agreement. I don't think models have hurt us in that regard at all. In fact, I think we have struggled with some of the intent of those, but it wasn't because we were explicit, it was because we weren't explicit enough or we didn't have a common enough understanding among the policy makers and scientists.

One of the interviewees also saw value in the process as a learning experience, and one which had increased mutual understanding between different scientists:

> (21) In that sense, even though the model is not going to be applied on the landscape as we originally envisioned, it has been an incredible learning process. This is one of those circumstances where, four years after the agreement was signed, agency biologists are in perfect agreement with industry biologists about the applicability of this model.

Finally, one of the interviewees commented on how the model still might be used, just in a more limited scope:

> (22) So the evolving use of this model, I think, is to identify areas where it will work well enough that you don't need to electro-fishing and walk away from those thereby reducing electro-fishing by some amount. Then target electro-fishing efforts on areas where the model is less reliable.

Summary of Key Points

- Agreeing to a scientific modeling procedure enabled a contentious policy process to move ahead
- Stakeholders on all sides required a high degree of accuracy in modeling results
- Landscape variability made it impossible to achieve a high level of accuracy given the limited resolution of the data
- The original shared desire to reduce electrofishing risk weakened, reducing a key rational for the modeling process and tolerance for modeling uncertainties
- The modeling effort led to improving some of the underlying data (stream network), which is already in regulatory use

Theoretical Analysis

The following sections analyze the case information using the four-part framework presented in Table 15.

Part 1. Participant Definitions of Success and Contributing Factors

Table 30 below summarizes the success measures and factors contributing to success identified from the case information.

Table 30. WWT Case Participant-defined Success Measures and Factors

	Analytical	*Social*
Success Measures	- consistency with electrofishing data - regulatory decision making use + led to improvement of streams data	+ helped move negotiations forward + increased mutual understanding among scientists - acceptance by stakeholders
Success Factors	- insufficient accuracy of base terrain data - electrofishing data used for model parameterization did not reflect full variability of ecological conditions	- stakeholder intolerance of modeling error - increasing acceptance of electrofishing as an alternative

Key: "+" = positive factor; '-' = negative factor; '▪' = undetermined effect (factor in parentheses indicates identified by researcher, not directly mentioned by participants)

Part 2. Assessment of Predefined Analytical and Social Factors

Analytical Factors

The following sections analyze the case information using the framework of the three social/interpretive factors presented in Table 13.

System Quality

None of the case study materials mentioned problems with ease of use, functionality or reliability of the software used. A temporary problem occurred with the integration of the model with the new hydrological GIS layer, but this appears to have been solved. The major system quality problem mentioned involved the underlying data. The 10-meter resolution of the digital elevation model used to define the input variables was not sufficient to accurately model important stream characteristics. In addition, the westside model parameters were developed from existing electrofishing datasets, which were concentrated in certain geographic areas and turned out not to reflect the full ecological variability of the region.

Information Quality

The limited dataset led to problems with the accuracy and consistency (across the various regions) of the WWT information products, and these factors appeared to be the main impediment to implementing the model results. Early on decision makers set a 95% accuracy standard, and results below this standard have not been considered adequate for decision making. Although there is still debate on how to measure this standard, there seems to be consensus in the science group that the current model cannot meet it.

Landowners were particularly concerned with the integration of their local data. Once the draft modeled map was shown to the public, landowners insisted that local electrofishing data (where available) be used to overwrite the model predictions. Small landowners also complained that stream changes they submitted on forest practices applications were not reflected in the WDNR maps. It appears this disconnect was largely due to the fact that the WDNR, for administrative clarity, uses separate forms for forest practice applications and water typing change requests (landowners were submitting the former but not the latter).

Service Quality / Modeling Capacity

The technical team (ISAG) appeared to have all the technical capacity they needed to run the model and had funding for contractors to help with the process. On a few occasions, the Forest Practices Board asked whether WDNR staff had the training needed to implement the model, and agency staffers affirmed that they did.

Table 31. WWT Case Summary of Analytical Factors

System Quality
- insufficient accuracy of base terrain data
- electrofishing data used for model parameterization did not reflect full variability of ecological conditions
Information Quality
- predictive quality of the model did not meet 95% accuracy standard set in policy
+ integration of locally-generated information important to stakeholders
Service Quality / Modeling Capacity
+ (specialist group (ISAG) had high capacity and ability to hire contractors)
+ WDNR field staff had capacity to implement model results

Key: "+" = positive factor; '-' = negative factor; '▪' = undetermined effect (factor in parentheses indicates identified by researcher, not directly mentioned by participants)

Social Factors

The following sections analyze the case information using the framework of the four social/interpretive factors presented in Table 14.

Participation

Participation in the WWT modeling process has been framed by the broader Forests and Fish process. This process is a much more formalized structure of participatory forest regulation than seen in most states; the participants are well defined and organized into broad caucuses. Participation related to the WWT occurred primarily in three forums: the technical working groups and CMER, the TFW Policy Group, and the Forest Practices Board.

The first effect the WWT modeling effort had on participation was to shift the locus of solution development from the FF Policy Group to the technical specialist group (CMER). This enabled the Policy Group to avoid getting mired in the minutiae of water typing, but it also meant that the pressure was off of them for continuing to refine the goals and standards for the model. Ultimately the modelers appear to have come back to a policy question (accepting reduced model accuracy or continuing extensive electrofishing), and have had difficulty in re-engaging the policy groups in this discussion. Part of the difficulty appears due to the technical complexity of the solution, another consequence of passing the problem to the technical group.

Small landowners were the only caucus without a clear representative on the technical committees. The ground rules of these committees included adhering to scientific standards and avoiding advocacy based on caucus affiliation; nevertheless, participant affiliations can have effects on how problems are framed and more generally on trust. The most vocal testimony against the model at the Forest Practices Board came from the small landowner representatives.

Participation beyond the three forums mentioned above did not occur until rather late in the process when the WDNR took the draft maps out for public review in July of 2004. Broader public involvement did not appear necessary or practical earlier for a number of reasons: 1) The FF representative structure had been designated as the main stakeholder input process; and 2) it is questionable whether the public could give practical feedback until a draft product was available. The broader input underscored, but did not appear fundamentally different from, the resistance to model implementation already expressed by the FF stakeholder representatives.

Communication

Communication within the technical specialist groups appeared to be regular and two-way: they held monthly meetings and issues related to the WWT model were frequently discussed. The CMER meeting notes revealed that the group gave considerable attention to building their communications protocols, since they were a new type of quasi-governmental entity with a diverse membership and a difficult role at the science/policy interface.

Communication of the modeling process with the policy groups was less regular and appeared to be driven by the requests of these groups to be updated. In the Forest Practices Board the WWT model was only discussed 3 times in the 20 meetings from

January 2001 to October 2003 (when the initial model was finished), but since that time has come up in 7 of the 10 last meetings. Communication has been two-way in the sense that scientists make presentations to the Board, and Board members ask the staff and scientists questions and voice concerns and opinions. However, it appears as if the scientists have been less able to get feedback on the policy issues confronting them in the modeling process (such as quote 7). No public documentation was available for analyzing FF Policy Group communication, but an extract from the CMER notes suggests a similar lack of feedback:

> (23) CMER presented information to the Policy committee regarding PIPs [Perennial stream Initiation Points] and watertyping issues. The policy committee was not ready to make a decision and suggested that we need workshops to address these issues. There is not sufficient time at the policy meetings to gain in-depth understanding and make decisions. (CMER 2002-04-18 p. 3)

As mentioned above, communication with the broader public (outside the core FF structures) only occurred after the release of the initial modeled map. WDNR did provide for a variety of forums, however, and the report to the FPB on feedback received demonstrated the two-way nature of the outreach.

Translation

One of the interviewees discussed how the explicitness inherent in models "made it easier to communicate among different levels of training and different objectives and value sets." At that point he appeared to be referring to the science committees, where he later remarked a common understanding had been achieved. Three of the interviewees commented on translation difficulties between the scientists and policy makers, especially in the area of thinking about model accuracy [9, 10, 12, 13, 14].

Mediation

The first and most obvious mediating effect of the model was to allow the last round of Forests and Fish negotiations to move on and avoid getting bogged down in the details of water typing [8]. The promise of this model seemed to make continuation of the interim rule acceptable to all parties. It changed the rules of conduct in the negotiation from political (lobbying based on values) to scientific. Unfortunately, the scientific process was not able to meet the established criterion for decision making (95% accuracy), and the policy makers have not seemed willing to revise this criterion [10]. It appears that through delaying a final policy decision, the model has actually had a mediating effect in the sense that all parties now seem more willing to accept the interim rule and electrofishing combination.

As mentioned above, the model does appear to have been effective in mediating different points of view among the scientists [21], but it is unclear how this understanding might affect the regulatory decision-making process.

Table 32. WWT Case Summary of Social Factors

Participation

- ▪ (formal, representative structure established by the FF policy process)
- ▪ (modeling approach shifted locus of participation from policy to science group)
- \- (lack of small landowners representation on the technical committee may have reduced their trust in the solution)
- \- difficulties re-engaging policy groups

Communication

- \+ (regular, two-way communication in the technical groups during model development)
- \- (little communication with policy groups during model building)
- \- more communication after model completed, but little feedback on policy issues
- ▪ two-way communication with the broader public in a variety of venues after initial model results available

Translation

- \+ explicitness of model facilitated coming to mutual understanding among scientists
- \- complexity of model (especially measures of error) was difficult for policy groups to understand, especially given their time constraints

Mediation

- \+ modeling approach enabled the FF policy process to move on
- ▪ (model shifted rules for negotiation from political to scientific)
- ▪ (model caused a policy delay during which actors became more accepting of interim solution)

Other

- \- stakeholder intolerance of modeling error
- \- increasing acceptance of electrofishing as an alternative

Key: "+" = positive factor; '-' = negative factor; '▪' = undetermined effect (factor in parentheses indicates identified by researcher, not directly mentioned by participants)

Other Factors

Although the case description included a number of aspects relating to the four social factors from the theoretical framework, the two principle social factors noted above in Table 30 did not fit well into these structures: “increasing acceptance of electrofishing as an alternative” and “stakeholder intolerance of modeling error.” These factors are discussed further in the conclusions below.

Part 3. Analytical - Deliberative Interactions

The WWT case exhibits a quite structured approach to analytical-social interactions, building on the TFW experience and considerable thought about organization for adaptive management (Figure 8). Even with this structure and experience, the task proved challenging.

At the problem framing stage there appeared to be little feedback between the analytical and deliberative aspects of decision making. The modeling solution appears to have been adopted without much debate due to political pressure to conclude the negotiations (18, 19). Representation was less than complete, the Conservation Caucus had withdrawn from the process, and skepticism from some technical specialists did not receive much consideration. Nor did the 95% accuracy requirement in the rule appear to have been deliberated between the policymakers and specialists [3].

From the adoption of the Forests and Fish regulations (7/2001) until FPB’s decision to delay deployment (2/2004), referred to here as the problem analysis stage, there was regular communication about the model in the technical groups (ISAG and CMER) but only sporadic interactions with the FPB. Little feedback was given by the FPB in 2001-2003, except that one small landowner representative testified three times in 2001 about the inappropriateness of the model for low elevation areas. The only information on feedback from the FF Policy Group suggests it was similarly light [23].

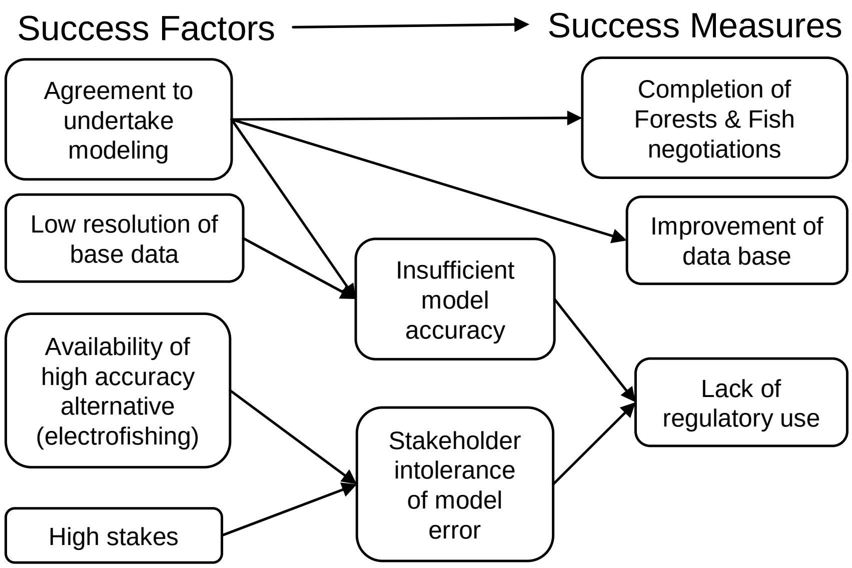
Deliberation became the dominant activity once the model was completed, transferred to the WDNR hydrology maps, and presented to stakeholders in late 2003 / early 2004. The Board held a field tour followed by a meeting devoted entirely to water typing in February 2004, where they endorsed stakeholder feedback that called for overriding modeled values where electrofishing results were available and delaying release of the map until this was done (to prevent possible confusion from multiple drafts) (FPB 2004-02-11). WDNR performed this analytical task and then took the resulting map out for public review in mid-late 2004. This public deliberation yielded feedback against implementing the model as the rule. Based on this feedback, WDNR was able to craft a hybrid solution, which took advantage of the improved GIS maps but retained the interim rule. This hybrid was endorsed by all parties and accepted by the Board when they again focused on water typing in February 2005. As of the end of 2005, analysis related to the model now continues, but the plan for future deliberative actions is unclear.

Conclusions

On the face of it, an instrumental explanation appears to describe the WWT modeling process well. The goal was spelled out in the water typing regulations, which have not changed since they were enacted in 2001. The technical group has strived to create the most accurate model possible to meet this objective. The ongoing delays in using the WWT model as a regulatory instrument are due to information quality issues; it has not been able to meet the 95% accuracy standard set in the policy.

The specific social factors reviewed (participation, communication, translation, mediation) highlighted a number of interesting aspects of the case, including the shift in participation from policymakers to scientists, and the limited communication between the two groups during model building. Although difficulties related to each of these aspects were evident, none appeared to be a major impediment to model implementation. Instead, the major challenges seemed to come more from the decision-making context and shifting perceptions of the advantages and disadvantages of the modeling approach. Figure 9 summarizes these relationships from the case description.

Figure 9. WWT Case Key Relationships between Success Factors and Measures



First, the complexity of the decision context was extremely high. On the social side, the intended purpose of the model was to directly set regulations with large, direct economic and biological consequences. There is a natural tendency in policymaking to look for certainty (Bradshaw and Borchers 2000), and this tendency was likely increased by the high stakes. On the analytical side, although the model itself was relatively straightforward, the underlying biophysical complexity was quite high—predicting fish habitat is a difficult endeavor, especially across varying landscapes. The availability of electrofishing, a more accurate if less economical method, has made the parties reluctant to accept the modeling approach. Models are abstractions of reality and as such inherently contain error; the uncertainty intolerant decision context for water typing has made it extremely difficult to implement a model-based approach.

Second, the case history seems to reveal a more subtle change in perspective on the advantages and disadvantages of the modeling approach by many of the parties involved, consistent with the interpretive emphasis on shifting goals. Minimizing the use of electrofishing was one of the key reasons for developing the modeling process, but the priority and urgency of this objective appear to have declined over the past five years. At the same time, the stakeholders' intolerance for uncertainty has remained high. The timber industry had sought a more equitable balancing of risk compared to the interim rule, and in the beginning they seemed to think the model would provide this. In the past year, though, they have continued to testify against the adoption of the model, even though it appears to balance risk better. They cite concerns about model accuracy (especially in the northwest region). Their main issue, and that of non-industrial owners as well, appears to be that the model will preclude electrofishing, which provides the surest test of fish presence and a relatively narrow definition of habitat. Non-industrial owners complain about the expense of electrofishing but seem to believe there is a chance that the state will provide the service. They also complain about the complexity of the model, which may reflect a general lack of trust of government regulation. Electrofishing is concrete and localized evidence, whereas a model appears abstract and under the control of regulators. The environmental caucus originally professed support for the model because it would reduce electrofishing impacts and was assumed to take a broader definition of habitat than current fish presence. However, their concerns over electrofishing seem to have subsided and the model's definition of habitat is not as broad as the one in force under the interim rule. They have consistently pushed for holding the model to the 95% accuracy level, presumably since it makes no sense for them to support a model which would narrow the currently enforced habitat definition.

The scientists involved see this policy trade-off between accepting model error on one hand or costs and impacts of electrofishing on the other [7], but this question does not seem to have been taken up directly in the policy forums. The state of Washington is clearly a national leader in implementing participatory and science-based forest regulation. As Figure 1 shows, they have carefully designed a firewall to minimize undue influences between the policy and science elements. However, NRC's (1996) ideal of a mutual and recursive analytical-deliberative process emphasizes the need for mechanisms to integrate science and policy deliberation. The analytical approach has not been able to provide the certainty policymakers sought, and now it appears as if scientists and policymakers are working together more closely to craft a solution using both analysis and deliberative policy decisions [23].

CHAPTER 10 – CASE STUDY : WILLAMETTE BASIN ALTERNATIVE FUTURES ANALYSIS

Sources

This case study was developed from interviews with three people closely associated with the project: the two principle investigators and an individual who was both a member of the citizen modeling group and a staff member of one of the regional organizations which provided input and used the results. This description also draws on previously published sources, including the atlas produced by the project (Hulse, Gregory and Baker 2002), and a series of papers on the experience published as an invited feature of the journal Ecological Applications in 2004 (Baker et al. 2004; Hulse et al. 2004). A draft of the case study was circulated to the interviewees; one response was received, and it simply confirmed the accuracy of the draft.

Case Description

Background

The Willamette Basin Alternative Futures Analysis (WBAFA) was designed to help diverse stakeholders understand the ecological consequences of possible societal decisions related to changes in human populations and ecosystems in the Pacific Northwest and to develop transferable tools to support management of ecosystems at the scale of a large river basin. WBAFA's origins trace back to the Northwest Forest Plan process in 1993-4. The Clinton administration directed the federal agencies to devote some portion of their activities in the Northwest to look at ecosystem management issues. At the same time EPA researchers were also being encouraged to work more closely with universities and local decision makers. The EPA's Western Ecology Division issued a Request for Assistance (proposals) to conduct research supporting community-based decision making in western Oregon and Washington (Baker et al. 1995). A proposal from the University of Oregon, Oregon State, and the University of Washington was accepted, and created what became known as the

Pacific Northwest Ecosystem Research Consortium (PNW-ERC) comprised of 34 scientists from 10 institutions. The project was budgeted at five million dollars over a five year period.

Problem Framing

An initial decision, which appears to have had an important positive impact, was that the EPA asked the governors' offices in Oregon and Washington for recommendations on what geographic areas to study. Oregon recommended the Willamette Valley, which put the project on the same scale as two existing policy efforts: the Willamette Valley Livability Forum (WVLF) and the Willamette Restoration Initiative (WRI). These groups became natural policy "clients" for the modeling effort.

Project scientists made the next framing decisions, including the scenarios to model and the indicators ("endpoints") to use. Because of the time intensive nature of participation envisioned, a minimal number of scenarios were chosen to "bracket" the possible futures (Hulse et al. 2004 p.321). As one interviewee elaborated:

> (1) One of the things that I've learned from having done this kind of work for a number of years, is that there's some real advantages to…being clear from the beginning (and we were clear from the beginning) that what we're not trying to do is predict the future. We were not trying to make a map that says, 'This is the way the basin's going be in 2050.' What we were trying to do, is bracket a range of plausible options that we would be comfortable with at the end of this project."

Scientists also chose the indicators (or "endpoints") to measure. Four indicator groups (river condition, stream conditions, terrestrial wildlife, and water availability and use) were chosen. In reflecting on the project, the scientists regret the lack of stakeholder input on endpoint selection and the under-representation of social and economic endpoints (Baker et al 2004 p. 322). While the four indicator groups were environmental, it could be noted that the land use/land cover maps probably provided considerable social and economic information to the participants.

Problem Analysis

The modeling effort consisted of two stages, each approximately 2.5 years long. First the ERC researchers worked to construct a base of demographic, historical and biophysical data for the basin (Hulse, Gregory and Baker 2002). Baseline information for pre-European settlement (~1850) as well as the current (~1990) landscape was assembled. One of the interviewees noted that many futuring efforts are significantly quicker and less expensive because they decide to work with only the data that are already available. However, this project decided to make a greater investment in developing its information base. Researchers believed that this legacy of information would boost the community's capacity for decision making.

The second phase of the modeling effort involved engaging community representatives with researchers to model three alternative scenarios. A base scenario reflected current trends, while two other scenarios were meant to bracket the plausible range of futures by presenting more development- and conservation-oriented visions. The project management team developed a communication strategy with four levels (Hulse et al. 2004 p. 328):

1. Technical Expert Groups
2. Possible Futures Working Group (PFWG)
3. Willamette Restoration Initiative and Willamette Valley Livability Forum
4. Entire Willamette basin population

The technical expert groups formed around the areas of transportation, agriculture, forestry, urban development, water use, and biodiversity and were largely comprised of scientists working on the project. Communication was ad hoc, dependent on the individuals involved.

The project team also selected 20 citizens for the so-called Possible Futures Working Group (PFWG), which helped define model assumptions. Here is how one interviewee described the participant selection process:

> (2) We chose them to really be representative of the citizenry of their basin, but with a particular eye toward their expertise. We wanted

> people who were knowledgeable about the major land use and cover types of the basin-urban, rural residential, agricultural, forestry. We also wanted people who had not only deep expertise in their own areas, but had a track record of working with people from other areas.

Over the second 2.5 years of the project, the PFWG met approximately monthly with a facilitator from the project leadership, and occasionally other technical representatives, to refine the assumptions driving scenario development. These assumptions were then fed to the technical groups, who incorporated them into their dynamic models and returned output to the PFWG for review. GIS-generated maps were used as the core medium for information exchange:

> (3) The analytical framework for the Possible Futures Working Group really had to do with this iterative “to-ing and fro-ing” where they would define assumptions, we would map them, we’d bring the maps back and they would point out all the ways that what we had done really didn’t quite capture their intentions and then we would sort of iterate our way through that for each scenario for each of the major land-use cover types.

The 19-member PFWG included 11 participants from governmental organizations (3 federal, 6 state and 2 local), 3 from the governor-appointed task forces (WVLF and WRI), 3 from environmental NGOs, and 2 from private development/real estate firms. None of the PFWG members were from private farm or forestry interests, although a few such representatives did serve on “Technical Support Groups” to the PFWG. The Oregon Forest Industries Council, a trade organization, chose not to participate after the researchers declined to purchase and use their more detailed forest data. Some interviewees believed this distancing was more due to past conflicts with PNW-ERC members around the spotted owl / timber debate leading up to the federal Northwest Forest Plan.

One interviewee described the PFWG minimum consensus level for decisions at about 80 percent; another attributed much of the conflict resolution to the facilitator’s skills:

> (4) He had a way of working with people and suggesting that, … "well I see your point but it sounds like most people think this and that's not an unreasonable way to go so why don't we for purposes of our exercise do it this way." He had… a quiet authority. He had the respect of the group and so I think that kind of leadership and facilitation minimized the amount of time in butting heads.

The third level in the WBAFA communication strategy involved communicating with the two governor-appointed task forces, the Willamette Valley Livability Forum (WVLF) and the Willamette Restoration Initiative (WRI). Consultation with the Oregon Governor's Office at project initiation had established these groups as natural clients for the modeling effort. The interaction was on the line between what might be considered modeling participation and outreach. Project representatives presented progress reports to the groups on approximately a quarterly basis and solicited feedback. The WVLF actually conducted an electronic voting exercise on a draft of the assumptions for the Plan Trend scenario, which was then fed back to the PFWG. The WRI provided multiple reviews of the Conservation scenario during its development.

<u>Problem Resolution</u>

The modeling did not conclude with a specific decision, but rather with the acceptance of the three scenarios by the PFWG, after taking into account input from the regional stakeholder groups. Once the scenarios were finalized, the project shifted to a fourth level of the communication strategy, one aimed primarily at public outreach. The principle product of the project was a planning atlas (Hulse, Gregory and Baker 2002). The Atlas is a glossy, large-format, 178 page document. It is highly graphical, including over 200 figures and maps, which communicate much of the detailed data and analytical techniques used.

The project reached the most people through its partnership with the WVLF. Project findings were published as part of an eight-page newspaper insert that the WVLF placed in all the major papers in the region, reaching an estimated readership of approximately 465,000 households (WVLF 2001a). Shortly after the insert appeared, WVLF held a public forum where WBAFA results were presented along with those from several other research projects, and participants voted on priority strategies for the future (WVLF 2001b)

A grant from a local foundation enabled dissemination of information produced by the project to continue as one of the initial activities of a new Institute of National Resources, created by the state legislature in 2001 and housed at Oregon State University. The Institute's mission is to "provide Oregon leaders with ready access to current, science-based information and methods for better understanding our resource management challenges and developing solutions." (INR 2006). The WBAFA project had always maintained a website with access to their GIS datasets, and the INR project transferred this information to the OSU library permanent collection and used it to create a multi-media rich website with online mapping capabilities (http://willametteexplorer.info). One of the more high-tech pieces is an 8-minute simulated flight through the predictions of the three scenarios for an illustrative section of the valley. The OSU library is now using this Willamette Explorer as a model for creating "explorer" websites for other regions of the state (INR 2005).

The INR project participants also decided that a more accessible print publication was needed, given the cost (~$100) and technical depth of the Atlas. With the help of the local arm of a national nongovernmental organization (Defenders of Wildlife), the project raised $30,000 in additional funds to produce a 40-page, glossy, 8.5 x 11" booklet and distribute 7000 copies for free to a broad audience.

Problem Evaluation

In a series of journal articles on the project, the project team directly addresses the question of impacts and success. Baker et al. (2004 p. 320) state in their introduction that,

> (5) The most important end product of this process is development of consensus, or compromise, about desired goals and priorities, that is a shared vision for the future. The purpose of an alternative futures analysis is to facilitate this consensus-building process.

They cite production of consensus documents by the WRI and WVLF as examples of positive influence, although how and how much the WBAFA process itself contributed to these consensus documents cannot be specified. The consensus reached by their own PFWG on the scenarios is a more easily attributable example. As described above, one of the interviewees credited much of this success to the skills of the facilitator. Another factor appears to have been the understanding of and trust in the model resulting from the stakeholder participation. As one participant put it:

> (6) With each meeting, there was an increment of work and progress and accuracy with regard to the tool. For example, in terms of when what densities should be used for different scenarios. That was discussed, agreements were reached and they were implemented. The tool coming out of it, namely the comparisons between different futures, was therefore all the more useful because the people who are going to be using it, I think felt comfortable that there were reasonable assumptions behind tool development.

In turn, another interviewee commented, this understanding was facilitated by the use of explicit scenarios and maps.

> (7) The scenarios helped people think about conditions and time and things as opposed to an open-ended analysis of trajectories or trends. They can look at a map and look at conditions and see what they think about it.

Hulse et al. (2004 p. 339) also emphasizes the importance of maps in helping to focus the PFWG to come up with acceptable parameters for the models:

> (8) "Researchers presented maps that functioned as iteratively defined drafts…[which] allowed the effects of potential values and parameters and their interactions to be perceived in a tangible and spatially explicit, rather than abstract, manner."

In the discussion section of Baker et al. (2004 p. 320), they cite direct impacts on decision making as the ultimate measure of success but concede that they must settle for less direct measures:

> (9) Did our analyses help shape the Forum's vision of the basin's future or the WRI's basin-wide restoration strategy, or lead to more informed decisions by local citizens and governments? Unfortunately, we have no direct measure of our influence on such

> deliberations… Although more informed decisions are the ultimate measure of success, other indicators include: Did people listen? Were the tools or results used? Did stakeholders change their way of doing business? In each case, the answer is yes.

They cite examples of how their data were picked up and used by other groups: the WVLF and the Oregon Department of Transportation used it to evaluate alternative transportation futures and effects on traffic congestion, and 1000 friends of Oregon assessed the implications of landscape futures for infrastructure costs as well as losses of farm and forestry lands. One interviewee mentioned that a number of counties and conservation districts also approached the project about information on where to look at conservation easements and restoration opportunities. Interviewees also saw what they believed were more subtle influences of their work in other affiliated groups such as the Defenders of Wildlife, the Lane Councils of Governments, and to a lesser extent Oregon Department of Fish and Wildlife. Participation and familiarity with WBAFA's development process appeared to be the major factor influencing its further adoption. All these groups had participants involved in the WBAFA process.

One of the interviewees also mentioned the production of non-obvious results as a success measure:

> (10) "One of the critical things about our analyses is that I think that it showed we didn't know going into it what the outcome would be in terms of the future scenarios."

The example given was that non-radical (politically-plausible) behavior changes under the Conservation scenario led to an unexpectedly large rebound in biodiversity. Baker et al. (2004) also identified how the modeling process extended and reinforced some perhaps better known but often forgotten aspects of our management, such as the general concentration of conservation in uplands and neglect of lowlands, and the cumulative impacts of the frequent granting of exceptions to the existing land use regulations. At the same time, Baker et al. (2004) note that:

> (11) …by tying scenario design so tightly to what stakeholders considered plausible, the range of variation among alternative futures was fairly constrained. Stakeholders were reticent to

incorporate drastic shifts from current policies, and as a result less likely to develop innovative future visions.

In the second article of the series, Hulse et al. (2004) characterizes success in three measures. These measures are, 1) politically plausible scenarios, 2) scientifically researchable alternatives, and 3) results that increase capacity for community-based environmental planning. Interviewee statements, the general level of PFWG consensus, and use of the data by other groups indicate some political plausibility, apparently provided by the stakeholder involvement strategies. It is unclear, however, to what extent this plausibility extended to other parties, and reactions from more political bodies (mayors, legislators) would have been useful in this regard.

Capacity development is perhaps the most ambitious goal, even more so than direct effects on decision making, and also hard to measure. Hulse et al. (2004) discuss "tools, information, and skills available to citizens" as elements of capacity and cite examples of the data and tool use by others (discussed above) as evidence. The main impact they present is the passage by the state legislature of the 2001 Oregon Sustainability Act, which created a state-wide Institute of Natural Resources. This institute's mission is to supply natural resource information and analyses, and the adoption, and ongoing provision of the WBAFA data was one of their first projects. One of the interviewee's also emphasized the importance of personal capacities:

(12) "But I think more the conduit of influence is more the particular people who worked as lay and expert stakeholders on the project than are published reports of a group."

Hulse et al. (2004 p. 340) close by noting that it is not only individual abilities but also the links between people that determine community capacity,

(13) "…perhaps the least measured of the influential changes in capacity are the enduring human relationships that are part of the legacy of projects such as this."

<u>Key Points</u>

- Engaged a small, selected set of stakeholders to work with scientists to iteratively refine the analysis

- Used maps and scenarios in a facilitated group setting to translate knowledge between technical experts and stakeholders
- Had policy organizations at the same scale as the analysis, which were cultivated to become clients for the modeling results
- Used a multi-level communication strategy to share results and solicit feedback from successively larger audiences, from their core team to the general public

Theoretical Analysis

The following sections analyze the case information using the four-part framework presented in Table 15.

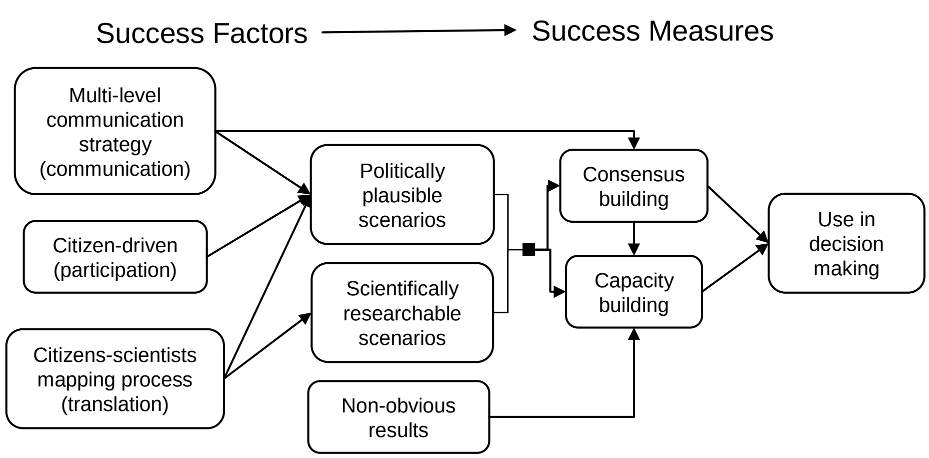
Part 1. Participant Definitions of Success and Contributing Factors

The case materials reviewed in the Problem Evaluation section above include a wide variety of success measures. Table 33 summarizes and sorts these measures into the broad categories of analytical/instrumental and social/interpretive. Figure 10 displays principle effects of the elements on each other. Both analytical and social aspects were named by participants. Table 33 also reveals the dearth of information discovered on what are the antecedents of success. The next section attempts to uncover more of these factors by applying theories from the literature.

Table 33. WBAFA Case Participant-defined Success Measures and Factors

	Analytical / Instrumental	*Social / Interpretive*
Success Measures	▪ use in decision making ▪ scientifically researchable scenarios ▪ improved data base ▪ reveals non-obvious or forgotten aspects of the issue ▪ individuals' capacities increased	▪ consensus building ▪ politically plausible scenarios capacity building ▪ use in further analyses ▪ new institutions ▪ enduring human relationships
Success Factors	▪ use of explicit scenarios	▪ multi-level communication strategy ▪ citizen-driven scenarios

Figure 10. WBAFA Case Key Relationships between Success Factors and Measures



Part 2. Assessment of Predefined Analytical and Social Factors

Analytical Factors

The following sections analyze the case information using the framework of the three social/interpretive factors presented in Table 13.

System Quality

None of the case information directly mentioned aspects of system quality as success factors. However, it is apparent that data quality was quite important to the project managers, as reflected in the high investment of time and resources in preparing the information base. ‘Ease of use’ was not a factor in the original project, since most of the researchers designed and ran their own models, and there was no plan to transfer these models directly to others. It received some attention during the building of the Willamette Explorer website, when testing revealed that the original GIS interface was too complex for most users needs.

Information Quality

Two success factors related to information quality were directly identified in the case materials. The first was the meaningfulness that the use of explicit scenarios provided [quote 7]. Second, having the scenarios be “citizen-driven” was seen as fundamental to ensuring their relevance [13]. Besides these two factors, significant investments of time and resources were also made in other activities related to information quality. The publication of the large-format, color atlas and the use of 3-D fly-throughs emphasized the visualization of information as a principle communication strategy. The detailed descriptions of the analyses in the atlas demonstrated the information quality aspect of “completeness” as well. The project also took advantage of other information dissemination opportunities generated through its work with other organizations. These included the WVLF newspaper insert and forum, and the Willamette Explorer website and a booklet produced under the follow-on grant to the Institute of Natural Resources.

Support Quality / Modeling Capacity

Support quality and modeling capacity did not appear to be important issues, again because researchers were designing and using their own models rather than trying to adopt systems designed by others.

Table 34. WBAFA Case Summary of Analytical Factors

System Quality
+ (high initial investment in generating data)
▪ (‘ease of use’ not an issue, since researchers used their own models)
Information Quality
+ use of explicit scenarios
+ having the scenarios be citizen-driven
+ (visualizations: atlas, 3-D fly-throughs)
+ (two levels of publication: detailed atlas, overview booklet)
Service Quality
▪ (external support not needed, since analysts were both authors and users of models)
Other
▪ none

Key: “+” = positive factor; ‘-‘ = negative factor; ‘▪’ = undetermined effect (factor in parentheses indicates identified by researcher, not directly mentioned by participants)

Social Factors

The following sections analyze the case information using the framework of the four social/interpretive factors presented in Table 14.

Participation

All of the documents and interviews mentioned the importance of citizen participation. As one interviewee put it,

> (14) to me, is the most important one [factor] …is having these alternative futures be citizen driven. If people are going to be interested in the work that gets produced then they have to have some reason to believe the scenarios are plausible

Participation was not “open” participation of any interested party, however, as is the case for many public planning exercises, such as for national forests. The closest participants (the PFWG) were hand-picked by the project management team for their expertise, willingness for extended engagement, and "track record of working with people from other areas."

The WVLF and WRI can be seen as a second level of participants, as they provided regular feedback to the model developers. They also were "closed", hand-picked groups (although this time by the governor), and so shared many of the same success traits of the PFWG just mentioned. The lack of institutions operating at the same scale has reduced the effectiveness of a number of ecosystem management models and assessments (Yaffee 1997; Costanza et al. 2001; Johnson, Duncan and Spies, in press). In this case, the presence of such organizations provided fertile ground for the use of WBAFA's results in policy processes.

Communication

Communication, in terms of the simple sharing of information, was not explicitly mentioned as a success factor in the interviews but was emphasized in the two journal articles. The four-tiered communication strategy is presented in Hulse et al. (2004), which focuses on the interactions with the PFWG, WRI and WVLF. Monthly meetings of project staff with the PFWG and quarterly presentations to the WRI and WVLF over at 2.5 year period show the project's commitment to iterative communication. Furthermore, communication was two-way, since feedback was regularly solicited from these groups. An electronic voting procedure was even used in one WVLF meeting to capture individuals responses to the Plan Trend scenario's assumptions.

Communication with the broader public was more one-time and one-way. The project reached its broadest audience through contributing to the publication of a newspaper insert. On the other side, they produced a detailed atlas, which would appear to appeal to and reach only a highly interested audience. When stakeholders took more responsibility for communications in the follow-on effort, they produced two more easily accessible products, the booklet and website. They did not start any major new efforts involving iterative, two-way communication, and it is difficult to conceive how such communication might be carried out with general public, beyond the existing mechanism of the WVLF.

Translation

Translation of information from scientific analysis to understandable, map-based scenarios was also seen as very important by the interviewees. For example, one participant stated about success factors:

> (15) number one: the development of scenarios and how we developed them. The scenarios helped people think about conditions and time and things as opposed to an open-ended analysis of trajectories or trends. They can look at a map and look at conditions and see what they think about it.

Star and Griesemer (1989) coined the term "boundary objects" to refer to things which help bridge conceptual boundaries between two individuals or groups. In their study of communication between museum curators and specimen collectors (hunters), maps were seen as one type of boundary object based on abstracted information. Maps appear to have played a similar role in WBAFA. They were able to capture both the information from the scientists' models and the local knowledge of the PFWG members, and to make each type of information accessible to the other group.

In turn, the PFWG could be seen as a "boundary organization," in this case mediating knowledge between scientists, managers, and the broader citizenry. According to Guston (2001), boundary organizations require opportunities to create and use boundary objects, participation from both sides, and possibly the allocation of authority from the "principle" organizations to their "agents" in the boundary organization. WBAFA provided the opportunity to create boundary objects (e.g. the scenarios), and the PFWG meetings included scientists and many (although not all) major stakeholder groups. It is unclear to what extent these participants were delegated decision-making authority by their organizations. The WRI and the WVLF could be considered secondary boundary organizations, which had less participation but still helped to further translate between the project and broader audiences.

Mediation

In this case, “consensus building” appears to be both an end in itself (a success measure), as well as a factor contributing to the other success measures of “capacity building” and “use in decision making” (see Figure 10). In their introduction, Baker et al. (2004 p. 314) describe it as a goal:

> (16) The most important end product of this process is development of consensus, or compromise, about desired goals and priorities, that is a shared vision for the future. The purpose of an alternative futures analysis is to facilitate this consensus-building process.

In their conclusion they focus instead on “more informed decisions” and use of the results in decision making. The underlying assumption appears to be that greater consensus on a policy analysis leads to more use and greater impact.

They cite four ways in which futuring helps build consensus. The first is by “helping to clarify differences of opinion by forcing stakeholders to be very explicit about their individual goals and priorities, expressed as written assumptions for a specific future scenario” (p. 314). This assumption appears to be at odds with an observation from the literature that modeling strives for explicitness while policy consensus may more often be aided by ambiguity (Greenberger et al. 1976). Conflict over specifics does not seem to have been a problem in this case, and having both specific and holistic information appears to have helped. Hulse et al. (2004) describe how PFWG members initially resisted setting riparian buffers in the conservation scenario to the level estimated as needed to meet biodiversity targets. A compromise was eventually worked out through reviewing equity between different types of land uses and discovering that there was a considerable amount of already fallow land in the riparian areas.

As quoted above, one of the interviewees noted very little enduring conflict in the PFWG, and attributed it largely to the facilitator’s skills. A second reason likely has to do with the selection of participants. Fourteen of the nineteen participants were governmental employees or appointees, with only five representing NGOs or private business. Governmental officials would likely be more oriented towards and experienced in consensus building. None of the PFWG members were directly from farming or forestry operations, which may have avoided most of the traditional conflict between these interests and the environmental NGOs. Third, neither WBAFA nor its main clients, WRI and WVLF, were decision-making organizations. They did not have the power to directly allocate resources or create regulations, only to recommend policy actions.

Other

The existence of institutions (WVLF and WRI) operating at the same scale as the analysis appears to be a success factor that does not neatly fit within any of the social categories. This was not explicitly cited in the case materials as a factor, but it appears evident from the emphasis the participants put on communicating with these two groups and the use they made of the WBAFA results.

Table 35. WBAFA Case Summary of Social Factors

Participation
- lack of stakeholder participation in endpoint selection
+ citizen-driven scenarios
+ (only consensus-oriented participants selected for participation)
Communication
+ two-way, iterative process over a long time period with 3 stakeholder groups
▪ one-time communication via newspaper insert and detailed atlas
Translation
+ used maps and scenarios to translate knowledge between technical experts and stakeholders
+ citizen-scientist working group (PFWG) as translation forum
Mediation
+ (selective core group with long-term participation)
+ model explicitness helped in consensus building
+ ability to view information both in detail and holistically
+ skilled facilitator
Other
+ (client institutions operating at the same scale)

Key: "+" = positive factor; '-' = negative factor; '▪' = undetermined effect (factor in parentheses indicates identified by researcher, not directly mentioned by participants)

Part 3. Analytical - Deliberative Interactions

The WBAFA case began and ended with very analytically-focused stages. In the beginning, the project leaders defined the scope of the modeling exercise and the endpoints of interest with little external social deliberation. One key input they solicited was from the governor's office, which recommended focusing on the Willamette River Basin, and thus provided WBAFA with two important user groups for their product. This initial phase also included 2.5 years of building up the database to run the scenarios. While there was no mention of stakeholder involvement in this activity, there was no downside expressed. Scientific deliberation was probably high given the large number of scientists involved in the project.

The second stage of the project, the elaboration of scenarios, showed a high degree of analytic-deliberative interaction. The analytic procedures designed by the modelers were reviewed by the citizen planning group (PFWG) approximately monthly and by two other larger groups (WRI, WVLI) quarterly. Both sides appeared to profit from this process, and it appeared critical to achieving a broad awareness and buy-in to the modeling exercise.

The third stage, evaluation of the effects of the scenarios on selected indicators, was again highly analytical. As mentioned above, the project leaders ended up regretting the lack of stakeholder input on endpoint selection because some stakeholders expressed disappointment at the under-representation of social and economic endpoints. The project leaders had intentionally separated scenario generation from endpoint evaluation, and did not mention any downside to not deliberating the evaluation process more broadly.

The follow-on grant to the Institute of National Resources could be seen as a fourth stage to the project. It appeared to be precipitated by deliberation among a number of the stakeholders on how to better capture and use the large amount of information generated by the project. The focus of this stage itself was more on deliberation, but not through the direct organization of forums rather through diffusion of information products.

Conclusions

Even though WBAFA was not designed for use in any specific decision process, its leaders still looked for instrumental effects on decision making as one of their top success measures. They found evidence of decision effects to be as elusive as has past research on policy analysis and assessment (Feldman 1989; Cash et al. 2001). However, they did see the effect of their work on subsequent analyses and on more interpretive goals, such as consensus and capacity building. Two of their success measures, scientifically researchable and politically plausible scenarios, focused more on the immediate information products rather than their social effects.

Factors leading to these successes were more difficult to discern from the case materials. Only two were clearly expressed: the use of explicit scenarios and having a citizen committee design these scenarios. Here the application of existing theory greatly helped to further illuminate aspects of these expressed reasons as well as identify additional factors. For example, the concept of “translation” and previous studies on boundary objects and organizations highlighted the importance of the PFWG as a mechanism for combining citizen and scientist knowledge to create products that were both politically and scientifically credible. The theoretical framework also revealed a number of factors which appeared important but were not explicitly mentioned as such in the case materials. These included data and information quality on the analytical side, and selective participation and iterative, two-way communication on the social side.

One critical factor not directly identified by the participants or the theoretical framework was the availability and interest of client organizations operating at the same scale as the assessment. Previous ecoregional assessments have found the lack of such scale-appropriate clients to be a problem (Johnson, Duncan and Spies, In press). The project extensively engaged these clients and in turn these organizations have continued to generate outreach opportunities for the project results.

The analytic-deliberative lens provided by the NRC (1996) highlighted how the balance between these aspects changed over the course of the project. Following the prescription of applying both to each stage might have resulted in more relevant endpoints; however, it is less clear if deliberation might have contributed to the analytically-focused data compilation or endpoint evaluation stages.

CHAPTER 11 – CROSS CASE ANALYSIS: RESULTS AND DISCUSSION

This chapter looks across the four cases to compare and contrast their measures of success and contributing factors. It also more explicitly compares these findings to the existing theories discussed in the Methods chapter. Central questions are:

- To what extent do participants see DSS success in instrumental versus interpretive terms?
- How well do the factors identified in the research framework contribute to explaining successful DSS use?
- Do these measures and factors appear to change with the analytical and social complexity of the case?

Because the cases will be referred to frequently throughout the text, the acronyms listed in Table 36 will be used.

Table 36. Case Study Acronyms

Acronym	Case
IPFP	International Paper's Forest Patterns
AREMP	Aquatic and Riparian Effectiveness Monitoring Program (aka Northwest Forest Plan Watershed Assessment)
WWT	Washington Water Typing model
WBAFA	Willamette Basin Alternative Futures Analysis

Results

<u>Success Measures</u>

Table 37 summarizes the success measures identified in the four cases. Some measures were difficult to unambiguously classify as analytical/instrumental or social/interpretive. For example, "results consistent with expectations" (AREMP) could be considered analytical and interpretive, or “meets certification requirements” could be considered more about meeting an instrumental goal than an example of aiding a social, interpretive process. Nevertheless, barring some undetected classification bias, these results should be reasonably reliable in aggregate. The principle finding revealed by the table is that participants in all the cases used analytical and social measures and in approximately equal numbers.

Table 37. Cross-case Summary of Success Measures

Case	*Analytical / Instrumental*	*Social / Interpretive*
IPFP	+ use of system by operations foresters + prevention of forest operations errors	+ response of users and experts + increases public credibility + reduces conflict with public + meets certification requirements
AREMP	+ consistency of evaluations + quantitative results + results consistent with expectations	+ helped bring local knowledge into process + (helped to structure discussion and achieve consensus) + participants gave positive reviews
WWT	- accuracy (in comparison to electrofishing data) - use in regulatory decision making + improvement of streams data	+ helped move negotiations forward + increased mutual understanding among scientists - acceptance by stakeholders
WBAFA	+ scientifically researchable scenarios + reveals non-obvious or forgotten aspects of the issue - social and economic measures underrepresented - use in decision making + use in further analyses + improved available data + individuals' capacities increased	+ politically plausible scenarios + consensus building (WRI, WVLF, PFWG) + new institutions (INR) + enduring human relationships

Key: "+" and '-' indicate whether the participants perceived the measure as a positive or negative measure of success in the particular case.

Table 38 looks more specifically at individual measures and summarizes success themes in terms of the number of cases in which they were observed. Six measures appear in two or more cases and are discussed below.

Table 38. Cross-case Frequency of Success Measures

Success Measure	*# Cases*
Reviews by Users / Stakeholders + response of users and experts (IFPF) + participants gave positive reviews (AREMP) - acceptance by stakeholders (WWT) + politically plausible scenarios (WBAFA) + scientifically researchable scenarios (WBAFA)	4
Consensus Building + increases public credibility (IFPF) + reduces conflict with public (IFPF) + (helped to structure discussion and achieve consensus) (AREMP) + increased mutual understanding among scientists (WWT) + consensus building (WRI, WVLF, PFWG) (WBAFA)	4
Use in Decision Making + use of system by operations foresters (IPFP) - use in regulatory decision making (WWT) - use in decision making (WBAFA)	3
Consistency with Expectations + results consistent with expectations (AREMP) + reveals non-obvious or forgotten aspects of the issue (WBAFA)	2
Improvement of Data Base + improvement of streams data (WWT) + improved available data (WBAFA)	2
Accuracy + keeping data up to date (IPFP – factors) - consistency with electrofishing data (WWT)	2

Key: "+" and '-' indicate whether the participants perceived the measure as a positive or negative measure of success in the particular case.

Reviews by Users / Stakeholders

One of the most common success measures expressed in the cases is the reaction of users and/or stakeholders. As one of the IPFP participants put it:

> I look at the response of my customers, specifically the foresters. I also look at the response from my peers that have seen the tool and seen it in action.

Two of the AREMP interviewees also mentioned positive reviews by workshop participants and others as a success measure. Negative reviews by stakeholders and the science group has been the major factor delaying implementation of the WWT model. The WBAFA case used more oblique terms, "scientifically researchable" and "politically plausible" scenarios, but these ideas seem to tie back similarly to reviews of the product by certain stakeholders (scientists and citizen groups, respectively).

Consensus Building

More clearly on the social/interpretive side, measures related to consensus building were cited in all the cases. The IPFP system was indicated as a tool for increasing public acceptance of their forest practices. It also contributed towards their third-party certification processes, which themselves can be seen as consensus building exercises, and it was the focal point for an internal consensus-building process on setting operating standards. In AREMP, their model was seen as useful in structuring the concept of watershed condition and providing a platform on which to build consensus among the experts contributing. The decision to create the WWT model was itself a path to consensus on the issue when a political compromise was not forthcoming. Even though it was not able to meet the decision criteria established, it was cited as contributing to further agreement among the scientists involved. One of the main objectives in the WBAFA case was to build consensus among stakeholders, as one of the review articles described it:

> The most important end product of this process is development of consensus, or compromise, about desired goals and priorities, that is a shared vision for the future. The purpose of an alternative futures analysis is to facilitate this consensus-building process. (Baker et al. 2004 p. 320)

As an indirect measure of success, the authors cite that the two regional groups that collaborated on the project were able to produce consensus documents concerning visions and strategies. Unfortunately, it would be difficult to disentangle the effect of WBAFA on these agreements from other influences. Not explicitly named, but perhaps assumed, is the evidence in the project results themselves: the citizen advisory group did come to consensus on three possible future scenarios.

Use in Decision Making

Participants in three of the four cases (IPFP, WWT, WBAFA) identified "use in decision making" as one of their success measures. The target decisions were clear from the outset in the IPFP and WWT cases, but the nature of the intended model use was quite different. In WWT the model was intended to be a *surrogate* for the problem (Strauch 1976), that is, the model would directly define how riparian lands were regulated; the model was to be the decision. In contrast, the IPFP system was seen more as a *perspective* on the problem. Field foresters consulted it through a "map check" to inform, but not determine, their decisions.

The WBAFA system was not designed to support any specific decisions, but rather to provide a general forum for discussion about development options. Nevertheless, their capstone journal article stated "more informed decisions are the ultimate measure of success" (Baker et al. 2004 p. 320). They were able to cite incorporation into a restoration priorities map and a few spin off futuring exercises, but were not able to trace use to a specific decision, in the classical sense of an allocation of resources.

Consistency with Expectations

In the AREMP case, the fact that model results were consistent with the managers' expectations gave the results more credibility. In a somewhat opposite take, the WBAFA modelers thought that finding non-obvious or "forgotten" results was success. The difference appears traceable to the project context. AREMP was looking at the past of one issue and trying to consolidate expert opinion on how to evaluate it. In such an expert systems approach, consistency with expert opinion is the standard success metric (Turban and Aronson 2001). On the other hand, WBAFA was trying to model numerous resources into multiple futures; the lack of emergent behavior in the latter would suggest that WBAFA's effort in explicit modeling had been superfluous (i.e. why create a complex computer model if it tells you no more than a simple mental projection?).

Improvement of Data Base

Improvement of the available data was a measure also referred to in two of the cases, namely WWT and WBAFA. In WWT the modeling process led to improving the state agency's mapped streams data, and although the model has not been adopted, the new streams data are already in regulatory use. In WBAFA an improved data base was more deliberately part of the project design. The project spent the first 2.5 years developing the data, and worked to create a public repository that would continue their distribution after the project ended.

Accuracy

Accuracy of the information product was cited as important in the WWT and IPFP cases, although in IPFP it is characterized more as a factor contributing to system use than a success measure itself. In the WWT case the model was originally intended to serve as the regulatory definition of fish habitat. The principle reason given by participants on why it has not been adopted is that it has not been able to meet the 95% accuracy criterion specified by the decision makers.

Success Factors

This section examines success factors across the cases using the analytical/instrumental and social/interpretive theoretical frameworks established earlier. To facilitate comparison among cases each factor category is presented in the four-square matrix of levels of analytical and social complexity

Analytical/Instrumental Factors

System Quality

DeLone and McLean (2003) describe system quality as comprising concepts such as ease of use, functionality, reliability, flexibility, data quality, portability, and integration. Table 39 summarizes aspects of the cases related to the concept of system quality. Although it was seldom mentioned as a success factor, the fact that data compilation was one of the most time and resource intensive tasks for all four cases demonstrated its importance. WBAFA spent the initial two years of the project building up the databases used to run their scenarios. In AREMP, data preparation and linking to the model took longer than the model structuring, and the longest delays were due to waiting for external data sources. The conceptual model used in WWT was simple, but it took a consultant months to conduct the analysis, largely due to structuring and processing the large amount of data. Ultimately it has been the quality of the underlying data that has prevented the model from achieving the accuracy required by the stakeholders to serve as the regulatory definition of fish habitat. Maintaining current data was identified as critical in the IPFP case, as one interviewee expressed it:

> And what I spoke to earlier, the maintenance of it, if you don't have a good maintenance process, a yearly update process at least, or whatever your schedule is, it's going to fail. You have got to keep it current. People have to believe the information in there is good, if they think it is faulty than they will use it.

Table 39. Cross-case Comparison of System Quality Factors

High	*WWT* - insufficient accuracy of base terrain data - electrofishing data used for model parameterization did not reflect full variability of ecological conditions	*WBAFA* + (high initial investment in generating data) ▪ (usability not an issue, since researchers used their own models)
Low	*IPFP* + keeping data up to date + flexibility to customize for local conditions/priorities + ease of use	*AREMP* + (considerable investment in generating data) + flexibility of the modeling tool + ability to integrate diverse indicators - some difficulties with model interface
Social ^ **Complexity** Analytical >	Low	High

Key: "+" = positive factor; '-' = negative factor; '▪' = undetermined effect
(factor in parentheses indicates identified by researcher, not directly mentioned by participants)

Flexibility of the modeling system was identified as important in the two less socially complex cases. Two of the AREMP interviewees mentioned flexibility in the context of making models as simple or complex as desired, as well as the ability to easily group and evaluate criteria in different ways. The flexibility of the IPFP system was seen as important for accommodating the differences in forestry concerns across regions:

> To me the most important thing is you have a design that doesn't have relevance in just one particular place but has the flexibility to have relevance everywhere. The success of the tool is because the foresters in one state, once they realize it's their tool and have had an opportunity to add features other than the riparian and some of the other resource information that I was controlling, they had an opportunity to put a lot of information that had operational relevancy to them. (IPFP interview)

Ease of use was not mentioned in the WBAFA and WWT cases; in these cases the researchers built and ran their own models. The AREMP analysts encountered some difficulties with the interface of one of its subprograms, but sufficient support was available to overcome these problems. IPFP interviewees mentioned ease of use as an important success factor, since a goal was to get the system used by field foresters, who did not always have much prior computer experience.

Information Quality

Information quality factors include information product accuracy, meaningfulness, timeliness, completeness, relevance, consistency (DeLone and McLean 2003).

Accuracy of the information products was mentioned explicitly in the analytically less complex cases (IPFP and WWT) rather than the more complex ones (WBAFA and AREMP). As discussed above, accuracy may not have been mentioned in the WBAFA and AREMP cases because there was no independent, external source for assessing it. Concern over accuracy in the WWT case elevated it essentially to a success measure, rather than simply a contributing factor. Accuracy was also considered critical in the IPFP case, but as a factor contributing to use in decision making by the field foresters. There was no accuracy measure or threshold cited in IPFP, it appears to be rather the foresters make their own judgments as to its adequacy. Interestingly, accuracy also depends to a large extent on the foresters updating the database, creating a circular dependency.

Factors related to meaningfulness and relevance were evident in all the cases. Visualization of the data through maps was cited as an important strategy for communicating results in IPFP and WBAFA. IPFP foresters were accustomed to maps and maps were simply the best way to organize a land classification system. WBAFA spent considerable resources on the publication of a large-format, color atlas, and they experimented with more 3-dimensional views and “fly-through” visualizations, although the impact of these was not mentioned. AREMP used maps as inputs in their expert workshops, but maps were less meaningful as outputs. Rather, the team found they had to spend considerable time reformatting the detailed results of the model (using Excel tables) in order to make these results accessible to the experts for checking.

Meaningfulness and relevance were also closely linked to the social factor of participation, as they are frequently in the broader literature (Fischer 2000, Cash and Clark 2001). Participation enabled the integration of local information and expertise, which was seen as an important aspect of perceived information quality in all the efforts. WBAFA used a stakeholder group to vet their scenarios. They also found two regional groups whose geographic scope matched their own and involved them in the process. AREMP used local expert groups to build their provincial models. Stakeholders in the WWT case insisted that localized stream maps and electrofishing data (where available) be used to overwrite the modeling results. IPFP foresters not only participated in maintaining the database but also are assisted in customizing the system to meet local needs.

Table 40. Cross-case Comparison of Information Quality Factors

High	*WWT* - predictive accuracy did not meet 95% standard set in policy + integration of locally-verified information (electrofishing)	*WBAFA* + use of explicit scenarios + having the scenarios be citizen-driven + (visualizations: atlas, 3-D fly-throughs) + (two levels of publication: detailed atlas, overview booklet)
Low	*IPFP* + information up to date + visualization via maps + customization for local relevance	*AREMP* + transparency and consistency of evaluations + use of gradients for parameters + (additional effort given to formatting outputs)
Social ^ **Complexity** Analytical >	Low	High

Service Quality / Modeling Capacity

Service quality refers to the reliability, responsiveness, assurance, and empathy in support provided for users of an information system (DeLone and McLean 2003).

Aspects of service quality and modeling capacity were only briefly mentioned in the AREMP and IPFP cases and not at all in the other two. However, "reading between the lines" indicates that this omission may be because there was considerable modeling capacity available in all of these cases, so that it was not a limiting factor. IPFP was the only case where a system was intended for more broad use by non-modelers, and in this case a strong commitment from upper management to provide training and enforce system use was seen as critical. The AREMP team had easy access to the software developers for the few problems that came up. They were also able to devote considerable capacity to the project (an aquatic ecologist, GIS analyst, and DSS specialist). In both the WBAFA project and the WWT the same scientists were involved in both creating and running the models, so capacity and support were not a problem. An important capacity issue was raised in the WWT case, however, which was whether the state agency had the capacity to implement the model results. The agency had to consider how to distribute the model results to the regional regulatory staff members, how to inform staff on their use, and how to incorporate feedback from forest practice applications.

Table 41. Cross-case Comparison of Service Quality Factors

High	*WWT* + (specialist group had high capacity and ability to hire contractors) + implementation needs go beyond running the model, e.g. training of WDNR staff and funding to assist landowners	*WBAFA* ▪ (external support not needed, since analysts were both authors and users of models)
Low	*IPFP* + training supported/required by upper management	*AREMP* + (good support from software developers)
Social ^ **Complexity** Analytical >	Low	High

Social / Interpretive Factors

Participation

Important aspects of participation found in the literature include identifying and including all stakeholders and having numerous and varied opportunities for input through the decision-making process. Providing opportunities early in the problem framing stage is important, rather than only after specific alternatives have been analyzed.

In three of the four cases DSS were used as part of a participation process. The WBAFA model played a central role in a participatory process that went beyond normal institutional processes in terms of its involvement of multiple levels of government, stakeholders, and scientists. AREMP used a DSS to incorporate the knowledge of provincial expert groups into their evaluation. The IPFP process expanded participation in setting silvicultural guidelines from operations foresters to cross-departmental groups, outside experts, and regulatory agencies.

It is worth noting that the expanded participation was tightly controlled in all three cases. WBAFA managed participation by hand selecting stakeholders likely to work well with others. AREMP initially excluded regulatory agencies. Most of the IPFP participants were internal to the company, and the company was able to select the external participants and reviewers. All three cases cited expanded participation as an important success factor, and all assumed a “trickle up” validating influence from a small, engaged group the to broader stakeholder community.

In contrast, as a public regulatory process, participation in the WWT modeling process was required to be more open than in the other cases. Instead of allowing the program leaders to select the individuals they would work with, the process required that members of the diverse interests involved be allowed to participate. What occurred was not a controlled expansion of participation, but rather a shift in who was involved; the locus of problem solving shifted from the policy groups to a scientist group. Although the expectation of an analytical solution may have been sound in theory, the high level of model accuracy required by the policy makers and the relatively coarse data available made it impossible. As described in the case, this shift may have gone too far and delayed an inevitable debate in the policy arena.

Table 42. Cross-case Comparison of Participation Factors

High	*WWT* ▪ (formal, representative structure established by the FF policy process) ▪ (modeling approach shifted problem solving from policy to science group) ▪ (lack of small landowners representation on the technical committee may have reduced their trust in the solution) - difficulties re-engaging policy groups	*WBAFA* + citizen workgroup defined assumptions in collaboration with scientific teams + (Participants hand-selected for expertise, willingness for extended engagement, and track record of working with people from other areas)
Low	*IPFP* + cross-departmental teams, outside experts helped to set management guidelines + participation of end users (field foresters) in system design	*AREMP* + engagement of regional expert groups + limited to land management agencies
Social ^ **Complexity** Analytical >	Low	High

Communication

The literature recommends communicating with stakeholders throughout the process in an iterative, two-way manner. In all the cases there was iterative, two-way communication among the analysts/technical specialists. In the IPFP case, the cross-sectional teams met regularly during the development period, and their proposals went through a few iterations of review by outside experts. The AREMP team held two workshops, separated by about a year, for specialists from each province, and in the intervening time they continued to communicate with these specialists to elaborate the models. The WWT scientists have met almost each month for the past 5 years. The WBAFA technical specialist teams interacted regularly for over two years.

In contrast, the patterns diverged with respect to communications between analysts and other groups. In some respects, the IPFP cross-sectional groups could be considered to be inclusive of decision makers (especially field foresters) and stakeholders (from other business functions of the company). State regulatory decision makers also reviewed their guidelines, but there was no mention of communication with interested publics during the system development.

In AREMP, communication with other audiences was more one-time and one-way. The main formal avenue of communication was the watershed assessment section of the 10-year report on the Northwest Forest Plan and an associated symposium. The team gave a number of ad hoc presentations to interested groups, which were important in generating support from different parts of the agencies involved. These communications appeared sufficient for the situation because the assessment was not very controversial and the backing of a broad cross section of regional specialists provided the credibility needed for acceptance within the agencies involved.

Similar to AREMP, the WWT problem had been defined as scientific, so iterative, two-way communication with decision makers and stakeholders was not a natural priority. Policy questions did come up in the modeling process, however, and the analysts struggled with engaging policymakers further, given the latters' limited time and full agenda. After the model was completed, the Department of Natural Resources initiated two-way communication with the public by presenting and discussing the maps at regional review fora. The results were also made available via the department's interactive mapping website and hardcopies mailed upon request. Discussion at the Forest Practices Board meetings increased, including special workshops, but the formal nature of venue and its time constraints did not appear conducive to an interactive dialog among the interests.

By instituting a citizen modeling review team, WBAFA created an iterative and two-way communication mechanism between analysts and stakeholder representatives. Further, the WBAFA leaders gave presentations and received feedback quarterly from two regional commissions. Communication with broader audience was more one-time and one-way. The project published results in a newspaper insert that reached over 400,000 households and a detailed atlas for the highly interested audience. This planned, multi-tiered communication plan was seen as critical to the effort's success.

Table 43. Cross-case Comparison of Communication Factors

High	*WWT* + regular, two-way communication in the technical groups - difficulties in engaging policy groups + two-way communication with the broader public in a variety of venues after initial model results available	*WBAFA* + two-way, iterative process over a long time period with 3 stakeholder groups ▪ one-time communication via newspaper insert and detailed atlas
Low	*IPFP* + iterative, two-way communication in cross-departmental teams + reviews by outside experts, regulators	*AREMP* + engaged regional experts through extended, iterative process + (ad hoc presentations within the agencies involved) ▪ (limited, more one-way communication with other audiences via report and symposium)
Social ^ **Complexity** Analytical >	Low	High

Translation

According to the literature, two areas where translation is commonly needed are 1) between people with different levels and types of knowledge (e.g. scientists, policymakers, and the public), and 2) between different interest groups and people with different worldviews.

Translation between different types of knowledge was cited as successful in three of the four cases and problematic in the fourth (WWT). IPFP cited the simple categories and visual mapped outputs as strategies that helped translate management guidelines both within the firm and with the public. These top-level categories were shared across the organization, while their subcategories are allowed flexibility to best meet local needs. This arrangement serves to translate knowledge across geographies. The translation capabilities of the AREMP models with decision makers and the public were not evident in the case materials, however the models were cited as very successful in translating between the modeling team and the experts providing input to the model. It is important to note that the computer software was not used directly in these interactions, rather its concepts were used to structure inputs from the local expert workshops, and considerable effort was needed to reformat software input and output to be accessible to these groups. WBAFA placed the most emphasis on translation of the four cases. As with IPFP, they relied heavily on maps to translate knowledge between the technical science teams and the citizen working group, and in communicating to the public via their published atlas. They also believed that using specific scenarios, as opposed to more general trend relationships, was key. Their most intensive translation strategy was the facilitation of a citizen working group to devise the scenarios. Similar to the AREMP workshops, this working group translated between the modelers and the experts (in this case citizens) providing the model parameters. The WWT model appeared to be successful in achieving a common understanding among the scientific group but was less successful in between the scientists and policy makers, especially in the area of thinking about model accuracy.

A second aspect of translation is between interest groups and worldviews. Achieving understanding among the WWT science representatives was significant in itself, since the group included the most diverse and polarized participation of all the cases. One interviewee attributed this understanding to the explicit nature of modeling:

> One of the things that happens in these negotiations, where you have all levels of expertise, is that people bring their preconceptions, their biases to these forums. I think in the process of having to be explicit about models, we've been able to expose those and get very explicit about what it is we are all after. To me it has been the thing that has made it easier to communicate among different levels of training and different objectives and value sets.

Unfortunately, the shared understanding was that the model was not accurate enough in all regions to be an acceptable policy solution. Explicitness was also mentioned as helpful for translation between worldviews in the other more socially complex case:

> The purpose of an alternative futures analysis is to facilitate this consensus-building process. It does so in four ways: (1) helping to clarify differences of opinion by forcing stakeholders to be very explicit about their individual goals and priorities, expressed as written assumptions for a specific future scenario (WBAFA)

Although the AREMP modeling process did not include interaction between different interest groups, one of the outsiders interviewed liked the process because it was explicit:

> But as a monitoring tool the reason I like it is that it puts some teeth in what are otherwise vague Aquatic Conservation Strategy objectives.

There was not mention of specific interest group interactions in the IPFP case, but as mentioned above, maps (spatially explicit statements) were seen generally as key to successful interactions with the public.

Table 44. Cross-case Comparison of Translation Factors

High	*WWT* + explicitness of model facilitated coming to mutual understanding among scientists - complexity of model (especially measures of error) was difficult for policy groups to understand, especially given their time constraints	*WBAFA* + used maps and scenarios to translate knowledge between technical experts and stakeholders + citizen-scientist working group (PFWG) as translation forum
Low	*IPFP* + a simple set of common land use categories with underlying flexibility + maps make IP's management strategy explicit for the public	*AREMP* + transparency of the modeling approach + (effort made by analysts to translate model descriptions and outputs)
Social ^ **Complexity** Analytical >	Low	High

Mediation

Successful mediation has been linked to some of the concepts already discussed, such as participation of the affected parties and understanding (translation) of the process and terms. Other aspects of mediation derived from the literature include providing rules of conduct and establishing criteria for decision making.

Small group, face-to-face meetings was the principle strategy used to mediate between different interests during the development of all four systems. Composition and facilitation of the groups varied, however. The IPFP cross-sectional teams were the smallest (with about 6 people on the wildlife team), but with diverse representation from within the company. Each had a team leader, but facilitation was not mentioned as an important factor. The AREMP workshops were typically larger but less diverse, consisting mostly of aquatic biologists. The project analysts facilitated the meetings, but it was up to the participants to come to consensus on model recommendations. In

WBAFA the core group was larger (~20) and the most diverse in terms of experience. The facilitation skills of one of the principle investigators was specifically mentioned as a success factor. Quarterly presentations at two other regional stakeholder groups provided additional mediated input to the modeling process. Principle input to the WWT model came from a committee (~20) of scientists drawn from the diverse interests. It was a new type of quasi-governmental, policy-oriented science group, and so struggled with defining decision making protocols, but their shared scientific background seemed to facilitate coming to a common understanding on the model.

Use of these DSS had a variety of mediating effects on their respective problem solving processes. IPFP most clearly provides rules of conduct (management guidelines) and establishes criteria for decision making (land classifications) within the organization. It was also cited as helping with public relations by making the company's activities more transparent and with avoiding harvesting in sensitive areas. The finished AREMP model also provided decision criteria in the form of a method to evaluate watershed condition. The DSS software itself, even though not used interactively during the workshops, provided rules of conduct in terms of a methodology for extracting and combining expert judgments on a variety of watershed attributes. One of WBAFA's top stated goals was increasing consensus among stakeholders. They cited making stakeholders values apparent through explicit modeling as an advantage in this regard. They also cited the ability to see holistically as well as locally. The WWT model had the most immediate mediating effect, in that the promise of a scientific solution allowed the policy makers to put the contentious issue on a back burner. This changed the rules and criteria for decision making from political to scientific. Among the scientists working on it, the explicit nature of models was cited as a positive mediating influence here also. Ultimately, the model has not proven accurate enough for policy makers, but the delay and debate it caused appear to have brought the parties more into agreement on maintaining the interim solution.

Table 45. Cross-case Comparison of Mediation Factors

High	*WWT* + modeling approach enabled the FF policy process to move on - model shifted rules for negotiation from political to scientific ▪ model caused a policy delay during which actors became more accepting of interim solution	*WBAFA* + selective core group with long-term participation + model explicitness helped in consensus building + ability to view information both in detail and holistically + skilled facilitator
Low	*IPFP* + helps avoid conflicts with conservation interests + provides rules of conduct (management guidelines) + establishes criteria for decision making (land classifications)	*AREMP* + helped to structure experts' debate so as to achieve consensus + (homogeneous group)
Social ^ **Complexity** Analytical >	Low	High

Other Factors

Four other success factors were identified in the cases but did not neatly fit into the theory-based categories. In IPFP, top management support was cited as fundamental to the success of the effort. Second, the value of having organizations operating at the same geographic scale appeared critical to the perceived success of the WBAFA modeling. The WWT case included two important factors, which were more a reflection of the context than the model or modeling process: stakeholder intolerance of modeling error and increasing acceptance of electrofishing as an alternative.

Table 46. Cross-case Comparison of Other Factors

High	*WWT* - stakeholder intolerance of modeling error - increasing acceptance of electrofishing as an alternative	*WBAFA* + (client institutions operating at the same scale)
Low	*IPFP* + support from top management	*AREMP* +
Social ^ **Complexity** Analytical >	Low	High

Analytical – Social Interaction

A number of publications have emphasized the need for integrating analytical and social problem solving strategies. A National Research Council called for "mutual and recursive" interaction (NRC 1996 p. 163). All the cases involved some instances where analysis and deliberation were "mutual and recursive," but the pattern tended to vary during the progression of the case and the extent of deliberation varied considerably between the cases. The success (or lack thereof) in combining analytical and deliberative elements appeared critical in the overall success of all the cases.

Champion International and subsequently International Paper used small, cross-cutting teams to analyze and deliberate the framework and guidelines for their Forest Patterns system. They went beyond their organizations to recruit reviews from outside experts, and repeated the review cycle multiple times. AREMP showed a similar pattern of involving small, expert groups to generate a model, then gathering data and analyzing it, and presenting the results back to the group for deliberation and revision. AREMP's participation was more restricted to certain agencies and types of expertise, but it proved adequate for their purposes. WBAFA participants saw a lack of social and economic outputs as a weakness that they traced back to a lack of deliberation in the problem framing stage. In contrast, their modeling stage involved the most extensive analytical-deliberative interaction among the four cases, in both its duration and breadth of involvement. They identified this process as key to their success. Initial deliberation on the WWT modeling approach was curtailed by a political push to conclude the Forest and Fish negotiations. The problem was defined as scientific, and, for a long period, the analytical team found it difficult to engage the policy representatives in deliberation due to the press of other issues and the highly technical nature of the modeling process. More deliberation has occurred since the production of the first model, but at least some of the scientists involved believe that key policy questions must be answered before the use of the model can be resolved.

Levels of social-analytical complexity

These four cases were chosen because of their differing levels of social and analytical complexity. Two hypotheses were made as to how DSS use strategies would change according to these characteristics and the results are discussed below.

1. As problems become more socially complex, social/interpretive factors and measures will become more important.

In terms of success measures, this did not appear to be true. Reviewing Table 37, the more socially complex cases did not have more social/interpretive goals than the less socially complex ones. The measures across cases were not only similar in number but also in kind. Consensus building and user reviews were common to all the cases. One of the socially simple cases, the IPFP, had very broad social goals, including influencing the perception of the general public.

The number of social factors also did not appear to differ across cases. All included examples from each of the categories: participation, communication, translation, and mediation. The effect of social complexity, however, can be seen in the scope of activities within these categories. The socially complex cases were responsible to a broader set of stakeholders, which required broader participation and higher investments in communication, translation, and mediation. AREMP's primary audience of regional federal agency decision makers was relatively narrow, so they were able to be successful with participation of only small groups of technical experts and modest investments in the other factors. Even though IPFP was aimed at the general public, participation was primarily from within the company and a few outside experts. Most of the participation in WWT came from a relatively small technical group, but their model had to pass muster with broader policy groups in a polarized environment. They also felt it necessary to take the model out for direct public review and feedback. WBAFA made an extensive commitments to all of the factors, assembling a diverse citizen modeling group, soliciting regular feedback from other regional groups, and investing in a number of outreach products.

2. As problems become more socially complex, analytical strategies must become simpler.

The cases reviewed in depth do not appear to support this hypothesis. Given this premise, the WBAFA case would be predicted to be the least successful, since it combined both high social and high analytical complexity. However, it was the WWT case, which used a fairly simple model in a socially complex situation, which participants saw as the least successful effort. Unfortunately, differences between these two cases extend beyond the analytically simple versus complex categorization used. First, the social complexity of WWT was considerably higher than WBAFA, more so than the five-point scale in Figure 5 suggests. Acceptance of the WWT model by decision makers would mean immediate, high stakes gains and losses for particular stakeholders, whereas the WBAFA had no such immediate effects. The high stakes and availability of a more reliable alternative (electrofishing) in WWT meant that stakeholders were highly intolerant of model error. In the WBAFA context, fish models that did not approach the 95% accuracy required by WWT were accepted. Second, WBAFA made a greater investment in social processes. They were able to regularly engage a range of decision makers in the model building process over a two year period. In contrast, the WWT was defined as a purely scientific task, and when policy questions came up, it was difficult to engage the policy makers. While the general pattern in these two cases refutes the stated hypothesis, these differences in deeper aspects of the cases confound drawing any firm conclusions from this sample.

Discussion

Success Measures

Analysis and social deliberation have been identified as distinct approaches to decision making. The use of computers in problem solving is typically associated with analytical tasks, but the framework revealed that even from the point of view of modelers, many of their measures of success were social/interpretive (Table 37). On the other hand, analytical success measures were also identified in almost equal numbers. These cases do not support a position as extreme as that found by Greenberger (1976) where "the usefulness of models has little to do with technical development but much to do with communication of results, the institutional setting, the modeler's credibility, and how ongoing development of a model enhances the modelers expert judgment."

It was no surprise to find that "user reviews" were a top success measure. Such evaluations are a widely recognized measure in the information systems field (Marakas 1999; DeLone and McLean 2002). What is interesting to note in these cases is the extent to which the concept of "user" broadens from a more hands-on operator to all decision stakeholders as indirect users. In this situation, it becomes difficult to separate the model from the rest of the modeling process, and Greenberger's (1976) points about communication, setting, and modeler credibility are obviously important. More fundamentally, user reviews can be seen as both instrumental and interpretive. On the instrumental side, users are often seen as the best judges as to whether a system helps them accomplish their goals. In this respect, use and user attitudes have been widely embraced by the more instrumental information systems literature (Marakas 1999). Fincham's (2002) narrative approach portrays the expression of success more as a social construct. It emphasizes that a researcher must be cognizant of reasons why participants might want to characterize an effort as a success or failure. Given this complexity, user evaluations must be careful about the phenomena they purport to measure. This study has attempted to separate the effects of technology and process by using different indicators for each, and it has tried to discern interpretive effects through a detailed description of context and a critical evaluation of informants' reports.

Given the analytical orientation of computer modeling, it was surprising to find that consensus building was a success measure in all four case studies. Previous DSS reviews have called for the need to support social negotiation (Mowrer et al. 1997; Rauscher 1999). Even though the DSS in these cases did not exhibit any features specifically designed for social negotiation, they were found useful in these processes.

The most surprising finding is that all cases cited "consensus building" as a measure of success, since the use of technical tools and methods are often considered an impediment to participation in decision making (Fischer 2003) and ambiguity is preferred to explicit analyses in policy making (Greenberger 1976). Reviewing the specifics of each case helps to resolve these apparent contradictions. The consensus groups varied greatly, from narrow technical specialists in the AREMP case to more broadly representative citizen groups in WBAFA. In two of the cases (AREMP and WWT) consensus is built principally among technical specialists. While they may not run the software, they have the background to readily understand the concepts, and being science-oriented, the explicitness of modeling helps them find common ground. Many of the participants in IPFP were also technically-oriented professionals in the forest industry. Consensus building in the WBAFA case was among a more broadly representative group, yet, as with the other cases, consensus was focused on the models and their outputs. In contrast, both Fischer (2003) and Greenberger (1976) were discussing the effect of analysis on consensus at the more contentious level of decisions involving the public allocation of resources.

Despite the limited purview of consensus in all these cases, agreement within the modeling groups was intended to be a bridge to consensus among broader audiences. In the IPFP case one of the primary rationales of the DSS was to build credibility and reduce conflict with the public. Two of the three interviewees mentioned that it had been useful in this regard, and some external validation was apparent in the contribution of the system to achieving sustainable forest management certification. In the AREMP case, one of the regional decision makers stated that consensus among the technical groups led to credibility with his peer group. In WWT, consensus among the scientists was intended to lead to agreement among the policy makers and resolution of a contentious issue. Lower than expected accuracy meant that the model was not able to achieve consensus among the stakeholders, except possibly in the indirect sense that they became more tolerant of the interim, non-model-based solution. WBAFA was somewhat unique, in that they did try to engage a broad set of stakeholders more directly using a complex set of models. They were able to achieve consensus on three scenarios among three stakeholder groups.

Predictably, "use in decision making" was given as a success measure in a majority of the cases. The only case in which it was not identified as a success measure was AREMP. Similar to WBAFA, AREMP was designed to produce an assessment rather than a decision, but in contrast to WBAFA it was clear that the assessment was to contribute to a specific decision (whether the Northwest Forest Plan standards and guidelines for management needed revision). One explanation would be that the more structured, bureaucratic context of AREMP encouraged them to more narrowly define their task as simply completing the assessment, whereas the more independent situation of WBAFA left its leaders looking for relevance in the decisions of others. It is interesting to see that "decision use" does not appear to be tied to analytical or social complexity, but rather the scope of goals as defined by the participants.

Out of the four DSS cases, only two were designed to directly affect specific decisions (IPFP, WWT) and only one was successful in this regard (IPFP). The other two cases were more generalized assessments, and although the WBAFA participants looked for decision effects, they found them as elusive as previous studies of the use of technical information in decision making (Feldman 1989; Weiss 1980).

According to DeLone and McLean's (2003) information systems success theory, "information product accuracy" as a component of information quality, is an expected success measure -- so why was it not emphasized in two of the four cases (AREMP, WBAFA)? Two differences are apparent. First, WWT had a widely accepted, external accuracy measure: electrofishing. The AREMP and WBAFA cases did not have any such clear, external comparison measures; their accuracy checks were based in the opinions of experts and stakeholders who built the models. Second, the accuracy requirements in both the WWT and IPFP cases were high because the systems were intended to have a direct effects on decision making, while there was no such direct, immediate effect on decisions associated with the other two models.

Success Factors

The use of theoretically-derived factor categories was useful in bringing order to the description of these complex situations and in identifying factors which were not directly expressed. What seems like a straightforward question ("What factors were important for success?"), proved surprisingly difficult for interviewees to answer. Even in the WBAFA case, where participants had formally reflected on and presented success measures, few causal factors were directly identified. For example, data quality was not mentioned in two of the cases (WBAFA, AREMP), yet constructing the data sets was one of the most resource intensive activities. Similarly, iterative, two-way communication among modeling participants appeared to contribute to success in all the cases, yet it was not explicitly identified by the participants in any, with perhaps the exception of WBAFA, where the communication process was described prominently.

Analytical

A number of analytical factors were found to be important in the cases. As predicted from information systems theory, data quality appeared important in all the cases, although it was only directly named in two. If data quality is important, it might be assumed that accuracy of the information product is also. However, accuracy was not named in two cases (WBAFA and AREMP) because there was no independent, external source for assessing it.

Flexibility of the modeling system was identified as important in the two less socially complex cases. No rationale for a direct link between social complexity and flexibility is evident, in fact one might hypothesize that flexibility is more important in socially complex situations. Instead, I propose an indirect connection. The socially complex cases built systems customized to their problems, so flexibility was assumed (of course one can change one's own model). In contrast, AREMP used off-the-shelf software, and IPFP transferred a system built for one company in the Northeast to other regions of a larger, nationwide company.

The customized solutions used in two of the cases (WBAFA, WWT), along with the fact that the model designers were the model users, led to less importance of ease of use and service quality aspects than is typically found in information systems studies. These factors were found to be important in the one case were a system was rolled out to a larger, non-technical user group (IPFP).

Information quality is based on the concepts of communication effectiveness, so it is not surprising that close connections were seen between it and the social factors. In particular, the information quality factors of meaningfulness and relevance were closely linked to the social factor of participation, as they have been in the literature on environmental policymaking and assessment (Fischer 2000, Cash and Clark 2001).

Social

The increase in the technical complexity of social decisions has been identified as an impediment to broad participation (Dewey 1927; Fischer 2000). The history of FORPLAN use in national forest planning demonstrated how DSS could exacerbate this problem (McQuillan 1989; Barber and Rodman 1990; Healy and Ascher 1995). However, in three of the four cases in this study DSS appear to have been used successfully to help expand participation. The IPFP, AREMP, and WBAFA cases all used models to help structure and capture the input of participants beyond the immediate modeling or decision making team. All three cases also made a strategic choice to limit and control participation. In contrast, participation played out quite differently in the WWT case, the one example which was directly part of a public decision. In that case the choice of a technical approach had the more classic effect of discouraging broader participation, and it has proven unsuccessful at resolving the issue at hand, despite the increased consensus among the technical group. In sum, DSS can be used to expand participation, at least in a limited way, or they may inhibit it, depending on how the problem solving process is structured. Although the ideals of democracy suggest that more participation is better in public decision making, controlled expansion of participation seemed key to success in the more restricted sphere of these modeling exercises.

The case evidence seems to support the importance of iterative, two-way communication found in Cash et al.'s (2003) work on environmental assessments. In all the cases there was such communication among the analysts/technical specialists, and they were able to come to consensus on the models. This limited scope of participation and communication appeared adequate for the purposes of the IPFP and AREMP cases, along with some more one-way communication for wider audiences. The WBAFA case illustrated how iterative communication and translation of knowledge and values could work with broader, non-technical groups. In contrast, the WWT model was developed by a small, relatively isolated scientific group, but its implementation was dependent on acceptance by the broader policy community. The careful separation of science and policy functions in this case seems to have had a downside. There has not been a good forum to bridge the science-policy divide to discuss relaxing model expectations or the changing attitudes on the electrofishing alternative. Previous work on environmental assessments and regulations has found the need for such boundary organizations, especially as the science work gets closer to affecting policy (Jasanoff 1990; Farrell and Jäger 2006).

Other Factors

The generality of the categories contrasts with the specific factors listed in some of the literature (see Appendix A), but this generality also provides a more holistic view of possible factors and is applicable to a wider variety of cases. Even though the theoretical factors are very general they served to focus attention to reveal the more specific mechanisms in each case. Despite the breadth of the framework, it did not cover all the factors identified. Specifically, it did not cover two social factors: support of top management and client organizations at the same scale. The former has long been recognized in the IS literature, and the latter has come out in the frequent mismatch between ecological and administrative boundaries in recent work on environmental assessments. These factors seem to contrast with those in the framework used in a fundamental way. The framework factors are descriptive of the problem solving process, while these factors are more reflective of the problem context. This study only looked at context in the sense of social and analytical complexity, but there are a number of other such context frameworks which will be reviewed in the following chapter. In addition, a finer grained analysis might be useful, such as Walsham's (1993) interpretive work on information systems that explicitly looked at both context and process factors.

<u>Analysis and Deliberation</u>

This group of cases provided support for the prescriptive theory of NRC (1996) for a "mutual and recursive" relationship between analytical and deliberative actions. The three more successful cases all described functional patterns of analytic-deliberative interactions. A number of breaks in this pattern were identified as problems in the less successful WWT case. Both the WWT and WBAFA cases separated the activities and responsibilities of scientists from policy makers, but the more regular meetings between the two in the latter case provided more opportunities for exchange and mutual learning. Even in the case with the most extensive recursive process (WBAFA), one of the principle regrets expressed was the lack of stakeholder deliberation on endpoint measures. It is interesting to note that this pattern appeared important no matter what the extent of public involvement. It was important for AREMP's technical teams as well as WBAFA's interactions with broad citizen groups.

Analytical and Social Complexity

The effects of analytical and social complexity were not as simple as originally envisioned. First, analytical and social complexity appeared to be positively correlated. Some literature suggests why this might be. Smith-Korfmacher (1998) noted tendency to use the most complex model available because they often are considered the most advanced, are the most difficult to challenge, and provide the most prestige for the modeler. As problems become more complex, it is natural that the models do also. More complex social problems tend to attract more resources, which means more investment in modeling. Second, success measures and factors did not vary in type (social versus analytical) according to socially complexity, but rather in magnitude. The cases had similar types of measures and used similar strategies; socially complex cases simply spent more effort in trying to make their work relevant to broader audiences. Third, the cases also did not support recommendations from the literature for simpler models in more socially complex situations. A complex set of models performed well in the case of WBAFA, while a simpler model was not successful in WWT.

Rather than social/analytical complexity as defined, the more telling relationship appeared to be between "decision stakes" and "investment in modeling participation."

PART III: SYNTHESIS

CHAPTER 12 – SYNTHESIS OF ADVICE ON THE USE OF FOREST BIODIVERSITY DECISION SUPPORT SYSTEMS

The purpose of this chapter is to provide a framework for people to consider when and how to apply DSS. The chapter is organized around the common interrogative framework of "why, when, what, who, where, and how." These questions are presented in the order I believe they most commonly should be addressed, but they are also interdependent. Concepts or choices related to one question will necessarily reflect back on others, so the order should not be interpreted as recommending a strict stepwise progression. A holistic perspective is also needed.

The framework is synthesized from knowledge covered in previous chapters. It draws upon the existing literature and supplements it with examples from the four core case studies covered in chapters 7-10 and the shorter descriptions of the other 10 cases from the original screening group (Appendix C). This chapter also uses additional data from the DSS capabilities survey that was not used in Chapter 4, such as the modeling approach and capacity issues.

Why **use a DSS?**

The first question to ask in considering DSS use is "Why – what is hoped to be gained from the effort?" The most obvious advantages are analytical. Computers are better than the human mind at tracking voluminous amounts of information and making complex calculations. But there are also more social/communicative reasons for using DSS. As was seen in the four core cases, "consensus building" was one of the most frequently expected success measures.

Analytical Reasons

Psychological decision research has delved into the strengths and weaknesses of the human mind. Hastie and Dawes (2001) identified two primary categories for departures from formal rationality: the limited capacity of our short-term working memory and the tendency for our minds to make automatic associations between what we observe and schemas stored in our long-term memories.

Cognitive Limitations

In 1956, George Miller published a classic review on cognitive limits entitled "The Magical number seven (plus or minus two)." Seven was the approximate number of unrelated items a person could reliably hold in short-term memory and also the number of categories a person could deduce from various types of sensory input. Herbert Simon won a Nobel prize for applying similar concepts to the domain of decision making. His theory of "bounded rationality" simply stated that human decision makers can only be expected to be rational within the bounds of their cognitive abilities (Simon 1955). He also found that instead of optimizing (even within bounds), decision makers often appear to mentally set a minimum acceptable outcome and terminate their search with the first solution which meets this criterion ("satisficing").

More recently, Klein (1998), studying the strengths of expert decision makers, found that their construction of mental simulations was generally limited to three factors and six transition states. But counter to much of the decision research field, his work has focused more on the strengths of human decision making than the limitations. Klein's work on expert decision makers found that while their mental simulators are limited in capacity they are also extremely flexible. We can "think through" an enormous variety of situations, in contrast to computer models, which must be specifically programmed for each different application. He also showed how the human capacity for pattern matching has contributed to our ability to make quick decisions on little information.

Cognitive biases

Our pattern matching also has its problems. Decision making is often described as making choices with uncertainty. Tversky and Kahneman (1974) identified three of the major human biases involved in judging probabilities as availability, representativeness, and anchoring and adjustment. Availability refers to a bias we have towards recalling situations that were more recent or dramatic, rather than thinking through the complete sum of past experience. We also tend to form stereotypical categories and assign our observations to them, which leads to assuming characteristics for which we have no or even contrary information (representativeness bias). Anchoring and adjustment refers to the tendency to stick with first impressions (anchoring) and not adjust sufficiently when presented with additional data.

Model advantages

Meadows and Robinson (1985) provided a succinct list of five advantages to using formal models: rigor, comprehensiveness, logic, accessibility, and testability. Models are rigorous in the sense that assumptions must be made explicit. Computerized models can integrate a much larger volume and variety of information than a human decision maker (comprehensiveness) and process it consistently (logic). These factors can help address human biases by storing and drawing conclusions from a more complete and unbiased data set. Since the logic must be spelled out in computer processing terms, it is, at least to those who understand the code, more accessible than the internal workings of a decision maker's mind. Finally, a model facilitates setting up and running different scenarios (testability). Besides raw processing power, many DSS, especially those referred to as "expert systems," also incorporate domain-specific knowledge. In this way they can supplement a user's expertise. Walters (1997) identified two other benefits of modeling. First, the explicit nature of models can help clarify problems, and second, they can help identify critical knowledge gaps.

Analytical reasons played a part in the choice to use a DSS in all the four core case studies. As described in the previous chapter, all the cases linked the explicitness of modeling to improvements in consensus building. The WBAFA case also emphasized comprehensiveness and testability. They used a common land use/ land cover GIS layer to coordinate the inputs and outputs of models for many different resources and processes, and their overall goal was to test three different scenarios. The WWT case just involved one model, and its purpose was to handle the intensive calculation needed to run their statistical model on the spatial data set. Although AREMP was also judging fish habitat, their model was considerably less focused on computation. In their case the DSS purposes were mainly to make the experts assumptions explicit (rigor) and consistent (logic) and thus more transparent (accessibility). It also helped the AREMP team identify missing information to help guide their future monitoring and assessment effort. The IPFP system also was designed to make their management system more explicit and so understandable to outside audiences. It also helps their foresters take a more comprehensive view of forest planning.

Social and Political Uses

DSS are also used for social and interpretive reasons. The literature has tended to consider many of these more political aspects as “misuses” of models. Smith-Korfmacher (1998) summarized such reasons found in past studies: rationalize a past choice, delay action, justify staff and computers, win credibility to policy recommendations, or demonstrate progressiveness. March and Feldman (1981) described how information is often used as a “symbol and signal” in organizational decision making. It symbolizes that decisions are being made rationally and it signals to other organizations that the holder of the information is best qualified to make related decisions. Similarly, using structuration theory from sociology, Walsham (1993) showed how information systems were used in the social processes of signification, domination, and legitimation. Some of the studies of FORPLAN reviewed in Chapter 5 also suggested that it was used to open up the planning process alternative forms of expertise (wildlife, recreation) but at the same time obfuscate decisions, making them harder for the public to challenge.

Other studies have focused on more positive social contributions of modeling. Klein (1998) described group decision making as often chaotic, plagued by the same problems as individuals, such as limited memory and attention, and perceptual filters. Van den Belt (2004) presented a number of case studies on the use of models in mediating disputes by helping to stabilize group thinking, provide transparency and accountability, institutional memory. Although McCown (2002b), documented considerable failure in the use of DSS in agriculture, he also found that they could be useful in facilitated farm consulting and farmer learning, as well as for organizational coordination and control needed to meet regulatory demands.

The cases reviewed in previous chapters showed this more positive side to social/interpretive uses. Models were expected to contribute to consensus building, and often had beneficial effects on success factors of participation, communication, translation, and mediation. The IPFP system provided the organizational coordination and control needed to meet regulatory demands and public expectations. The AREMP system played a crucial role in structuring the interaction and input of numerous expert groups. WBAFA's central land use model also helped to structure citizen input and come to three "politically plausible" scenarios. The WWT model has facilitated greater understanding among the scientific representatives but unfortunately not among decision makers.

These models also had some of the more questionable effects cited by Smith-Korfmacher (1998), although these influences were more difficult to document. One clear example is that the WWT model did provide a justification for delaying a final decision on designating fish habitat, but in doing so allowed a contentious negotiation process to finish. It also seems likely that the models were intended to bolster the implementers' credibility and image of progressiveness in all cases but not necessarily in a deceitful way.

While computer-based DSS are most commonly considered as a supplement to analytical tasks, they will inevitably have social effects also, whether intentional or not. When thinking through the rationale for using a DSS, both their social as well as analytical effects should be thought through. The social-analytical framework used in previous chapters provides a means to do so.

<u>When</u> **to use a DSS?**

A second aspect to consider is *when* the use of a computer-based DSS likely to be productive. Two major approaches to this question are evident in the literature on recommending decision-making methods: context and capacity

Decision Context

Chapter 2 discussed how DSS are sometimes defined by the type of decisions they are applied to. Gorry and Scott Morton's (1971/1989) matrix (Table 1) is the best known in this regard. They identified DSS as most commonly associated with semi-structured problems, that is problems where analytical processing could serve some but not all of the decision-making needs. Chapter 5 reviewed a number of frameworks for recommending decision modes based more on the social context. Thompsen and Tuden (1959), Lee (1999), and Salwasser (2004) classified contexts by the stakeholders' level of agreement on means and ends. Chess et al. (1998) used "level of knowledge" and "level of value agreement", and Shannon (2003) used "level of organization of actors" and "problems and interests." Only in one of these combinations is computation indicated as the preferred method. I would argue that this does not mean that analysis is not useful in the majority of situations, rather that if analysis is employed, it should be in a way designed to support the preferred mode of decision making.

DSS development in all four of the core cases began after their problems and approaches had been structured to the extent that the utility of a DSS was apparent. Structuring in the AREMP case was perhaps the most difficult, but the design results were also the most prescriptive. A number of iterations of an interagency science group spent a few years debating whether measuring watershed condition was even feasible and how before settling on a recommendation to use a particular DSS approach. The approach focused on supporting expert judgment in a collegial structure, which appears appropriate for a context that exhibited agreement on the ends/values (pre-specified as the condition of streams for fish) but not on means (of assessment) or knowledge. The situation for the development of IPFP (at least within the company) could be seen similarly, with agreement on ends (sustainable forestry) but a need to determine means (land use designations) resulting in the use of collegial teams. The WWT modeling attempted a computational approach because there appeared to be agreement that fish-bearing streams would be regulated differently (ends/values) and on how to define them (means/knowledge). But the values agreement was tenuous leading to a certainty requirement that was unattainable given the current state of knowledge. WBAFA's choice of integrating scientists and stakeholders in deliberation appears to be the recommended choice since the states of both scientific knowledge and value agreement appeared to be low.

Capacity

In the information systems literature on technology adoption, capacity has received more attention than context. Two types of capacity appear in the literature on DSS use, which I will refer to as technical and technological.

Technical Capacity

Technical capacity is an often used factor in predicting information systems success. It was incorporated into the "Support Quality / Modeling Capacity" measure used in evaluating the core cases in this study. Capacity is commonly thought about in terms of a computer user's experience with a particular program, type of software, or methods of analysis.

On the flipside, capacity needs can be thought of from the software point of view as the relative effort required to learn to use a particular system. A number of questions relating to transferability were asked in the Part I survey, including the "Level of effort needed to become functional." It is a difficult question to answer, since what is "functional" often depends on the complexity of the user's problem as well as the user's past experience. Given these caveats, Table 47 provides a relative categorization of DSS by technical capacity needs. Sixteen of the 30 systems provided a reply to this question, and I provided some of the rest (indicated by placing in parentheses) where I felt my understanding was sufficient. In making the decision whether or not to use a DSS, an assessment should be made of the software complexity, user experience, and time, money, and materials available for learning the necessary skills.

Table 47. Relative DSS Technical Capacity Needs

Category	*DSS*	*Capacity Needs**		*Category*	*DSS*	*Capacity Needs*
For & Bio	CLAMS	(High)		Forestry	FVS	(Medium)
For & Bio	Harvest	Low		Forestry	LANDIS	High
For & Bio	LUCAS	(High)		Forestry	LANDSUM	
For & Bio	MRLAM	(High)		Forestry	LMS	(Medium)
For & Bio	NED	(Medium)		Forestry	RELM	
For & Bio	WBAFA	(High)		Forestry	RMLANDS	(High)
Biodiversity	BMAS	High		Forestry	SIMPPLLE	(High)
Biodiversity	CAPS	(High)		Forestry	Spectrum	(Medium)
Biodiversity	C-Plan	Medium		Forestry	TELSA	(Medium)
Biodiversity	MARXAN	Medium		Forestry	VDDT	Low
Biodiversity	PATCH	(Medium)		Forestry	Woodstock	(High)
Biodiversity	RAMAS	(Medium)		General	DEFINITE	Low
Biodiversity	RefugeGAP			General	EMDS	(Low)
Biodiversity	ResNet			General	EZ-IMPACT	Low
Biodiversity	Restore			General	MAGIS	(High)
Biodiversity	Sites	Medium				
Biodiversity	Vista	Low				

** Items not in parentheses are based on answers to the specific capacity survey question; items in parenthesis indicate the author's estimate based on other system information available.*

Technological Capacity

Technological capacity refers to having the computer hardware and software necessary to implement a DSS. With the widespread diffusion of inexpensive and powerful personal computers, and the dominance of the Windows operating system, technological capacity has become much less of a limiting factor than when FORPLAN was initiated in the early 1980s. Hardware requirements were seldom given for the 30 DSS reviewed in Chapter 4, but it can be said that they are generally modest compared to current desktop computers. Almost any of the DSS reviewed could be expected to run on a Pentium III with 256 megabytes of memory and 50 megabytes of disk space. However, as the complexity of analyses and spatial extent and detail increase, more computing power can greatly affect the speed of processing.

For ensuring the basic capacity to run a DSS, software considerations are generally more important. DSS are programmed to run under specific operating systems; most are designed for Microsoft's Windows, but a number will only run under the Unix system (details are available in the online DSS database). A number of the DSS reviewed also require other pieces of software. The most common requirement is for a separate geographic information system (GIS), with ESRI's ArcView program being the most popular. ArcView is moderately expensive, has fairly high hardware requirements, and also requires time to master – all of which must be figured into technical and technological capacity needs.

Data

A very important and sometimes overlooked aspect of capacity relates to data. As was seen in the four core case studies, data preparation was often the most resource intensive activity. The DSS reviewed in Part I vary widely in their data needs. There are some patterns by DSS focus (forests, biodiversity, general) and approach (simulation, optimization, evaluation). The most general use systems (see Table Table 48 below for examples) tend to be the most flexible on data requirements, relying on anything from expert opinion to empirical databases. Simulation systems require information on the starting state and often parameters for expected changes over time. Optimization systems require a carefully thought out scoring system for comparing the different possible combinations. Biodiversity-focused systems often require habitat requirements and maps (possibly over time), and species demographic responses. Forest systems require anything from generalized forest type and age to specific tree counts from a detailed forest inventory.

Time

Time could be considered both a feature of the decision context and a resource related to capacity. In any case, time is needed to implement a DSS and this must be reconciled with the decision environment. In the literature exploring the difficulties of integrating science into policy, time is often cited as a major disconnect (Dale et al.

2003). New research typically takes longer than decision imperatives allow, and even science assessments specifically for decision making can face this problem (Johnson et al. 1999). McComb (in prep) has documented three specific cases where decision needs changed so radically while the DSS was under development that the systems were no longer useful. The estimated time needed to gather data and implement a DSS must be compared against expected decision deadlines and the general volatility of the decision making process. If the former takes longer than the latter, a DSS approach is unlikely to succeed.

Cases

Only one of the four cases exhibited a capacity problem: the data available for the WWT did not allow their model to be sufficiency accurate for acceptance by the decision makers. Technical capacity needs varied from fairly low for operating the AREMP and IPFP models, to fairly high for devising the statistical and heuristic models for WWT and WBAFA. Technical capacity came up as a limiting factor in a few of the ancillary cases. One of the interviewees for the Sandy Basin Anchor Habitats case mentioned that he had tried to use the EMDS modeling system for a previous effort but had failed due to lack of time and expertise. In the Chesapeake Forestlands Project, the Department of Natural Resources did not have the capacity to take over the modeling done by a consultant using the HABPLAN system. Rapidly shifting decision making needs were also a factor in this case. As the properties shifted from private to public management, public input suddenly shifted the debate from endangered species versus timber (the subject of the DSS analysis) to hunting access.

What **kind of DSS to use**

Many different DSS are available. For the current study, over 100 systems were screened and thirty chosen for the survey described in Part I. The previous DSS reviews discussed in Chapter 2 used a number of different categorization methods to help users find appropriate systems. The Type 1 and type 3 studies used more functional attributes, such as purpose, resources addressed, and analytical techniques, while the Type 2 studies discussed how different DSS would be useful in different stages of decision making. Issues discussed in the previous sections of this chapter—deciding on the questions of interest, evaluating the decision context and judging implementation capacity—also all bear on the decision of what type of DSS to use and are discussed below.

Question(s) of Interest

The first two categories in the tools matrix presented in Chapter 4 are intended to help decision makers choose a DSS that will answer their questions of interest. Characterization addresses what it is that they want to know about biodiversity—is it coarse habitat estimates or more fine scale population attributes? Most questions will involve how changes in the forest affect biodiversity, and the Forest Influences category documents which DSS address which change agents.

The questions of interest will also help determine an appropriate modeling approach. DSS texts list a variety of approaches, such as expert systems, group support systems, executive information systems, agent-based models, and so on (Marakas 1999; Turban and Aronson 2001). Instead of focusing on the modeling style, the Part I survey in this study classified DSS approaches into three more ends-based categories: simulation, optimization, and evaluation (see Table 48). Questions such as "What is the best parcel to conserve / silvicultural practice / etc?" lead naturally to an optimization approach. Simulation systems are best at addressing "What if?" questions (e.g. "What if we change our streamside buffer widths?"). Tools including evaluation functions provide methods to evaluate forest biodiversity in some way; they are appropriate for answering questions such as, "What is the biodiversity impact of X change in forest cover?" The more generalized systems (e.g. EMDS) provide a framework for setting up an evaluation, while the forest and biodiversity-centric tools tend to provide specific templates (e.g. LMS includes a number of forest structural stage metrics).

Many systems include more than one function, usually pairing either optimization or simulation with an evaluation function. By definition, optimization systems must include an evaluation function to compare alternatives, but systems only received an 'X' in the evaluation column if they provide specific functionality to help users structure an evaluation. Often more than one type of system will be needed to answer a question. For example, harvest scheduling models (e.g. Spectrum) require some estimates of tree growth and management, which are usually provided by growth models (e.g. FVS).

Decision Context

In his review of agricultural DSS, McCown (2002a) presented a continuum between highly structured DSS, that were primarily the product of scientists and DSS builders, and minimally structured decision aides, which required the user to provide most of the structure. Because optimization approaches require more structure, they will tend to be more appropriate in situations with relatively high levels of agreement/knowledge/problem definition. The "What if" scenarios answerable by simulation systems generally need less agreement/knowledge/problem definition. They are often used to project different means for addressing a problem and do not have to incorporate an evaluation mechanism for explicitly comparing results. Evaluation systems focus attention on explaining differences in means and ends. When the problem is very unstructured, a DSS is not recommended, rather conceptual modeling and problem structuring methods are likely to be the most useful (Gorry and Scott Morton 1989). Rosenhead (1989) has edited a volume which provides introductions to six such problem structuring methodologies.

Table 48. DSS Approaches from Part I Survey

Category	*System*	*Simulation*	*Optimization*	*Evaluation*
For-Bio	CLAMS	X		
For-Bio	Harvest	X		X
For-Bio	LUCAS	X		
For-Bio	MRLAM	X	X	X
For-Bio	NED	X		X
For-Bio	WBAFA / PNW-ERC	X		X
Biodiversity	BMAS		X	
Biodiversity	CAPS			X
Biodiversity	C-Plan		X	
Biodiversity	MARXAN / SPEXAN		X	
Biodiversity	PATCH	X		X
Biodiversity	RAMAS	X		X
Biodiversity	Refuge GAP			X
Biodiversity	ResNet & Surrogacy		X	
Biodiversity	Restore	X	X	X
Biodiversity	Sites		X	X
Biodiversity	Vista		X	X
Forestry	FVS	X		
Forestry	LANDIS	X		
Forestry	LANDSUM	X		
Forestry	LMS	X		X
Forestry	RELM		X	
Forestry	RMLANDS	X		
Forestry	SIMPPLLE	X		
Forestry	Spectrum		X	
Forestry	TELSA	X		
Forestry	VDDT	X		
Forestry	Woodstock	X	X	
General	DEFINITE		X	X
General	EMDS		X	X
General	EZ-IMPACT	X		X
General	MAGIS		X	

Another aspect of decision context to consider is the different needs in different decision stages as proposed by Costanza and Ruth (1998). They discuss modeling trade-offs between the aspects of realism (degree to which the model structure reflects real world processes), precision (in predicting outcomes), and generality (of the model's applicability). For the initial scoping stage they recommend starting with an emphasis on generality and moving towards realism in specifying problem structure. Flow charts and systems dynamics modeling software are recommended (two such programs are STELLA and VenSim). The second "research" stage typically requires sacrificing generality to move towards realism and precision. The final management stage is most concerned with predicting outcomes, and so should move further towards precision.

Capacity / Time

Capacity issues also figure into the choice of DSS, including how much time is available for the analysis compared to the available technical capacity to implement various approaches. The level of capacity needs in Table 47, as well as the case studies provide some information on the time needed to implement various approaches. Special attention should be given to data needs, since they often are the most time consuming to meet. In a survey of water quality modeling efforts, Smith-Korfmacher (1998) found a tendency to choose the most complex system available because they appeared more credible and state-of-the-art, as well as more difficult to challenge and more career enhancing. The costs of this preference tend to be borne later in more complex data needs, difficulty in updating, and inaccessibility to decision makers.

Case Examples

Examination of the case studies reveals more about how people choose what type of DSS to use, as well as the benefits and drawbacks of their approaches. International Paper's principle question of interest was: "How do we communicate our forest practices to the public?" The question does not involve simulation or optimization, rather it is focused on evaluation of their practices. Land allocation is at the root of these practices and is a spatial issue, so a GIS-based system was chosen. Their own foresters used maps often and maps also appeared to be a good public communication tool. After meeting regulations for stream buffers and other special habitats, their major challenge was to characterize biodiversity in general at the landscape scale, which led them to a coarse filter approach of tracking habitat types.

AREMP also asked an evaluation question: "What is the condition of watersheds?" Previous structuring of the problem within the Northwest Forest Plan gave them a decision context with agreed upon "ends/values" but without explicit agreement on a means for evaluation. Lee's (1999) framework would recommend "judgment in a collegial structure". EMDS was chosen because it was a system designed to support expert judgment that had proven fairly easy to use in past watershed evaluations.

WWT's question was very similar to AREMP's, although it was phrased in more absolute terms: "Does fish use extend to stream segment X?" A statistical evaluation approach was taken because an external source of information (electrofishing) was available to calibrate and check model results.

In contrast to the other cases, the WBAFA leaders posed a hypothetical "What if?" type question: "What would be the results under different policy scenarios?" Similar to IPFP, they were interested in the intersection of many factors at the landscape scale, and they also saw maps as an integrating and easily accessible format. For these reasons they also chose a GIS database as their core system. They wished to estimate biodiversity effects at both the coarse and fine scale, so they used a species-habitat matrix for the former and the PATCH model for the latter. For aquatic diversity they used statistical models, where relationships were sufficiently well understood, and expert judgment models where definitive data were lacking. Relative to many efforts, they had a wealth of time and capacity, and so were able to build a number of custom models particularly suited to their needs.

<u>How</u> **to Use the DSS**

The FORPLAN studies reviewed in Chapter 2 found more at fault with the Forest Service's use of the model than with the model itself. Barber and Rodman (1990) saw it manipulated to justify current practices rather than to truly analyze new possibilities.

In a similar vein, Johnson (1987) saw its complexity used as a way to impede outside criticism; he also saw it being applied mechanically to address the planning requirements rather than creatively to address planning needs. More recently, summarizing their study of 50 decision support tools, Johnson and Lachman (2001) wrote, "The process for using the tool is as important as the tool." The "how" of DSS use is examined using the categories above, as well as the success factors covered in the previous chapter.

<u>Question(s) of Interest</u>

Taking the time to clearly define the problem is seen as a critical and often under-appreciated part of the modeling process (Meadows and Robinson 1985; Johnson et al. 1999; Johnson and Lachman 2001). At the same time, others emphasize the need for the problem definition to evolve along with understanding (Nicolson et al. 2002), which is mor consistent with the view that values depend on context and preferences are socially constructed during the policy making process (Smith 1997). These recommendations are not necessarily contrary: one can take time to define the problem well, yet also allow it to evolve with understanding.

Strauch (1975) argues that any problem definition can only be represented imperfectly in an analytical framework. A danger is that the model is taken to be a true "surrogate" for the problem, and model results adopted without further thought. Rather, he argues, models are best thought of as perspectives on a problem to be complemented by decision makers' more qualitative understanding of the issues. Along this line, Sterman (1991) emphasizes that the best use of models is for learning rather than directly evaluating choices.

<u>Decision Context</u>

The various decision context frameworks seldom recommend analysis as the preferred method of decision making. This advice is especially likely in regards to biodiversity decisions, where knowledge is typically insufficient and agreement among actors low. Yet three of the four cases reviewed in depth claimed successful DSS applications—how is this possible? The conclusion from this study is that the DSS were used successfully by putting them in the service of a more dominant decision making approach.

When computation is not the preferred decision method, the DSS is best seen as part of an analytical–deliberative framework, as described by NRC (1996). Just as there are many DSS available, so are there many deliberative possibilities. A whole literature on participation exists, including various handbooks for practitioners (see Webler (1997) for a review of three). A summary list of approaches is presented in Table 49. What is largely missing is studies of how and how well different analytical techniques can support these processes (National Research Council 2005). The current study provides some insights into the effectiveness of the particular analytical-deliberative matches found in the case studies. This study's analytical and social success factors framework also provides more generalized help in thinking about the integration of these aspects.

Table 49. Participation Model Alternatives

▪ Public hearings
▪ Public inquiries
▪ Social surveys
▪ Arbitration
▪ Scientific advisory groups
▪ Citizen advisory committees
▪ Citizen panels (planning cells)
▪ Citizen juries
▪ Citizen initiatives
▪ Negotiated rule making
▪ Mediation
▪ Compensation and benefit sharing
▪ Dutch study groups

Sources: Renn et al. (1995); NRC (1996)

Procedural Suggestions

The success factor framework developed in Chapter 6 proved useful in understanding the four core cases in previous chapters. Here the results are further synthesized and rephrased in a more prescriptive fashion to help guide the "how" of DSS use.

Understand the (relative) information credibility demands of decision makers. Scientists and modelers tend to look for quantitative accuracy thresholds, but decision makers may not be able to articulate their needs in this regard. No specific levels were discussed in the AREMP and WBAFA cases; it was just assumed that the best available information within the bounds of the projects' budgets would be generated. In the IPFP case, the information had to be current or the users would lose faith in the system. The accuracy threshold in all these cases was not an absolute scientific measure rather it was the level of confidence in the system developed by the participants. The confidence of these groups was in turn the primary evaluation metric seen by uninvolved decision makers. Decision makers in the WWT case actually set a quantitative accuracy threshold, but the primary lessons from the case show two ways in which information credibility is relative to context. First, where the stakes are high and immediately related to DSS results, accuracy demands are likely to be very high as well. Second, the case showed the relative nature of quality judgments; stakeholders had what they felt was a more accurate measure in electrofishing and so were unwilling to accept less accuracy, even though it was much more costly to landowners and potentially harmful to fish.

Pilot test on data diversity. Data quality is of course a major determinant of information quality ("garbage in, garbage out"). The nature of natural resource data is that it is likely to vary considerably over different geographies and ownerships. The AREMP team struggled with the comparability of public and private roads and streams data, while in the WWT case, the data available appear insufficient to model the flatter regions. Pilot testing the DSS on samples reflecting the data's diversity is recommended. All in all, data preparation was one of the most resource-intensive aspects of DSS implementation, so potential users should plan for these costs upfront (and perhaps double this estimate, then double it again, as I have heard recommended!).

Solicit and incorporate local information. Generating data that is accurate enough to satisfy stakeholders appears to usually require their "local" input. Participation of local experts/stakeholders was a success factor in three of the cases. In IPFP this was accomplished by having the field foresters help maintain the data directly. Local experts were engaged in building the AREMP and WBAFA models. The exception, the WWT case, had the participation of stakeholder representatives, but it lacked local representation in a local geographic sense. Stakeholders are now demanding that local stream location corrections and electrofishing results be integrated into the WWT fish presence maps.

Limit and target participation to the extent the problem allows. Our democratic ideals and much of the literature on policy making call for making participation as broad as possible. Yet participants in three of the four cases reviewed (those that did not have a direct effect on public decisions about the allocation of resources) believed that being selective about participation helped them be more successful. In the case tied to a policy decision, trying to transfer considerable decision responsibility to a technical group proved problematic, suggesting that one must be much more careful when considering limiting participation in such situations. When targeting participation, as just discussed, local input appears essential. Participation of decision makers also seems important but not universally so. WBAFA integrated governmental decision makers at a number of levels to help put its ideas into use. AREMP succeeded without the participation of the regional decision makers; instead the support of local experts provided the assessment with the needed credibility in the eyes of the decision makers.

Use iterative, two-way communication in small groups to lead the integration of knowledge and/or perspectives. In all the four core cases, FBDSS design and implementation integrated multiple perspectives and/or types of knowledge through the use of small groups. Many were temporary, such as IPFP's cross-sectional groups, AREMP's regional expert groups, and WBAFA's technical and stakeholder groups. The WWT case involved more permanent structures. Group size varied from 5-20 people. These groups are where the translation and mediation between different interests and knowledge levels occurred. The interchange between modelers and participants was important in all the cases and multiple rounds of refinement were needed. WBAFA demonstrated how a multi-level communication process could be structured.

Visualizations help translate between different levels of knowledge. Maps were a principle translation tool in all of the cases. Scientists and lay persons may start with quite different conceptions and interpretations of maps, so arranging time for joint exploration has been recommended (Duncan 2004). Maps may be very limited in the forest information they convey because of their abstracted nature. WBAFA experimented with the use of three-dimensional landscape visualizations, but did not comment on their effectiveness. Research in this area exists to help gauge its usefulness and guide its application (Meitner et al. 2005).

DSS can help structure group work and accumulate results. Research on has shown how erratic group decision making processes can be (Klein 1998). The cases reviewed in this study showed how DSS can be used to provide a structure to the decision making process. At the same time, the system needs to be flexible enough to be adapted to participants needs. In the more successful cases, participants had a feeling of control over the DSS. The cases also demonstrated how DSS are used to keep track of and integrate diverse sources of information. They serve as repositories for group decisions. These data/model repositories were only directly accessible to users in one case (IPFP); the others required access through a facilitator or translation products (hardcopy maps, tables, etc.). Even so, the repositories appeared effective if their structure was transparent enough for the group to understand in concept.

<u>Who</u> **will Implement the DSS** <u>Where</u>?

Studies of information systems, policy analysis, and environmental assessments have all identified the importance of the organizational aspects of conducting an analysis. This section focuses on the modelers and their organizational relationships with other participants and stakeholders. Key issues appear to be where to find or develop modeling capacity and the levels of science-policy and inter-organizational integration needed. As discussed by Cash et al. (2002), these issues bear upon stakeholders perceptions of salience, credibility, and legitimacy.

<u>Capacity and Time</u>

Most of the DSS in the Part I survey were developed either at universities or federal research labs. Engaging these system designers directly is one possibility for securing the capacity to apply a DSS. Such arrangements may or may not require compensation for the researchers time, depending on the fit of the application to the research organization's mission and the availability of other research funds. It should be recognized that researchers, especially self-funded ones, will often have their own objectives. Trying new, unproven methods and publicizing results are two research attributes that can conflict with those of other participants. Formal organizational arrangements may be necessary, which in turn require time to set up.

DSS development or expertise is sometimes available from commercial businesses (e.g. RAMAS, Woodstock). Engaging such consultants is probably the quickest and surest way to access DSS expertise. They should tend to be more client-focused than research institutions but also potentially more expensive.

A third way to access DSS capacity is to develop it in-house, either through hiring people with the existing skills or training current employees. This option requires more time than the others and suggests a continuing need for the DSS (as opposed to a one-time use). Many of the FBDSS reviewed have not been applied widely enough for a pool of skilled individuals to develop, but a few have. The review website lists the estimated number of uses for each system, which can help gauge the potential for hiring (Gordon 2003). For in-house training, Table 47 above characterizes learning needs, and the website provides more information on the documentation and training opportunities available for each system.

Organizational Relations

Organizations relate to each other in different ways, and the choice of who implements the DSS where will inherit the attributes of these relationships. Some of the most discussed aspects in the literature include the client-modeler relationship, inter-organizational trust, and the science-policy interface.

One of the major unexpected influences in Meadows and Robinson (1985 p. 10) studies of modeling was "the organizational situation of the model: the interrelationships, forms of communication, pressures, deadlines, and motivations that characterized each set of modelers and policymakers." The cases they studied involved distinct client-modeler relationships. Particular factors they found important in this setting were participation of the client in the modeling process and tailoring of the output to the client's level of understanding.

At an inter-organizational level the "not invented here" barrier is commonly recognized (Dale et al. 2003). Analysis coming from outside an organization is less likely to be accepted than internal information. The most obvious barrier is trust; each organization has its own methods for vetting the accuracy of information. A second issue is control, accepting outside information can be seen as ceding power to outside forces. A third issue is salience, outside information is less likely to fit an organization's particular context. As Rayner et al. (2000) write,

> Integration of new information into this decision process is a challenge of articulating that information within an organization's frameworks of meanings and collective action, not merely a problem of removing exogenous barriers to information.

Another aspect of who and where to implement DSS is the framework for science-policy integration. In their review of environmental assessments Farrell and Jäger (2006) found that the appropriate degree of integration could vary by the level of issue development. At identification stage the interface between science and policy was typically quite distinct, but as issues develop into proposals for management action, the line becomes more blurred to allow closer interaction between scientists and policymakers. Jasanoff (1990 p. X) found that, "proceedings founded on the separatist principle frequently generate more conflict than those which seek, however imperfectly, to integrate scientific and political decision making." A further complication to the interface is that questions asked by decision makers generally can't be answered with existing science, and so require a measure of judgment (Jasanoff 1990; Johnson et al. 1999). Such extrapolations are especially vulnerable to the inter-organizational trust issues discussed above.

One solution to the vetting of information between different organizations and types of expertise is the creation of boundary objects and organizations (Star and Griesemer 1989; Guston 2001). As discussed in Chapter 6, such objects or organizations are designed to provide meaningful information for both sides of the boundary and handle translation as necessary. The federal science advisory committees studied by Jasanoff (1990) are examples of boundary organizations, and

Cash et al. (2002) cited the collaborative building of models, forecasts or reports as examples of boundary objects. The need for boundary spanning (or horizontal coordination) has long been recognized within organizations as well. Table 50 summarizes a range of mechanisms based on resource costs and the level coordination needed. These mechanisms are not mutually exclusive, so again information systems can be used to support the other methods.

Table 50. Boundary-spanning Coordination Mechanisms

↓ increasing coordination	↓ increasing resources required	*Mechanism*
		Information systems
		Direct contacts
		Task forces
		Full-time integrators
		Teams

Source: Adapted from Daft (2001)

<u>Case Examples</u>

The cases in this study demonstrate a wide variety of arrangements for the who and where of DSS use. IPFP, as a core business function of a private company, was naturally developed for internal use. At the time of inception they did not see any specialized systems that would meet their needs, and they had the resources to build their own on top of a generic GIS platform. They used cross-cutting teams to design the system and involved outside experts as participants and reviewers to help provide scientific credibility. Their biggest decision on use was to push it out to the field foresters, which required more training and design effort, but minimized boundaries by putting the tool and data maintenance in the hands of the field decision makers.

The scientists who designed AREMP faced an early decision on whether to create a centralized monitoring team or push the responsibility to more local levels. They opted for the former, primarily for ensuring analytical consistency, but it meant the monitoring team had to spend more effort on getting participation from local experts. The policy question had been broadly framed (condition of watersheds for fish), and the local expert workshops provided the scientific interpretation and information needed to answer it. Focusing on land management agencies minimized the management-regulatory boundary spanning needed. The DSS developer was in the research arm of one of the agencies involved and agreed to provide partial support to the effort through a graduate student. Since the system was relatively easy to use and the monitoring team intends to use it for yearly evaluations, the team also developed their own in-house capacity.

In the WWT case, an official science committee, and numerous subcommittees were set up by drawing scientific expertise from the participating stakeholder representative groups. One of these subcommittees had responsibility for designing and executing the model under the oversight of the main group. Inter-organizational credibility was established by this diverse participation. Because of worries about the interest groups unduly affecting the science, the science groups were purposefully distanced from the policy groups and scientist participants were told to leave their organizational affiliations at the door. Individually the science and policy committees appear to have been quite successful at bridging the boundaries between organizations and interests. However, the "firewall" between the science and policy groups may have worked too well, not allowing the level of interchange needed for them to come to a common understanding.

WBAFA also created a type of science-policy firewall; in their case it was between the stakeholder group overseeing development of the three scenarios and the scientists estimating the impacts of each scenario on various resources. No problems were expressed with this arrangement, but since the predicted impacts were not tied to regulatory mechanisms, the level of scrutiny was much lower. The citizen modeling group served as a boundary organization between different interests and organizations, although it was not as strictly representative of stakeholders as the WWT groups. Involving this citizen group and soliciting regular feedback from two other regional groups involved more potential users of the results in the process and served to increase their salience and legitimacy. Since the project was initiated by the research arm of the Environmental Protection Agency and a university consortium, modeling capacity was readily available in these organizations.

Summary

Deciding whether and how to use a DSS involves a host of interrelated questions. Instrumental goal definition, analytical functionality, and capacity considerations tend to dominate the system development or choice strategies presented the in the information systems literature and in DSS reviews (Part I of this study included). These considerations are undoubtedly important to successful DSS use, and they form two of the three threads running through the questions addressed above ("question of interest" and "capacity"). However, these aspects are by no means the whole story. Studies of the use of DSS in real-world decision-making situations have documented the often dominant importance of more social or interpretive factors. While no hard and fast rules are likely to suffice in addressing highly complex and situational nature of social systems, the literature and cases reviewed for Part II of this study have provided some general guidance on considering the decision context and interpretive roles of DSS.

Table 51. Summary of DSS Use Recommendations

Why Use a DSS

- rigor, comprehensiveness, logic, accessibility, and testability
- stabilize group thinking, provide transparency and accountability, institutional memory
- organizational coordination and control
- learning

When to Use a DSS

- decision context
- after initial problem structuring
- issue stability allows time for analysis
- data, technical and technological capacity available

What kind of DSS to use

- question(s) of interest: simulation, optimization, evaluation
- decision context and structure
- capacity and time

How to Use the DSS

- serve the primary mechanisms appropriate for the decision context
- understand the (relative) information credibility demands of decision makers
- pilot test on diversity of data
- solicit and incorporate local information
- limit and target participation to the extent the problem allows
- use iterative, two-way communication in small groups
- visualizations help translate between different levels of knowledge
- DSS can help structure group work and accumulate results

Who and Where

- DSS designers / researchers, consultants, or in-house
- client-modeler relationship
- inter-organizational trust
- the science-policy interface
- boundary spanning mechanisms

CHAPTER 13 – CONCLUSIONS

The question posed at the outset of this study was a practical one: "How can stakeholders in forest biodiversity issues find the tools that best meet their needs and use them effectively, given the wide range of technical needs and social contexts associated with forest decisions?" However, answering this practical question led to a number of more theoretically abstract themes, such as "How can decision needs and the adequacy of decision support tools be characterized?", "How can decision success be measured and important factors identified?", and "What are the roles of analysis and deliberation in decision making?"

Part I attempted to answer the first question using an analytical/instrumental approach of comparing system capabilities to functional needs. Few systems were found that integrated both forest and biodiversity modeling capabilities. Most of these integrated "systems" were really suites of models brought together under regional assessment exercises, as distinct from a single, easily-distributable piece of software. There was a distinct split between the capabilities of forest-centric and biodiversity-centric DSS. Together they could cover many of the hypothesized needs, but only a few have begun to make such links. As a whole, forest biodiversity analysis appears to be in a pre-paradigm state where few standard procedures exist. The simple diversity of biodiversity and biogeography make standardization difficult, nevertheless, standards for biodiversity classification and forest certification are bringing more regularity to the field. Future DSS development might most profitably be tied to such initiatives.

As earlier reviews of the FORPLAN tool revealed, analytical capabilities are only one factor contributing towards successful DSS use in any given situation. Beyond FORPLAN few such usage studies on forest or biodiversity DSS were found, but a variety of examples exist in the broader fields of information systems, planning, and policy analysis. Part II of this study constructed a theoretical framework from these sources and tested it on the use of models in four forest biodiversity problem-solving situations. Interviewees were asked to define "success," and in turn one of their top responses was "user reactions". Not only did they indicate success was socially constructed in this way, their other top success measure, "consensus building," indicated that their DSS use was socially-oriented. The framework of contributing success factors constructed from information systems theory and environmental assessment studies proved quite comprehensive. Only a few reasons given by participants did not fit in well, and the framework helped identify a number of factors which the case histories supported but the interviewees did not mention. For example, data quality tended not to be mentioned but behavior and allocation of resources would indicate otherwise.

The most direct advice on the combination of analysis and social deliberation was found in the environmental risk assessment literature (NRC 1996, 2005), which called for a "mutual and recursive" relationship. Three of the cases studied which showed successful "mutual and recursive" patterns were judged as successful by their participants, while the promise of the model has foundered in the fourth case where such interchange was sparse. At least two of the cases demonstrated planned, intentional integration of DSS and social processes. The AREMP design team recommended a system based on its past use in similar expert deliberations, and the WBAFA case demonstrated a purposeful integration of modeling into a multi-tiered, two-way communication strategy.

Social complexity did not preclude analytical complexity, as hypothesized from the literature (Allen and Gould, Jr. 1986; Sterman 1991). In the two more socially complex case studies, a complex analytical model was found to work in one, where a simpler model has so far failed in the other. The relationship here may be more fine-grained and malleable. First, the study framework may not have captured the true difference in social complexity between these cases. The problematic case involved the direct allocation of considerable resources; the other involved many interests but no such direct effects. Second, the more successful case also spent far more time and energy on integrating the model into social deliberation processes, which appeared to successfully compensate for its higher analytical complexity.

Further Research

As an attempt at detailed research into a complex topic tends to do, this study has raised more questions than it has contributed to answers. Part I already identified some specific DSS development needs and those will not be repeated here. A more fundamental issue is the lack of any synthetic description of who is making what kind of forest biodiversity decisions. Federal, state, and local governments, industry, environmental groups, and citizen organizations are all making explicitly biodiversity-related decisions, some as land managers, some as advocates, and some from a regulatory perspective. Describing this milieu is important for understanding decision needs and the development of relevant DSS.

Another aspect of the Part I study, which was not addressed in the Part II cases, is how DSS can help address some of the most distinctive needs of forest biodiversity and ecosystem management decisions, such as the integration of disciplinary information and coordination across geographic scales. It did not seem profitable to ask these questions here, since some of the Part II cases only addressed very narrow questions within the broader framework of ecosystem management. The Mowrer (1997) DSS review originally raised these needs in the sense of DSS functionality, but a case study approach similar to Part II could look how analytical and social mechanisms combined to attempt to meet these needs.

The greatest need, especially in the eyes of the National Research Council (1996, 2005), may be for more investigation into the design of better analytic-deliberative processes. Individually, research into analytic and deliberative methods both have considerable histories, but there are very few studies which attempt to combine them, especially in a comparative design. Perhaps it is because they comprise such different disciplinary orientations. Yet it could be argued that almost all decisions of consequence attempt to combine these techniques, or at least they pretend to. One approach is from the macro scale of investigating different combinations, such as linear programming and planning cells. One could also conduct a more micro-level investigation of connections between specific analytical and social factors, such as the participation-information quality link seen in many of the cases here.

BIBLIOGRAPHY

Allen, G.M.; Gould, E.M., Jr. 1986. Complexity, wickedness, and public forests. Journal of Forestry 84(4): 20-23.

ATFS. 2006. Standards of Sustainability for Forest Certification. Washington, DC : American Tree Farm System. Retrieved March 1, 2006 from the World Wide Web: http://www.treefarmsystem.org/cms/pages/26_21.html

Anthony, R.N. 1965. Planning and Control Systems: A Framework for Analysis. Boston : Harvard University Graduate School of Business Administration.

Bailey, R.G., (tech. ed.) 1986. Proceedings of the workshop on lessons from using FORPLAN. Washington, DC : USDA Forest Service, Land Management Planning Systems Section.

Baker, J. P., D. H. Landers, H. Lee, II, P. L. Ringold, R. R. Sumner, P. J. Wigington, Jr., R. S. Bennett, E. M. Preston, W. F. Frick, A. C. Sigleo, D. T. Specht, and D. R. Young. 1995. Ecosystem management research in the Pacific Northwest: five-year research strategy. U. S. Environmental Protection Agency, Office of Research and Development, Washington, D.C., USA. EPA/600/R-95/069.

Baker, J.P.; Hulse, D.W.; Gregory, S.V.; White, D.; Van Sickle, J.; Berger, P.A.; Dole, D.; Schumaker, N.H. 2004. Alternative futures for the Willamette River Basin, Oregon. Ecological Applications 14(2): 313-324.

Bakke, B. 1997. Washington Trout finds lost salmon habitat. NW Fishletter #48. http://www.newsdata.com/enernet/fishletter/fishltr48.html

Barber, K.H.; Rodman, S.A. 1990. FORPLAN: The marvelous toy. Journal of Forestry 88(5): 26-30.

Barrett, T.M. 2001. Models of vegetation change for landscape planning: a comparison of FETM, LANDSUM, SIMPPLLE, and VDDT. General Technical Report RMRS-GTR-76-WWW. Ogden, UT : USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. [http://www.fs.fed.us/rm/pubs/rmrs_gtr76.pdf]

Bradley, G.A. 1986. Organizational response to integrated land management planning: NFMA and the U.S. Forest Service. Doctoral dissertation. Ann Arbor, MI : University of Michigan.

Bradshaw, G.A.; Borchers, J.G. 2000. Uncertainty as information: narrowing the science-policy gap. Ecology and Society 4(1) [http://www.ecologyandsociety.org/vol4/iss1/art7/]

Carey, A.B. 2002. Globalization of Flora: Inviting Worldwide Ecosystem Disaster. Renewable Resources Journal 20(1): 13-17.

Cash, D.; Clark, W. 2001. From science to policy: Assessing the assessment process. Faculty Research Working Paper RWP01-045. Cambridge, MA : John F. Kennedy School of Government, Harvard University. [http://ksgnotes1.harvard.edu/bcsia/sust.nsf/publications]

Cash, D.; Clark, W.; Alcock, F.; Dickson, N.; Eckley, N.; Jäger, J. 2002. Salience, credibility, legitimacy and boundaries: linking research, assessment and decision making. Faculty Research Working Paper RWP02-046. Cambridge, MA : John F. Kennedy School of Government, Harvard University.

Cash, D.W.; Clark, W.C.; Alcock, F.; Dickson, N.M.; Eckley, N.; Guston, D.H.; Jäger, J.; Mitchell, R.B. 2003. Knowledge systems for sustainable development. Proceedings of the National Academy of Sciences of the United States of America 100(14): 8086-8091. [http://www.pnas.org/cgi/doi/10.1073/pnas.1231332100]

Checkland, P. 1981. Systems thinking, systems practice. Chichester [Sussex] ; New York : J. Wiley.

Checkland, P.; Holwell, S. 1998. Information, systems, and information systems : making sense of the field. Chichester ; New York : Wiley.

Chess, C.; Dietz, T.; Shannon, M. 1998. Who should deliberate when? Human Ecology Review 5(1): 45-48.

CMER. (year-month-day). Minutes of the Cooperative Monitoring, Evaluation, and Research Committee. http://www.dnr.wa.gov/forestpractices/adaptivemanagement/cmer/meetings/

Cohen, M.D.; March, J.G.; Olsen, J.P. 1972. A garbage can model of organizational choice? Administrative Science Quarterly(17): 1-25.

Conrad, R. H.; Fransen, B.; Duke, S.: Liermann, N.; Needham, S. 2003. The development and assessment of the preliminary model for identifying fish habitat in western Washington

Cortner, H.J.; Moote, M.A. 1999. The politics of ecosystem management. Washington, D.C. : Island Press.

Cortner, H.J.; Schweitzer, D.L. 1983. Institutional limits and legal implications of quantitative models in forest planning. Environmental Law 13(2): 493-516.

Costanza, R.; Low, B.S.; Ostrom, E.; Wilson, J. 2001. Institutions, ecosystems, and sustainability. Boca Raton, FL : CRC Press.

Cupp, E. 2004. Water typing model field performance assessment. Washington Forest Practices Adaptive Management Science Conference. April 5, 2005. Olympia WA.

Daft, R.L. 2001. Organization theory and design. 7 ed. Cincinnati, OH : South-western College Publishing.

Dale, V.H.; English, M.R. 1999. Tools to aid environmental decision making. New York : Springer. [http://www.ncedr.org/]

Dale, V.H.; Rewerts, C.; van Winkle, W.; Harwell, M.A.; Vasievich, M. and Hodapp, S. 2003. Barriers to the use of ecological models in decision making. In: Dale, V.H. Ecological modeling for resource management. New York, NY : Springer 109-122.

Davis, F. 1989. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly 13: 319-340.

Davis, L.S.; Johnson, K.N.; Bettinger, P.S.; Howard, T.E. 2001. Forest management: to sustain economic, ecological, and social values. New York : McGraw-Hill.

DeGraaf, R.M. and M. Yamasaki, 2001. New England Wildlife: Habitat, Natural History, and Distribution. University Press of New England. Hanover, New Hampshire. 482p.

DeGraaf, R.M., M. Yamasaki, W. Leak, and J. W. Lanier. 1992. New England Wildlife: Management of Forested Habitats. Gen. Tech. Rep. NE-144. USDA, Forest Service, Northeast Forest Experiment Station, Radnor, Pennsylvania. 271 p.

DeLone, W.H.; McLean, E.R. 2003. The DeLone and McLean Model of Information Systems Success: A Ten-Year Update. Journal of Management Information Systems 19(4): 9-22.

Dewey, J. 1927. The public and its problems. New York : Swallow.

Diamond, H.L.; Noonan, P.F. 1996. Land use in America. Washington, DC : Island Press. 351p.

Donovan, G. 2005. Forest Patterns™ : A landscape management tool. Presentation to the SFI Conference, Portland ME, Sept. 20, 2005. [http://www.aboutsfb.org/workshopPDFs/Eco1a.pdf]

Duncan, S. 2004. Technology and Meaning in Natural Resource Management: The Story-Making Role of GIS in the CLAMS Project. Environmental Science. Ph.D.. Corvallis, OR : Oregon State University.

Farrell, A.E.; Jäger, J. 2006. Assessments of regional and global environmental risks : designing processes for the effective use of science in decisionmaking. Washington, DC : Resources for the Future.

Feldman, M.S. 1989. Order without design : information production and policy making. Stanford, CA : Stanford University Press.

Feldman, M.S.; March, J.G. 1981. Information in organizations as signal and symbol. Administrative Science Quarterly 26: 171-185.

Fichman, R.G. 1992. Information technology diffusion: a review of empirical research. Paper Presented at Proceedings of the Thirteenth International Conference on Information Systems (ICIS), Dallas, TX. [http://www2.bc.edu/~fichman/]

Fincham, R. 2002. Narratives of success and failure in systems development. British Journal of Management 13(1): 1-14.

Fischer, F. 2000. Citizens, experts, and the environment : the politics of local knowledge. Durham, NC : Duke University Press.

Fischer, F.; Forester, J. 1993. The Argumentative turn in policy analysis and planning. Durham, N.C. : Duke University Press.

FPARS (Forest Practices Application and Review System). http://www3.wadnr.gov/dnrapp4/fparsweb/public/

FPB. (year-month-day). Minutes of the Washington Forest Practices Board. http://www.stage.dnr.wa.gov/forestpractices/board/meetings/minutes/

Franklin, J.F. 1986. Structural and functional diversity in temperate forests. In: Wilson, E.O. Biodiversity. Washington, DC : National Academy Press 166-175.

Fransen, B. R., S. Needham, G. McWethy, and V. Kim. 1997. Development of a process to delineate potential fish habitat based on physical characteristics measured at the upper extent of known fish distribution. Unprocessed report to the Timber, Fish, and Wildlife Water Typing Committee.

FSC 2006. Principles and criteria. Washington, DC : Forest Stewardship Council - US. Retrieved March 1, 2006 from the World Wide Web: http://www.fscus.org/standards_criteria/

Galliers, R. 1992. Information systems research : issues, methods, and practical guidelines. Oxford ; Boston : Blackwell Scientifc Publications. 277 p.p.

Giddens, A. 1984. The constitution of society. Berkeley, CA : University of California Press.

Gieryn, T.F. 1983. Boundary work and the demarcation of science from nonscience: Strains and interests in professional ideologies of scientists. American Sociological Review 48(6): 781-795.

Gieryn, T.F. 1995. Boundaries of science. In: Jasanoff, S., Markle, G.E., Petersen, J.C. and Pinch, T. Handbook of science and technology studies. Rev. ed. Thousand Oaks, CA : Sage Publications 393-443.

Gordon, J.C. 1994. From vision to policy: a role for foresters. Journal of Forestry 92(7): 16-19.

Gordon, S.N.; Johnson, K.N.; Reynolds, K.M.; Crist, P.; Brown, N. 2004. Decision support systems for forest biodiversity: Evaluation of current systems and future needs. Final Report on Project A10. Washington, DC : National Commission on Science for Sustainable Forestry.

Gorry, G.A.; Scott Morton, M.S. 1989. A Framework for Management Information Systems. Sloan Management Review 30(3): 49-62.

Greenberger, M.; Crenson, M.A.; Crissey, B.L. 1976. Models in the policy process : public decision making in the computer era. New York, NY : Russell Sage Foundation. 355 pp.

Grumbine, R.E. 1994. What is ecosystem management? Conservation Biology 8(1): 27-38.

Guimaraes, T.; Igbaria, M.; Lu, M.-t. 1992. The Determinants of DSS Success: An Integrated Model. Decision Sciences 23(2): 409-431.

Gustafson, E.; Nestler, J.; Gross, L.; Reynolds, K.; Yaussy, D.; Maxwell, T. and Dale, V. 2002. Evolving approaches and technologies to enhance the role of ecological modeling in decision-making. In: Dale, V. Ecological modeling for resource management. New York : Springer-Verlag 135-164.

Guston, D.H. 2001. Boundary organizations in environmental policy and science: an introduction. Science, Technology & Human Values 26(4): 399-408.

Healy, R.G.; Ascher, W. 1995. Knowledge in the Policy Process: Incorporating New Environmental Information in Natural Resources Policy Making. Policy Sciences 28(1): 1-19.

Hickson, D.J.; Butler, R.J.; Cray, D.; Mallory, G.R.; Wilson, D.C. 1986. Top decisions : strategic decision-making in organizations. 1st ed. ed. San Francisco : Jossey-Bass Publishers.

Hoekstra, T.W.; Dyer, A.A.; LeMaster, D.C. 1987. FORPLAN: An evaluation of a forest planning tool. Proceedings of a Symposium, November 4-6, 1986 GTR-RM-140. Denver, CO, USA : USDA Forest Service, Rocky Mountain Forest and Range Experiment Station.

Hulse, D.; Gregory, S.; Baker, J. 2002. Willamette River Basin Planning Atlas: Trajectories of Environmental and Ecological Change. Corvallis, OR : Oregon State University Press. 192p.

Hulse, D.W.; Branscomb, A.; Payne, S.G. 2004. Envisioning alternatives: using citizen guidance to map spatially explicit assumptions about future land and water use. Ecological Applications 14(2): 325-341. [http://www.fsl.orst.edu/pnwerc/wrb/Atlas_web_compressed/PDFtoc.html]

Hunter, M.L. 1990. Wildlife, forests, and forestry : principles of managing forests for biological diversity. Englewood Cliffs, NJ : Prentice-Hall.

Hunter, M.L. Jr. 1995. Personal comments at Champion International Corporation meeting.

Hunter, M.L. Jr. 1996. Fundamentals of Conservation Biology. Blackwell Science, Inc. Cambridge, Massachusetts. 482 p.

INR 2005. Willamette Basin Conservation Project Final Report. Corvallis, OR : Institute for Natural Resources [http://hdl.handle.net/1957/469]

INR 2006. About INR. Corvallis, OR : Institute for Natural Resources. Retreived March 6, 2006 [http://inr.oregonstate.edu/about_index.html]

IP 2002. Northeast Area Sustainable Forestry Policy. International Paper internal document dated 9/5/2002.

Iverson, D.C.; Alston, R.M. 1986. The genesis of FORPLAN: a historical and analytical review of Forest Service planning models. General Technical Report INT-214. Ogden, UT : USDA Forest Service, Intermountain Research Station.

Jasanoff, S. 1990. The fifth branch: science advisers as policymakers. Cambridge, Mass. : Harvard University Press.

Johnson, K. N.; Duncan, S.; Spies, T. A. In press. Barriers to applying ecological science in forest biodiversity policy debates: Lessons from coastal Oregon. Ecological Applications, in press.

Johnson, K.N. 1987. Reflections on the development of FORPLAN. In: Hoekstra, T.W., Dyer, A.A. and LeMaster, D.C. FORPLAN: An evaluation of a forest planning tool. Denver, CO : USDA Forest Service, Rocky Mountain Research Station 45-51.

Johnson, K.N.; Stuart, T.W.; Crim, S.A. 1986. FORPLAN version 2: An overview. Washington, DC : USDA Forest Service, Land Management Planning Systems Section.

Johnson, K.N.; Swanson, F.; Herring, M.; Greene, S. 1999. Bioregional assessments : science at the crossroads of management and policy. Washington, D.C. : Island Press.

Johnson, P.; Lachman, B. 2001. Rapid scan of decision support system tools for land-use related decision making. Arlington, VA : NatureServe.

Kappelle, M.; Van Vuuren, M.M.I.; Baas, P. 1999. Effects of climate change on biodiversity: a review and identification of key research issues. Biodiversity and Conservation 8(10): 1383-1397.

Kelly, J.M.; Hodge, M.R. 1996. The Role of Corporations in Ensuring Biodiversity. Environmental Management 20(6): 947-954.

Kent, B.; Bare, B.; Field, R.; Bradley, G. 1991. Natural resource land management planning using large-scale linear programs: The USDA Forest Service experience with FORPLAN. Operations Research 39: 13-27.

Kepkay, M. 2003. Complexity and adaptive management in Washington state forest policy, 1987-2001. Master Thesis, Simon Fraser University, BC. Canada.

King, J.L. and Kraemer, K.L. 1993. Models, facts, and the policy process: the political ecology of estimated truth. In: Goodchild, M.F., Parks, B.O. and Steyaert, L.T. Environmental modeling with GIS. New York : Oxford University Press 353-360.

Klein, G.A. 1998. Sources of power: how people make decisions. Cambridge, Mass. : MIT Press. 330p.

Kline, J.D.; Alig, R.J.; Johnson, R.L. 2000. Forest owner incentives to protect riparian habitat. Ecological Economics 33: 29-43.

Kohm, K.A.; Franklin, J.F. 1997. Creating a forestry for the 21st century : the science of ecosystem management. Washington, D.C. : Island Press.

Kraemer, K.L.; Dickhoven, S.; Fallows Tierney, S.; King, J.L. 1987. Datawars: the politics of modeling in federal policymaking. Computing, Organizations, Policy, and Society. New York, NY : Columbia University Press. 326p.

Larsen, K.R. 2003. A Taxonomy of Antecedents of Information Systems Success: Variable Analysis Studies. Journal of Management Information Systems 20(2): 169-178.

Lasswell, H.D. 1971. A Pre-view of policy sciences. New York, NY : American Elsevier.

Laudon, K.C.; Laudon, J.P. 2000. Management information systems: organization and technology in the networked enterprise. 6th ed. Upper Saddle River, NJ : Prentice Hall.

Lee, B.; Meneghin, B.; Turner, M.; Hoekstra, T. 2003. An evaluation of landscape dynamic simulation models. Fort Collins, CO : USDA Forest Service, Inventory and Monitoring Institute. [http://www.fs.fed.us/institute/news_info/evaluation_LDSM.pdf]

Lee, K.N. 1993. Compass and gyroscope : integrating science and politics for the environment. Washington, D.C. : Island Press.

Lee, K.N. 1999. Appraising adaptive management. Conservation Ecology 3(2) [http://www.consecol.org/vol3/iss2/art3/]

Lexer, M.J.; Lexer, W. and Hasenauer, H. 2000. The use of forest models for biodiversity assessments at the stand level. In: anonymous. Silviculture and biodiversity of scots pine forests in europe. Valencia, Spain : Conselleria de Agricultura, Pesca y Alimentación 297-316.

Lindenmayer, D.; Franklin, J.F. 2002. Conserving forest biodiversity : a comprehensive multiscaled approach. Washington, DC : Island Press.

Little, J.D.C. 1970. Models and managers: the concept of a decision calculus. Management Science 16(8): B466-85.

Marakas, G.M. 1999. Decision support systems in the 21st century. Upper Saddle River, N.J. : Prentice Hall.

March, J.G. 1994. A primer on decision making. New York : Free Press.

McClure, R. 2001. Forest-Fish Plan: Was it Too Political? Seattle Post-Intelligencer, January 29.

McComb, B. In prep. Forest biodiversity decisions. In: Johnson, K.N. et al, Using Decision Support Systems in Forest Biodiversity Decisions: A Guide for Stakeholders. Washington, DC : National Commission on Science for Sustainable Forestry.

McCown, R.L. 2002a. Locating agricultural decision support systems in the troubled past and socio-technical complexity of 'models for management'. Agricultural Systems 74(1): 11-25.

McCown, R.L. 2002b. Changing systems for supporting farmers' decisions: problems, paradigms, and prospects. Agricultural Systems 74(1): 179-220.

McQuillan, A.G. 1989. The problem with economics in forest planning...An overview at three levels. The Public Land Law Review 10: 55-72.

Meador, C.L.; Guyote, M.J.; Keen, P.G.W. 1984. Setting priorities for DSS development. MIS Quarterly 8(2): 117-129.

Meadows, D.H.; Robinson, J.M. 1985. The electronic oracle: computer models and social decisions. New York : John Wiley and Sons. 438p.

Meitner, M.J.; Gandy, R. and Sheppard, S.R.J. 2005. Reviewing the role of visualization in communicating and understanding forest complexity. Paper Presented at Ninth International Conference on Information Visualisation (IV'05),.

Miles, M.B.; Huberman, A.M. 1994. Qualitative Data Analysis: An Expanded Sourcebook. 2 ed. Thousand Oaks, CA : Sage Publications Inc..

Miller, A. 1999. Environmental problem solving : psychosocial barriers to adaptive change. New York : Springer.

Miller, G.A. 1956. The magical number seven, plus or minus two: some limits on our capacity for processing information. The Psychological Review 63: 81-97.

Mintzberg, H.; Raisinghani, D.; Theoret, A. 1976. The structure of 'unstructured' decision processes. Administrative Science Quarterly 21: 246-275.

Monserud, R.A. 2003. Evaluating Forest Models in a Sustainable Forest Management Context. Forest Biometry, Modelling and Information Sciences 1: 35-47. [http://www.fbmis.info/A/3_1_MonserudR_1]

Montgomery, C.A.; Pollack, R.A. 1996. Economics and biodiversity - Weighing benefits and costs of conservation. J. For. 94(2): 34-38.

Mowrer, H.T. 1997. Decision support systems for ecosystem management: an evaluation of existing systems. General Technical Report RM-GTR-296. Fort Collins, CO : USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. [http://ncseonline.org/NCSSF/DSS/Documents/docs/Mowrer1997.doc]

MPCI. 1998. Montreal Process Criteria and Indicators. Retrieved November 12 from http://www.mpci.org/criteria_e.html

NCSSF 2003. Fire, Forest Health and Biodiversity. Washington, DC : National Commission on Science for Sustainable Forestry. [http://www.ncseonline.org/ewebeditpro/items/O62F3312.pdf]

Nicolson, C.R.; Starfield, A.M.; Kofinas, G.P.; Kruse, J.A. 2002. Ten heuristics for interdisciplinary modeling projects. Ecosystems 5: 376-384.

Noon, B.R.; McKelvey, K.S. 1996. Management of the spotted owl: a case history in conservation biology. Annu. Rev. Ecol. Syst. 27: 135-162.

NRC (National Research Council) 1996. Understanding risk : informing decisions in a democratic society. Washington, D.C. : National Academy Press.

NRC (National Research Council) 2005. Decision making for the environment: Social and behavioral science research priorities. Washington, D.C. : National Academy Press.

Nyhus , P.; Westley , F.; Lacy , R.; Miller, P. 2002. A role for natural resource social science in biodiversity risk assessment. Society and Natural Resources 15(10): 923-932.

Oliver, C.D. and Twery, M.J. 2000. Decision support systems: Models and analyses. In: Johnson, N.C., Malk, A.J., Sexton, W.T. and Szaro, R.C. Ecological Stewardship: A Common Reference for Ecosystem Management. Elsevier Science Ltd. 661-685.

Oliver, C.D.; Larson, B.C. 1996. Forest stand dynamics. New York : John Wiley and Sons. 544p.

OTA 1987. Technologies to Maintain Biological Diversity. Washington, DC : U.S. Congress Office of Technology Assessment.

Overbay, J.C. 1992. Ecosystem management. Paper Presented at Taking an Ecological Approach to Management, Salt Lake City, UT.

Patton, D.R. 1997. Wildlife habitat relationships in forested ecosystems. rev ed. ed. Portland, OR : Timber Press.

Perry, R.W. 2000. Diffusion theories. In: Borgatta, E.F. and Montgomery, R. Encylopedia of sociology. 2nd ed. New York, NY : Macmillan Reference USA 674-681.

Rai, A.; Bajwa, D.S. 1997. An empirical investigation into factors relating to the adoption of executive information systems: An analysis of EIS for collaboration and decision support. Decision Sciences 28(4): 939-974.

Rauscher, H.M. 1999. Ecosystem management decision support for federal forests in the United States: a review. Forest Ecology and Management 114: 173-197. [http://www.srs.fs.fed.us/pubs/viewpub.jsp?index=755]

Rayner, S.; Lach, D.; Ingram, H.; Houck, M. 2000. Weather forecasts are for wimps: why water resource managers don't use climate forecasts. Washington, DC : NOAA Office of Global Programs.

Reeves, G.H.; Hohler, D.B.; Larsen, D.P.; Busch, D.E.; Kratz, K.; Reynolds, K.; Stein, K.F.; Atzet, T.; Hays, P.; Tehan, M. 2003. Aquatic and Riparian Effectiveness Monitoring Plan for the Northwest Forest Plan. General Technical Report PNW-GTR-577. Portland, OR : USDA Forest Service, Pacific Northwest Research Station.

Rein, M. and Schon, D. 1993. Reframing policy discourse. In: Fischer, F. and Forester, J. The argumentative turn in policy analysis and planning. Durham, NC : Duke University Press 145-166.

Renn, O.; Webler, T.; Wiedemann, P. 1995. Fairness and competence in public participation: evaluating models for environmental discourse. Dordrecht, The Netherlands : Kluwer Academic Press.

Reynolds, K.; Bjork, J.; Hershey, R.R.; Schmoldt, D.; Payne, J.; King, S.; DeCola, L.; Twery, M. and Cunningham, P. 2000. Decision Support for Ecosystem Management. In: Johnson, N.C., Malk, A.J., Sexton, W.T. and Szaro, R.C. Ecological Stewardship: A Common Reference for Ecosystem Management. Elsevier Science Ltd. 687-721.

Reynolds, K.M.; Rodriguez, S.; Bevans, K. 2002. Ecosystem management decision support 3.0 user guide. Corvallis, OR : USDA Forest Service, Pacific Northwest Research Station. [http://www.fsl.orst.edu/emds/]

RIEC. 2005. Meeting notes of the Regional Interagency Executive Committee. Oct 18, 2005. Internet: http://www.reo.gov/library/riec/2005/2135Riec10182005.htm

Rittel, H.W.; Webber, M.M. 1973. Dilemmas in a general theory of planning. Policy Sciences 4: 155-169.

Rittel, H.W.J. 1984. Second-generation design methods. In: Cross, N. Developments in Design Methodology. New York : Wiley 317-327.

Robinson, A.P.; Monserud, R.A. 2003. Criteria for comparing the adaptability of forest growth models. Forest Ecology and Management 172(1): 53-67.

Robson, C. 2002. Real world research : a resource for social scientists and practitioner-researchers. 2nd ed. ed. Oxford, UK ; Madden, Mass. : Blackwell Publishers.

Rogers, E.M. 2003. Diffusion of innovations. 5th ed., Free Press ed. New York : Free Press. 551p.

Rogers, E.M. and Singhal, A. 1996. Diffusion of innovations. In: Salwen, M.B. and Stacks, D.W. An Integrated approach to communication theory and research. Mahwah NJ : Lawrence Erlbaum 409-420.

Rosenhead, J. 1989. Rational analysis for a problematic world : problem structuring methods for complexity, uncertainty, and conflict. Chichester [England] ; New York : Wiley.

Rouwette, E.A.J.A.; Vennix, J.A.M.; van Mullekom, T. 2002. Group model building effectiveness: a review of assessment studies. System Dynamics Review 18(1): 5-45.

Ryan, B.; Gross, N. 1943. The diffusion of hybrid seed corn in two Iowa communities. Rural Sociology 8: 15-24.

Salwasser, H. 2004. Confronting the Implications of Wicked Problems: Changes Needed in National Forest Planning and Problem Solving. Corvallis, OR : Oregon State University.

Sample, A.; Olsen, J. 1993. Defining Sustainable Forestry. Washington, DC : Island Press.

Schuster, E.G.; Leefers, L.A.; Thompson, J.E. 1993. A Guide to Computer-Based Analytical Tools for Implementing National Forest Plans. General Technical Report INT-296. USDA Forest Service, Intermountain Research Station.

Sedjo, R.A. 1987. FORPLAN: An evaluation of a forest planning tool -- Summary. In: Hoekstra, T.W., Dyer, A.A. and LeMaster, D.C. FORPLAN: An evaluation of a forest planning tool. Denver, CO : USDA Forest Service, Rocky Mountain Research Station 161-162.

SFI 2004. Sustainable forestry initiative: 2005-2009 standard. Arlington, VA : Sustainable Forestry Board. Retrieved March 1, 2006 from the World Wide Web: http://www.aboutsfb.org/sfiprogram.cfm

Shannon, M.A. 1999. Moving from the Limits and Problems of Rational Planning toward a Collaborative and Participatory Planning Approach. Paper Presented at Formulation and Implementation of National Forest Programmes, Freiburg, Germany.

Shannon, M.A. 2003. Mechanisms for coordination. In: Paveri, M. and Dubé, Y.C. Cross-sectoral policy impacts between forestry and other sectors. Rome : FAO Forestry Paper 142.

Shindler, B.; Neburka, J. 1997. Public participation in forest planning: 8 attributes of success. Journal of Forestry 95(1): 17-19.

Simberloff, D. 1999. The role of science in the preservation of forest biodiversity. Forest Ecology and Management 115(2-3): 101-111.

Simon, H.A. 1960. The New Science of Management Decision. New York : Harper & Row.

Simon, H.A. 1976. Administrative behavior: A study of decision-making processes in administrative organization. 3 ed. New York : Free Press.

Smith, G.R. 1997. Making decisions in a complex and dynamic world. In: Kohm, K.A. and Franklin, J.F. Creating a forestry for the 21st century : the science of ecosystem management. Washington, D.C. : Island Press.

Smith-Korfmacher, K. 1998. Water quality modeling for environmental management: lessons from the policy sciences. Policy Sciences 31(1): 35-54.

Smythe, K.D.; Bernabo, J.C.; Carter, T.B.; Jutro, P.R. 1996. Focusing Biodiversity Research on the Needs of Decision Makers. Environmental Management 20(6): 865-872.

Star, S.L.; Griesemer, J.R. 1989. Institutional ecology, 'translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology. Social Studies of Science 19: 387-420.

Sterman, J.D. 1991. A skeptic's guide to computer models. In: Barney, G.O., Kreutzer, W.B. and Garrett, M.J. Managing a Nation: The Microcomputer Software Catalog. Boulder, CO : Westview Press 209-229.

Strauch, R. 1975. Squishy problems and quantitative methods. Policy Sciences 6: 174-184.

Susskind, L.; Jain, R.K.; Martyniuk, A.O. 2001. Better environmental policy studies : how to design and conduct more effective analysis. Washington, DC : Island Press.

Takacs, D. 1996. The Idea of Biodiversity: Philosophies of Paradise. Baltimore, MD : Johns Hopkins University Press. 393 pp.p.

Taylor, S.; Todd, P.A. 1995. Understanding information technology usage: A test of competing models. Information Systems Research 6(2): 144-176.

Thompson, J.D. and Tuden, A. 1959. Strategies, Structures and Processes of Organizational Decision. In: Thompson, J.D., Hammond, P.B., Hawkes, R.W., Junker, B.H. and Tuden, A. Comparative Studies in Administration. Pittsburgh, PA : University of Pittsburgh Press 195-216.

Turban, E.; Aronson, J.E. 2001. Decision support systems and intelligent systems. Upper Saddle River, NJ : Prentice Hall.

Udo, G.J.; Guimaraes, T. 1994. Empirically assessing factors related to DSS benefits. European Journal of Information Systems(July)

USDA; USDI 1994. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl. Washington, DC : U.S. Department of Agriculture, Forest Service and Department of Interior, Bureau of Land Management.

Van Den Belt, M. 2004. Mediated modeling : a system dynamics approach to environmental consensus building. Washington, DC : Island Press.

WAC-222-16-030. Washington Administrative Code Title 222 (Forest Practices Board), Chapter 16 (Definitions), Section 030 (Water typing system).

Walsham, G. 1993. Interpreting information systems in organizations. Chichester, West Sussex, England ; New York : Wiley.

WDNR. 2000. Forest and Fish Report. Washington Department of Natural Resources. Olympia, WA.

WDNR. 2006. Washington forest practices board manual. Washington Forest Practices Board. Olympia, WA.

Webler, T. 1997. Organizing public participation: a critical review of three handbooks. Human Ecology Review 3(2): 245-254.

Weiss, C.H. 1980. Social science research and decision making. New York : Columbia University Press.

WRI; IUCN; UNEP 1992. Global biodiversity strategy. Washington, DC : World Resources Institute, World Conservation Union, and United Nations Environment Programme.

WVLF. 2001a. The Willamette chronicle. Newspaper insert. [http://www.lcog.org/wvlf/chronicle.html]

WVLF. 2001b. Willamette Valley: Choices for the Future. Proceeding of a conference held April 26, 2001. Willamette Valley Livability Forum [http://www.lcog.org/wvlf/pdf/wvlfconfpro.pdf]

Yaffee, S.L. 1997. Why environmental policy nightmares recur. Conservation Biology 11(2): 328-337.

Yaffee, S.L.; Phillips, A.F.; Frentz, I.C.; Hardy, P.; Maleki, S.; Thorpe, B.E. 1996. Ecosystem management in the United States : an assessment of current experience. Washington, DC : Island Press.

Yin, R.K. 2003. Case study research : design and methods. 3rd ed. ed. Thousand Oaks, CA : Sage Publications.

APPENDICES

Appendix A – Lists of Success Factors from the Literature

The electronic oracle: computer models and social decisions, D.H. Meadows and J.M. Robinson. ©1985 by John Wiley and Sons. Reproduced with permission.	*Ten heuristics for interdisciplinary modeling projects, C.R. Nicolson. ©2002 Springer Science and Business Media. Reproduced with permission.*
Rules for effective modeling 1. Do what is appropriate for the situation 2. Plan implementation along with the model 3. Respect all parties to the relationship 4. Support the needs of all parties Guidelines for effective modeling 5. Avoid hungry modelers; they cannot adhere to these recommendations 6. Work only for the person who can actually implement results 7. State all biases openly and be aware of others' 8. Take time to define the job precisely and completely 9. Insist on a clear and significant problem definition 10. Keep emphasis on the defined problem 11. Match method to the problem not vice versa 12. Expect the problem to be solved, do whatever it takes to solve it, including making mistakes 13. Arrange for the modeler to experience the system being modeled 14. Include the client in the modeling process 15. Have a rough model operating quickly (within one month) 16. Use a level of detail just necessary to capture the problem and to communicate it, no more 17. Design the model to generate the client's usual criteria for system performance and validity 18. Describe the model in terms the client can understand 19. Document the model with scientific precision and completeness 20. Design policy recommendations with a clear understanding of real world constraints and possibilities 21. Test the model carefully and completely 22. Use the model and modeler as aids to promote change	1. Know what skills to look for when recruiting an interdisciplinary team 2. Invest strongly in problem definition early in the project 3. Use rapid prototyping for all modeling efforts 4. Allow the projects focus to evolve by not allocating all funds up front 5. Ban all models or model components that are inscrutable 6. Instead of concentrating on one all-purpose synthesis model, invest in a suite of models, each with a well-defined objective 7. Maintain a healthy balance between the well understood and poorly understood components of the system 8. Sensitivity analysis is vital that all stages of the modeling effort 9. Work hard at communication and budget for face-to-face meetings 10. Approach the project with humility

Rapid scan of decision support system tools for land-use related decision making, P. Johnson and B. Lachman ©2001 NatureServe. Reproduced with permission.	*Tools to aid environmental decision making, V.H. Dale and M.R. English. ©1999 Springer Science and Business Media. Reproduced with permission.*
1. Clarity about purpose, decisions, decision-makers & users 2. The process for using the tool is as important as the tool 3. Building on existing tools and software 4. Listening to users & relevant stakeholders throughout the tool development process 5. Meets important unmet needs of users 6. Is effectively marketed 7. Users have necessary skills & training 8. Build on sound data 9. Plan to evolve tool over time 10. Capitalize on partnerships	1. Tools (and tool users) should be explicit about what the tool can and cannot accomplish, the assumptions that are built into the tool, and how terms used in the tool's application are defined. 2. Tools should clearly specify the types of data to be used, including their spatial and temporal scales, along with possible data sources. 3. Qualitative information, expert judgments, and sources of "soft" information such as role-playing should be considered as integral to tools rather than as add-ons. 4. Tools should be able to integrate the perspectives of various disciplines (e.g., economics and ecology) and various interests (e.g., economic growth and environmental protection); their viewpoints should be as encompassing as possible, and feedbacks and linkages across disciplines should be fostered. 5. Tools should be able to incorporate new knowledge and new understanding as they become available. 6. Tools should take advantage of the new capabilities offered by technological advances. 7. Ideally, tools should proceed from input to output fairly rapidly. 8. Both the results of tools and how they work should be clearly communicated via diverse approaches. 9. Tools' results should be accurate and clear, not misleading; factors affecting their validity and reliability (including assumptions, data accuracy and precision, sensitivity to altered conditions, and sources of uncertainty) need to be explicit parts of the results. 10. Tools should be easily explained and disseminated; the dissemination plan should be part of the tool design rather than an afterthought.

Appendix B – Decision Support System Survey

Review of Decision Support Systems for Forest Biodiversity

- *This document uses Microsoft Word "form" fields, which restrict data entry to the grey areas (use Tab or mouse to move between them).*
- *Please fill it out using Word, save it, and e-mail it back to sean.gordon@orst.edu*
- *Help text is available for fields marked with a '*' – select the box and press F1.*
- *For help with the form or question clarification please contact Sean Gordon (Tel: 503-569-0912 - Oregon).*
- *Results are available on our project web site: http://ncseonline.org/ncssf/dss*

1. System name:

1.1. Acronym:

Summary

[1-2 sentence summary of system]

Brief overview

[purpose & capabilities for addressing biodiversity issues]

Major DSS components

[if important for understanding tool & capabilities]

1.2.

System focus

Choice	Definitions
[select]	1. DSS (or component) designed to specifically address forest biodiversity issues 2. DSS designed primarily for biodiversity issues 3. DSS designed primarily for biodiversity issues 4. General purpose DSS with known applications to forest biodiversity

1.3. Comments:

General DSS approaches used

1.4. ☐ simulation
1.5. ☐ optimization
1.6. ☐ evaluation
1.7. Other/Comments:

Types of information used

1.8. ☐ completely user defined * (help text available, select box & press F1)

1.9. ☐ management interventions
1.10. ☐ biophysical
1.11. ☐ economic
1.12. ☐ social
1.13. Comments:

Typical spatial extent of application

1.14. ☐ user defined
1.15. ☐ regional (variety of ecosystems)
1.16. ☐ multi-owner forest ecosystem
1.17. ☐ single ownership forest
1.18. ☐ site / project
1.19. Comments:

Typical unit of data input

1.20. ☐ completely user defined
1.21. ☐ forest ecosystem / metapopulation
1.22. ☐ stand / local population
1.23. ☐ individual tree / animal
1.24. Comments:

Spatial analysis & display capabilities

	Analysis	Display	
1.25.	☐	☐	integrated capabilities
1.26.	☐	☐	facilitates links to GIS (wizards, etc.)
1.27.	☐	☐	provides standard data import/export formats
1.28.	☐	☐	none

1.29. Comments:

Abilities to address interdisciplinary, multi-scaled, and political issues

[Since these concepts are rather vague, including brief descriptions is very important here]

1.30. ☐ evaluate interactions between different basic information types (biophysical, economic, social) * (help text available, select box & press F1)
1.31. Brief description:

1.32. ☐ produce coordinated results for decision makers operating at different spatial scales *
1.33. Brief description:

1.34. ☐ facilitate social negotiation and learning *
1.35. Brief description:

Support for specific biodiversity issues

1.36. ☐ completely user defined
1.37. ☐ includes guidance on ways to characterize biodiversity
1.38. ☐ economic-biodiversity tradeoff analysis methods
1.39. ☐ risk assessment methods
1.40. ☐ landscape analysis methods
1.41. ☐ timber harvest effects
1.42. ☐ development effects
1.43. ☐ climate change effects
1.44. ☐ biological effects (pests, pathogens, invasives)
1.45. ☐ fire effects
1.46. Other/Comments:

Support for general classes of biodiversity indicators

[based on the Montreal Process Criteria & Indicators framework]

1.47. ☐ indicators are completely user defined

Coarse filter measures

1.48. ☐ Forest types
1.49. ☐ Forest age classes or successional stages
1.50. ☐ Forest management classes (incl. protected areas)
1.51. ☐ Fragmentation of forest types

Fine filter measures

1.52. ☐ Species richness measures
1.53. ☐ Species viability measures *
1.54. ☐ Species distribution measures
1.55. ☐ Species abundance measures
1.56. Comments:

Types of decisions supported

1.57. ☐ Silvicultural
1.58. ☐ Certification
1.59. ☐ Conservation
1.60. ☐ Restoration
1.61. ☐ Transportation
1.62. ☐ Development choices / land use zoning
1.63. ☐ Policy alternatives
1.64. Other/Comments:

Types of outputs produced

[tables, maps, 3-D visualizations, pre-programmed summaries, etc]

1.65.

Biodiversity-related Applications / Examples of use in decision processes

[publication citations or descriptive title, time period active, contact name & phone/e-mail]

1.66.

Transferability

1.67. Development status: [select]
1.68. Individualized assistance from the developer is [select] for installation & configuration
1.69. Available for download from the Internet: ☐
1.70. Cost: [select]
1.71. Compatible Operating Systems:
MS DOS ☐ | MS Windows 3.x ☐ | 95/98 ☐ | NT ☐ | 2000 ☐ | XP ☐
Web-based ☐ | Unix ☐ variants | Macintosh ☐ versions |
Other
1.72. Other software needed (and costs):
1.73. Documentation:
1.74. Training available:
1.75. Support available:
1.76. Prerequisite knowledge:
1.77. Level of effort to become functional:
1.78. Data requirements:
1.79. Comments:

Extent of use

[a group of users applying the tool to the same problem is one user-application]

1.80. [select] user-applications to biodiversity issues
1.81. [select] user-applications to other issues
1.82. Comments:

Future development plans

Developer / Distributor contact

1.83. Web site:

Other sources of information

[literature, web sites, etc.]

1.84.

Appendix C – Case Study Briefs

Mixed-level Decisions

Willamette Basin Alternative Futures Analysis

Timeframe: 1996-2001

DSS used: PATCH + variety of custom models

Description

WBAFA was designed to help diverse stakeholders understand the ecological consequences of possible societal decisions related to changes in human populations and ecosystems in the Pacific Northwest and to develop transferable tools to support management of ecosystems at multiple spatial scales. It has been used to simulate the effects of three possible development scenarios on eight regional measures of biodiversity over the next 50 years. The process included a four-tiered stakeholder involvement and outreach plan and multiple biodiversity modeling efforts. Elements of ecosystem management it addressed included cutting across ownerships and integrating biophysical and socio-economic information.

Analytical Complexity: High (5)

The WBAFA case involved high analytical complexity in terms of space, time, forest influences, and biodiversity measures. The overall geographic scope was large (~30,000 km^2) and was modeled in considerable detail (30 m^2 cells reflecting 65 land use/cover classes). Natural vegetation change and four other influences were modeled (urbanization, rural residential, agriculture, forestry) for 10 year intervals over a 60 year time period. Impacts of these land cover changes on the four core resources were estimated for each period using a wide variety of models, for example seven different models were used for impacts on aquatic life. The principle strategies to limit the analytical complexity of the case with regards to forest biodiversity were as follows: used explicit, bounded scenarios as opposed to an open-ended analysis of trends; evaluated only 3 scenarios; did not model selective timber harvesting (thinning & uneven age management).

Social Complexity: Medium-High (4)

Social complexity was assessed as medium-high because the citizen group directing the modeling (PFWG) involved stakeholders representing diverse interests. Additionally, two other publicly appointed groups (WRI, WVLF) regularly reviewed the modeling process. However, its social complexity was a step below a typical public resource decision process. WBAFA's participation was not as wide-open, and the project was not making any direct decisions about resource use or regulation. Two strategies which limited social complexity were the selection of PFWG participants on their willingness to work towards consensus and the separation of scenario development (PFWG) from estimating impacts (scientists).

Key lessons

- engaged stakeholders in constructing analysis, so had buy-in/trust of results
- facilitated working group as expert-stakeholder translation forum

- did not engage stakeholders in defining overall framework, so missed key concerns such as economic outcome measures
- had a multi-level communication strategy
- decision-making organizations at the same scale existed
- did not directly involve political allocation of resources, so less controversial (aimed at deliberation support rather than decision support)

More information

http://www.orst.edu/Dept/pnw-erc/
http://willametteexplorer.info/

Sandy River Basin (OR) Anchor Habitats Project

Timeframe: 2004-2005

DSS used: EMDS

Description

The convening purpose of this project was to bring all the entities (federal, state, local governments, watershed council, NGOs) together and develop a basin-wide watershed restoration strategy for the Sandy River Basin in northwest Oregon. The process was structured to focus on aquatic habitat and produce a collaborative, stakeholder vision across all ownerships. This first phase of the project identified anchor habitats, distinct stream and river reaches that harbor specific life history stages of four species of salmon and steelhead to a greater extent than the river system at large and/or are areas critical for the creation and maintenance of high quality habitat. Three data sources were used: empirical data from existing stream surveys, habitat modeling data generated by the Ecosystem Diagnosis and Treatment model, and professional judgment from three local experts. Anchor habitat stream segments were identified for the four species, and these priority areas can now be used to help guide habitat restoration planning activities.

Analytical Complexity: Medium (3)

The analysis looked at a medium-sized area (325,000 acres) and only at one time period (the present). They simplified the task by excluding fish harvest, fish hatcheries, and hydroelectric influences. Looking at four different species using three different measures of habitat quality made the treatment of biodiversity measures moderately complex.

Social Complexity: Medium-High (4)

Since all parties with an interest in the subject were invited to participate, the project resembled an open-stakeholder process. Setting restoration priorities did not, however, directly allocate resources or drive regulations.

Key lessons

- DSS helped to combine different sources of information
- DSS helped to structure an explicit approach to evaluation
- the model enables future efforts to rerun analysis with new data or understandings
- the DSS required some time and effort to learn, and so depended on interest and dedication of one of the individuals involved (without this interest, they probably would have used a simpler spreadsheet-based scoring procedure)
- making evaluation procedures and results explicit also made errors/omissions very visible (e.g. one dewatered reach got a high score); each error made people doubt the whole model, so one needs to be very careful of what is shown

More information

http://www.oregontrout.org/images/8success/Sandy%20Habitat%20Report.pdf

Federal

Northwest Forest Plan Aquatic & Riparian Monitoring Program

Timeframe: 2003-2005

DSS used: EMDS

Description

The goal was to evaluate and compare watershed conditions over the area of the Northwest Forest Plan for two periods (1994, 2004). A number of workshops were held in which USFS and BLM scientists helped build models of how to evaluate watershed condition for the seven different aquatic provinces using the EMDS tool. The results were integrated into a 10-year evaluation of the NW Forest Plan, which was presented at a conference and published in a report.

Analytical Complexity: Medium (3)

The analytical complexity of the AREMP modeling process was judged to be medium. The overall geographic scope was large (~24 million acres), but the analysis was restricted to a sampling of 250 watersheds within the broader region. Only two past time periods were considered, so the model did not require any simulation dynamics. A number of different vegetation, roads, and in-stream indicators were used, and the stand replacing habitat influences of harvesting and fire were integrated. Assembling these data across three states and two Forest Service regions was a moderately complex task. Finally, different models were developed to represent the seven provinces.

Analytical complexity was limited in a number of ways: the broader concept of watershed health was limited to a fish habitat analysis; the in-stream indicators were limited to those already collected by the monitoring program; landscape (GIS) indicators were limited to those available for roads and derivable from the Forest Service vegetation inventory; and indicators were scored on a their general contribution to habitat, rather than an absolute influence on fish habitat.

Social Complexity: Medium-low (2.5)

The complexity of the immediate social context of the modeling process was medium-low. The modeling occurred within the highly contentious and political context of the NW Forest Plan, and its Aquatic Conservation Strategy was recently re-written to address what the authors perceived as misinterpretations of their intent by the courts; and this new strategy is being challenged in court. However, in contrast, the monitoring program itself has not been particularly contentious. All sides seem to agree that monitoring is essential, and the monitoring results are not directly tied to any reallocation of resources. Social complexity was limited by focusing participation to mostly staff from land management agencies to avoid potentially contentious arguments with regulatory agencies and the public

Key lessons

- regulatory agencies were not initially invited to participate (to avoid typically contentious ESA consultation procedures)
- although the NWFP has been a highly contentious, this analysis was not, most likely because it was not directly tied to any allocation of resources
- relatively simple evaluation model (roads & vegetation) used for complex concept
- neither scientists nor stakeholders complained about simplicity and both supported the attempt at making the evaluation explicit and quantitative
- results were presented to the Regional Interagency Executive Committee, but there are no clear mechanisms for how results are expected to influence decision making

More information

http://www.reo.gov/monitoring/watershed/

Boise-Payette-Sawtooth National Forest Plan

Timeframe: 1997-2003

DSS used: Spectrum, RELM, VDDT, web-based mapping

Description

National forests are required to update their management plans every 10-15 years. The adjacent Boise-Payette-Sawtooth National Forests in southern Idaho and northern Utah decided to update their plans together in order to better understand larger landscape issues and to efficiently address their many common concerns. National forest plans do not make specific decisions about timber harvesting or other activities, but rather have been described as more akin to land use zoning in determining overall rules and activities appropriate for certain areas. As part of planning, forests are required to calculate an "Allowable Sale Quantity" (ASQ) of timber, which led the forest to use Spectrum, the standard DSS used for this purpose on national forests. The Forest soon realized that the basic forest growth and harvesting model could be expanded to help evaluate other effects of the different possible management alternatives. The model was expanded to include 120 different vegetation classes (combinations of vegetation types, successional stages, and canopy closures) that were distributed across 7 different land allocation zones over a 50-year period for each of 7 broad management alternatives. To get a more detailed view of the feasibility of these alternatives, the RELM DSS was used to take these Spectrum outputs and distribute them further down to 6th field watersheds (about 200 per forest). Because fire is an important influence in the region that was not explicitly modeled by Spectrum and because there was some suspicion of inherent biases in optimization modeling, a parallel modeling exercise using the VDDT DSS was also undertaken near the end of the planning process (VDDT had also been used to model the nonforested parts of the planning area).

Analytical Complexity: High (5)

The forests cover a relatively large area (6.6 million acres), and analyses of management options were disaggregated to the subwatershed level (approximately 200 per forest). Habitat trends were analyzed for 7 alternatives over a 50 year period. The effects on approximately 20-30 different species were analyzed, ~10 quantitatively and the rest qualitatively.

Social Complexity: High (5)

National forest planning is an open stakeholder process, which has a direct effect on the allocation of resources.

Key lessons

- the scope of the modeling project can change significantly during the project; initial calls for "back of the envelope" analyses for ASQ eventually evolved into a model with 120 vegetation classes
- DSS traditionally used to calculate timber harvest levels are now being used to model more complex vegetation dynamics over time for a variety of resource outputs
- multiple DSS are often needed to meet complex needs: separate models were needed to handle the strategic (Spectrum) and tactical (RELM) aspects of planning; a simulation approach (VDDT) was also done to provide an alternative view

More information

http://www.fs.fed.us/r4/sawtooth/arevision/revision.htm

Red-cockaded Woodpecker Foraging Matrix Application

Timeframe: 2006 - present

DSS used: Custom ArcGIS 9.x extension

Description

The red-cockaded woodpecker (RCW, *Picoides borealis*) is one of the longest recognized federally endangered species. It endemic to open, mature and old growth pine ecosystems in the southeastern United States, a habitat that has declined rapidly due to fire suppression and short rotation forestry. Its current abundance is estimated at less than 3 percent of abundance at the time of European settlement.

In 2003 the US Fish and Wildlife Service published a major new revision of the RCW recovery plan that includes updated management guidelines for both federal and non-federal lands. Applying these guidelines on the ground can be complex because breeding groups often occupy a cluster of nesting trees and multiple groups may be found adjacent to one another. To encourage compliance with the new regulations the FWS has developed an extension to the popular ArcGIS software which can assist managers in meeting the new guidelines. The software is referred to as the “RCW Foraging Habitat Matrix Application” and can be freely downloaded from the internet (http://www.fws.gov/rcwrecovery/matrix_info.htm). It builds on previous work by Fort Bragg on automating habitat evaluations based on digital forest inventories. The GIS software company (ESRI) and U.S. Army Environmental Center also contributed significant resources to the effort. One important difference from the past effort is that the new guidelines require habitat details not normally present in forest inventories, including ground cover and mid-story hardwoods.

Since the software was just released in April 2006, it is too early to gauge its impact. The authors expect considerable feedback and refinement of the tool, and a central design goal was to build in as much flexibility as possible.

There have also been a number of RCW modeling efforts which simulate how populations of the bird will fluctuate over time given environmental influences. These models are considerably more complex in that they simulate individual birds over time in a spatially explicit manner. Designers of one of these models will run it on their mainframe computer for clients on a contractual basis. They have also recently (2006) received a contract from the Department of Defense to create a desktop computer version for managers, expected for completion in 2009.

Analytical complexity: Medium-low (2)

The analytical complexity of the tool is rated at medium-low. The geographic resolution is high (stands with individual tree lists) but the scope considered is very local (RCW group home ranges, ~80-500 acres each). The application does not inherently simulate over time, but it does enable the user to enter changes in habitat values (such as a planned clearcut) and see the resulting changes in the suitability scores. A number of coarse filter habitat indicators are used, including forest types, basal area of different forest structural stages, canopy cover, and fire history.

Social complexity: Medium (3)

The social complexity is rated at medium because the software development and use process involves mainly shared decisions between two organizations (a regulator and the regulated). At least in the development stages of the software, the discussion appears to have been dominated by a well-established community of experts rather than a more publicly-oriented process, like a national forest plan.

Key lessons

- as the sophistication of our understanding of habitat needs increases, computer tools may be able to help managers keep up
- build in flexibility for users to modify model parameters to reflect their local conditions
- data not commonly collected for forest inventories is often needed for habitat evaluations

More information

http://www.fws.gov/rcwrecovery/rcw_model.htm
http://www.serdp.org/Research/upload/SI_FS_1472.pdf

Federal-State

Forestry Support Program - Spatial Analysis Project

Timeframe: 2001 - present

DSS used: Standard GIS systems plus a new web-based database system

Description

The US Forest Service Forestry Support Program (FSP) provides technical assistance, through State forestry agency partners, to nonindustrial private forest owners to encourage and enable active long-term forest management. A primary focus of the Program is the development of comprehensive, multi-resource management plans that provide landowners with the information they need to manage their forests for a variety of products and services. Under pressure from OMB to better demonstrate program effectiveness, the FSP has been developing the Spatial Analysis Program to track and summarize information about properties enrolled in the program. It is providing an online interface that facilitates creation of stewardship plans that qualify for the program and stores the information in a central database. It provides a basic set of GIS data which can be used to evaluate impacts of (and possibly prioritize) stewardship activities. States can add their own data layers and weighting systems.

Analytical complexity: Medium (3)

While the forest and biodiversity measures used are likely to be relatively simple, the overall analytical complexity was rated medium because of the very large geographic scope and likely state-to-state variability of the analyses. The spatial coverage of the DSS is very large, the 354 million acres of the U.S. estimated to be under nonindustrial private ownership, and spatial resolution needs to be is relatively fine to pick out properties down to 10 acres (or less in some states). However, the actual analysis area is reduced because individual states have the responsibility for determining their priority areas and only a small portion of private lands are actually involved in the program. Twelve basic data layers are proposed nationally (including threatened and endangered species) and more can be added by states, if they wish.

Social complexity: Medium-low (2.5)

Social complexity is rated medium because the interactions are primarily decisions shared between two organizations, between the state and the Forest Service for the priority analyses and between the state and the landowner for stewardship plans. Stewardship plans involve incentives rather than regulations, so they are not as controversial. The state prioritization processes may become more controversial as they will have an influence on the allocation of resources locally (and possibly eventually nationally).

Key lessons

- involvement of state representatives since the initial pilot phase has created a broad buy-in from the states
- flexibility given to state analytical methods has created consistency problems and made quality control/oversight more difficult
- information privacy is a big issue because system deals with private lands data; arranging appropriate levels of access for different hierarchical levels is a major task (records must be anonymous at higher levels)
- although not originally intended to prioritize assistance (a somewhat sensitive issue; FSP support has been on a first-com first-serve basis), it appears that state and federal pressures for efficiency are driving it that way

More information

http://www.fs.fed.us/na/sap/

State

Chesapeake Forest Project

Timeframe: 1999-present

DSS used: Habplan used for initial plan; now just using GIS queries

Description

The Chesapeake Forest consists of 58,000 acres of forest land scattered over the eastern shore of Maryland, and it makes up about 12 percent of productive timberland in the region. In 1999 the state of Maryland and the Conservation Fund cooperated to purchase the lands from an exiting industrial owner. The Conservation Fund transferred title to the state the next year, but also included a sustainable forestry management plan and ongoing contract with consultants for management. As part of the management plan, the Habplan DSS was used to model a possibility curve for endangered Delmarva fox squirrel habitat versus timber volume extraction. The Habplan model has not been re-run since the transfer, but a recent certification audit recommended more attention to future habitat modeling.

Analytical complexity: Medium (3)

Analytical complexity was rated medium because of relatively high spatial and temporal complexity but relatively low complexity of the forest and biodiversity measures. Spatial complexity was medium, due to a moderate sized area (58,000 acres) and a fairly high resolution (2080 individual stands). The area was modeled over a fairly long 50-year time period. Only two resources were modeled: wood products (sawtimber and pulp) and fox squirrel habitat.

Social complexity: Medium (3.5)

Although the project became an open stakeholder process, which involved the allocation of public resources, this process occurred after the modeling was complete. The model was not a focus of controversy in the public planning process, rather it was mostly irrelevant as the process became dominated by the issue of hunting rights. The model was more relevant in the pre-public phase, where the endangered species was being considered from a regulatory and species recovery standpoint by the governmental agencies involved.

Key lessons:

- the Habplan model helped frame broad management options, and is still referred to
- the model was run by a consultant, and the state agency overseeing the plan never developed the in-house capacity to run it (although certification may now give them an impetus to do so)
- the state agency is currently using simple GIS overlays to screen sites for management, but would like to project timber yields
- broad biodiversity issues/analysis did not generate much interest in the public planning process; the stakeholder group became dominated by public input and discussion on opening lands for hunting

More information

http://www.dnr.state.md.us/forests/chesapeakeforestlands.asp

Oregon Harvest and Habitat Model

Timeframe: 1999-present

DSS used: FVS plus a custom-developed scheduling model

Description

For its latest revision of state forest management plans, the Oregon Department of Forestry (ODF) decided to model different alternatives on timber production and habitat. They used a spatially-explicit harvest scheduling model created by a professor at Oregon State University, and supplied it with a variety of growth and thinning options modeled using the US Forest Service Forest Vegetation Simulator (FVS) program. Since the forest inventory had been discontinued in the 1980s due to budget cuts, it took a full year to get workable inventory estimates ready for modeling. Three basic alternatives were modeled (with up to 10 variations for some areas): one emphasizing NPV, another creating old growth reserves on 50% of the land, and a compromise designed to create a dynamic balance of age classes (structure-based management) with the potential to secure a habitat conservation plan from the federal government. The primary indicators used to describe the alternatives' results were harvest volume, net present value and area of land in the oldest two (of five) structure classes. The Board of Forestry approved a structure-based management plan in early 2001.

The model was aimed at the strategic-tactical level; although it was spatial, it was not designed to take into account all the constraints on actual operational harvesting on the ground. Model results for the alternatives had been portrayed as relative not absolute. Nevertheless, when operational estimates from the districts came in (after the plan had been adopted) at only about half the model-predicted harvest, it became a major political issue. It was agreed that the modeling should be improved. The inventory, growth estimates, and spatial data were enhanced, and the model solutions are now iteratively refined through "feasibility checks" by the district foresters. ODF worked with stakeholder groups to elaborate timber and conservation-oriented alternatives, and modeled a "take avoidance" scenario in addition to the HCP alternative. The final results of this second phase were presented to the Board in early 2006. Although Board members seemed to understand the model results, they were not clear on their "decision space", i.e. how much legal latitude do they have to adjust the plan and what are the specific features they can adjust. Timber interests questioned the validity of the plan (not the model) because the new model estimates are considerably below earlier estimates and what they consider sustainable.

Analytical Complexity: Medium-high (4)

Analytical complexity was rated medium high because of the relatively high number of spatial (~150,000) and temporal units (150 years by 5 year intervals) modeled. Stands were modeled using individual tree lists, and results were grouped into six general stand classes for wildlife and other analyses. Thirty-nine wildlife species were placed in three groups (generalists, simple structure specialists, complex structure specialists). Four high-level management options were modeled, most with various sub-options.

Social complexity: High (4.5)

Social complexity was quite high because it is a public open-stakeholder process which directly allocates resources (to harvest or conservation). It was ranked slightly below the Washington Water Typing case (which involved regulation of private lands) and the Boise-Payette National Forest planning (a federal process involving more public involvement rules and a wider stakeholder base).

Key Lessons

- Data preparation was a major task
- Although initial results were characterized as relative, they created concrete expectations that have been hard to break
- The first version of the tool underestimated on-the-ground constraints, so a new process was derived to iteratively refine the model with input from field personnel
- modeled a wide range of alternatives, from very conservation to very production-oriented, but decision makers were left without a clear picture of their decision space

More information

http://www.oregon.gov/ODF/STATE_FORESTS/state_forests.shtml#Harvest_Habitat_Model_Project

<u>Washington State Water Typing Model</u>

Timeframe: 1999-present

DSS used: logistic regression model

Description

The Washington Forest Practice rules require different riparian buffer widths to fish-bearing and non-fish bearing streams (making this distinction is referred to as "water typing"). The regulatory maps in force in the mid-1990s were found to significantly underestimate fish habitat, so the multi-stakeholder group negotiating the new regulations agreed to develop a new scientific, model-based approach. The state Board of Forestry adopted a regulation supporting the model-based approach, with the stipulations that the model achieve 95% accuracy and that during model development, a precautionary interim rule, which overestimates fish presence, would be followed. A multi-stakeholder science group has been working on the model since 2000, but their modeling has not been able to meet the 95% accuracy threshold in all areas of the state due to geomorphic variability and the limited resolution of the topographic data. Debate on the further development and potential use of the water typing model continues and the interim rule remains in force.

Analytical Complexity: Medium-low (2)

The extent of the modeling task was large, the whole state of Washington, but the analytical complexity of the modeling process was deliberately kept low (at least conceptually). The model results were simply fish presence versus absence, which was based on only four geographic attributes: basin size, elevation, downstream gradient, and mean annual precipitation. The model was designed to just represent one snapshot in time. Analytical complexity was limited by limiting the number of models developed to two (east/west) and using only a small subset of possible habitat variables.

Social complexity: High (5)

The social complexity of the case was very high because it occurred in an open stakeholder context involving direct allocation of resources. The purpose of the model was to set regulations, which have large, direct economic and biological consequences. Social complexity was limited by asking scientists to set aside their organizational goals in the scientific work groups.

Key Lessons

- the burden of proof can swing dramatically in a political process
- DSS can improve the accuracy of predictions, however this inevitably threatens those parties whose interests are favored by the existing burden of truth
- basing model acceptance on a standard of accuracy (especially a high absolute one) appears to be a common sense approach, but parties can use technical debate to delay implementation on what ultimately must be a political decision

More information

http://www.dnr.wa.gov/forestpractices/watertyping/

State – Nonprofit

Washington State – TNC Ecoregional Planning Model

Timeframe: 2002-present

DSS used: Sites, Marxan

Description

To guide biodiversity conservation and land use planning across Washington State, the Washington Departments of Fish and Wildlife (WDFW) and Natural Resources (WDNR) joined The Nature Conservancy in a partnership to do an ecoregional assessment for each of Washington's nine ecoregions. Each assessment attempts to identify and prioritize places for the conservation of all biodiversity in an ecoregion. The relative priorities are based on such factors as species rarity, species richness, species representation, site suitability, and overall efficiency. Statistical models for suitability are typically not available, and therefore, much of the index is based on expert opinion. Expert opinion was incorporated using an abbreviated version of the analytic hierarchy process. The analysis utilizes an optimization program known as MARXAN to find the most efficient set of conservation units.

Analytical Complexity: Medium (3.5)

The characterization of biodiversity was quite complex, with over 800 kinds of biodiversity elements considered, and the spatial complexity was also medium-high, comprising over 8000 polygons. On the other hand the analysis only focused on the current situation (no temporal projection) and so dynamic forest influences were not considered. These high and low complexity aspects led to an overall rating of medium.

Social complexity: Medium (3)

Although the assessments are a public, open stakeholder process, they do not have an immediate effect on regulations or the allocation of resources. Participants described the process as a primarily technical one, although involving multiple stakeholders.

Key Lessons

- used coarse filter (habitat types) and fine filter (individual species occurrences) approaches to best characterize biodiversity
- there is little statistically rigorous data at the ecoregional scale, so assessments tend to rely on expert opinion
- explicit modeling forced the partners to come to consensus about evaluating conservation priorities
- the NGO partner was able to set a specific conservation goal, but the state agencies did not feel they had the policy authority to do so

More information

http://www.ecotrust.org/placematters/assessment.html
http://conserveonline.org/workspaces/ecotools

Local Government

Baltimore Reservoirs Forest Conservation Plan

Timeframe: 2000-2003

DSS used: NED-1 and ArcView GIS

Description

The city of Baltimore, Maryland used a combination of computer-based tools, primarily the ArcView geographic information system (GIS) and the NED-1 system, to analyze risks to the long-term sustainability of their reservoir lands and to develop and evaluate alternative scenarios for management of the lands. While maintaining water quality was the primary goal, the second and third goals were maintaining and enhancing the forest habitat as a contribution towards regional biodiversity. NED-1 inventories incorporated data needed to evaluate wildlife habitat composition and structure and the quality of habitat along first and second order streams. While providing a platform for the management and analysis of data on numerous key abiotic and biotic forest characteristics, the NED-1 decision support software did not provide a mechanism for evaluating the relationships of these landscape elements. The need to understand how landscape context and current ecological processes were shaping the forest required a synthesis of tools and often required stepping outside the decision support mechanism for critical answers to conservation problems.

Analytical complexity: Medium-low (2.5)

The spatial complexity of the analysis was relatively low: it covered 17,580 acres divided into 836 stands. Fourteen types of forest plant communities were distinguished, and a number of elements of forest habitat structure were analyzed (vertical canopy structure, interior habitat, coarse woody debris). No temporal aspect of the analysis was mentioned, so it appears it was based only on the current inventory.

Social complexity: Medium-high (4)

The social complexity of the case was rated medium-high because the report was expected to have a significant influence on the management of these public lands. A number of local recreation groups (bird watchers, mountain bikers, hunters, boaters) had considerable interest in the lands.

Key Lessons

- NED provided the best data structuring mechanism analyst could find, but it still left out major ecological elements, such as streams, roads, nutrient movement, and disturbance regimes

- GIS provided a platform that was generic enough to integrate these other ecological elements, but because it was generic, much work was required to model these elements from scratch
- the analyst emphasized that the final product needed to be more than a report, it needed to include an information system that could be transferred to the City
- the analyst thought that communication was best if organic and flexible, and he considered the term "communication strategy" to imply selling a predetermined solution. The best approach was to attend citizen advisory group meetings from the start, express openness to their ideas, and volunteer to attend their interest group meetings (which minimized need for advisory members to be messengers)

More information

http://cityservices.baltimorecity.gov/dpw/waterwastewater03/watershed_fcp/cfcp2004.pdf

Industry

International Paper's Forest Patterns System

Timeframe: 1996 - present

DSS used: Forest Patterns (internally developed system based on ArcGIS and Microsoft Access)

Description

IP developed their Forest Patterns system to help them manage at the landscape level and comply with environmental laws and the sustainable forestry certification standards. The program tracks a hierarchy of land uses beginning with three broad tiers of management: timber production, conservation, and non-forest. It contributes to the conservation of biodiversity via management of landscape units (typically 40,000 to 60,000 acres). Landscape units can be assessed to determine structure and forest cover type gaps or surpluses when compared to regional vertebrate landscape scale models developed by the U.S. Forest Service.

Analytical Complexity: Medium-low (2)

Forest Patterns is implemented at the regional division scale, so the Northeast system covers a relatively large 1.6 million acres. The relative biophysical complexity used in the system, however, is moderate to low. The system uses coarse filter habitat indicators, does not model habitat over time, nor does it explicitly try to estimate or characterize uncertainties. Analytical complexity was limited by using a relatively small number of habitat classes and assuming that the habitat targets will sustain biodiversity over time (a "coarse filter" approach).

Social complexity: Medium-low (2)

The system's original purpose was is to address high social complexity in the form of a distrustful public; however, conflict in the immediate operating environment is relatively low because the development and use of the system is controlled by one company. It is also used as documentation and a way to communicate practices in governmental regulation and forest certification processes, which involves the more complex social scenario of communication between two organizations, yet there were no mentions of the system's use in conflict situations. The principle day-to-day use of the system is in coordinating multiple decision makers within a single organization. Although participation in system design and review was extended beyond the organization, social complexity was limited to technical specialists rather than trying to directly integrate public input.

Key lessons

- Top management support is critical
- Involve a diverse group and external reviewers in the system design
- It takes a large commitment to keep data up to date
- Maintain regular, direct contact with state agency personnel for updating data
- Create a flexible framework that can be adapted to the needs of different regions
- Provide training and a simple software interface to make the system relevant and usable for the foresters making decisions on the ground

More information

http://www.aboutsfb.org/workshopPDFs/Eco1a.pdf
http://ipaper.com/Our%20Company/Environment/EnvironmentalStewardship.html

Small Landowners

Vermont Consulting Foresters

Timeframe: 2000 - present

DSS used: NED-1

Description

In the Phase I review of available decision support tools, NED was the system most oriented towards small landowners. In an interview with the software developer, he noted that few small landowners appear to use it themselves, rather the main users seem to be consulting foresters. Three foresters were contacted and interviewed about their use of NED with small landowners. The NED system contains a wildlife module which uses a forest inventory to estimate habitat types and qualitative likelihood of wildlife presence/absence (based on DeGraaf and Yamasaki 2001); however, none of the consultants interviewed has used the NED wildlife module with clients, instead they simply use their own knowledge to advise landowners on wildlife issues.

Analytical Complexity: Low (1)

Analytical complexity was rated low because the spatial complexity was limited by the small properties involved. The DSS was generally only used to structure the current forest inventory, rather than project forest growth over time. As mentioned above, the DSS was not used to assess biodiversity indicators, and the type of analysis needed for the situation was a simple, qualitative assessment of wildlife effects of different forest management options.

Social complexity: Low (1)

Social complexity was low because the decisions involved only the goals of individual landowners.

Key lessons

- main appeal of the software has been to calculate inventories from sample cruises
- many landowners are interested in wildlife, but the qualitative evaluation provided by the software does not provide any "value-added" to the consulting foresters who use the system; it is easier for them to simply draw on their own knowledge

More information

http://www.fs.fed.us/ne/burlington/ned/index.htm