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The challenges associated with developing science-based landscape scale management plans

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Abstract

Planning activities over large landscapes poses a complex of challenges when trying to balance the implementation of a conservation strategy while still allowing for a variety of consumptive and nonconsumptive uses. We examine a case in southeast Alaska to illustrate the breadth of these challenges and an approach to developing a science-based resource plan. Not only was the planning area, the Tongass National Forest, USA, exceptionally large (approximately 17 million acres or 6.9 million ha), but it also is primarily an island archipelago environment. The water system surrounding and going through much of the forest provides access to facilitate the movement of people, animals, and plants but at the same time functions as a barrier to others. This largest temperate rainforest in the world is an exceptional example of the complexity of managing at such a scale but also illustrates the role of science in the planning process. As we enter the 21st century, the list of questions needing scientific investigation has not only changed dramatically, but the character of the questions also has changed. Questions are contentious, cover broad scales in space and time, and are highly complex and interdependent. The provision of unbiased and objective information to all stakeholders is an important step in informed decision-making.
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1. Introduction

Times are changing the way people view, understand, and value the natural world is in a period of transition and intense conflict. Under traditional resource management approaches, achieving the goal of sustaining desired levels of environmental quality will become increasing difficult as demand for resources continues to grow (Silver and DeFries, 1990). As a result, in the United States, not since the early 1900s

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have so many varied interests had such an intense focus on public lands and their professional management of the associated natural resource values (Szaro et al., 1998). Natural resource managers are grappling with the need for public approval of management decisions and with the public's involvement in making these decisions (Brunson and Kennedy, 1995; Clausen and Schroeder, 2004). The roots of the developing ecologically based approach to management have evolved from increased understandings and articulated values provided over time by the scientific community, natural resource managers, legislative actions, judicial reviews, and widespread public comment.

How to help failing rural economies and provide for desired goods and services from public lands while dealing with concerns over the long-term health and viability of the environment has proved to be an extremely complex problem. The public land manager's role as provider of goods and services has evolved and matured beyond an output quantity focus to one that blends not only extractive uses but also social concerns and environmental objectives. The evolution of the public land manager's provider role will be toward greater incorporation of stakeholder service with an emphasis on broad social value outcomes (Szaro and Kennedy, 1999). As public servants, public land managers are often challenged to serve as social value brokers and conflict management facilitators.

Managing large landscapes is a multidimensional challenge in balancing conflicting and overlapping uses and values (Szaro et al., 2000). For example, activities that enhance the productive function of forests may challenge the protective capacity of the forests. To do this, managers need the best possible information on which to base their decisions. In order to provide this information, scientists need to adopt a multidisciplinary approach. This is not easy to do given that scientific activities in the forest sector have traditionally been oriented by discipline. Forestry research scientists and institutions will meet this challenge by reviewing the assumptions and research methodologies built into their strategic research plans, and by revising the philosophies underlying those methodologies and assumptions. Science has a vital role in generating new information that can inform the dialogue on forests and their management through the synthesis of existing information and knowledge, the generation of new policy-relevant information in identified priority areas, and the input of expert technical advice (ICRIS, 1998; Szaro et al., 2000).

This paper presents an approach for incorporating the best available science in the planning process for a large landscape. The planning is further complicated by the fact that a small proportion of the landscape (i.e., private and tribal lands) are not included in the plan activities but whose impacts on the plan area must be considered in the decision-making process. The approach challenges the traditional paradigm where management waits for newly developed information. Rather it incorporates the best of what we know now and allows for the development of new information to be incorporated in future revisions of the planning process.

2. The Tongass Land Management Plan (TLMP)

The world's cool temperate rainforests reach their greatest extent in the Pacific northwest of America from northern California to Alaska and on the western coast of South America, New Zealand, and Tasmania (Brown and Read, 1996). To set the context for the development of the Tongass Land Management Plan (USDA Forest Service, 1997b) it is important to recognize that the principles applied in southeast Alaska are broadly applicable to regional-scale planning efforts elsewhere. The Forest contains abundant timber, wildlife, fisheries, mineral, and scenic resources. The water system surrounding and going through much of the forest provides access to facilitate the movement of people, animals, and plants but at the same time functions as a barrier to others. However, the Tongass National Forest is unique not only because it is exceptionally large (approximately 6.9 million ha) but that it also is primarily an island archipelago environment distributed across more than 22,000 islands and a narrow strip of mainland in southeast Alaska (Everest et al., 1997).

Geographic extent and isolation, physiographic variation, and elevational and climatic gradients combine to produce numerous spatially and temporally heterogeneous environments that support a diverse indigenous biota including several endemic plants and animals (Everest et al., 1997). About 4 million ha is timberland; the remainder is fen, sphagnum bogs, rock, glaciers, ice fields, and water (Table 1). Before

Table 1
Tongass National Forest information

Category	Hectares (thousands)	Percentage of Tongass
Non-national forest	383	6
Wilderness	2343	34
Inventoried roadless areas	3801	55
Other designations	327	5
Total	6854	100
Nonforested land	2834	41
Forested land	4020	59
Congressionally designated protected areas	2672	39
Forest plan protected areas	3908	57
Forest plan timber management potential areas	274	4

large-scale industrial logging began (ca. 1954), there was about 2.2 million ha of productive old-growth forest with nearly half that area in high-volume old-growth forest. During the last half of the 20th century, about 162,000 ha of primarily high-volume old-growth forest was clearcut, which further fragmented naturally dissected landscapes and forest habitats. Balancing the levels of protection and use of natural resources across such a vast and diverse landscape has been an ongoing challenge for the USDA Forest Service in southeast Alaska.

3. The role and use of science in landscape planning

Although science information is only one consideration in natural resource decisions, credible science information is increasingly necessary to gain public support and acceptability (Mills et al., 2002). The importance of a scientific basis for decisions has been well recognized in other fields such as health care (Jasanoff, 1990). The scope of topics in natural resource decisions that require increased consideration of science information is broad. Science can contribute in (1) assessing the trends and conditions of the resource and associated human systems, (2) making individual land management decisions, and (3) designing and implementing adaptive management and monitoring systems.

Full consideration of the relevant and available scientific information can help improve the decision-making process by providing an understanding of the natural and human systems and their interactions. A science foundation helps people understand a system in which they are interested and improves their ability to estimate consequences and risks of decision alternatives (Mills et al., 2002). Science insights may occasionally lead to a wider range of management alternatives that increase the potential compatibility among people holding differing values for how the land should be managed and used (Mills et al., 2002).

Full consideration of the best available science is an important foundation of the legal defense of decisions and adds to the credibility of the decision in the eyes of the public. However, it is important to realize that political or legal arguments cannot often be "solved" by more or better science (Clark et al., 1998). It is imperative that the roles, strengths, and weaknesses of science in resolving policy problems be clear from the onset of a project. The focus on crisis-driven scientific assessments or panels should not overshadow the need for day-to-day integration of scientists and scientific information into resource policy and decision-making. In some respects, the increasing number of large assessments and scientific panels (e.g., FEMAT, 1993; Iverson et al., 1996; Quigley et al., 1996; Sierra Nevada Ecosystem Project Science Team and Special Consultants, 1996; Southern Appalachian Man and the Biosphere Cooperative, 1996a, 1996b, 1996c, 1996d, 1996e; University of California, 1996a, 1996b, 1996c; Quigley and Arbelbide, 1997; Quigley and Bigler-Cole, 1997; Swanston, 1997; Clark et al., 1998; Johnson et al., 1999) indicates a recognition of the need to ensure that science is readily available, understandable, and relevant to policymakers (Clark et al., 1998). These science assessments are examples of syntheses of understanding about a particular system and its associated issues that can be useful in supporting current and future decisions (Mills and Clark, 2001).

Research on complex systems is not simple, because of multiple scales of interaction and response; a high frequency of nonlinearity, uncertainty, and time lags; and multiple stakeholders with often contrasting objectives and activities. Furthermore, many earlier attempts to conduct research at the level of large, complex systems are widely seen to have generated needs for excessive amounts of data, to have been very costly to conduct, and to have yielded few results of immediate practical value (Sayer and Campbell, 2001).

4. Gathering existing information and expertise

During the formulation of TLMP, emphasis was placed on the acquisition, assessment, and synthesis of available information. Options were displayed and the likely levels of risk to resources and society were associated with various decisions (Everest et al., 1997). The information, with a scientific interpretation of it, was provided to the managers responsible for deciding the content and direction of the Tongass Land Management and Resources Plan. Managers considered this information as they developed an array of draft alternatives and, subsequently, a draft of the preferred alternative for management of the Tongass. Key scientific findings for consideration in the TLMP planning process were developed from three primary sources: (1) assessment and analysis of current scientific information; (2) critical review and analysis of items used in the Forest plan; (3) estimations of risk for various issues and resources through implementation of different management alternatives (Swanston et al., 1996).

4.1. Science assessments

Assessments of the current and most applicable scientific information involved national and international literature searches; consultation with recognized experts in private industry, in the Federal government, and at universities; and application of professional knowledge and experience (Swanston et al., 1996). These assessments built on the Forest Service's 100-year history of timber assessments and its Resources Planning Act mandates. Analysis of assessment results provided an improved database and a measure of quantity, quality, and scientific significance of available data and theory for addressing the focal issues in this revision of the forest plan. Scientists on the planning team reviewed existing literature, commissioned short-term assessments and analyses, and used expert opinion to facilitate the plan revision. In total, thousands of relevant publications in the professional literature were located, analyzed, and synthesized for the planning effort. For example, more than 1500 publications relevant to management of fish habitats on the forest were analyzed during development of the Anadromous Fish Habitat Assessment requested by Congress in 1995 (AFHA, 1995).

Scientists were asked to assure that credible, value-neutral, scientific information was developed independently without reference to management decisions (Shaw et al., 2000). Emphasis was placed on identification, acquisition, assessment, and synthesis of available information. Examples of assessments produced during this process include regional and community economics (Allen et al., 1998); karst landscapes (Baichtal and Swanston, 1996); timber volumes (Julin and Caouette, 1997), timber outputs (Brooks and Haynes, 1997), and the suitability of forested wetlands for timber harvest (Julin and Meade, 1997); conservation status of the marbled murrelet (DeGange, 1996), northern goshawk (Iverson et al., 1996), and Alexander Archipelago wolf (Person et al., 1996); a conceptual approach to maintaining wildlife habitat (Iverson and Rene, 1997); wind as an agent of disturbance (Nowacki and Kramer, 1998); and slope stability (Swanston, 1997). A popular summation and synthesis of the above information was also developed for the general public (Julin and Shaw, 1999). Many of these publications are available electronically (pdf format) at: http://www.fs.fed.us/pnw/publications/gtrs.shtml.

4.2. Resource analyses

Resource analyses, review and analysis of data, information, and assumptions previously used in the TLMP process, identified important information gaps, shortcomings of model assumptions, and areas where data analyses and theory needed to be revised to reflect current levels of knowledge (Swanston et al., 1996). An earlier review and synthesis of wildlife management and conservation biology on the Tongass National Forest was prepared by Kiester and Eckhardt (1994). Resource analyses were conducted on forested wetlands (Julin and Meade, 1997), slope stability (Swanston, 1997), old-growth timber volume strata (Julin and Caouette, 1997), wind disturbance (Nowacki and Kramer, 1998), a synthesis of wildlife viability (Iverson and Rene, 1997), and timber demand (Brooks and Haynes, 1997).

4.3. Risk assessment panels

To assist with development of the effects analysis and other components of the revision of the Forest plan for the Tongass NF, a new planning approach was applied by the Forest Service (Shaw, 1999). Research scientists from the Pacific northwest (PNW) Research Station were incorporated directly into the planning team (Swanston et al., 1996; Everest et al., 1997; Mills et al., 1998; Shaw, 1999) although they had separate and distinct roles (Shaw, 1999). One role was to provide information for development of the effects analysis for the draft forest plan (USDA Forest Service, 1996a, 1996b) by organizing and conducting a series of risk assessment panels that followed an approach used previously in the Pacific northwest (Cleaves, 1993; FEMAT, 1993; Starkey, 1998). Besides its past use in the Pacific northwest, the approach of using professional judgment structured in risk assessment panels was chosen because various wildlife habitat and community relations were poorly understood and there was generally inadequate information on which to base predictive models. In addition, the desire was to complete the planning process quickly, leaving no time for additional data collection.

The purpose of conducting these panels was to provide decision-makers and the public with information on the relative risk from implementing each alternative to the continued persistence across the landscape of the species or resource in question and the potential socioeconomic effects on communities (Shaw et al., 2000). Two sets of panels were conducted. The first set examined potential effects of proposed alternatives on brown bear (*Ursus arctos*), northern goshawk (*Accipiter gentilis*), American marten (*Martes americana*), marbled murrelet (*Brachyramphus marmoratus*), Alexander Archipelago wolf (*Canis lupus ligoni*), Sitka black-tailed deer (*Odocoileus hemionus sitkensis*), other terrestrial mammals, fish and riparian conditions, old-growth ecosystems, subsistence, and socioeconomic issues (Swanston et al., 1996; Shaw, 1999). As the final planning alternative was emerging, a second set of panels was commissioned to evaluate risk to brown bear, northern goshawk, American marten, Alexander Archipelago wolf, other terrestrial mammals, and fish and riparian conditions (Shaw, 1999).

Options were displayed along with the likely levels of risk to resources and society associated with various decisions. This risk assessment was primarily accomplished by conducting two sets of risk assessment panels that were designed to elicit informed professional judgments from knowledgeable experts in a structured format (Shaw, 1999).

These panels focused on the likelihood that various management alternatives would impact the viability of an array of old-growth-associated wildlife species, old-growth forest ecosystems, the sustainability of the fisheries resource, the subsistence use of fish and game (primarily Sitka black-tailed deer and salmon), and socioeconomic conditions.

The information generated from these panels (Swanston et al., 1996; Everest et al., 1997; USDA Forest Service, 1997d) was used in the effects analysis for the draft Forest plan (USDA Forest Service, 1996a) and a summary of results and implications was incorporated into the draft environmental impact statement (USDA Forest Service, 1996b).

5. Developing and using new information

New challenges are confronting the managers of the world's forests, with stakeholders demanding a broader range of goods and services, as well as a voice in setting priorities on the use of forests. Changing social contexts have necessitated a new approach to forest management (Clausen and Schroeder, 2004). Management is becoming more sophisticated and adaptive, seeking to achieve balance among multiple products and services. As we enter the 21st century, the list of questions needing scientific investigation has not only changed dramatically, but the character of the questions has changed as well. Questions are contentious, cover broad scales in space and time, and have a high level of complexity and interdependence. Relevant and credible information about complex systems is increasingly essential to forest policy decisions, and such information covering both natural and human sciences is an essential ingredient in policy deliberations in a world where forest management is the focus of intense national and international debate (ICRIS, 1998). The provision of unbiased and objective information to all stakeholders is an important step in informed decision-making. In response to these increasingly complex natural resource issues and changing societal attitudes, the science needed to answer management relevant questions has similarly become more complex and must focus on the interplay and interrelations among biophysical, social, and economic dimensions.

During the development of the Tongass Land Management and Resource Management Plan, there were

Table 2
Priority Research Information Needs (listed in priority order) from USDA Forest Service (1997a, 1997b, 1997c)

Information need	Objectives
Timber productivity and response to harvest of forested wetlands in southeast Alaska	a. Examine the response of forested wetlands following timber harvest on Kaikli, Karheen, Kitkun, and Maybeso series soils and a Lithic Cryosaprist soil b. Document the effects of timber harvest on stocking (tree numbers, species, distribution) and growth response (timber volume)
Determine the relationship between socioeconomic conditions in rural communities and resource allocations on the Tongass National Forest	a. Develop baseline data to better identify the social and economic conditions within southeast Alaska communities. These conditions include perceived needs and desires of local residents as well as basic social and economic trends b. Determine linkages between resource allocations and social and economic conditions in southeast Alaska communities on the Tongass National Forest c. Test the applicability of current social and economic models to southeast Alaska communities d. Determine effects of national forest planning decisions on these community-level conditions and desires, focusing on changes related to plan implementation
Determine subsistence resource patterns in southeast Alaska	a. Update community traditional resource use patterns survey through a series of community self-assessment surveys integrating standard scientific methodologies and traditional environmental knowledge b. Identify and monitor ongoing subsistence needs and uses through available data, e.g., Alaska Department of Fish and Game surveys and the process outlined in (a) above
Identify and measure the interactions between aquatic/riparian habitat and perturbations in upland areas and the response of anadromous and resident salmonids	a. Systematically evaluate existing habitat and its relationship to salmonid populations in old-growth (unmanaged watersheds) and managed watersheds (logged watersheds) b. Evaluate interactions between aquatic habitat, salmonid productivity, and geomorphic processes in stream channels and in watersheds c. Evaluate the effects of land management activities on geomorphic processes in high gradient channels and on downstream aquatic habitat d. Further develop the fish habitat objectives system used to measure changes in the natural range and frequency of aquatic habitat conditions
Determine the geographic and habitat distribution of endemic mammals on the Tongass National Forest	a. For several recognized mammalian taxa with limited historical ranges, continue to document geographic extent and habitat distribution within and across islands and the mainland portion of the Tongass National Forest b. Determine population levels and associated distribution of mammalian endemics on islands and portions of the mainland that have had timber harvest
Evaluate the future timber productivity of young-growth stands on the Tongass National Forest	a. Conduct baseline studies on the future timber productivity of young-growth stands including distribution of site indexes, modeling (SEAPROG) routines, stem quality, intermediate treatments, harvesting standards, and alternative harvest systems b. Evaluate these factors in terms of future timber production projections on the Tongass National Forest c. Evaluate the influence of these factors on restoration and enhancement of deer and other wildlife habitat
Evaluate alternatives to clearcut timber harvest on the Tongass National Forest	a. Conduct baseline studies on the effects of alternative silvicultural, logging, and regeneration systems on the ecology of late-successional commercial forest stands b. Evaluate the effectiveness, operability, costs, and ability to meet management needs and social desires of these alternatives c. Determine the influence of alternative silvicultural systems on restoration and enhancement of deer and other wildlife habitat
Determine Alaska timber prices and market arbitrage in the Pacific northwest	a. Examine the relationship between timber prices in Alaska (sold price, Tongass NF) and timber prices in the Pacific northwest b. Describe factors common to both markets, and factors unique to each market c. Review statistical models that forecast the price of timber sold in Alaska (Tongass NF) d. Based on this review, revise existing models, or develop new models that can forecast Alaska prices as a function of explanatory factors for which forecast values are available

Table 2 (*Continued*)

Determine prices and costs in Alaska timber production and product supply	a. Compile data and assess patterns and trends in key factors that determine competitiveness in forest products industries; compare data for Alaska to that for the Pacific northwest, Canada, and major overseas competitors b. Conduct a preliminary analysis to estimate export supply relationships for Alaska, to determine the change in quantity exported in response to changes in export and domestic prices, costs, exchange rates, and other factors c. Review the data from the Tongass NF on logging costs and timber availability; if possible, develop a preliminary method to incorporate these data in projections of demand for Tongass NF timber
Study lumber recovery of second-growth timber from southeast Alaska	a. Conduct a baseline lumber recovery study on second-growth western hemlock and Sitka spruce from southeast Alaska. This will provide estimates of the timber volume, lumber volume by grade, and lumber value recovery by diameter class and species b. Evaluate the characteristics of second-growth timber (wood density, juvenile wood, etc.) for their significance in the product potential of trees from southeast Alaska

identified a number of priority information needs important for further forest plan amendment or revision and information needs that would help to implement the Tongass National Forest Land and Resource Management Plan (USDA Forest Service, 1997b) (Table 2). New research on these priority information needs was targeted to substantially strengthen the scientific information base to support the development of alternatives and future revisions to the plan. An important element of the priority information needs and other additional information needs is the implementation of an "adaptive management" feed-back loop to evaluate current plan direction, design monitoring programs to measure effects, and adjust future management activities to better address economic, social, and environmental concerns on the Tongass National Forest. As a part of this process, statistically sound sampling design and analysis techniques were also included as part of the needs to assure the reliability of monitored data and their interpretations. Out of necessity, the highest priority needs were addressed first: understanding the priorities requires looking at the needs of the overall planning effort and not as an overall strategy for research on the Tongass.

Resource specialists for Tongass National Forest also identified a number of other additional information needs identified by considering input from within the Forest Service, other Federal agencies, state and local governments and universities, and public comments. Filling these needs would considerably improve the knowledge base for the next plan revision but will have to be addressed as part of ongoing research efforts as resources allow.

Taken in total, this additional information will enhance the forest manager's ability to integrate and synthesize knowledge across discipline areas (e.g., fish and wildlife, landscape dynamics, and socioeconomics). This process should allow us to more fully understand and appreciate the intricate interactions and balance among biological, physical, and socioeconomic components of the Tongass and its people. Thus, scientific information will continue to provide highly relevant input into policy decision-making, on-the-ground management, and the needs of the people who use and appreciate the Tongass and its resources (Julin and Shaw, 1999).

6. Conclusions

Landscape-scale research often, but not always, requires integration of several scientific disciplines (Gucinski et al., 2004). Undoubtedly, more research is needed that examines ecosystem structure, composition, and function simultaneously, and at multiple scales. However, landscape science may be burdened with the a priori expectation that it will produce more than just scientific information. Scientists, managers, and the public may develop exaggerated expectations about the nature of results of studies about landscapes, perhaps even more than about finer scaled research studies. Sound scientific information is an essential ingredient to sound decisions, but information alone does not make decisions.

Much of the controversy surrounding resource management questions is not from the lack of science, or disagreements about the state of nature, but instead involve basic disputes about human values. Science can aid in the development of informed choices and sustainable solutions by incorporating human needs and values with our best understanding of the environment. Any decision invariably requires the integration of multiple components that can only be accomplished by value-based weighing of tradeoffs among those components. That is the stuff of decision-making, not science.

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