# Using Analytical Tools for Decision-Making and Program Planning in Natural Resources: Breaking the Fear Barrier

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## Planning and Program Development: Stuck on Hold?

Natural resource management has become increasingly complex during the past two decades due to the multiplicity of management objectives that must be considered to address public interest, legislative requirements, and environmental compliance. "Ecosystem management" is the paradigm most commonly cited as the appropriate template for resource management by public agencies. Indeed, this single concept has provided a vehicle for a transition from predominantly commodity-dominated and output-based management on federal lands. The critical tenet of ecosystem management—and the one that drives its inherent complexity—is the need to address social, economic, and biological interactions at *multiple* spatial and temporal scales.

Although increased complexity of decision making in natural resources is common knowledge, the basic decision-making *process* of most agencies has changed little. The most common approach is sometimes termed BOGSAT (Bunch of Guys [and Gals] Sitting Around a Table), which refers to a relatively unstructured discussion of objectives and priorities, normally without much quantitative documentation or tracking of how decisions are derived. Although the National Park Service, U.S. Forest Service, and other agencies use formal and often structured frameworks (including standard software) for project statements and management alternatives, actual decisions are typically made without quantitative input or analysis. This is generally true even when there are hundreds of individual projects and alternatives being considered simultaneously, a situation that is not atypical for a national park or national forest.

Some group-interaction techniques (e.g., nominal group technique, Delphi process) have been used to assist decision-making and assessments in natural resource agencies, although these techniques are typically focused on components of a larger issue. Formal decision support systems (DSS) are more recent developments, and despite the fact that a number of them are designed specifically to aid resource managers, very few of these systems are routinely used. Resistance to using DSS in a group setting is likely due to: (1) fear of losing individual input or control, (2) an aversion to, or inadequate understanding of, computer-oriented techniques, and (3) lack of interest or training in group dynamics. Unfortunately failure to use a consistent and formal process leaves the decision-making group open to criticism (and litigation) for lack of objectivity and quantification. Long-term strategic planning for resource management, inventory and monitoring (I&M), and project implementation (tactical planning) is more important today than ever before. An analytical decision-making framework is needed to quantify and document decisions, thereby improving the credibility of agencies in the public eye.

## An Analytical Framework for Making Decisions and Setting Priorities

The analytic hierarchy process (AHP) (Saaty 1980; Saaty 1990) is a decision-making framework that uses a hierarchical structure to decompose a problem, paired comparisons to quantify value judgments (items at each hierarchy level are ranked with respect to importance or preference or likelihood), and matrix multiplication to convert level-specific, local priorities into global decision priorities (aggregation). This technique has been applied to a wide variety of decision problems, including resource management and monitoring plans in national parks (Peterson et al. 1994;

Schmoldt et al. 1994). A number of other forestry and natural resource applications of AHP have been reported, including a framework for participatory decision-making (Schmoldt et al. 1995). The AHP can also be used in group settings by obtaining group agreement on paired comparisons (e.g., Peterson et al. 1994) or by geometric averaging of judgments (Saaty 1980; Schmoldt and Peterson 1999; Schmoldt et al. 1999).

Ratio-scale ranking of list items is a key feature of the AHP. Normalized, principal right eigenvectors are used to estimate priorities from ratio-scale judgments. Matrix multiplication integrates values derived at different hierarchy levels (e.g., criteria and objectives) to obtain a prioritized list of decision alternatives (see Schmoldt et al. 1994 for details). Because individual judgments are made in a pairwise fashion and collective judgments can be mutually inconsistent, the AHP also permits inconsistency estimation.

This approach can be easily extended to decision-making in resource management, and is helpful for both long-term (strategic) and implementation (tactical) planning levels. For example, the AHP has been used to develop priorities for I&M activities as a component of the resource management plan at Olympic National Park. (Peterson et al. 1994) (Table 1). In this case, a diverse group of park managers provided input to pairwise comparisons of eight park I&M activities, resulting in both an ordinal list of priorities and a numerical ranking of their relative priority for different management emphases. In addition, the AHP was integrated with a simple, linear optimization model that allocated funds and personnel based on project priorities, funding and personnel availability.

| | Objective importance assigned by park staff | | All objectives ranked equally | | Management decision-making has highest priority | |
|---|---|---|---|---|---|---|
| I&M project | Priority | Ranking | Priority | Ranking | Priority | Ranking |
| Air quality | 0.137 | 5 | 0.130 | 6 | 0.099 | 7 |
| Anadromous fish | 0.128 | 6 | 0.143 | 4 | 0.145 | 3 |
| Avalanche monitoring | 0.069 | 8 | 0.057 | 8 | 0.111 | 6 |
| Elwha River | 0.148 | 1 | 0.163 | 1 | 0.168 | 2 |
| IPM program | 0.095 | 7 | 0.077 | 7 | 0.042 | 8 |
| Mountain goat impacts | 0.141 | 3 | 0.135 | 5 | 0.197 | 1 |
| Sensitive wildlife | 0.143 | 2 | 0.149 | 2 | 0.134 | 4 |
| Water quality | 0.140 | 4 | 0.146 | 3 | 0.122 | 5 |

**Table 1. Priority ratings and rankings for I&M projects at Olympic National Park under different management objective priorities (from Peterson et al. 1994).**

The mathematical components and calculations of the AHP can be challenging for resource managers as well as scientists. However, several commercial software implementations of the AHP shield the user from those details, so that a technical *understanding* of the computational aspects is not necessarily required for effective *application*. Our experience with using the AHP in group settings (e.g., Schmoldt and Peterson 1999) is that acceptance of the AHP approach quickly follows initial hesitancy and a brief learning period. Implementing AHP decision making interactively in a group setting, for example by projecting a computer display that shows decisions and scores instantly, helps to engage participants and facilitate rapid decisions. Most participants find that this rapid feedback improves their understanding of the decision-making process and speeds up the process by keeping discussions focused. Some participants even remark that applying AHP interactively in a group setting is fun.

During the past decade, there has been a proliferation of workshops associated with planning and decision making in federal agencies. However, the personal experiences of many workshop participants are that such meetings are often unfocused and unproductive, wasting both time and money, and producing relatively sterile results. Although the AHP has most often been applied in small-group settings, it is also effective in facilitating the conduct of workshops that include decision-making as a component of their objectives (Schmoldt et al. 1999).

## Developing an Inventory and Monitoring Program: A Dynamic Workshop

*Focused* workshops are an effective means for eliciting information as a basis for strategic planning. This is particularly true for national parks and national forests that need to develop or update I&M programs. No individual park or forest can be expected to have the necessary expertise to develop a comprehensive plan (e.g., Peterson et al. 1995). Therefore, an expanded group of experts is generally needed to collaborate on identification of critical concepts, methodologies, and implementation priorities.

Workshops will succeed only if (1) the workshop host has clearly stated the objectives (Silsbee and Peterson 1991, 1993), (2) the workshop process is highly structured, and (3) there are specific products resulting from the workshop. It is normally helpful to present workshop participants with a "strawman" structure as a framework for discussion and potential revisions. In the case of an I&M program, the straw man can be a summary of key scientific/managerial questions and responses, sample project statements, or a programmatic plan developed by someone else. The straw man may eventually be completely revised in the course of the workshop, but its presence is extremely helpful in reducing unfocused discussion. In addition, smaller workgroups designated prior to the workshop can convene separately to address specific issues, typically according to general resource categories (e.g., aquatic biota, and cultural resources). Any introductory information and plenary sessions should be relatively brief and directly relevant to the objectives of the workshop.

The principal tasks within each workgroup should be as follows.

**Brainstorm the key issues**. Key issues typically include specific taxa or processes to be monitored. These issues can be taken directly from the workshop straw man, modified from the strawman, or developed as new concepts. Key issues should be simple and concise, and participants should avoid combining multiple or related ideas within the same item. The intent of brainstorming is to generate lots of ideas quickly with relatively little discussion. Because this process involves idea generation rather than judgment, workgroup participants should be able to reach consensus about the most important subset of key issues without formal procedures. While we suggest brainstorming for idea generation, there are other methods, e.g. nominal group technique (Van de Ven and Delbecq 1971), that can also be used to generate a list.

**Discuss the key issues**. Each key issue should be further refined to develop a clear and unambiguous statement of the issue and a thorough explanation of its rationale. It is helpful to record these discussion points on a standard I&M component template which contains (1) critical I&M and scientific issues relevant to the I&M component, (2) stressors and related factors, (3) specific taxa or processes to be measured, (4) location of I&M activities, (5) justification and other information critical to successfully implementing the component. Information from the component template can be transferred directly to project statements within the I&M program plan or other document.

**Rank the key issues**. The AHP is used to prioritize and rank the individual key issues within the list generated by each workgroup. As described above, this is conducted by all workgroup members (who make pairwise comparisons of the issues), with final scores calculated for the entire group. Individual rankings should generally be compiled privately by each person to avoid the possibility of biases. It is recommended that rankings be developed for both importance and feasibility (or practicality), because these different criteria may have very different implications for program development. By having AHP software available at the workshop, all the raw data for pairwise comparisons can be entered, and final rankings quickly calculated and reported to workshop participants.

An example of the brainstorm-discuss-rank process is shown in Figure 1 for monitoring aquatic biota. There is no "right" or "wrong" in this process, only the expert judgment of workgroup participants. Straightforward "step-down" charts (Figure 2) provide an effective visual summary of workshop output and the framework for an I&M program within a resource category. The AHP can then be used to collectively analyze work group outputs in developing global priorities for the overall I&M program.

**Brainstorm**

| | |
|---|---|
| Anadromous fish | Resident fish |
| Water quality | Amphibians |
| Phytoplankton | Zooplankton |
| Benthic invertebrates | Ducks and geese |
| Aquatic vascular plants | |

**Discuss**

- Need to divide water bodies into lakes/ponds, streams, and reservoirs; different relevant I&M components for each category
- Water quality is easiest thing to measure
- Fish populations are difficult to measure
- Vascular plants should be considered by the terrestrial vegetation workgroup
- Birds should be considered by the terrestrial fauna workgroup

**Rank**

| I&M component | Lakes and ponds | | Streams | | Reservoirs | |
|---|---|---|---|---|---|---|
| | AHP priority | Ranking | AHP priority | Ranking | AHP priority | Ranking |
| Anadromous fish | not included | — | 0.240 | 2 | not included | — |
| Resident fish | 0.212 | 2 | 0.205 | 3 | 0.460 | 2 |
| Water quality | 0.233 | 1 | 0.247 | 1 | 0.540 | 1 |
| Amphibians | 0.171 | 3 | 0.148 | 5 | not included | — |
| Phytoplankton | 0.106 | 6 | not included | — | not included | — |
| Zooplankton | 0.112 | 5 | not included | — | not included | — |
| Benthic invertebrates | 0.165 | 4 | 0.160 | 4 | not included | — |

**Figure 1. An example of the brainstorm-discuss-rank process for monitoring aquatic biota. This type of information is typically recorded on a flip chart or laptop computers during the workshop. Adapted from workshop output for the North Cascades national Park Service Complex.**

Resource categories can be compared at the next highest level in the I&M hierarchy, as shown in the right-most portion of Fig. 4. This allows disparate resource categories such as aquatic resources, atmospheric resources, and vegetation to be compared objectively and quantitatively. At an even higher level, monitoring objectives are considered (Fig. 4). Priority weights assigned to the two types of monitoring objectives (management and scientific understanding) are distributed to specific objectives. In turn, those weights are further distributed among the resource categories. Pair-wise comparisons are made between elements within each level that are connected to a common element in the level above. This may be seem like a cumbersome task, however, we have found that it can be accomplished quickly and efficiently by natural resource staff members who are familiar with the operation of the AHP (Peterson et al. 1994). These global rankings can be performed after the completion of the formal workshop.

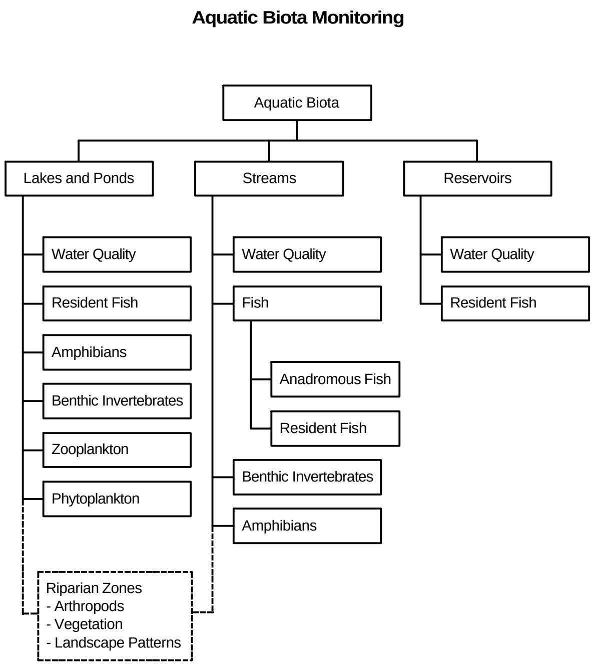


**Figure 2. A conceptual framework for monitoring aquatic biota, based on information in Figure 1. Adapted from workshop output for the North Cascades National Park Service Complex. The dashed-line enclosure at the bottom identifies possible linkages to other I&M issues.**

While there are many ingredients to a successful workshop, these are the most critical:

- Clearly describe workshop objectives and distribute them and other relevant materials to participants *before* the workshop.
- Limit attendance to no more than 50 people for effective group dynamics; a maximum of six people per workgroup will greatly facilitate decision making. A combination of scientists and resource managers works best, and substantial participation by personnel from the host agency ensures local ownership of work-

shop output. Resource managers generally are more amenable to using AHP and less argumentative than scientists.

- Allow movement of individuals between workgroups to allow for sharing of expertise and developing linkages between related topics.
- Develop a clearly defined product from the workshop output (Davis 1989, Schmoldt and Peterson 1999). This product will typically be an I&M plan that is collated and edited by the host agency. A draft plan should be developed by resource management staff and be made available for review by workshop participants (posting the plan on a Web site is highly effective). Post-meeting follow-up will ensure that attendees know that something tangible resulted from their hard work, and they will be more like to participate in future, similar efforts.

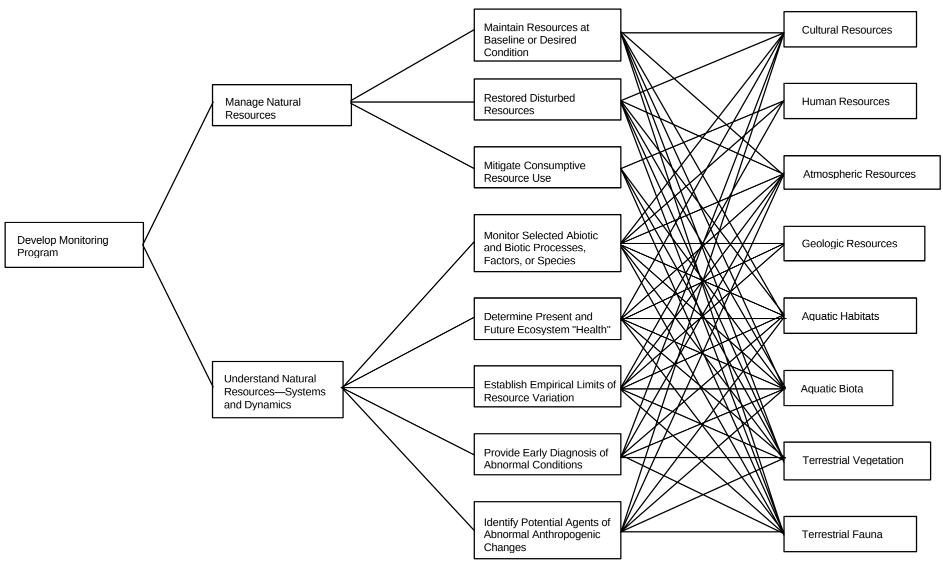


**Figure 3. Using the judgments and priorities developed in Figures 1 and 2, it is possible to create a more global perspective of I&M program planning by adding a level of monitoring objectives (of two types: management and scientific) and a level containing resource categories (items within each of these levels are also prioritized).**

A highly structured workshop can elicit a large amount of expert knowledge in a short amount of time. We have found that two days is sufficient to produce the template of entire I&M plans and similar documents. Economic efficiency is an important benefit of the workshop, because each extra day can cost the host agency several thousand dollars for salaries, travel, and facilities, in addition to potential frustration of participants. More protracted meetings produce rapidly diminishing returns for attendees' time.

## Analytical Decision Making for Resource Management: Another New Paradigm?

Science-based resource management generally is acknowledged as one of the important developments of the past decade. It is now time for the decision-making process in public agencies to match this increasing level of sophistication. Quantitative and analytically-based procedures are needed to ensure not only good decisions, but greater accountability within agencies and with the general public (e.g., Schmoldt and Rauscher 1996; Rauscher 1999). Agencies must document decisions more effectively and go beyond compiling information (i.e., the scientific data) on which decisions are based.

How do we make this paradigm shift in decision making? There must be commitment of public agencies at the national and local levels to do a better job of documenting the decision-making process. Agencies need resource management staff with a higher level of skills in quantitative applications, as well as the sociological and psychological components of decision making. A policy of aggressive evaluation and application of potentially beneficial new technologies is critical. Coordinators for I&M planning, who possess analytical and management science skills, are a valuable asset for land management agencies. Finally, good coordination and working relationships with local scientific organizations will ensure that the AHP and other analytically-based approaches can be customized for specific management applications.

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# On the Frontiers of Conservation:

## Proceedings of the Tenth Conference on Research and Resource Management in Parks and on Public Lands

***Edited by David Harmon***

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March 22-26, 1999 • Asheville, North Carolina

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## Acknowledgments


Ever year the logistics and planning for these conferences become more complicated, and the success of the meeting is a product of many volunteers working with the GWS. We want to thank the members of the Conference Committee, and past and present members of the GWS Board of Directors, for their help in planning and carrying out the conference. We are very grateful to the two co-sponsors and one supporting institution, and to the persons within them who helped arrange funding: the U.S. National Park Service (John Dennis, Deny Galvin), the U.S. Geological Survey Biological Resources Division (Denny Fenn), and Eastern National (Chesley Moroz). We are also grateful to the U.S. National Park Service and to IUCN-US (Sharon Cleary and Ang Sherpa, respectively) for providing travel scholarships for participants from developing countries. For the field trips and local arrangements, we are indebted to Connie Backlund, Patty Lockamy, Bob Miller, Pat Momich, Ina Parr, Carol Tingley, Karen Wade, and the staffs of the trip sites. We also extend our thanks to all the people who volunteered to chair concurrent sessions, to Chuck Rafkind for acting as the ad hoc conference photographer, and to Jonathan Bayless, Hardy Pearce., Kate Stevenson, and Marie Rust for assistance in publicizing the conference. Special thanks go to Emily Dekker-Fiala for her outstanding organizational work.





Paste-up by Robert M. Linn • Printed by Greenlee Printing, Calumet, Michigan
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