Confronting the Implications of Wicked Problems: Changes Needed in Sierra Nevada National Forest Planning and Problem Solving[1]

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Thirty years ago, the fate of migratory deer in the Sierra Nevada was thought to be the major forest wildlife issue. Ten years later, agencies were building the California Wildlife Habitat Relationships System to allow managers to integrate all terrestrial vertebrates with timber management in comprehensive National Forest planning. Another ten years after that, Tom Knudsen wrote his Pulitzer Prize–winning series, "Sierra in Peril," describing the complexity of environmental problems. Now, managers are trying to improve the lot of all native species in the Sierra Nevada, address fire hazards and a host of ecological processes, and deal with the complex interactions of people and nature in forest planning. The past three decades have been a turbulent ride for those who work and live with the National Forests of the Sierra Nevada. Why have we not been able to solve the Sierra Nevada's problems? I propose that it is because we have not been using the right methods for solving such complex problems.

Two challenges in managing public natural resources are especially vexing: improving the prudence and sustainability of resource management direction for Federal lands and improving institutional effectiveness in carrying out that direction. On the basis of my first-hand experiences as a regional executive with shared responsibility for guiding the Interior Columbia Basin Ecosystem Management Project and the Sierra Nevada Framework and Forest Plan Amendment environmental impact statement (EIS) process and my review of the Sierra Nevada National Forest Plan Amendment Record of Decision and its supporting documents, I suggest three lessons for future problem solving. First, we have been trying to solve natural resource problems with methods insufficient to handle their multi-dimensional complexity by continually applying more and better science (or new and improved models), reanalyzing the problem(s) *ad infinitum,* and making decisions through political or judicial power plays. Secondly, we can improve the utility of science in helping us solve natural resource problems but only within the context of social and managerial tools useful in addressing multi-dimensional complexity. Finally, these tools include coping strategies and structured decision analysis leading to the continuous improvement process of "learn by doing" and "learn by using," which is called active adaptive management.

Multiple Dimensions of Natural Resource Problem Complexity

Difficulties in solving complex problems often start with describing the problem itself. Natural resource problems are inherently complex and messy (Gunderson 1999, Shindler and Cramer 1999). There is often no definitive statement of what the problem is. Absent a definitive problem statement, there can be no definitive solution. Clearly articulating the problem to be solved through continual iteration and refinement of the problem statement is

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key to successful planning. Typically, multiple problems and multiple objectives characterize natural resource plans, each framed by a particular stakeholder pursuing a distinct mission.

The first Sierra Nevada National Forest Plan Amendment Record of Decision (USDA Forest Service 2001) is by no means the first or only example of this, but it does illustrate the situation well. Five problem areas are described:

1. Protect, increase, and perpetuate old-forest ecosystems and provide for the viability of native plant and animal species associated with old-forest ecosystems,
2. Protect and restore aquatic, riparian, and meadow ecosystems and provide for the viability of native plant and animal species associated with these ecosystems,
3. Manage fire and fuels in a consistent manner across the National Forests, coordinate management strategies with other ownerships, integrate fire and fuels management objectives with other natural resource management objectives, address the role of wildland fire, and set priorities for fire and fuels management actions,
4. Reduce and, where possible, reverse the spread of noxious weeds, and
5. Maintain and enhance hardwood forest ecosystems in the lower westside of the Sierra Nevada.

These "problem areas" read more like multiple objectives to be met than a definitive statement of what "the problem" is. The Record of Decision says that these are "areas where National Forest management needed improvements." Thus, the problem must be that existing management direction does not adequately address these multiple objectives and that a better solution is needed. But these problem areas are not consistent in stating an expected outcome. "Protect, restore, and increase" refer to both processes and outcomes. Viability is an outcome that cannot be measured. The expected outcome for fire and fuels is unstated; process goals are to manage, coordinate, integrate, and set priorities. Unstated in the "problem areas" is the possibility that goals for old-forest and aquatic systems and species could conflict with goals for fuels and fire. Clearly, there are multiple objectives, and a definitive statement of "the problem to be solved" is not clearly articulated.

The Record of Decision also says that the Chief of the Forest Service instructed the Regional Forester to "develop a strategy to ensure ecological sustainability." The assumption here must be that existing direction for Sierra Nevada National Forests did not do this; thus, the problem is lack of ecological sustainability. The standard for "ensure" and what, exactly, "ecological sustainability" means must be deduced from other statements in the Record.

From the five problem area statements, one can deduce that sustaining ecosystems must mean, at a minimum, providing for old-forest and aquatic ecosystems and the viability of their native species first, managing fire and fuels second, and reversing the spread of noxious weeds and enhancing hardwood forests as a third-tier action. The rationale for the decision given later in the 2001 Record attests to these as the priorities used in weighing tradeoffs. Other components of the ecosystems in question, such as water, wood, recreation, cultural resources, diversity of human lifestyles, local communities, and local economies, all commonly considered to be integral parts of sustainable forest ecosystems, are addressed through discussion of impacts or effects on them posed by the solutions proposed for the five problem areas.

The deciding officer set some conditions for the solution: "amendments (must) be scientifically credible, legally sufficient strategies for sustaining National Forest ecosystems." The implication here is that prior plan directions (that is, solutions to the problem) are not scientifically credible or legally sufficient for the purpose of sustaining ecosystems.

No mention is made in the Record of Decision about a desire to improve institutional effectiveness. The Record briefly outlines a decade-long history of attempts to develop adequate protection for California spotted owls in Sierra Nevada forests, work that actually began in the late 1970s, not just in the 1990s. Large investments of time, people, and financial resources have been made in planning to bring us to a decision that, in 2004, easily 30 years after the first species concerns surfaced, is still under review and potentially subject to litigation. This is evidence of institutional ineffectiveness, yet there are no goals or strategies for addressing this "problem." Society is confronting a very complex problem, and even its definition eludes clarity.

Social Complexity—Fragmented Stakeholders

Part of the complexity reflects our society. Stakeholders for Federally managed natural resources are often highly fragmented in their interests and in the tactics they use to pursue those interests. This includes specialists within the various agencies with responsibilities for resource stewardship. There is essentially no stakeholder group for balance among the multiple problems and multiple objectives except for the agency line officers mandated to create that balance. In some cases, such as wildlife, fish, and recreation, there are multiple stakeholder subgroups that do not agree on which aspects of "their" resource should be featured in the National Forest System, for example, recreationists who use mechanized vehicles versus backpackers or horsemen.

Collectively, the multiple stakeholders see "the problem" and objectives differently; in other words, they are not likely to agree on the definitive "problem" to be addressed. Conklin (in press) calls this aspect of a problem social complexity. Stakeholders are also likely to have different value preferences and different tolerances for risk; not only do they not see "the problem" alike, they do not see "the solution" alike either. Roberts (2001) says that disagreement on both the problem and its solution characterizes a wicked problem, a concept first articulated by Rittel and Webber (1973), extended to forestry by Allen and Gould (1986), and recently discussed in relation to natural resources issues by Gunderson (1999) and Shindler and Cramer (1999).

Scientific Complexity

From a scientific perspective, natural resource problems are also complex because multiple factors are at work, influencing each problem area or objective. For example, the condition and trend of a wildlife population are a result of interactions among the prior population, habitat, weather, predators, disease, off-site factors, and chance events. Resource managers can influence only some of these factors, and scientists only vaguely understand how they all operate together to affect a population outcome for many, if not most, species. Most of what affects wild plant and animal populations falls into the arena of uncertainty and unknowns. This point has important implications for how biological diversity is addressed, especially attempts to estimate species viability on the basis of projections of habitats only.

Wildlife populations are not the only example of scientific complexity. The vulnerability of a forest or rangeland to uncharacteristic fire is a result of past fire suppression, past land management, climate/weather, perhaps invasive species, and chance events. The hazard that risk poses depends on how close the forest or rangeland is to something of value that could be harmed by the fire, such as houses, sensitive natural resources, or municipal watersheds, and how easy it might be to get initial-attack firefighters to where ignitions start. But the fire-prone forest or rangeland is also habitat for certain wildlife species, and any action or inaction taken for one objective, say fire risk or wildlife habitat, affects the outcome for the other. Thus, natural resource problem areas or objectives are not independent; they are linked. How science from multiple disciplines is handled and integrated in planning will influence the effectiveness of a plan in problem solving.

Uncertainty

Regardless of how much is known about a problem or objective and the factors influencing its status and trends, areas of uncertainty will always exist. Uncertainties can take two forms: (1) we do not know but can eventually learn through observation or research, or (2) we cannot know until it occurs, such as future weather events. Uncertainties are typically more significant to planning than what is known. When there is uncertainty, we are as uncertain about the potential for positive outcomes as we are about the potential for negative ones. This adds to the complexity. Brooks (1996) describes three types of surprises, or potentials for unknowns to occur: unexpected discrete events, discontinuities in long-term trends, and emergence of new factors.

The Mount St. Helens volcanic eruption is an example of an unexpected discrete event. An example of a discontinuity in a long-term trend is the climate shifting from cooling to warming. We cannot know for certain where or when the discontinuity is going to occur or how long it will last, but when it does occur, it shifts ecosystems to a new trajectory of change. An example of a new factor is the arrival of an invasive species that radically changes the ecological structure and process of a place, for instance, cheatgrass, chestnut blight, or white pine blister rust. To be successful in coping with a dynamic and largely unpredictable world, land and resource management planning needs to be resilient to uncertainty and surprises.

Gunderson (1999) talks about building “robust responses” to uncertainty by building system resilience. The way in which people choose to deal with uncertainty either increases or decreases a system’s resilience to surprises. One approach is to choose to do nothing by ignoring or assuming uncertainty away. Another is to choose to replace uncertainty with faith that the matter will resolve itself. A third approach is to choose to confront the uncertainty in a systematic way and try to restore resiliency to the system.

Ignoring the fire risks in Western dry forests is an example of the first choice. Having faith that nature will fix the problem is an example of the second choice. An example of the third approach is to choose to do something to change the behavior of a fire when it occurs, from catastrophic to something less transforming. Planning, either implicitly or explicitly, involves deciding which of these choices to make when confronted with uncertainty, risk, and unknowns. The 2001 Sierra Nevada Forest Plan Amendment Record of Decision appears to have favored the first two choices over the third in regard to fire risks outside the urban interface and long-term wildlife habitat suitability in densely stocked mixed conifer forests. The revised 2004 Decision for the Sierra Nevada Forest Plan Amendment favors the third choice.

Conflicting Risks

As if this is not enough complexity, we usually encounter conflicting risks to each objective, and these risks vary over the short and long terms and among objectives. An example of multiple objectives and variable risk is the intersection mentioned above between wildlife habitats and wildfire created by the conditions of dry, fire-prone forests throughout the West. Managers and stakeholders want to sustain healthy populations of all wildlife species, especially those associated with old forest, native shrub lands, and aquatic ecosystems. Most also want to restore forests and rangelands to conditions more resilient to the inevitable fires, droughts, and insect epidemics, in which the characteristics of disturbance events do not create unacceptable risks to life, property, natural resources, or County, State, and Federal treasuries. Pursuing either the wildlife protection objective or the fire risk–reduction objective changes the short- and long-term risks to the other. Inaction lets the risks accumulate. This intersection of objectives and risks for wildlife (or water or biological diversity) and wildfire (or drought or invasive species) is typical of the major tensions in planning for National Forest and National Grassland management in many parts of the western United States. Any plan to solve complex and wicked problems must address how conflicting risks are handled.

System Dynamics

Ecosystems are dynamic. Social systems, economic systems, and public attitudes are also dynamic. Our state of knowledge and technologies is dynamic; therefore, plans and their management strategies must also be dynamic. They must be designed for local application and continual adaptation to change. According to Lindbloom (1979), Wildavsky (1995), and others, the only way to make steady progress and improve problem solving in dynamic and uncertain situations is to take incremental actions that are bold enough to have the potential for errors so that we can learn from those errors and make course corrections. Furthermore, these actions need to actively involve users of plans, and not just designers of plans, because most innovations come from users trying out novel solutions to local problems. This means that active adaptive management must engage every field unit that implements a plan, not just a few for the benefit of others.

The weaker the knowledge about system dynamics and the greater the uncertainty, the stronger the need for action-based learning to reduce uncertainty in the future. The 2001 Sierra Nevada Forest Plan Amendment Decision appears to do just the opposite: its premise appears to be the greater the uncertainty, the greater the caution in taking action that could lead to learning, which could reduce uncertainty. Unfortunately, as Gunderson (1999) and Stankey and others (2003 have pointed out, natural resources professionals have yet to demonstrate great capacity for making adaptive management work, and this must be taken into consideration in assessing the effectiveness of a plan that depends on adaptive management. The more prescriptive and constraining a plan is on permitted actions or on processes required to get to action, the less likely adaptive management is to succeed. This is the major reason why adaptive management in the Northwest Forest Plan has failed. A similar undesired outcome for Sierra Nevada National Forests could occur if the revised plan amendments are overly prescriptive and cautious.

Diagnosing Wicked Problems Correctly

For the past two decades, National Forest planners and managers have been misdiagnosing or underdiagnosing the nature of the problems they are trying to "solve." They have been thinking that the problems are simple enough or maybe insufficiently complex that they are solvable with traditional scientific tools and plans, for example, linear programming models and increasingly sophisticated analyses. While such tools are necessary, they are not sufficient. Too frequently, Federal agencies get stuck on analysis and planning without ever getting to the implementation and learning stage (Cortner and others 1996). Addressing the more intractable social aspects of adaptive management is even more problematic under current policies and practices (Shindler and others 2002). For example, the current procedural requirements of the National Environmental Policy Act (NEPA) and easy access to judicial review of forest plans actually hinder collaboration as a tool for dealing with social complexity.

Conklin (in press) says the failure to recognize and deal with "wicked problems" leads to organizational pain—a sense of futility in expecting things to get done one way and repeatedly banging into a different reality, or, in the case of recent Forest Service planning, making only minor changes in how planning is done, yet expecting different results. This pain may be caused in part by misunderstanding the complexity of the problems at hand and trying to solve them with tools and methods useful only for simpler problems, for example, attempting to solve problems fraught with social complexity or value conflicts by adding more science or running more sophisticated systems models. It may also be explained in part by agency managers who actually do understand that they are dealing with wicked problems but are constrained by law, rule, or policies to employ methods that still empower special-interest combatants who use traditional power tactics suitable for simpler problems.

This description of the complex and wicked nature of natural resource problems, depicted in *figure 1,* characterizes the decision environment for National Forest plans. It was certainly true for the Pacific Northwest Forest Plan, Interior Columbia Basin Ecosystem Management Project, and Sierra Nevada National Forest Plan Amendment. Complexity and wickedness in natural resources problems will not go away. Organizational pain is clear in the Forest Service. We need to learn how to function well in such a world.

Simple	**Complex**	**Wicked**
clear, all agree	**Problem**	fuzzy, disagreement
single	**Objectives**	multiple
aligned	**Stakeholders**	fragmented
few, controllable	**Factors Influencing Objectives**	many, beyond control
low	**Uncertainty**	high
low variability	**Relative Risks**	high variability
leads to clear choice	**Role for Science**	informs choices
not contentious	**Coping Strategies**	contentious
less valuable	**Decision Analysis**	more valuable

Figure 1— Spectrum of complexity involved in natural resources problems.

We need to develop effective methods to improve (1) the quality of our decisions, (2) the degree to which decisions are deemed prudent by the various stakeholders—in other words, the degree to which they garner enough support and commitment to action so that learning is possible, and (3) the health of our institutions of governance for Federal lands.

Navigation Tools

Let us now turn to tools that can help those who wish to work on solving wicked problems: science, coping strategies, decision analysis, and adaptive management.

Science

Science is vital in helping stakeholders address wicked problems in at least six ways. Science helps stakeholders:

1. understand and define the problem(s) they are trying to solve;
2. develop objectives relevant to solving the problem(s);
3. design creative yet feasible alternatives to meet those objectives in ways that lead to problem solutions;
4. elucidate the likely consequences (good, bad, and neutral) of those alternatives;
5. characterize and understand uncertainty and risks inherent in each alternative; and
6. design and carry out monitoring, research, and adaptation sufficient to address major uncertainties, reduce risks, and test assumptions made in planning.

The word "helping" is italicized because scientists usually do not conduct these roles in a vacuum and then hand off the products to managers and stakeholders; they interact and work with managers and stakeholders to make sure their work is relevant to the problem(s) and is practical. An exception to this was made for the Northwest Forest Plan, which, by 1993, was judged by political leaders as being at sufficient gridlock to warrant giving Forest Ecosystem Management Assessment Team (FEMAT) scientists the authority to carry out steps 3 through 5 above in isolation, after political authorities had defined steps 1 and 2. Sustainable approaches to solving wicked problems normally require full openness in how steps 1 through 6 above are handled. This was a major reason for the openness of science in the Interior Columbia Basin and Sierra Nevada cases, beginning with science assessments and the Sierra Nevada Ecosystem Project (SNEP) process. Regional assessments, for example, FEMAT, Interior Columbia Basin Ecosystem Management Project) and SNEP, have proven extremely useful in providing a scientific foundation for comprehensive land and resource management planning (Johnson and others 1999).

Very few natural resource decisions are blessed with the quality, comprehensiveness, understanding, and public support of the science that now supports problem-solving efforts for Sierra Nevada Federal lands (Sierra Nevada Ecosystem Project 1996 Sierra Nevada Science Review 1998, Sierra Nevada Forest Plan Amendment Final Environmental Impact Statement 2001). It is truly a most impressive body of knowledge for such a large and complex region. It can and will get better. But better science, by itself, will not lead to better solutions for natural resources problems in the Sierra Nevada if it continues to be used in ways insufficient to solve wicked problems. A new approach is needed.

Coping Strategies

Three alternative coping strategies for dealing with complex problems are the use of authority, competition, and collaboration (Roberts 2001, *fig. 2*). Authoritative strategies try to "tame" problems by putting problem solving into the hands of a few stakeholders who have the authority to define the problem and solve it. In a democracy, authoritative coping strategies work and are sustainable only if all the stakeholders yield power and authority to the anointed few and agree to abide by their decisions. In other forms of governance, authoritative copying strategies last because those in power force others to accept the solution. Reducing the number and diversity of stakeholders with authority to define and solve the problem decreases complexity. But it has some disadvantages: the authorities can be wrong about the problem and wrong about the solution, and authoritative strategies do not keep the citizenry informed and engaged in the governing process.

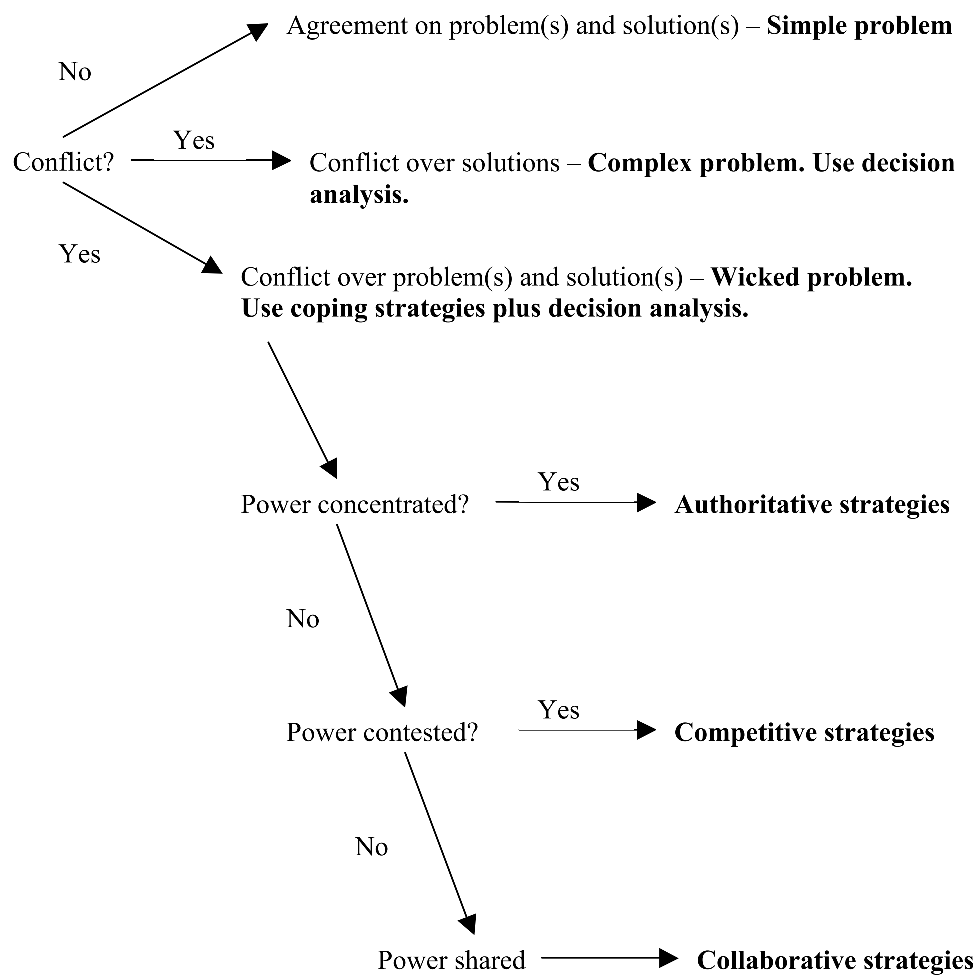

Figure 2–– Coping strategies for dealing with wicked problems (adapted from Roberts 2001).

Competitive strategies assume a zero-sum game, and a win-lose attitude permeates the environment. Central to the pursuit of competitive strategies is the quest for power. As more power is acquired and held, it can change the coping strategy from competitive to authoritative. Competition can be an efficient temporary way of solving problems; however, pushed to the extreme, it can lead to violence and warfare. It can also lead to an intermediate situation of gridlock because stakeholders have enough power to block one another, such as through judicial rulings or political means, but not enough power to actually arrive at a solution or get something done.

Collaboration is the third coping strategy. It occurs when multiple stakeholders who share power work together to jointly define "the problem(s)" and find acceptable and realistic solutions to them. It seeks win-win solutions. The advantages of collaboration are sharing in both the costs and benefits of solutions, strength in numbers, and organizational efficiencies. Disadvantages include the increased transaction costs of adding more stakeholders, more meetings, more time, and the need to learn new interpersonal skills. Collaboration also requires compromise. And it can and does on occasion go awry.

Collaboration is expensive and time consuming and can weary participants beyond their tolerance limits. But, if it works and is linked to continuous improvement processes to learn and make periodic course corrections (in other words, active adaptive management), it may be the only sustainable coping strategy for addressing wicked problems in a democracy. The hope for such an outcome was what led Forest Service executives to design the Sierra Nevada Framework for amending National Forest plans on the basis of principles of collaboration.

Whatever coping strategy is chosen, that strategy is the process wherein the wicked problems get defined, where objectives are set, where alternatives are framed, and where likely consequences are evaluated for how well they are likely to address objectives and solve the problem(s) vis-à-vis scientific, logistical, social, economic, and political criteria. I did not say this is where the problem gets solved. It only gets "solved" through adaptive management. Science can help each coping strategy reach its goals, but it does not drive them; coping strategies are social and political processes, not scientific methods. This is the fundamental reason why natural resources policies and plans are never science based, despite the sloppy use of that term. They are always value based. They are, at best, science informed. They are also, at best, socially, politically, and logistically feasible.

Our current laws, policies, and procedures do not enable collaboration because they do not vest shared power in the collaborators. Power still belongs to those who can prevail in court or Congress or the White House. And this is why we do not yet have sustainable strategies to solve the wicked problems in the Northwest Forest Plan area, the Interior Columbia Basin, or the Sierra Nevada. We do not have the social will or the capacity to make collaborative problem solving work over large areas yet. And agencies still suffer from organizational pain, caught in the crossfire from the gladiators of conflict.

To succeed, collaborators must agree to share power, and the process of collaboration must increase the likelihood that the various stakeholders will have equity in how their concerns and interests are addressed. It must increase the likelihood that critical and creative thinking will occur and that the decision process will lead to higher "buy in" from those affected by the decision. It should go without saying that collaboration cannot occur without full openness and mutual respect in how all aspects of the decision process are handled. Openness means full disclosure and honest and appropriate use and characterization of knowledge, uncertainties, risk, and values. Mutual respect means a commitment to stay within the process and not resort to power plays. Collaboration on complex problems requires a willingness to compromise for the larger, collective good for the greatest public benefit.

As a fundamental goal, collaboration should increase credibility and trust in the solution to the problem, including the adaptive management strategy and the institutions that will carry it out. To reach this goal, collaboration must:

- decrease the potential for the problem or objectives to be incorrectly stated;
- increase creative thinking in designing alternative solutions;

- increase the likelihood that assessments of the alternatives make appropriate use of science *and* the subjective values of the stakeholders; and
- decrease the likelihood for a dysfunctional solution to the stated problem(s).

If collaboration cannot do these four things, it will likely be perceived as not warranting the extra costs. If compromise is unacceptable to stakeholders with sufficient access to power, collaboration will fail. Hence, if power cannot be shared equitably among stakeholders, collaboration should not be used as a coping strategy. To achieve equity in power sharing, the role of the judiciary in natural resource problem solving must be limited to matters of equity and not process or substance of decisions. New governance mechanisms for arbitration or mediation among the collaborators must replace litigation.

Decision Analysis

Regardless of which coping strategy is at work, decision analysis methods can improve the prudence of solutions to complex problems. Decision analysis is likely analysis overkill for simple problems and will probably be most useful for complex problems, those for which people can agree on the problem but need some help finding agreeable solutions.

According to Hammond and others (1999), an effective decision-making process fulfills the following six criteria:

- focuses on what is important;
- is logical and consistent;
- acknowledges both subjective and objective factors and blends analytical with intuitive thinking;
- requires only as much information and analysis as necessary to resolve a particular dilemma;
- encourages and guides the gathering of relevant information and informed opinion; and
- is straightforward, reliable, easy to use, and flexible.

For maximum effectiveness, the decision process must:

Work on the right decision problem(s). This means that, to choose well (make prudent decisions), the decision problem(s) must be stated carefully, acknowledging complexity but avoiding unwarranted assumptions or option-limiting prejudices.

Specify objectives for solving the problem(s). The decision is a means to an end. What are the ends that must be achieved to solve the problem(s)? Which interests, values, concerns, fears, and aspirations are most relevant to achieving the goals?

Create imaginative alternatives. Alternatives are the different possible courses of action to choose from in working toward the objectives. The decision can be no better than the best alternative or the best complementary parts of several alternatives.

Understand the consequences. How well do the alternatives satisfy all the objectives and address the problem(s)?

Grapple with the tradeoffs. Each alternative will fulfill a suite of objectives to different degrees. Choosing intelligently means setting priorities and openly addressing tradeoffs among competing objectives. If the world was certain and everyone had the same tolerance for risk and the same values, this would be the end of the road. But it is not and they do not. So we move on.

Clarify the uncertainties. Effective decision making demands that uncertainties be confronted and the likelihood of different outcomes and possible impacts be assessed.

Think hard about risk tolerances. When decisions involve uncertainties, there is some risk that the desired outcome will not accrue to the course of action taken. How important is this for the various objectives; in other words, what are the costs of being wrong?

Consider linked decisions. What is decided here today may affect outcomes elsewhere or options for decisions in the future.

These eight elements of the decision process provide a framework for making better use of science and coping strategies in decision making. The framework is very similar to how agencies structure their decision making. But agency performance in defining problems, identifying uncertainties and risks, and linking objectives has been weak. Also, this framework must be iterative rather than linear. And it must conclude an approach to implementation that we commonly call active adaptive management (Wildavsky 1995).

There are several barriers to success in applying the above decision-making framework. Reviewing these barriers helps us identify how future Sierra Nevada decisions could be improved.

Barrier: *The problem statement is poorly defined: key factors are minimized or left out, or the wrong priority is assigned.*

The problem statements in the Sierra Nevada Record of Decision appear to be quite fuzzy and poorly focused. They may not be the most useful statements to focus further work. Ideally, the problem statements should have been reviewed thoroughly throughout planning in collaboration with the stakeholders who had authority to share power.

Barrier: *Objectives are either too narrow or too comprehensive.*

As previously noted, the five "problem areas" in the Record of Decision are not the most useful characterization of the multiple objectives that must be addressed to make progress on the problem(s). Not all are necessary, nor are they collectively sufficient to guide further action.

Barrier: *Alternatives are overly constrained by prejudices or weakly reflect science and/or values.*

This is not a weakness of the Sierra Nevada National Forest plan amendment process because stakeholder groups were invited to forge their own alternatives, and these are fully reflected in the EIS. The science consistency check indicated that the science was fully and appropriately used. The evaluation of alternatives in the Record of Decision indicates that all of the action alternatives perform well in regard to the five problem areas; they vary in how well they address each problem area, but all make the future better for all areas.

Barrier: *Assessment of consequences confuses objectivity with subjectivity. Both are necessary to prudent decisions but are not useful when confused.*

Subjectivity in science is inescapable. In the assessment of alternatives in the Sierra Nevada environmental impact statement, scientists were honest and candid about the necessary use of subjectivity: "In summary, there is considerable uncertainty regarding viability" (USDA Forest Service 2001). The explanation of what went into the viability ratings in the FEIS is as comprehensive and sound as can be found to date for such work. But they are still subjective assessments, influenced greatly by both available data and necessary assumptions.

The issue here is not the efficacy of the science *per se* and its necessary use of subjectivity but rather how the science and its attendant subjectivities and uncertainties were used in decisionmaking. When the product of science is stated as a working hypothesis with uncertainties disclosed, the only viable measure of its veracity is to test it in the real world. That requires actions bold enough to push systems to where errors and learning can occur.

Barrier: *The weighing of science, risk, uncertainty, and values is unclear in the decision-making process.*

The precautionary principle (Wingspread Declaration 1998) is often advocated as the "safest" path to species or ecosystem protection when an effective characterization of comparative risks is lacking, when there is an inability or unwillingness to fully describe the implications of uncertainty, and in the absence of a decision making process that takes these into consideration in a transparent way.

Precaution has long been a basis for taking action to prevent harm. But it has lately gone beyond this to say that, in the absence of full certainty that an action will not do harm, do not take the action (Morris 2000). A weaker and often used form of precaution says that lack of full certainty that a proposed action will or will not cause harm is not a justification for letting that action go forward. These postulates are reflections of a philosophical position regarding risk and uncertainty.

The precautionary principle has several flaws that make it questionable as a guide to decision making (Beckerman 2000). First, if the future is really all that uncertain, then we cannot be confident that action taken or not taken today will not make the future better rather than worse. Second, what constitutes harm is not always clear and could vary over time and space. When the precautionary principle is applied to dynamic ecosystems to constrain actions, such as fuels thinning needed to restore the system's resilience to fire, it sets up the potential for major long-term harm: harm from inaction could be greater than harm from proposed action. Inaction creates "opportunity benefits," that is, benefits foregone because action was not taken (Wildavsky 1995).

It is not possible to have full certainty regarding most of the important things in life, and ecosystems are certainly no exception. The standard for burden of proof about certainty in the precautionary principle is infinitely high. And taking no action precludes the opportunity to learn from trial and error. The upshot of applying the precautionary principle is either nothing will ever get done or the preconditions for action are so time consuming and burdensome that action is excessively costly, too timid, or too late. The consequence will be countless unintended harms as a result of inaction. Care, thoughtfulness, and testing of ideas make sense, but extreme precaution is hardly prudent in a dynamic ecosystem, especially one that is vulnerable to uncharacteristic disturbance events. Thus, in situations such as those that confront Sierra Nevada ecosystems, stakeholders, and managers, the precautionary principle sheds no light on prudent choices.

The precautionary principle appears to have greatly influenced how risk or uncertainty about forest management impacts on certain fish and wildlife entered the decision rationale in the 2001 Sierra Nevada Forest Plan Amendment. It appears that uncertainty was assumed to have only negative potential outcomes; however, uncertainty means outcomes or future events are uncertain in both directions. The rationale for how tradeoffs were made warrants open critical thinking and review of what uncertainty implies, what harm is, and how it is judged vis-à-vis other objectives. The 2004 revised Record of Decision handles risk with more boldness, yet even it is insufficient to address the magnitude of risk to late successional forests and their ecological values posed by uncharacteristically intense fires.

Barrier: *Backroom deals and political power plays can pervert the appropriate use of science, nullify investments in structured decision analysis, and scuttle collaboration if that is the coping strategy being openly pursued.*

When Forest Service executives tried to brief a high administration official on the scientific comparison of alternatives in early spring 1999, it was clear that the collaborative strategy and honest use of science to which those executives had publicly committed had been nullified by stakeholders with enough authority to impose competitive or authoritative power. This also happened to FEMAT's Option 9 as it morphed into the untenable Northwest Forest Plan.

There are paths around these barriers to prudent decisions if people are willing to pursue them. Not surprisingly, they involve recognizing the complex nature of the problem(s) in the first place, and then navigating the barriers to effective solutions.

- Define the problem(s) as clearly and concisely as possible: through collaboration to decrease social fragmentation if possible, or through other means if not. Revisit the problem definition frequently as planning proceeds and fine-tune it as needed. Accept that precise problem definitions are unlikely for wicked problems.
- Frame objectives relevant to the problem(s) in its full dimensions. Help people see what the desired outcomes will be and where the stopping point is for planning and analysis so that action and new learning can begin.
- Create innovative and feasible alternatives—those that can be tried and abandoned or discarded easily if they do not work as intended and that can be objectively evaluated as better or worse.
- Distinguish science from values and treat them accordingly; both are important. Shifting from conventional statistical inference tools to Bayesian inference would help in this task.
- Structure the decision-making process so that science, risk, uncertainty, values, and tradeoffs are clear to all stakeholders.
- Insist on total openness from start to finish, from integrity in commitments made to stakeholders to appropriate use of science.
- Know when to stop planning and start learning through adaptive management.

These may be utopian wishes. But, if the goal is to make prudent, sustainable decisions or more prudent decisions than those we have for complex, dynamic ecosystems, it will take more than just bringing better science to the table or simply doing a better job of science integration. If that is all that gets done, it will be like the common definition of insanity: doing things the same way and expecting different results. Social complexity, rather than lack or misuse of science, is a major barrier to solving complex dynamic natural resource problems. Bogging down in analysis so that action and learning never occur is quite another.

Active Adaptive Management

Numerous times in this paper, active adaptive management has been referred to as key to actual problem solving for complex problems. There is a rich literature on adaptive management (Holling 1978, Walters 1986, Stankey and others 2003). Several points are key to making adaptive management work on Federal lands.

Active adaptive management means that management projects are treated as experiments with sufficient scientific design so that they clearly lie in the interface between research and routine management. It requires that scientists work side-by-side with managers in designing, implementing, and monitoring project work. And, it requires that ecosystems be treated boldly enough to learn where the cause-effect relationship boundaries are between action and response. The Forest Service has experience with such projects, but they have been the exception rather than the rule. To solve wicked problems, active adaptive management must become the rule and routine management the exception. Without major cultural change in both the research and management branches of the agency, adaptive management is a pipe dream.

Large areas were dedicated to adaptive management in the Northwest Forest Plan, and they were determined by the scientists who designed the plan to not be needed for species recovery. Yet these areas were eventually held to the same rules as the rest of the landscape, and little experimentation occurred (Stankey and others 2003). For the Sierra Nevada Forest Plan Amendment to succeed in solving the problems it addresses, active adaptive management should characterize the program of work for every ranger district.

Closing Thoughts

Like many recent National Forest plans, the 2004 Sierra Nevada National Forest Plan Amendment decision contains some very innovative approaches to solving the wicked problems that stakeholders face. Use of science in policy, fuels strategies in the wildland-urban intermix and dense fire-prone forests, the administrative study for California spotted owl responses to habitat alterations, and the tiered approach to ecosystem analysis are all excellent improvements over prior direction for the Sierra Nevadan National Forests. But the collaborative coping strategy set in place by SNEP and the Framework process in 1998 floundered in the closing days of decision making in 2001 and again in 2004. Decision analysis was also weak throughout planning, making it very difficult to understand how risks, uncertainties, science, and values were considered and balanced. And our cumulative laws and policies coupled with severe stakeholder polarization have not yet allowed active adaptive management to serve its problem-solving role.

On the basis of the cases mentioned above and my personal experiences, the future for collaboration as a coping strategy for Federal natural resource problems appears cloudy. Success will require changes in laws and processes, changes that powerful interests have signaled they are not about to tolerate. This was clear as recently as 2003 in the compromises necessary to enact the Healthy Forests Restoration Act. If such changes in laws and procedures to assure equity in access to governance are not possible, collaboration will likely work on only the least controversial problems, those that might be complex but are not wicked. This leaves a discomforting feeling about our societal ability to create sustainable solutions to our toughest Federal natural resource problems.

Even with the uncertain future for collaboration, future natural resources problem solving could benefit from adapting decision analysis and adaptive management learning processes used in other disciplines for complex problems. It is plausible that society could reap greater benefits from National Forests by shifting part of the enormous investments currently made for planning and analysis to investments in active adaptive management and the monitoring and research that support and improve it over time. But we also have a long way to go in making cultural changes in the agency that will be necessary to enable active adaptive management. Yet, these are where the most likely payoffs exist in creating sustainable solutions to wicked problems.

Existing procedural and natural resources laws, judicial precedents, and policies may not allow these innovations to occur. It is also possible that sufficient crisis to effect reform in those laws and policies do not yet exist. Absent such reform, we may well be stuck with the same outcomes we have been getting. But these outcomes are increasingly intolerable to many sectors of society—witness responses to recent catastrophic fire seasons. Thus, we must try something different or we will lose opportunities to learn what we must learn to improve future stewardship of Federal forestlands.

The organizational pain felt so pervasively by the Forest Service these days is caused by fragmentation of direction and mission caused by changes in political leadership, fragmentation of competing stakeholder interests, and strained interpersonal relationships across Federal agencies that must work together on complex and wicked problems. This pain can lead to misdiagnosis of wicked problems as tame problems, leading to delusionary notions that those problems can be solved by simply doing more of what has always been done or just doing it better. The antidote for fragmentation is coherence, shared understanding, and shared commitment, shared meaning for terms and concepts, shared commitment for solutions that are good enough to get on with the real business of learning through action—in other words, willingness to share power and share the benefits of a common cause. Only such a shared commitment to workable solutions and mutual learning will ease the pain and restore health to our Federal forestlands and venerable government institutions for natural resources stewardship.

References

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

Beckerman, W. 2000. **The precautionary principle and our obligation to future generations.** In: Morris, Julian, editor. Rethinking risk and the precautionary principle. Oxford, UK: Butterworth-Heinemann.

Brooks, H. 1996. **The typology of surprises in technology, institutions and development.** In: Clark, W.C.; Munn, R.E., editors. Sustainable development of the biosphere. Cambridge, UK: Cambridge University Press.

Bruntland, G., editor. 1987. **Our common future: The world commission on environment and development**. Oxford: Oxford University Press; 398 p.

Cortner, H.J.; Shannon, M.; Wallace, M.; Burke, S.; Moote, M.1996. **Institutional barriers and incentives for ecosystem management.** Gen. Tech. Rep. PNW-GTR-354. Portland, OR: Pacific Northwest Research Station, USDA Forest Service.

Conklin, J. [In press] **Wicked problems and fragmentation.** In: Conklin, J. Dialog mapping: Making sense of project fragmentation. http://www.cognexus.org/wpf/wpf.htm. Also see revision: http://cognexus.org/wpf/wickedproblems.pdf.

Firey, W. 1960. **Man, mind, and land.** Glencoe, IL: The Free Press.

Gunderson, L. 1999. **Stepping back: Assessing for understanding in complex regional systems.** In: Johnson, K.N.; Swanson, F.J.; Herring, M.; Greene, S., editors. Bioregional assessments: Science at the crossroads of management and policy. Washington, DC: Island Press; 27-40.

Hammond, J.S.; Keeney, R.L.; Raifa, H. 1999. **Smart choices: A practical guide to making better decisions.** Boston, MA: Harvard Business School Press.

Holling, C.S. 1978. **Adaptive environmental assessment and management.** London, UK: John Wiley and Sons.

Johnson, K.N.; Swanson, F. J.; Herring, M.; Greene, S. editors. 1999. **Bioregional assessments: Science at the crossroads of management and policy.** Washington, DC: Island Press.

Lindbloom, C. 1979. **Still muddling, not through yet.** Public Administration Review (39): 517-526.

Matthews, R.A.J. 2000. **Facts versus fictions: The use and abuse of subjectivity in scientific research.** In: Morris, J., editor. Rethinking risk and the precautionary principle. Oxford, UK: Butterworth-Heinemann; 247-282.

Morris, J. 2000. **Defining the precautionary principle.** In: Morris, J., editor. Rethinking risk and the precautionary principle. Oxford, UK: Butterworth-Heinemann; 1-21.

Rittel, H.W.; Webber, M.M. 1973. **Dilemmas in a general theory of planning.** Policy Sciences 4: 155-169.

Roberts, N. 2000. **Coping with wicked problems: The case of Afghanistan.** In: Jones, L.R.; Guthrie, J.; Steane, P., editors. Learning from international public management reform, vol. 11B. Elsevier Science Ltd; 353-375. Also, see http://www.inpuma.net/research/papers/sydney/nancyroberts.html.

Shindler, B.A.; Brunson, M.; Stankey, G.H. 2002. **Social acceptability of forest conditions and management practices: A problem analysis.** Gen. Tech. Rep. PNW-GTR-537. Portland, OR: Pacific Northwest Research Station, USDA Forest Service; 68 p.

Shindler, B.; Cramer, L.A. 1999. **Shifting public values for forest management: Making sense of wicked problems.** Western Journal of Applied Forestry 14: 28-34.

Sierra Nevada Ecosystem Project (SNEP) 1996. **Status of the Sierra Nevada.** In: Sierra Nevada Ecosystem Project: Final report to Congress. Davis, CA: University of California Wildland Resources Center, Report No. 36.

Soule, M.E., editor. 1987. **Viable populations for conservation**. New York: Cambridge University Press.

Stankey, G.H. 1996. **Defining the social acceptability of forest management practices and conditions: Integrating science and social choice.** In: Brunson, M.W.; Kruger, L.E.; Tyler, C.B.; Schroeder, S.A., technical editors. Defining social acceptability in ecosystem management: A workshop proceedings. Gen. Tech. Rep. PNW-GTR-369. Portland, OR: Pacific Northwest Research Station, USDA Forest Service; 99-111.

Stankey, G.H.; Bormann, B.T.; Ryan, C.; Shindler, B.; Sturtevant, V.; Clark, R.M.; Philpot, C. 2003. **Adaptive management and the Northwest Forest Plan.** Journal of Forestry 101(1): 40-46.

USDA Committee of Scientists. 1999. **Sustaining the people's lands: Recommendations for stewardship of the National Forests and grasslands into the next century.** Washington, DC: USDA Forest Service.

USDA Forest Service. 1998. **Sierra Nevada Science Review**. Unpublished review on file at Pacific Southwest Research Station, USDA Forest Service, Albany, CA.

USDA Forest Service. 2001. **Sierra Nevada Forest Plan Amendment Final Environmental Impact Statement and Record of Decision**. Pacific Southwest Region, Jan 2001.

Walters, C.J. 1986. **Adaptive management of renewable resources.** New York: Macmillan.

Wildavsky, A. 2000. **Trial and error versus trial without error.** In: Morris, J., editor. Rethinking risk and the precautionary principle. Oxford, UK: Butterworth-Heinemann; 22-45.

Wilson, E.O., editor. 1988. **Biodiversity.** Washington, DC: National Academy Press, 538 p.

Wingspread Statement on the Precautionary Principle.1998. See http://www.gdrc.org/u-gov/precaution-3.html. Also see http://www.healthytomorrow.org /pdf/wingspread.pdf