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# Accepting uncertainty, assessing risk: Decision quality in managing wildfire, forest resource values, and new technology

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**Abstract**

The risks, uncertainties, and social conflicts surrounding uncharacteristic wildfire and forest resource values have defied conventional approaches to planning and decision-making. Paradoxically, the adoption of technological innovations such as risk assessment, decision analysis, and landscape simulation models by land management organizations has been limited. The infusion of a technological innovation into organizations is determined largely by a trade-off between its *compatibility* with existing values, past experiences and needs, and the *relative advantage* of the innovation over that which it replaces. For instance, while the methods and tools of risk assessment offer numerous advantages to managers, they may be largely incompatible with an undue desire for certainty that imbues the culture of their organizations. This, coupled with a complementary desire on the part of scientists to provide certainty, defines the traditional relationship between management and research. The efficacy of this relationship is challenged by the *law of conservation of risk*. This law suggests that much of the uncertainty and risk associated with managing ecosystems cannot be eliminated; it can only be transferred. In this systems, or ‘‘marketplace’’ view of risk, the demand for certainty by managers and policymakers may exceed the supply provided by science, particularly in conflicted-ridden resource problems. As a remedy, it has been suggested that managers renounce their desire for certainty and ‘‘embrace’’ uncertainty. This can be accomplished with a strategic focus on *decision quality* that would accommodate even the large uncertainties associated with uncharacteristic wildfires, restoration activities, and sensitive species. Decision quality is defined as the outgrowth of a distinct decision science imbued with organizing principles, ethics, laws, or quantitative relationships that facilitate consistency with values, objectives, belief systems, and empirical evidence. While quality in ecological risk management can be improved by acquiring new technologies, the decision to acquire new technologies is itself a risky decision. Hence, ecological risks and organizational risks should be managed and assessed as part of a larger framework that consider the risk ‘‘marketplace’’ while addressing the challenge of ‘‘deciding how to decide’’.


*Keywords:* Forest management; Biodiversity; Wildfire; Decision-making; Decision support; Risk assessment; Risk management; Quality

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## 1. Introduction

The scientific and social issues surrounding uncharacteristic wildfire and conservation in managed forests represent a set of conflicting risks and uncertainties that have not been addressed by conventional analytical approaches. Land managers enmeshed in these issues require new approaches that can be integrated with existing modes of planning, analysis, decision-making, and public discourse. This need arises at a time when there is a growth of new technologies to support the practices of risk management, risk assessment, and decision analysis. Yet given the availability and appropriateness of these technologies, there are many barriers to their adoption within land management organizations.

While the ideas contained in this paper are applicable to environmental management in general, the language and examples reflect observations of national forests. My approach is to focus not on technology per se, but on *decision quality* (Keren and Bruine de Bruin, 2003; CENR, 1999). This will afford a view through one lens of two types of risks in forest management: (1) wildfire and the conservation of forest resource values; and (2) the adoption of technological innovations that support risk management. The first concerns risks to the environment, while the second concerns risks to the organization and its decision-makers. While these risks may appear distinct from the perspective of a manager or resource specialist, they will be viewed here as part of a larger social-ecological system wherein risk, like energy, is both conserved and transferred.

In both cases, the notion of decision quality poses some basic, but difficult questions: Are decisions "bad" if their outcomes are disappointing? Are decisions "good" if we are pleased with the results? What about decisions that are poorly defined, have large uncertainties, or have outcomes that lie far in the future? No strictly correct answers to such questions exist, but there are two schools of thought on the matter (Keren and Bruine de Bruin, 2003). The economist Herbert Simon (1976) distinguished between *procedural rationality* and *substantive rationality* in decision-making processes. A procedurally rational manager is one to whom the outcomes of a decision are irrelevant to its quality. If the process has quality (e.g., based on the "best available" science), then the decision has quality, and this will favor the emergence of desirable outcomes. Obviously, such a naïve manager would have difficulty in organizations where the rationality of business processes is measured largely by the standard of substantive rationality, the production of desirable outcomes.

In reality, land management organizations judge the quality of decisions (and decision makers) using a mix of procedural and substantive rationalities. However, I argue here that because managers face so much irreducible uncertainty in wildfire and conservation, risks and trade-offs can be managed more effectively by critically examining and improving the procedural rationality of their planning and decision-making processes. The rationale for this is simple, the long-term outcomes of many of today's decisions will not be apparent for decades to come. In complex systems, surprises—pleasant and unpleasant, are the norm, not the exception (Gunderson and Holling, 2002). A fixation on short-term, local outcomes of management decisions as a measure of decision quality constitutes, in effect, a costly over-emphasis on precision that may create a false sense of accuracy. In the end, this may obscure the uncertainties associated with long-term changes in landscapes and ecosystems.

Decision quality, therefore, is constructed from the building blocks of procedural rationality. "Quality", as used here, refers to group and individual decision-making processes that are consistent *by design* with organizational values, objectives, and belief systems, as well as empirical evidence. "Quality" also implies that a distinct "decision science"—principles, ethics, laws, quantitative relationships, etc., provides a set of criteria for designing decision-making processes and judging their performance.

Because more than one definition, or model of rationality (and reality) exists, the concept of decision quality must remain somewhat relative. This allowance provides for decision-making contexts where stakeholders hold what Slovic et al. (1985) have called *rival rationalities*. Hence, if procedural rationality is the basis of decision quality, then there may also be rival frameworks for defining and assessing decision quality (Borchers et al., in press; Keren and Bruine de Bruin, 2003). As we shall see, technology that can improve decision quality consists of more than hardware and software; it also includes any practical application of knowledge, including the diverse array of business processes that make up the daily life of a natural resource professional.

From a scientific perspective, improving decision quality in natural resource management begins with uncertainty management. Uncertainty may be seen as an insurmountable problem, in part because it is so difficult to quantify, e.g., in cumulative effects analyses. However, viewing uncertainty as ‘‘information about information’’ may be the first step in transforming a problem into knowledge (Bradshaw and Borchers, 2000).

## 2. Uncertainty is the problem

For most resource professionals today, uncertainty in planning and decision-making is inextricably tied to the complexities of social conflict and the dynamics of managed landscapes and ecosystems. According to theorists, much of the uncertainty that surrounds behavior of complex systems is intrinsically *irreducible* by science (Levin, 1998, 2002; Cilliers, 1998; Allen and Starr, 1982). In a more practical sense, management uncertainties may also stem from a simple lack of information or resources to obtain information and synthesize new knowledge.

Whatever the sources of uncertainty, conventional ‘‘command-and-control’’ management approaches may not succeed when a combination of high stakes and high uncertainties in resource management lead to social conflict (Shindler and Cramer, 1999; Funtowicz and Ravetz, 1993; Rittel and Webber, 1984). For example, efforts to manage concurrently biodiversity and wildfire have created a particularly volatile social mixture. Whereas conventional management responses to wildfire (e.g., suppression, mechanical fuels reduction, prescribed fire, and timber salvage) were once unquestioned, they are now criticized for their potential impacts on sensitive species and other ecological values.

In a socially and politically divisive climate, how should scientists and managers deal with uncertainty, particularly when it verges on ignorance? A straightforward public exposition of one's uncertainties and ignorance in the absence of an interpretive framework can be counter-productive, particularly as it may breed overly-cautious management approaches. An interpretive framework would guide researchers and managers in identifying the types of uncertainties that characterize specific decision problems and offer appropriate decision strategies. For example, several types of uncertainty, or knowledge problem have been suggested, each of which is present in most decisions:

- *Intricate*[1]: having to process more information than one can manage or understand. For example, a large number of interrelated elements may require the problem to be broken down into simpler parts. No individual can hold all the required knowledge.
- *Equivocal*: having several competing or contradictory risk models or hypotheses. Requires convergence on a definition of ‘‘reality’’.
- *Ambiguous*: not having a conceptual framework, hypothesis, or risk model for interpreting information; the inability to interpret or to make sense of something. Related to ‘‘wicked problems’’ (Rittel and Webber, 1984), (Adapted from Zack, 1999).

Managers may instinctively know that many problems contain a mix of these types of uncertainty. For example, in a landscape-scale project such as the Biscuit Fire Recovery Project (BFRP) in Southwest Oregon, there are generous portions of intricacies, equivocalities, and ambiguities, some of which have precipitated social and legal conflicts. Intricacies abound, from the diversity of vegetation types and burn severities to the identification, acquisition, and synthesis of relevant data and information. Equivocality, on the other hand, has arisen in the form of competing risk models that open the doors of social conflict. A debate rages over appropriate levels of post-fire salvage logging in the BFRP, in part because scientific information and judgment on the matter are equivocal. Finally, ambiguity represents the least addressed and least manageable type of uncertainty about complex social and ecological problems. For example, there are no conceptual models or frameworks that would help assess the long-term risks posed by the Pacific Decadal Oscillation (Mantua et al., 1997) or other climatic fluctuations to the Biscuit Fire recovery efforts.

In the absence of a scientifically-sound and socially-acceptable framework for interpreting equivocal and ambiguous knowledge problems; including

[1] Originally ‘‘complex’’ in Zack's typology. As described above, I reserve the term complex as it is used in theoretical ecology and elsewhere.

risks and trade-offs, efforts such as the BFRP may ultimately lead to social, legal, and political solutions that are less scientific or democratic; in short, unsustainable. There are several fundamental barriers to the development and adoption of such a framework; lack of appropriate technologies, however, is not one of them. While technological advances in methods and tools for risk assessment and management can stimulate adoption by new users, the ultimate barrier to their adoption is the intrinsic risk that accompanies them.

## 3. Risk is the barrier

Thus far, I have presented a situation in which the complexity of social and ecological systems presents particularly difficult types of uncertainty and risk management problems for land managers. These problems may contain irresolvable and unavoidable uncertainties. As Anderson (1998) maintains, embracing this troublesome adversary may be the only path available for resolving complex resource issues.

Yet given the availability and appropriateness of technologies for risk management, risk assessment, and decision analysis, what limits their adoption within land management organizations? In a word, risk. Decisions about adopting unfamiliar technologies are themselves complex risk management decisions that warrant a high level of procedural rationality, particularly in designing and evaluating trial applications. Rogers (2003) described fundamental barriers to the ‘‘diffusion of innovations’’ across a diverse set of governments, societies, and organizations. He listed five perceived attributes of innovations that dictate how they are received:

- *Relative advantage*: How much better is the innovation than that which it supersedes?
- *Compatibility*: How consistent is the innovation with the existing values, past experiences, and needs of potential adopters?
- *Complexity*: How difficult is the innovation to understand and use?
- *Trialability*: How easily can the innovation be experimented with on a limited basis?
- *Observability*: How visible are the advantages of the innovation to potential users elsewhere in the organization?

Rogers sees *relative advantage* and *compatibility* as the most critical factors in the acceptance of innovations. To illustrate, consider the decision faced by an organization in considering new technologies in risk assessment. The technologies may consist of revised business processes, new analytical software, and workforce re-education. In many ways, this decision resembles the quandary faced by forest managers who weigh the short-term risks of reducing fire hazard against the long-term risks of inaction. In each case, there are personal, organizational, and ecological risks and trade-offs to consider. While new risk assessment technologies can improve decision quality and credibility, the short-term costs of organizational incompatibility - fiscal and social - may be daunting. Yet the risk of inaction, however attractive it may appear in the moment, increases with time. Just as fuels and fire seasons accumulate, so too do the lost opportunities and costs of failing to adopt new technologies.

A risk-averse attitude toward certain innovations may appear wise, particularly when managers adopt decisions in a procedurally rational way, e.g., assessing trade-offs among long- and short-term risks. A decision to reject new technologies based solely on an incompatibility with organizational values may be necessary, for example, helping to preserve the organization’s identity, mission, and power base in times of crisis. However, to the extent that an organization sees its cultural attributes as a constantly evolving source of renewal, it may choose to develop a more coherent and procedurally rational framework for assessing new technologies. Ideally, such a framework would incorporate a hierarchical, systems view that links the assessment and management of ecological risks with the larger view of risk as a dynamic social and economic entity.

### *3.1. Compatibility of innovations and the conservation of risk*

A lack of compatibility between risk assessment and management innovations and land management agencies may stem from an undue desire for certainty on the part of managers (Maguire, this volume). As she puts it,

‘‘. . . [p]eople appear to have a strong urge for certainty, and they struggle to describe decisions so that at least one alternative looks 'safe'. They are reluctant to acknowledge that, seen broadly and over a long enough timeframe, most alternatives carry their own set of risks, necessitating risk-risk trade-offs among the uncertain costs and benefits of alternative management actions.''

From this perspective, a ''strong urge for certainty'' is fundamentally incompatible with the culture of risk assessment and management. If there exists a selective aversion to unfamiliar technologies, the capacity for land management agencies to address the core risks that are part of their identities and missions may be diminished. In the private sector, core risks are ''those risks that the firm is in business to bear and manage so that it can earn excess economic profits'' (Culp, 2004). By definition, a firm assumes core risks that carry large uncertainties because it believes it possesses unique capabilities, knowledge, and technology that are lacking in its competitors.

For federal land management agencies, core risks also carry large uncertainties. However, the ''marketplace'' for risk in land management agencies differs fundamentally. First, in government, core risks are rarely assumed, they are more often mandated or imposed. Second, resource problems have become more complex, evolving from intricate concepts such as sustained yield into more equivocal and ambiguous goals such as sustainability. Adding to this uncertainty is an increasingly ambiguous environment of law, policy, and regulations driven by external legal and administrative challenges.

To continue the analogy, in financial markets risks and the uncertainties that accompany them are viewed as labile commodities. Risk can be transferred, bought, and sold in the market place. Insurance, for example, is a valuable tool used by individuals and firms to transfer, or distribute risk within a group. In the case of land management agencies, science and the diffusion of innovation it engenders provide a mechanism to decrease exposure to risk, particularly with intricate and equivocal resource problems. Thus, the desire for certainty on the part of managers is mirrored in the research community as a desire to increase certainty in the form of knowledge.

However, this relationship may be undermined by two factors. First, in most complex resource problems today, the demand for scientific certainty exceeds the supply. In such cases, researchers can only provide expert judgment accompanied by models of uncertainty. The second factor has been described in the context of financial markets as the *law of conservation of risk* (Culp, 2004), or the law of conservation of uncertainty (Griffin, 1999). This ''law'' suggests that in financial markets the aggregate level of risk remains relatively constant due to a ''bidding-up'' process that counteracts any decreases in risk, returning levels to previously established thresholds of tolerance.

With intricate natural resource problems, risk transfer may occur, for example, when increases in the ''supply'' of certainty provided by research and technological innovations are offset by decreases in certainty due to greater resource demand (Fig. 1). With the advent of more equivocal and ambiguous resource problems, however, a widening gap has developed between the supply of and the demand for scientific certainty. Four factors in the natural resource ''marketplace'' have combined to raise the stakes for managers, scientists, and society alike: (1) increased social demands on ecosystems; (2) increased demands for certainty in resource protection; (3) diminished tolerance for risk; and (4) reduced expectations for obtaining scientific certainty.

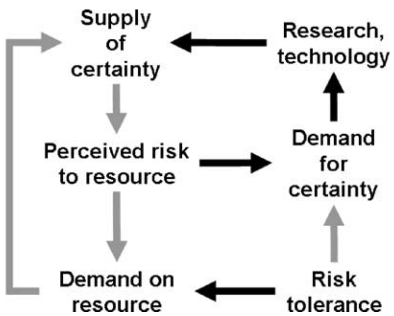


Fig. 1. The law of conservation of risk. Black arrows indicate positive correlations, while gray arrows depict negative correlations. This hypothetical model depicts risk tolerance as a governor on a cycle involving the supply of certainty, the demand for certainty, and the demand on a resource. As the demand on a resource increases, e.g., with economic or population growth, the supply of scientific certainty decreases, thereby raising the perceived risk to the resource. The new risk either is retained by consumers who reduce their demand or increase their tolerance for risk, or the risk is transferred to research institutions whose task is to supply certainty. Increased certainty diminishes the perception of risk, thereby allowing consumer demand to return to the former threshold of risk tolerance.

The conservation of risk model in Fig. 1 is admittedly an over-simplification of a complex social process. However, its hypothesis—that there exists a dynamic social context for forest management and research in which risk, like energy, moves along gradients of supply and demand, deserves consideration. If this is the case, then how can natural resource organizations improve their management of environmental and organizational risk given the current imbalance between the supply of and the demand for scientific certainty?

## 4. Risk management is the path

In the larger social context of increasing scientific uncertainty, risk transfers and shifting burdens of proof, those who are tasked with risk management may profit from specific attention to "the quality of the human judgments and decisions that support it" (CENR, 1999). A decision quality framework for risk management of wildfire and forest resource values would consider not only judgments and decisions about landscapes and ecosystems, but also strategic decisions that address the risks and trade-offs of acquiring social, technical, and methodological innovations, e.g., multiparty monitoring, active adaptive management, simulation models, and risk assessment.

In financial markets, there are well-established strategies that may be useful in shaping the framework for risk management that we seek. The following strategies of risk management (adapted from Culp, 2004) and tactical examples are by no means complete, but they do suggest that a more holistic framework for managing ecological and organizational risks is tractable.

### *4.1. Risk retention and risk avoidance*

Risk retention is a strategy wherein a risk is tolerated. Exposure to the risk may have been planned or unplanned, but the decision to retain it is conscious, e.g., when the costs of risk reduction exceed the benefits. The decision to retain risk is a form of specialization as well as an implicit decision to avoid other forms of risk. Retaining a risk may be part of a larger strategic vision wherein an organization believes it is qualified, perhaps uniquely, to handle that risk. In the private sector, such decisions may confer an advantage in the marketplace, while in government the advantages are less tangible, but no less real.

#### *4.1.1. Examples*

- A federal agency begins to incorporate sustainability concepts into its thinking. For example, the LUCID Project (Wright et al., 2002) directly addressed the challenge of establishing sustainability monitoring on national forests and grasslands.
- A district ranger convenes a group of contentious stakeholders to address long-standing conflicts surrounding wildfire risks to water quality and other resource values in an urban watershed.

### *4.2. Risk reduction*

An agency may attempt to reduce risk by decreasing uncertainty, controlling losses, or lowering hazard exposure. Technological advancement and research are primary mechanisms by which risk can be reduced (Fig. 1). However, risks stemming from uncertainties such as natural variability are irreducible, even if well described statistically.

#### *4.2.1. Examples*

- Monitoring spotted owl populations.
- Acquiring and deploying fire suppression equipment and personnel.
- Adopting new technologies for conducting risk assessments.
- Natural resource planning.

### *4.3. Risk consolidation*

An organization may aggregate multiple sources of uncertainty into a single "portfolio" of outcomes. For example, consolidation can be achieved by increasing the scale (spatial or temporal) at which planning and management are focused, resulting in an "economy of scale".

#### *4.3.1. Examples*

- A cumulative effects analysis extends beyond the borders of a project area to encompass broad-scale ecological trends that will determine if local management goals are achieved.

- Planning for invasive plant species is conducted at a regional level, as opposed to a national forest level.
- Meta-populations of a broadly-distributed sensitive species are managed collectively, instead of individually.
- Collaboration across multiple ownerships in a fuels reduction project decreases the likelihood of undesired impacts on sensitive species as well as appeals and litigation. In such a case, organizational risks are spread among stakeholder using participatory planning and research, and through risk communication (Morgan et al., 2002).

### 4.4. Risk transfer

Risk can be transferred from the organization, either intentionally or by inaction. For example, the risk of uncharacteristic wildfires on public lands traditionally has been borne by government agencies responsible for fire suppression. With increased regulations, environmental litigation, and administrative appeals, a more risk-averse management culture has developed in the US Forest Service (GAO, 2003; USDA Forest Service, 2002). When risk aversion leads to inaction, the net result can be a transfer of risk, in this case to policymakers who responded with the Healthy Forests Restoration Act (HFRA). In effect, the HFRA provided a sufficient level of indemnification for agencies to overcome the "certainty bias" (Maguire, this volume) of a "marketplace" (Fig. 1) that overestimated the value of inaction.

## 5. Decision quality is the goal

How does one decide among the numerous technological innovations that would facilitate decision quality in the management of wildfire risks and the diverse forest resource values? Such a decision problem is, in Zack's (1999) typology, *intricate*. As such, addressing the uncertainties requires us to reduce the problem to manageable proportions, i.e., simplify it. For example, the decision to adopt or reject a technological innovation such as risk assessment may require, paradoxically, some form of risk assessment. Almost certainly most organizations make strategic decisions about new technologies based on their tacit understanding of the trade-offs among competing risks, organizational and ecological. However, as I have maintained here, there is much to be gained by considering such "adoption" decisions as part of a larger framework for risk-based decision-making.

My goal in making the following recommendations is to identify some existing technologies that are likely candidates for such a framework, particularly regarding the risks and trade-offs associated with: (1) wildfire and conservation (ecological risks); and (2) the adoption of technological innovations (organizational risks). Each of the technologies represents at least one of the foregoing risk management strategies: risk retention, risk reduction, risk consolidation, and risk transfer.

### 5.1. Risk assessment as risk retention and risk reduction

Over the past several decades, the technology of risk assessment has evolved from a narrow focus on toxicant effects into a more comprehensive, quantitative framework for addressing multiple human and ecological risks (NRC, 1994; EPA, 1998). Quantitative methods now include probabilistic approaches such as Monte Carlo simulations (EPA, 1997).

How can the technology of ecological risk assessment with its underlying probabilistic approaches be adapted for analyzing trade-offs associated with managing wildfire and forest resource values? One example now under development is CRAFT (Comparative Risk Assessment Framework and Tools; Lee, 2002). CRAFT facilitates a risk-based approach to assessing trade-offs in management ecosystems, particularly biodiversity conservation in the context of fire and fuels management. CRAFT addresses the technological and organizational aspects of forest planning and provides portals to the knowledge, models, and databases that are suitable for different planning problems. It supports risk management by taking a risk assessment and decision analysis approach to conservation problems (Harwood, 2000), particularly where wildfire management is an issue.

One of the themes in CRAFT is decision quality. For example, its framework is adapted from *Decision Protocol* 2.0 (DP 2.0), a tool created by Forest Service researchers and managers. DP 2.0 is a "question-driven process and facilitation guide that helps teams engage in meaningful discussions, document rationale, and make decisions more efficiently'' (Yonts-Shepard et al., 1999; Berg et al., 1999). Grounded in the decision sciences, DP 2.0 emphasizes problem framing prior to the formulation of alternatives. It facilitates the construction of risk models by leading users to methods such as objectives hierarchies (Keeney, 1992), influence diagrams (Clemen, 1996), and mind mapping (Morgan et al., 2002).

As with any scheme for improving decision quality, CRAFT helps users avoid ''certainty bias'' (Maguire, this volume) by facilitating an assessment of the relative risks across a range of alternative actions, including ''no action'' (Bass et al., 2001). The comparative aspect of risk assessment is particularly important in a cumulative effects analysis that may depict risky baseline trends and the long-term potential for losses under ''no action'' alternatives.

### 5.2. Civic science as risk transfer

For land management agencies, the social conflict component of natural resource problems poses even greater challenges than ecological complexity. Lee (1991) proposed a *civic science* approach, one that directly addresses the fundamental barriers to participation and learning in a collaborative context. As he defines it, civic science is ''irreducibly public in the way responsibilities are exercised, intrinsically technical, and open to learning from errors and profiting from successes'' (Lee, 1991).

Building on this idea, a *civic science partnership* has been proposed as a strategic interaction among scientists, land managers, and the public that facilitates the practice of adaptive management (Borchers and Kusel, 2003). The central, procedurally-rational activity of a civic science partnership is to integrate collaborative approaches in natural resource management (Wondolleck and Yaffee, 2000) with the concepts, methods, and tools of decision analysis and risk assessment (Borchers and Kusel, 2003). As with any innovation, the effectiveness of a civic science partnership depends on its compatibility with a broad spectrum of users; in this case, stakeholders (Kusel et al., 1996), and the advantages it confers relative to business-as-usual (Rogers, 2003).

While managers may view stakeholder collaborations as intrinsically risky (i.e., incompatible) civic science approaches offer many relative advantages in the form of indemnification or insurance against undesired outcomes, i.e., risk transfer. For instance, one of the intended consequences of multi-party monitoring is an increased credibility with the public of federal land management agencies (Kusel et al., 2000). In terms of Fig. 1, this translates to an increase in risk tolerance on the part of stakeholders and greater forbearance for managers. This represents an accumulation of ''social capital'' (Sen, 1999; Kusel et al., 1996) that can be invested elsewhere, for example, in building consensus for a venturesome adaptive management experiments.

### 5.3. Scale-appropriate planning as risk consolidation

The unmanageable uncertainties of some risks can be made more manageable by consolidation with other risks. The strategy most familiar to investors, portfolio diversification, is applied often in forest management. For example, forest managers may invest in diverse management strategies, applying them in a diverse landscape. Timber companies may increase their land holdings as a buffer against demand peaks.

Consolidation through diversification may also occur when managers decide on an appropriate scale for addressing resource problems. For example, a bill introduced in the U.S. House of Representatives, the Northwest Rural Employment and Forest Restoration Act of 2004 (H.R. 4932), includes a provision stating that an ''administrative unit may prepare programmatic environmental documentation . . . at the appropriate scale (District, watershed, or subwatershed) to study the significant environmental effects of the major Federal actions contemplated'' (Library of Congress, 2004). This would authorize agencies to apply flexible strategic planning efforts at a diverse range of ecologically appropriate scales, regardless of size. An economy of scale and a significant risk consolidation may result as the redundancies inherent in a collection of similar environmental analyses are consolidated into a single strategic document.

### 5.4. Adaptive management as risk retention and risk reduction

Equivocal and ambiguous types of uncertainty represent a knowledge vacuum that may be filled by social conflict. When stakes are high and scientific uncertainties cannot be reduced in the near term, a number of technologies are available. To readers of this journal, the most familiar of these is adaptive management (Walters and Holling, 1990), an approach that bears a striking resemblance to a risk management cycle (CENR, 1999). For the most part, the adaptive management model has been understood and not implemented by much of the natural resource management community (Stankey et al., 2003; Walters, 1997). Adaptive management, particularly the active, experimental form, has great intuitive appeal, particularly for scientists, managers, and other stakeholders who may perceive it as a model for collaboration and risk management (Borchers and Kusel, 2003). Yet the very features that attract - hypothesis, monitoring, and evaluation - also pose obstacles to adopting this innovation.

I maintain that the fundamental incompatibilities of adaptive management are more than offset by its relative advantages, at least in the long run. While start-up costs may be substantial, the payoff includes a substantial amount of risk reduction, given the systematic approach to facilitating quality in hypothesis testing, monitoring, learning, and decision-making. Adaptive management is also an opportunity to re-examine and re-affirm an organization's commitment to managing the core risks it has retained as part of its identity and mission. To the extent this takes place in the company of multiple stakeholders, the risks of social conflict may be further diminished.

### *5.5. Precautionary management as risk avoidance*

In the absence of systematic approaches for managing complex and uncertain environmental problems, policy solutions such as the precautionary principle have arisen (Harwood and Stokes, 2003). Definitions abound, but perhaps the most widely used is from the 1992 United Nations Conference on Environment and Development: ''where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation'' (Harwood and Stokes, 2003). The language does not preclude action, but urges the application of cost-effective measures to mitigate risk.

In high stakes, high uncertainty situations, precautions may indeed be in order. At times, inaction by managers may even be the wisest course. Yet to the extent that managerial precautions are taken in response to policy mandates, they likely will not bear the imprint of decision quality as defined here. The precautionary principle is a fertile ground for breeding certainty bias, regardless of one's environmental politics. Managerial inactions regarding wildfire management or biodiversity conservation are not procedurally rational if they stem from policies, analyses, or decisions that fail to consider the risks of inaction. If wise precautionary strategies for managing forest ecosystems are to be developed, they must be based on high-quality decisions that have engaged the most appropriate knowledge and technologies available.

## 6. Conclusions

This paper began with a quote from Garret Hardin's *Filters Against Folly* (Hardin, 1986). This classic work is a call for decision quality and an elusive kind of rationality rarely found in organizations. For Hardin, early progress by science was defined by what it decided it could not accomplish, its ''postulates of impotence''. For the natural philosophers of old, this was parsimony writ large, a strategy for partitioning the possible, the feasible, and the profitable from alchemy and magic. The result was a modern or ''normal'' science that directed its energies along more feasible lines of inquiry (Kuhn, 1970).

Today's natural resource management professionals and the scientific institutions that support them face a similar challenge. Conventional approaches to complexity, uncertainty, and decision-making in forest management appear impotent because they are based on models of social and natural systems that largely exclude uncertainty and surprise. What is *not* known about ecosystems and about people now overshadows what *is* known, precisely because society has re-defined what it means by ''quality'' in research, forest management, and decision-making. The procedurally rational response to such a situation is not necessarily to seek certainty; in some cases this may be a fool's errand. Instead, new policies and strategies for managing risk, making high-quality decisions, and learning from uncertainty will ensure that forest resource values are sustained in perpetuity.

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