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Integrated Research in Natural Resources: The Key Role of Problem Framing

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Abstract

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Integrated research is about achieving holistic understanding of complex biophysical and social issues and problems. It is driven by the need to improve understanding about such systems and to improve resource management by using the results of integrated research processes.

Traditional research tends to fragment complex problems, focusing more on the pieces of problems rather than the whole that comprises multiple interrelationships and interactions. The outcome is that a lot is known about the parts (e.g., recreation, fish, and wildlife) but relatively little about how they are interrelated.

There seems to be general agreement that integrated questions must drive the search for integrated understanding, but tradition, inertia, institutional culture, budgets, training, and lack of effective leadership foster reductionism (at worst) or minimal degrees of integration (at best) rather than any substantial, sustainable effort toward integrated research.

In this paper, a phased approach to framing integrated research questions and addressing the substantial barriers that impede integrated efforts are discussed. A key conclusion is that to make any significant progress toward comprehensive integrated research will require more than rhetoric. Progress must begin with more effective leadership throughout various levels of research organizations.

Keywords: Research, integration, resource management, leadership, problem framing.

Foreword

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This paper about integrated research synthesizes our knowledge, experience, and perspectives gained over 70 collective years of conducting social science research. The focus of our studies has been on complex, often contentious natural resource issues, both in the United States and overseas. The goal of this research was to improve understanding of the complex problems facing managers of natural resources and citizens who use the land or care about land management. During much of this time, we have been part of a research program focused on improving the integration of biophysical considerations with social aspects of natural resource values and uses. And we have worked in a unit of a research organization that reorganized in the early 1990s in part to foster improved integration of diverse disciplines and interests.

During our careers, we have participated in many studies, some that clearly were disciplinary in nature and others that were either implicitly or explicitly focused on integrated questions. We have also been part of several large assessments founded on the principles of ecosystem management where integrated approaches are a requisite for success. Along the way we have struggled with both the substantive outcomes as well as the processes underlying integrated research.

Our overall conclusion is that most of the integrated efforts were incomplete at best and failures at worst. Why is this so? At the simplest level, one answer is that doing integrated work is hard. More fundamentally, whether in research or resource management, the challenges and barriers are often systemic in nature, rooted deeply in organizational, disciplinary, and educational beliefs and norms. All this reveals the persistence of traditional approaches in spite of the rhetoric. The mismatch between the rhetoric of integration and what really occurs is striking and gives emphasis to the work contained in this report.

The approach to integrated research proposed in this paper is grounded in the literature and numerous interactions with other researchers and research managers. Over the past 10 years, we convened fieldtrips, workshops, and discussions about what integration means, what it requires, and what gets in the way. We also were participants in other workshops and discussions where integrated research was the focus. In addition, we interviewed scientists engaged in some way with integrated studies. Many were with the Pacific Northwest (PNW) Research Station, located in

Oregon, Washington, and Alaska, but scientists from other regions of the country, different federal and state agencies, universities, and overseas were interviewed also.

From these multiple sources, we attempt here to distill better approaches to integrated research, including more effective problem framing. Addressing solutions to the many barriers to integrated efforts is also emphasized. These barriers exist at individual, team, and institutional levels. Because many of the barriers are systemic in nature, they require more than cosmetic or operational adjustments. Although our experience is focused primarily on the PNW Research Station and its collaborators, we believe that the findings and conclusions we discuss have broad application.

We envision that the primary audience for this work is people who want to organize and conduct integrated studies. The caveat is that for success, there must be institutional support. We also believe the perspectives offered will be useful to students in academic institutions and people early in their careers where there are opportunities to acquire additional training and experience to develop the necessary skills for success. And we hope that research and resource management organizations facing the need to improve understanding about complex social and biophysical issues surrounding natural resources values, use, and management will find this report useful.

In the end, this work was driven by a question: Can integrated research be managed to achieve true holistic understanding of complex problems? We believe that the answer is "yes," but there are significant obstacles in the way. We hope that readers of this paper will take up several challenges: honestly distinguish between the rhetoric vs. the reality of integrated research, find creative ways to resolve the many barriers in the way, hold leaders accountable for creating and maintaining environments where effective integrated problem solving can occur, and cultivate opportunities for mutual learning among diverse disciplines and interests.

Roger N. Clark
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Introduction

Periodically, particular words and phrases strike a chord with many people and take on a special if uncertain significance. In the field of natural resources, there are many examples–multiple use, sustainability, new forestry, new perspectives in forestry, collaborative stewardship, ecosystem management, ecological stewardship, forest health, adaptive management, and integrated resource management. Experience suggests that most, if not all, of these and other such concepts are used for different purposes and with different meanings (Clark and Stankey 1991). Many fade away and are replaced with another and better mantra when people recognize that they are mostly words and not deeds (Clark and Stankey 1991; Stankey et al., in press).

Scientists and managers of natural resources are increasingly called on to deal with complex problems where understanding the interactions between biophysical and social systems is necessary to balance the complex and diverse needs of society with increasingly threatened and scarce natural resources (Brunckhorst 2000, FEMAT 1993, Lang 1990). To understand such multifaceted systems, frameworks, concepts, models, and approaches are needed that allow us to isolate and explain the interactions within and among parts of the system (Blockstein 1999).

Developing an integrated approach to research is the topic of this report. It implies certain conditions or actions to those who use it. In research, we frequently cite the need for "better integration," or the desire for "integrated approaches" or

Box 1: The lack of clarity and preciseness with which the term "integration" is used is not unusual. In many ways, integration is a good example of the notions of "policy myths" or "guiding fictions." Policy myths include terms or ideas that "are important to the definition of problems because they link public issues to widely accepted ways of understanding the world and to shared…evaluations of…possible solutions to problems" (DeNeufville and Barton 1987: 181). Similarly, guiding fictions describe ideas that provide a sense of identity and purpose; they can help rally public support for the ideals imbedded in a concept such as integration (Shumway 1991). However, both policy myths and guiding fictions are characterized by a paradoxical tendency to garner support and enthusiasm at the abstract level, but to lose that support as efforts to define and specify them take place. This is vividly reflected in the discussions about integration. (Clark et al. 1999: 298)

"integrated teams." Nevertheless, exactly what makes something integrated remains elusive (box 1).

The literature is full of essays on why integrated approaches are important to resource managers (Clark et al. 1999). There is also a substantial volume of work on barriers (e.g., rewards for traditional approaches, reductionism) (Lachapelle et al. 2003, Margerum 2001, Margolis 1993, Socolow 1976). Many reports claim to be integrative, but few significant examples exist, particularly when the problems become socially and biophysically complex at multiple temporal and spatial scales. Some scientists, doing what they think is integrated research, find they are criticized for not doing integrated work. Such situations can become divisive unless a common understanding and agreement about expectations is reached. Without clarifying expectations for integration, there is a risk of perpetuating another round of confusing rhetoric and meaningless slogans best suited to bumper stickers.

Disciplinary, fragmented research (even if the sum includes all the parts) does not allow us to understand complex problems and systems. Reductionism can help fill critical knowledge gaps and contribute to holistic learning, but it is only one approach. Integrated research is not a panacea, but it is another means to help us understand the complexities of our world.

As Clark et al. (1999) contended,

> The root issue underlying the move toward integrated management (and research) is the long-term conflict in how society views forests and the priority of alternative uses. . . . Improved knowledge, concepts, and frameworks for integrated resource management are critically needed to deal with increasing conflict over limited resources. Integration must cross disciplinary lines—biophysical, ecological, social and economic—as well as management functions—recreation, timber, fish—and geographic and temporal scales—ranging from short to long term, and site specific to global.

In this paper, we offer a phased and stepwise approach for integrated research. By conducting integrated research in a systematic progression of phases and steps, many of the frequently cited barriers to this type of work can be avoided or overcome. We explore the concept of integrated research in general, and problem framing in particular, and how it can be used to achieve certain goals in research. We offer a general approach for defining, organizing, implementing, and evaluating integrated research efforts. Specifically we emphasize how problem framing (getting the questions right before acting) must be improved and steps for making this happen.

The approach described in this paper for integrated research draws on a variety of sources and research efforts. These include:

- A major synthesis of the literature and experience on integration (Clark et al. 1999).[1]
- Several data-gathering processes that included participants both internal and external to the Pacific Northwest Research Station.
- Workshops with scientists on topics such as integration, landscapes, and scale.
- Review of more than a dozen cases where there were attempts to integrate science into framing and evaluating forest policy.
- Guidance from other studies including the Adaptive Management Area Scientist Study (Graham and Kruger 2002) and the Adaptive Management Evaluation (Stankey et al. 2003, 2005, in press).

A basic conclusion of this report is that integrated research is essentially a human endeavor that, to be effective, must consider a complex set of human relationships, processes, and outcomes. Moreover, integration is a means to an end, requiring agreement about the goal before deciding on how to get there. This is a tall order but, if successful, can reap significant rewards for both scientists and those they serve.

Multiple Perspectives About Integrated Research[2]

What does "integrated research" mean? If reductionism leads to incomplete under standing of complex biophysical and social systems, what does an integrated research approach imply?

There are multiple perspectives when people refer to the need for integration in research and natural resource management. A common understanding is central to helping people from diverse backgrounds and with diverse interests effectively work together to reach a common goal. The following perspectives were identified in the literature, workshops, and discussions.

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[1] In this paper, we draw heavily from Senge (1990) and to a lesser extent Bardwell (1991) to emphasize key points. Excerpts from their papers are emphasized in boxed text. These are two important references for people interested in systems thinking, problem framing, and learning organizations.

[2] This section is adapted from Clark et al. 1999.

Integrated Research Is…

… a complex enterprise—it is easy to talk about but hard to do well; it is about how we do our work; it is about what we choose to study; and it is about a complex set of human relationships, processes, and outcomes.

… a process rather than a particular outcome, but the process will lead to integrated outcomes. As a human process, it helps us engage one another in a way that the outcome of joint work is greater than the sum of individual efforts.

… about how we engage one another to do work. It is akin to taking discrete lumps of colored clay and "smushing" them together into a new form and color that cannot be pulled apart into their original colors; they become inseparable, a new composition.

… a means to an end: it helps us understand complexity; it both facilitates and requires agreement on problems, issues, questions, and goals; it emphasizes an equal opportunity to influence the process and outcome(s); it includes consideration of multiple perspectives and diverse types of inputs and outputs; it is visible, open, and traceable.

… a way to mesh diverse subjects and disciplines across boundaries, and temporal and spatial scales; it focuses on the problem at hand, not on the functional disciplines of the participants.

… iterative and adaptive. It is dependent upon knowledge from a variety of sources (research, management experience, citizens) that considers a variety of resource issues, their consequences to research management decisions, and their impact on "larger systems." These things change, requiring adjustments to the process.

… alien to disciplinary-bounded research, but the latter can be a result of an integrated approach. An integrated approach will not necessarily replace "narrow and deep" research. Reductionism is not bad; the appropriate strategy depends on the questions needing answers. Both are necessary, but neither is sufficient.

… a fundamentally different way of doing business. A different paradigm or reality emerges from discrete entities and leads to synergy. Moreover, integration is more than just thinking about substantive issues to study and disciplines to include. It is also about ways of knowing, forms of knowledge, and research approaches, among other things. Integrated work represents efforts across boundaries of geography, time, functions, and different elements of a problem (Wondolleck and Yaffee 2000).

Considering what something is not helps reveal what it is or might be. There are many different views about what integration is not.

Integrated Research Is Not…

… an easy and well-understood process (particularly the first time around). If it were, many groups would be doing it and doing it effectively.

… necessarily efficient. To be effective (Shouldn't this be the goal?), integrated research might take more time and money, particularly up front. However, the benefits can far exceed the results from traditional, reductionist approaches.

… a final step in a fragmented, functional, or disciplinary process; nor a patchwork of independent pieces that are put together after the fact to give the appearance of a whole. Integrated efforts are not represented by a "state of the art" book or synthesis of research with chapters based on functional areas or disciplines (held together by a big staple).

… two or more separate studies done at the same place and time without synergistic planning, involvement of diverse "-ologies," and analysis. It is not simply interdisciplinary or cooperative work. (These are necessary but not sufficient for integration to occur.)

… when individual disciplines independently evaluate and recommend modifications to the results of another discipline's findings. Integration does not have a preconceived conclusion from any discipline or perspective. It draws from jointly agreed-upon problems followed by jointly conducted scholarly enquiry.

… about short- vs. long-term products and benefits. Integrated efforts will result in both short- and long-term outcomes and products. It may take considerable time to complete work on some complex topics. There must be short-term products along the way, however, to legitimize long-term efforts.

… the only game in town. Integration is not always necessary or appropriate. It depends on needs and objectives to be determined in the priority-setting and problem-framing processes. Disciplinary research may be appropriate (and critical) in some cases. Reductionist science, often maligned by those espousing more integrated approaches, may be essential to holistic understanding of parts of complex systems.

… a panacea for resolving conflicts in research or natural resource values and uses; integration may not be in everyone's best interest; it is not completely accepted as a common goal. It is not without costs and risks, and it is never complete (nor is traditional science.)

Box 2: There is a tendency to think of integration as simply fitting different disciplines and functional issues together, of adding perspectives to one another. However, integration is far more than this; it involves development of a comprehensive process for asking and answering integrative questions, involving multiple values, scales, tenures, uses, etc. It involves more than assembling massive collections of data. Successful implementation of integrative research and management will challenge our decisionmaking structure and institutions of resource management and research. (Clark et al. 1999)

In sum, integration is a process; it is a means to an end. It is believed that an integrated research process will lead to more complete understanding of complex interactions within and among biophysical and social systems. Integration is about creating a more holistic understanding of complex interacting systems. Integration is not a panacea. As an overall strategy, integration has merit when the problems or issues are complex and not well suited to a functional or disciplinary solution (box 2).

Integration is easy to say but hard to do well. Not only are the natural resource problems to be studied (and managed) complex and often controversial, often the necessary organizational capacity (or at times the will) does not exist to be successful in conducting integrated research, particularly on such complex problems.

Integrated research is a process that helps us understand complex biophysical and social systems at multiple temporal and spatial scales.

Why Are Integrated Research Approaches Needed?

"System thinking is a discipline for seeing wholes. It is a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static 'snapshots'" (Senge 1990: 68).

Holisms—The Root of Integration

In a review of the literature and experience, Clark et al. (1999) traced the evolution of integration from its roots in holisms (Smuts 1926) and examined parallels in other fields such as medicine. This review identified several basic tenets about integration that are briefly summarized here.

Smuts (1926) postulated that wholes are basic to the universe and amount to more than the sum of the parts. Von Bertalanffy (1968) added to Smuts' perspective by asserting that parts interact and are interdependent, all living systems are wholes, and that no part can function without affecting the whole. This means that to really understand complex natural resource systems, a more holistic approach is needed (Savory 1988).

There are several common elements of holisms as described by these and other authors.

- Analytical approaches are inadequate to understand complex systems.
- Wholes are more than the sum of their parts.
- Wholes determine the nature of the parts.
- Parts cannot be understood apart from the whole.
- Parts are dynamically related or interdependent.

These conclusions suggest that reductionist science that does not flow from integrated questions cannot hope to develop holistic understanding. Reductionism is not necessarily inappropriate; such research can be critical to understanding some aspects of complex problems. But it must be done within a framework that is driven by integrated rather than disciplinary questions if there is any hope to understand complex systems.

Integration is about bringing different things together:

- Including more than one perspective.
- Appreciating and respecting differences in how different people view the same thing.
- Meshing subjects and disciplines across boundaries, paradigms, and temporal and spatial scales.

Mutual learning is a central focus of integrated efforts.

- Considering a variety of resource issues, their consequences to management decisions, and their impact on "larger systems"; blending of components of most systems that compose the whole.
- Combining insights so that the sum exceeds the experience of any of the individuals.
- Results in a more holistic understanding where the whole is indeed more than summing up the parts.

Successful integrated research efforts require collective understanding and agreement at a fundamental level. To achieve the over-arching goals of integrated research, those involved need a common vision, an interest in the same outcomes, and to operate under the same paradigm with mutually agreed upon objectives and protocols. Further, they must agree on the problem and the need for collaboration to address it.

Because the problems are inherently complex, it is essential that teams representing diverse disciplines are the instrument of investigation. Integration is about working together because no single person or discipline is capable of understanding complex systems. It is not about being "smart" or not. Each of us are limited by our worldviews, life experiences, and training.

Mutual learning is a central focus of integrated efforts; it is both a means and end of successful integrated work where participants become both students and teachers. "Double-looped" learning (Argyris 1993) with the focus on both the process and substance of integrated research is essential. Without mutual learning and understanding of one another's points of view, it is inevitable that individual perspectives will limit the potential synergism of the team (Ortenblad 2004). When participants perform as a team, they come to understand the power of true teams and what such teams can contribute (i.e., the product of the team becomes greater than the sum of individual contributions). But effective teams do not just happen, and not everyone is effective in a team environment. Teams must develop capacity to interpret, assess, and evaluate the problems as well as the products of individual and team effort. This is the catalyst for recognizing and understanding emergent properties characteristic of complex, interacting systems that are not evident when disciplinary approaches are used.

The Need for Integrated Approaches in Natural Resources

Historically, many complex natural resource management problems that might have warranted an integrative management approach have been resolved through the allocation process; by spatially separating different uses and associated values and

purposes, it was possible to avoid thinking about how such uses might be managed in a more integrative manner. Today, however, the capacity to resolve such problems through the allocation process is increasingly limited by the growing scarcity of the resource base. Rather than working at the extensive margin, we need to give more attention to the intensive margin, looking for opportunities to manage for the joint production of two or more uses and values. This has created greater interest in how integrated approaches might be undertaken. A number of specific reasons underlie this interest.

The world is complex—
Either-or approaches are no longer tenable and can be unnecessarily divisive (owls vs. jobs, timber vs. recreation, fish vs. dams, riparian restoration vs. public access or recreation use). There is a need to embrace a wider range of values and uses to find ways to reject either-or solutions to complex problems. To understand multifaceted systems, approaches and models are needed that allow improved explanation of the interactions within and among its parts. As we attend to biological and physical factors, we must also deal with the social, cultural, economic, and institutional aspects of environmental values and uses. However, these aspects cannot only be considered after the fact as add-ons or things to mitigate for or against.

Substantive areas (basic processes, problems, issues, policies) require it—
Today's problems are about complex processes, connections, and interrelationships. Stewardship and sustainability involve relations between people, their environments, and processes that link them. Disciplinary, fragmented research (even if the sum includes all the parts) does not add up to understanding the complexity of the whole. The future will be more about understanding difficult problems where interactions between biophysical, social, cultural, institutional, and economic interactions

Box 3: From a very early age, we are taught to break apart problems, to fragment the world. This apparently makes complex tasks and subjects more manageable, but we pay a hidden, enormous price. We can no longer see the consequences of our actions; we lose our intrinsic sense of connection to a larger whole. When we then try to "see the big picture," we try to reassemble the fragments in our minds, to list and organize all the pieces. But, as physicist David Bohm says, the task is futile—similar to trying to reassemble the fragments of a broken mirror to see a true reflection. Thus, after a while we give up trying to see the whole altogether. (Senge 1990: 3)

and considerations must be addressed together (integrated) at multiple scales to find "answers." This may lead to new practices for research where support for and collaboration with land managers will be increasingly required (at least in greater proportion than current practice) (box 3).

Integrated research will lead to improved fundamental understanding of complex, interacting biophysical and social systems. Second, such understanding should facilitate creation of management strategies and techniques to improve resource management.

This will mean that managers, researchers, and citizens will have a better understanding about the value and use of knowledge held by science, management, and the public, and how this knowledge can be used in developing, implementing, and evaluating integrated management and research. This will result in improved capacity to design, evaluate, and communicate integrated resource management options and outcomes to people with diverse interests.

Results of integrated research are essential to more complete holistic understanding of choices facing society about natural resources. Such knowledge has the potential to lead to more integrated management approaches to dealing with complex values and uses. Integrated research provides an opportunity to facilitate truly integrated, multiple-value management strategies consistent with diverse public values and concerns (Lang 1990).

Integrated research will enable scientists and land managers to understand the complexities of interrelationships at different temporal and spatial scales; this will lead to better indicators and predictors of the consequences of management actions on the land for those who value and use it. More efficient land management may result from facilitating joint production of various goods and services.

On the one hand, one would hope that integrated research would lead to reduced conflict in resource management, thereby increasing support and trust of the institutions and practices of resource management. Under this scenario, polarization would decrease as compatibilities as well as conflicts between values and uses are better understood (a lofty goal indeed). We must acknowledge, however, that the opposite could occur. That is, integration could foster and aggravate conflict, especially as the complex relations and interactions among various resource systems become better understood. Competing interests could use such information to seek support for their particular views and concerns.

Integration of What, With What, to What Ends?

If integrated research is going to be undertaken, what to integrate with what and

Table 1—To include or not to include: discussion points for integrated approaches

Integrate	With	To achieve integrated. . .
Scientific knowledge	Management experience Indigenous experience	. . .forms of knowledge
What scientists do Science	What managers do Local knowledge and experience	. . .ways of knowing
Social sciences Economics	Biophysical sciences Ecological sciences	. . .scientific disciplines
Recreation	Silviculture Engineering Policy	. . .resource management functions
Qualitative Holistic and relative	Quantitative Reductionist Technical	
Experimental methods	Case studies Descriptive methods	. . .methods and research designs
Small scale Riparian Today	Large scale Uplands Tomorrow	. . .spatial and temporal scales
Human values and uses. . . Held by rural people Public uses Resource utilization Production of fiber Short-term needs Public land	Biophysical values. . . Held by urban people Resource protection Resource preservation Provision of settings Long-term needs Private land	. . .outcomes
Human preference and needs	Wildlife preference and needs	
Human population dynamics	Wildlife population dynamics	. . .populations and habitats

why needs to be determined. The most holistic and ideal response is "everything with everything else." Part of the difficulty discussing integrated research seems related to lack of clarity about what should be included in integrated approaches. Table 1 suggests some topics for consideration as decisions about what to include are made.

This table is not inclusive, nor does it suggest that all topics must be included in every integrated research effort. But all should be up for consideration. The items in this table represent large categories with many subsets that become relevant when specific issues or questions are defined. For example, people responsible

for guiding integrated research on the interaction between human communities and nearby watersheds must decide if different forms of knowledge (e.g., management experience and indigenous knowledge) will be included in addition to science.

The reason to do integrated research and development is to better understand the complexity of individual systems and the interactions between systems. So the choice of what to integrate with what must be driven by the system(s) and issues in question. There is no cookie cutter; decisions must be made as part of problem framing, which we discuss later.

In simple terms, integrated research is about understanding that complex systems are greater than the sum of the parts. Failure to achieve this will limit the effectiveness of resource management policies and practices and lead to limited and often polarized outcomes (box 4).

Box 4: For both social and technical reasons, many argue that either-or approaches are no longer tenable. Pressure for integration is drawn from several sources: increasing competition for multiple values by a pluralistic society; and increasing recognition of possibilities for joint production (for at least certain goods, services, and values). Some forest uses are incompatible (e.g., wilderness and timbering), but many uses are dependent on or at least compatible with, other uses. Several forms of recreation, for example, depend upon the roads built for timber harvesting and on the openings which are created by harvesting activities (Clark et al. 1984; Clark 1987). Either-or solutions can limit the opportunity for compatible co-existence in some situations.

Questions of forest stewardship and sustainability inevitably involve the relationships among people, their environment, and the processes that link them. Such relationships are complex and dynamic. Although uncertainty characterizes all decisions, the current situation surrounding forest management is one in which the levels of uncertainty seem inordinately high. We simply do not understand the nature of many people-environment relationships or the full or long-term consequences of actions taken to affect any given component of the ecosystem. In part, this is a result of the traditional orientation of our research and educational institutions (structured along disciplinary lines) and our management institutions (structured along geographic, political, and functional lines). Improving our capacity to integrate this complex array of uses, values, perspectives, and processes should result in a

reduction in the number and severity of the "surprises" confronting managers and policymakers in the future. At the same time, it is important that we acknowledge that the future remains unpredictable; surprises will remain the norm, not the exception. This realization underlies the growing interest in adaptive management (Lee 1993). However, we contend that an improved ability to apply integrated processes and solutions should make it easier to contend with the inevitable changes the future holds.

Although there is abundant information regarding specific functional areas of natural resource management (e.g., wildlife, recreation, timber), our understanding of the relationships among these functional areas is poor. It is even more limited when we examine the linkages between the biological realm and people. This is especially of concern, given that virtually all management actions lead to reciprocal impacts; changes in the forest lead to changes in human use and values of these areas and, conversely, changes in human communities and their values and concerns lead to changes in forests and the way they are managed. Thus, there is a need to improve our ability to integrate ecological and social information in decision making. (Clark et al. 1999)

Potential Substantive Areas for Integrated Research

There is no shortage of issues or problems for integrated research. Holistic understanding is absent and essential to fill gaps in knowledge or to resolve many important management problems. Examples are given below; selecting the topics is part of the priority-setting phase.

Interactions Within and Between Biophysical, Social, and Economic Systems

Improved understanding is needed about basic biophysical and social processes and the effects of one system on another at different scales. Major questions include: How do we integrate aquatic and terrestrial ecosystems to understand how actions in one system will affect ecological and social conditions in the other system? How do human values and uses interact with biophysical conditions at multiple scales? How do management policies and actions affect both? How do external factors influence these interactions?

Managing for Multiple Values

Issues in this category beg for integrated work, given the diversity of ecosystems and human values, goals, and perspectives that can be found in a multiownership landscape. Critical questions include the following: How do we manage lands for many values and uses while protecting species in jeopardy and fragile ecosystems, rather than just setting it aside or locking it up and locking humans out? What is the role of active vs. passive management? How can we better demonstrate integrative and adaptive approaches to natural resource management? How can we superimpose an adaptive management approach on conventional policy formulation and implementation? How might we redefine our thinking about transportation systems (e.g., roads, trails, and waterways) for multiple values and uses and special forest products for multiple values and uses to make them more holistic? How do we distribute forest uses across multiple ownerships to achieve different mixes of outputs and values?

Models and Tools to Look at Complex Systems

Integrating social, economic, and biophysical information is a challenge to both research and resource management. Studies might be done to improve the ability of research and management to compile, interpret, and communicate knowledge about a variety of complex issues.

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Simulating how areas may look at different points in time helps people understand how problems can be framed to account for temporal as well as spatial interrelationships.

Tools are needed for integrated research, resource decisionmaking, communicating complex ideas, mutual learning, increasing complex analyses of biophysical and social interactions, and adaptive management. Are there different conceptual models from ecology, economics, and social sciences that relate to use and management of natural resources?

Future research likely will be driven by the need to understand the interrelations and interactions between biophysical and social and economic systems; the need to think at multiple spatial and temporal scales; the increasingly ideological and polarized basis for public debate and resource management decisions; and the opportunity to address diverse approaches rather than either-or solutions to complex problems. Increasing public interest in issues related to natural resource management and use will put pressure on science and scientists to come up with "answers" to complex problems associated with competing uses of increasingly scarce resources.

Phases for Problem Solving—An Overview

There are three distinct phases in organizing and conducting integrated research: (1) problem selection, (2) problem framing, and (3) problem solving. Each phase achieves particular objectives and requires that the "right" people are included. In this section, we briefly describe the focus of each stage. This is followed by an expanded discussion of the problem-framing phase.

Phase 1—Problem Selection

This phase involves deciding which problems, issues, or questions warrant an integrative approach. As we have said before, integration may not be appropriate for every issue and question.

In many respects, the simplest step to designing and implementing integrated research and development is picking a topic, question, or issue on which to focus research efforts. It makes little difference if it is driven by policy or science concerns. There are many candidates, and priority-setting processes help identify the most important areas to pursue.

Problem selection is generally the responsibility of decisionmakers (both management and funding organizations) who allocate people, money, and time to get work done. The assessment and discussion of priorities, however, ought to in some way involve scientists to ensure that diverse perspectives and expertise are imbedded in decisions. In this sense, priority setting would be done at the top of the hierarchical organization, but would be grounded in bottom-up perspectives and insights.

The assessment and discussion of priorities ought to in some way involve scientists to ensure that diverse perspectives and expertise are imbedded in decisions.

Problem selection rests on several factors including strategic direction, the political environment, the budget outlook, and organizational capacity to respond to new work that might require significant new or redirected resources (people, time, money).

We do not elaborate further on this phase in this paper.

The way a problem is defined affects the solution.

Phase 2—Problem Framing

Problem framing is the most important and most difficult phase; it has the most profound effect on where one ends up (Bardwell 1991). Moreover, it is not a discrete step but the beginning of a process that must account for (1) building and sustaining relations among the players, (2) building and implementing processes that allow integration to occur, and (3) identifying and creating the outcomes. We elaborate on this process in the next major section.

Problem framing has multiple goals. Its main purpose is to generate a representation of the problem that truly is an expression of more than the sum of the individual perspectives. Framing problems helps people understand one another and results in mutual learning, which is both a product and the foundation for subsequent work of integrated teams. Effective problem framing will also help identify existing knowledge about the problem and disciplinary and cross-disciplinary gaps.

As discussed earlier, the perspectives (worldviews, beliefs) one chooses to adopt influence how one attacks the problem (Bardwell 1991), and worldviews may be in conflict (box 5).

> **Box 5:** The initial representation of a problem may be the most crucial single factor governing the likelihood of problem solution. What may appear as a formidable problem in one representation may be solved immediately in another format. A mere change of representation may by itself provide a solution. Whether a problem is solved or not, and how long the solution will take depend a great deal upon the initial representation. (Posner 1973: 149)

Phase 3—Solving the Problem

Phase 3 is about doing the work to solve the problem selected (phase 1) based on how it was framed (phase 2). This phase covers the substantive concerns of the research topic and processes for effectively managing and working on integrated teams.

In addition to inadequate problem framing, organizations have problems effectively organizing, leading, and managing resources to do integrated work from beginning to end. Even if the problem is appropriately selected and framed, there is much more to integrative problem solving. Critical barriers must be resolved; in particular, improvement is needed in managing the inevitable conflicts that occur among team members and between team members and hierarchical leaders.

All three phases (and steps within them) must be done in a sequential fashion, but they may be iterative and reflexive as well. For example, problem framing may clarify the problem selected or it may reveal other critical questions where a priority call may be needed before problem solving commences. Visible and traceable processes must be in place so that people up, down, and across the hierarchical organization can understand what is occurring, why, and to what ends.

Outcomes are uncertain and cannot and should not be dictated in advance. Iterations are necessary both within and between the phases. "Skipping steps creates only the illusion of speed and never produces satisfying results" (Kotter 1995: 59). Top-down direction may be appropriate in phase 1, but will be met with resistance and be counter-productive when framing the problem (phase 2) and doing the research in phase 3.

Integrated Problem Framing: From Rhetoric to Reality

A review of the literature on integrated resource management strongly confirms the importance of appropriate problem definition or framing—getting the context and questions right before actions are taken (Bardwell 1991, Clark et al. 1999, Elliot et al. 2003, Kakoyannis 2004, Senge 1990). Failure to ensure that effective problem framing and subsequent actions occur often leads to:

- Stating a problem so it cannot be understood by diverse interests.
- Stating the problem so it cannot be solved.
- Solving the wrong problem.
- Solving a solution (Bardwell 1991). For example, working on a technical solution for a problem that, at its core, requires a social or political solution.

Ready-made solutions for problem framing do not exist. However, there are some concepts and principles that may increase the likelihood of success. Questions to address at the beginning of the problem-framing process include: Who frames the problem? For whom? To what ends? How does one deal with scale within and among issues? Are there large-scale issues, or are they the sum of small scales?

Appropriate scale is defined by many factors including the broad issues and questions (drivers), processes at work (functions within and complex system components), and policy needs (What decisions need to be made? Where? When? Why?). Effective problem framing for complex issues and questions identifies policy needs and fundamental knowledge gaps.

The way a problem is defined affects the solutions (Wondolleck and Yaffee 2000). Much of the literature deals with problem framing as an abstraction or general process. Here, we discuss some ways to implement and sustain effective problem framing without stifling the enthusiasm and creativity of participants.

We believe, as do many people consulted in this effort, that problem framing is the most important, yet most poorly done part of integrated research. Doing this phase well will set the stage for merging diverse perspectives; doing it poorly makes us victims of ideologies imbedded in scientific disciplines, as well as individual and organizational power relationships.

Problem framing is more difficult than it first appears, but is critical to overall success. These efforts require an emphasis on leadership rather than management and administration, and commitment and patience from hierarchical leaders rather than command and control. Unfortunately the latter in both choices is more prevalent today than the former.

Basic Principles of Problem Framing

Some basic principles for problem framing have emerged from the literature and our discussions with scientists and science managers.

Problem framing will reveal if an integrated approach is required or if narrowly defined work is needed to improve understanding of complex issues. Both may be needed; it is not necessarily an either-or choice. Even when a problem (or part of a problem) falls within a particular discipline, integration may be critical at the theory or methodological level. How far one needs to "back up" in the process to improve integration in ongoing efforts must be decided on a case-by-case basis.

Integration is important when relevant knowledge is widely dispersed, multiple values and perspectives are present, multiple interests are at stake, power differentials exist, and capacity to understand or act is spread across multiple actors (i.e., disciplines, functions).

Learning by doing seems to be critical in processes of integration. Social scientists have often pointed to the importance of "self discovery" as an aid to learning. This all implies the importance of extensive documentation and ongoing feedback

Box 6: Just knowing is not enough. In the face of problems that are urgent, complicated, and far-reaching, people often fail to respond with the enthusiasm and commitment one might expect…. People are not computers. They cannot store and access all the information they receive…. They selectively use information from their environment relying on mental models or "cognitive maps" they have built through life experience…. People also are not passive receptors of this information…. They use these maps rapidly, almost automatically to access a reservoir of organized information with which to interpret and respond to their environment…. When it comes to problem-solving, this commitment plays itself out as a bias toward the familiar…. People tend to solve problems in ways that fit into their preexisting maps; they do what they did before…. Unfortunately, this also means that new problems may be cast as old ones and more effective options overlooked…. There are times, of course, when the models one has cannot accommodate the new information…. At other times, however, people jump to conclusions without adequately examining the problem. (Bardwell 1991: 604-605)

and evaluation so we do not forget or repeat ourselves later, and so that lessons can be shared (box 6).

The process through which problem formulation takes place is critical. A written document is just the culmination of the exercise. Essential features of the process are listed below.

- Include the full range of interests, values, and uses. An inclusive process is necessary to ensure that the questions posed are integrative at the outset, rather than assuming that this can be achieved later. The process is also a means of identifying fundamental conflicts and disagreements at the beginning rather than letting them emerge (as they inevitably will) later.
- Focus attention on complex biophysical and social questions, and allow these questions to drive the search for solutions. Only when the process has generated agreement on the nature of the problem should the search for solutions be undertaken. Avoid jumping to a solution before thoroughly understanding the problem.
- Define the questions in explicit terms. This should include measures of the appropriate spatial and temporal scales involved and should also be framed in terms that facilitate improvement in conditions. The process should also

Roger Clark

Integrated problem framing will reveal the appropriate scale(s) (temporal and spatial) on which integrated research should focus.

require that the key underlying assumptions are also made explicit and available for review, critique, and possible revision by all interested parties.

For policy applications, problem framing likely will require collaboration with managers and stakeholders to determine appropriate questions before initiating work. New approaches will be needed for defining integrative questions up front to ensure that the appropriate combination of social, cultural, biophysical, and economic aspects are considered throughout research and development and natural resource planning and management processes (box 7).

Box 7: …an adequate problem definition is a critical first step to effectively solving complex problems. The process of reframing or redefining a problem enhances one's understanding of that problem. …. Being able to problem-frame, to adopt different perspectives on a problem, makes people better able and more willing to think about and creatively address it. (Bardwell 1991: 606)

How often we've heard over the last several years that "integrated questions will drive…" Yet, we seem to be woefully inadequate in either getting the questions "right" or in following through once the questions are clear. There is a tendency to devolve into what is comfortable, i.e., what we have always done.

The problem-framing process is a prerequisite to successfully doing integrated research, as well as management. If done well, not only will the questions be properly framed, but the people expected to do the integrated work will have been transformed from isolated, individual disciplinarians to a team whose members have learned from and about one another sufficiently to work as a team even when working independently.

Practicing Problem Framing

When we tried problem framing at several workshops, we learned some interesting things.

Time to do the job must be sufficent and cannot be prescribed up front.

Participants all started from different perspectives; they each had a different sense of the context for the problem selected. Worldviews set the stage for how they interpreted places, and these need to be revealed. It was possible to look through one another's lenses, if enough time was allowed. This became the foundation for mutual learning and understanding.

Discussions about integrated approaches need to be informed by content, but it is not clear when or whether it is best to start with the biophysical or social component of the problem. Discussion of integration in the absence of a real place does not work very well. It is hard to share mental models and interpret what may be interacting components and elements when we each visualize different things. We found some improvement when using raised relief models with associated pictures as compared to verbal abstractions. But working together in the field, focusing on real places is even better. Personal perspectives affect how we "see" these places. Scales people focused on ranged from tiny to huge; some included the time dimension, others did not.

We observed situations where technical, social, and cultural perspectives were blended into a more complete "story" as the workshops progressed. In a sense, the frame of reference moved from the isolates to the center of the Venn diagram (fig. 1). How people told their stories about places differed considerably. Some were very analytical and technical; others were more abstract. But each perspective and approach added value.

Integrated problem framing is hard work: it involves learning and unlearning to get past trained incapacities; it can be psychologically uncomfortable; it can create fear owing to lack of knowledge or to recognition that our understanding and competence is less complete than initially imagined. At times it can feel like little progress is being made. This is further confounded by the lack of appropriate forums and facilitation processes to foster such "working through" (Yankelovich 1990).

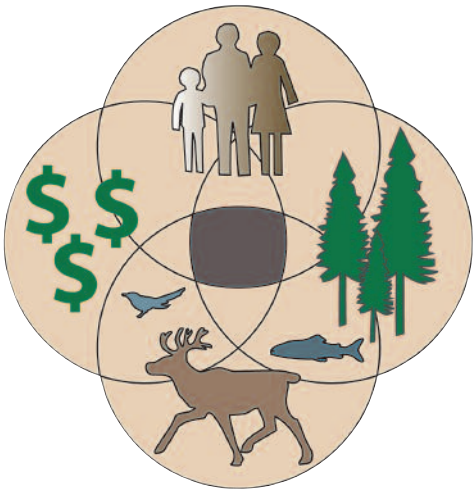

Figure 1—The Venn diagram is a tool that can help integrated teams identify and articulate overlapping questions and issues.

Roger Clark

Developing a common understanding among participants in integrated research requires time. Without both focused time and face time, mutual learning is difficult to achieve.

Time to do the job must be sufficient and cannot be prescribed up front. A common complaint was "We didn't have enough time." Rigid or unrealistic timeframes can lead to the premature closure to complex problems and ultimately failure to meet anyone's goals, even though some arbitrary deadline was met. It takes time to develop mutual understanding and the capacity to collectively move forward. Discomfort with what is often temporary inaction or indecision can lead to rushing the problem definition to get to the solution (Bardwell 1991). Yet, it often

is the ambiguity and associated discomfort that eventually leads to creative approaches as people with diverse perspectives learn to work in common. Time is at a premium and often is limited by decisions of team members or hierarchical leaders. This is usually shortsighted and limits the power and potential the team might otherwise develop. Examples were cited that confirm the old saying that while there was not enough time to do it right, there was always time to do it over.

Box 8: This inclination toward action and people's discomfort with indecision becomes problematic when it means they pass over the problem definition too quickly in order to get on with the solution. In their haste, people may define the problem inadequately or inaccurately; they overlook other alternatives or define the problem in terms of a solution. (Bardwell 1991: 608)

Problem framing requires mutual learning to get support and involvement (Wondolleck and Yaffee 2000) (box 8). Problem framing cannot be done **for** a group; it must be done **by** them.

- One cannot simply hand people a set of instructions about what and how to do integrated research and expect success. Yet this seems common in today's research environment.
- Integrated research requires that people engaged in the process understand one another's perspectives and have a common language; we do not need to agree, but we do need to understand. The problem-framing process, if well designed and conducted, usually leads to mutual learning. This means participants must teach as well as learn. Accelerated mutual learning comes with experience and practice.
- Mutual learning and shared language are essential to success. Mutual learning requires appreciation for worldviews; individual knowledge, beliefs, and attitudes; and the state of science (e.g., biology vs. sociology). Mutual learning helps us deal with the same place and problem but with different realities each of us brings. Holisms require merging these differences in some way. There are multiple ways to effectively communicate and present information, and using varied approaches will help diverse groups learn together. Not all people will be well suited or comfortable with such an approach.

Roger Clark

Problem framing to look at human values and uses associated with riparian and related environment must consider how they interact at multiple spatial and temporal scales.

Successful problem framing requires facilitation. This involves more than the rudiments of meeting management (e.g., creating agendas and handouts). Iterative and adaptive approaches must be in place to deal with inevitable surprises. Participants must understand that the fundamental emergent nature of the integrative process means that things do not always work out as envisioned. This also heightens the importance of documenting what was tried and why, and what did and did not work (box 9).

Creating an environment for joint fact-finding and learning together often leads to inventing options that none of the members could imagine on their own. Such options will emerge and new science and management approaches will evolve. Once a group achieves the ability to function as an integrated team, it cannot easily be reduced to fragmented disciplinary parts (Gibbons et al. 1994) except where this enhances an integrated solution.

Participants may be mistaken if they believe that being assigned a question to work on, or a team to work with, is inherently negative and limits what they might do as individuals. Ideally the participants help define the problem. The bigger problem, however, leading to conflict and limitations on creativity occurs when someone independently selects and frames the problem and assigns it to a team; this sets the stage for many failures. Those responsible for doing the work must be actively

Box 9: Team learning is the process of aligning and developing the capacity of a team to create the results its members truly desire. It builds on the discipline of developing shared vision. It also builds on personal mastery, for talented teams are made up of talented individuals. But shared vision and talent are not enough. The world is full of teams of talented individuals who share a vision for a while, yet fail to learn. The great jazz ensemble has talent and a shared vision (even if they don't discuss it), but what really matters is that the musicians know how to *play* together. (Senge 1990: 236)

More than other analytic frameworks, systems thinking requires mature teams capable of inquiring into complex, conflictual issues

Lastly, the discipline of team learning, like any discipline, requires practice. Yet, this is exactly what teams in modern organizations lack. Imagine trying to build a great theater ensemble or a great symphony orchestra without rehearsal. Imagine a championship sports team without practice. In fact, the process whereby such teams learn *is* through continual movement between practice and performance, practice, performance, practice again, perform again. (Senge 1990: 238)

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Joint factfinding and sharing perspectives about how complex biophysical and social systems function is a requisite to integrated research.

An explicit problem-framing process helps reveal what the problems are and who has articulated them.

engaged in both the problem selection at some level, and in actually conducting the problem framing.

People are at the mercy of how problems are framed if they are not involved in the process. Their interest in the substance may not matter if they feel someone has manipulated the problem (Slovic et al. 1984). Integrated efforts will stall if mutual learning does not occur or if members of the team are not involved in the process from the beginning or given a chance to catch up if they join later. Being present is not enough; people must be committed to the project, and if they are not, they should be removed. Unfortunately, problems can be framed at the political level in terms that satisfy particular interests, and the terms then imposed on scientists and managers. Again, this reinforces the need for an explicit and visible problem-framing process to help reveal not only what the problems are, but also who has articulated them.

Concerns about meddling and micromanagement occur when hierarchical decisionmakers delve too deeply, too soon, into the problem-framing process. Hierarchical leaders often are seen as inappropriately controlling the inputs, the outputs, and the means to accomplishing the tasks of integrated work. There will always be a tension; the goal is to prevent this tension from becoming a divisive conflict that stifles scientists' commitment, creativity, and productivity.

"What we have to learn to do, we learn by doing." Aristotle.

Tools to Aid Problem Framing

We do not start from a clean slate with respect to ideas, concepts, and tools to aid us in framing and solving complex problems. These legacies are revealed in policies, programs, and beliefs that can sharply distort how problems are framed and what solutions are sought (Socolow 1976). Some of the concepts that transcend disciplines were discussed earlier. In this section, we mention a few potential tools and aids that might be considered by people attempting integrated efforts.

The Venn diagram (fig. 1) helps illustrate connections among knowledge sets by using overlapping circles to show areas where shared knowledge or integrated research might be beneficial. Exercises to articulate and classify questions and issues into different parts of the Venn diagram can be challenging and instructive to integrated teams. For instance, if a team were trying to develop a research plan for a riparian area, the overlapping areas of the Venn diagram with circles representing knowledge about fish, people, trees, and wildlife management suggest the sort of interrelationships the team might consider. Of particular interest, and most difficult to address, is the dark center where all of the relevant components interact.

Kelly Lawrence

Workshops and discussion are aided with raised relief models. Coupled with photos and other information, these help participants share information leading to improved mutual learning.

The inability to describe one's perception about elements of the problem and the relation among elements is a potential barrier to working collaboratively. Cognitive maps and diagrams are powerful tools for conveying knowledge because spatial reasoning is highly developed in humans.

Raised relief models can be useful to facilitate discussion and understanding. They offer opportunities for "virtual fieldtrips" where people do not need to leave the office to see the world. Coupled with maps of various sorts, photos, and visualization tools, these models can be powerful aids to mutual learning and understanding among team members.

Workshops with intensive problem framing are fundamental to success. Often these are best done in the field where people can put real images to the words used to describe personal and expert perspectives. Usually more than one workshop will be needed throughout the course of an integrated project. Organizers and participants must recognize that people process information in different ways and in different timeframes. Using diverse approaches to help people process information is essential.

Stories. This may sound silly at first blush, but we have found that story telling is almost a lost (or never found) art that helps team members understand the diverse perspectives that each member brings (Brown et al. 2005). This is more effective when done with relief models, photos, or other such aids that help people "see" the

Cara Nelson

Engaging diverse interests and using multiple approaches to share information is critical to successful integrated research.

places in question, and is even more effective when done in the field. Stories can also reveal how perspectives are shaped by perceptions of scale.

Real places are best. Nothing beats going to actual places to make issues real to members of diverse teams. Fieldtrips, collaborative fieldwork, etc., might be done early and throughout the project. If the work is to be useful in general, however, then one must beware of being captured by localized conditions or by local experts. Real places help us understand the scales involved, and help us focus on the question without thinking about the disciplines. In addition, there is the notion of emergent properties that may come about with a discussion around a real place. It is important to consider alternative conceptions of scales because different properties (biophysical, social, cultural, and institutional) may emerge at each scale. Appropriate scales may be defined by the processes at work, interactions within and between components of complex biophysical and social systems, and policy or scientific needs. There is no one right definition for what a landscape is or what it means to different people or the scales appropriate for understanding relations between humans and natural resource values and uses (Clark et al. 2004, Stankey and Clark 1992). Various needs and questions will define the appropriate meanings and scales of analysis.

Linda Kruger

Field trips to discuss problems facilitate understanding. Each participant has the opportunity to learn and teach.

Proposed Process for Managing an Integrated Research Effort

Can integrated research be managed? Can it be reduced to a series of procedures, techniques, or steps? Some people at the workshops and in interviews thought not, others yes.

We believe that the answer is both yes and no. A cookie-cutter approach is likely to take us down many dead ends; however, the absence of some sort of process is also fraught with problems. Without a better way to avoid pitfalls, we are likely to repeat what has not worked before, waste time, and encourage scientists to avoid future efforts. Effective processes facilitate rather than constrain the work of integrated teams (or even individuals attempting to do integrated work on their own). Some sort of process is needed (with appropriate steps) to make integrated research a reality. Processes that are open and fair reveal when inappropriate controlling, and usually stifling, relationships exist.

When we discussed this topic with people, it became clear that those who generally favor some sort of process often are in positions without power, whereas those resistant to processes have the power and do not want to give it up. This will be tough to solve because power and control relationships are difficult to discuss and harder yet to resolve (Lee 1997).

It is important to emphasize again that integration is a group process that is essential to formulation of successful outcomes. It has several steps that generally must occur sequentially. Simply being present is not sufficient for success. For integrated teams to function, several things must occur.

- People must join, interact, and engage one another in freewheeling inquiry for problem framing and solving. Frequent contact is important, particularly early on.
- People must decide to commit to the team process and to reject barriers or find effective ways to deal with them.
- People must constructively and critically challenge each other's views, methods, and approaches as competition for ideas emerges. Holding shared perceptions of the problem is critical for an integrated team.
- After awhile people will be able to perform to meet individual and group expectations and goals.
- When goals are achieved, the group may disband or move on to other challenges that the team is capable of confronting.

Collaboration of any type has many difficulties (Gray 1985, Wondolleck and Yaffee 2000). Selin and Chavez (1995) summarized conditions that make collaboration difficult. These include situations where conflict is rooted in basic ideological differences, one stakeholder has the power to take unilateral action, constitutional issues are at stake or legal precedents are sought, past interventions have been unsuccessful, issues are too threatening because of historical antagonism, and a legitimate convener cannot be found. Selin and Chavez (1995) also cited rivals and power differences as impediments to collaborative efforts, of which integrated research and development is an example. In any new arrangements, such as a move to integrated research, changes lead to revisions in power relationships, a major barrier in any form of collaboration.

Many of these impediments apply to research organizations. However, such organizations have the opportunity to make changes. The often-asked question is, "Do we have the will and capacity to do so?"

To repeat and emphasize what we've said earlier, here are some basics to remember:

- Start at the beginning, stop at the end: a particular integrated research project should not become a never-ending crusade. Do what is needed now not later; do not do now what can be done later.

- Teams will need a common vision and explicit goals and clear expectations. The context must be set clearly. It will likely be a rocky start when teams must grapple with divergent worldviews, language, and beliefs. The efforts will evolve and cannot be rushed. Everyone must become aware of inter-dependencies.
- Specify objectives for the work to be done with clearly stated assumptions and caveats. Define questions before answers (Severide's rule). Use the Venn diagram (or other tools) to aid determination of variables and inter-actions to consider.
- Collaboration on desired outcomes is fundamental. This will require that groups dispense with functional, disciplinary cheerleading. This is not just a gathering of isolated individuals. Find out any hidden motives; personal agendas, worldviews, and ideologies must be transparent for groups to function best. Rather than being seen as impediments, they can be regarded as catalysts for new ways of thinking.
- Tension between worldviews is a good thing, but tension can become the basis for conflicts if not dealt with in an appropriate and timely manner. Make it clear who does what, when, how, for whom, where, and most importantly why. Working with diverse, integrated teams has parallels with how one best learns new languages: immersion in the project may be required for success.

USDA, Natural Resources Conservation Service

Integrated research requires that participants develop a common language and understanding. Mutual learning is a cornerstone of effective integrated research.

Roger Clark

Landscapes encompass diverse interests, values, and uses. Problem framing is an iterative process to define the scope of the problem and the integrated propositions, questions, and issues that will focus integrated research.

- Document what was tried and what was learned so the team can monitor, evaluate, learn, and adjust. This requires that assumptions and caveats and lessons are documented. Documentation will be critical as adjustments are needed and for transmitting lessons learned to others. Clear, comprehensive definitions and frameworks will be necessary for the project. These may morph or emerge as the project progresses.
- Recognize that this is an iterative, nonlinear process; it may be necessary to approach problem resolution in sequential fashion, but minor and major adjustments will be needed along the way. These adjustments may be minor, or in some cases it may be necessary to loop back and refocus the entire effort. This should not be seen as a failure but a success. Frequent interactions and communication will make all this easier for participants and observers.

Steps to Consider

Here we describe the steps that might be considered to conduct an integrated research effort. These steps cover all three of the phases discussed earlier (i.e., problem selection, problem framing, and problem solving).

1. **Determine the general focus of the effort** by using appropriate problem-identification and priority-setting processes. There are many entry points including places of concern, issues, or questions to explore. At this point, the affected parties will also become apparent.

   Initial problem framing commences here (just the broad strokes) to enable identification of an appropriate leader and initial team members. Take care not to overdefine the problem at this time; that is the job of the integrated team. Too much top-down problem framing will be met with criticisms about micromanagement and stifling.
2. **Identify the leader.** Make sure the person is a leader and a manager and has substantive expertise. This must be someone who has the motivation and skill to organize and guide a group through "uncharted waters" in a way that will inspire enthusiasm, commitment, and creativity. Not everyone can (or may wish to) do this. This person must know when leadership is needed and when management is required to move forward.

   People in this role must not be rigid controllers; their key responsibilities are to create an environment where team members are enabled to think and act creatively. People who have demonstrated ability to employ "power with" rather than "power over" skills are preferable (Lee 1997).

   Facilitation skills are critical. Facilitation includes, among other things, skilled listening, asking the right questions of the right people at the right time, developing shared vision and expectations, and capacity to resolve conflicts.

   Good leaders may not have all the requisite management skills, but they will know when they are needed or how to get them. The leader will also need to recognize the need for open, visible, traceable processes and logic trails. Honoring all points of view will help to minimize polarization. The leader must make sure all interested parties are included from the beginning, if possible, and that all perspectives are fairly considered.
3. **Decide on the degree of integration.** Will it be initiating a new project or reframing an existing one? Will all disciplines be included? How many resources will be needed and made available? Answers to these questions may change as a better definition of the problem occurs.

   There are several options, and choices must be made about how far to go toward integrated research and how much energy to expend to get there. Possible pathways (organizational and management changes) include the following.

Decide not to pursue integrated efforts. This might be the best choice if there is insufficient energy or commitment. Muddling through may be best; this is not a bad outcome if the rationale is clear.

Choose to do partial integration. Choosing this course may include making marginal adjustments to ongoing and future work and determining where integration will and will not be attempted. Use appropriate language about what is being attempted, and clarify expectations about what is planned (and not planned) and why. Provide adequate support to people directed to work on such projects. Outcomes of this approach will be limited but might include the development of some effective models and protocols.

Move toward complete integration. This may necessitate a transformation or reinvention at some level in all or parts of the research organization. It might entail making structural changes, e.g., create a specific organization to serve as a vehicle for integration (Clark et al. 1998). This might lead to moving people and funding to new organizational environments where integrated research is the primary way of doing business. Put people in charge who know how to lead and manage a team. Recognize the seriousness of disincentives to integration; for example, performance evaluations for scientists are perceived to reward individual work, whereas integrated efforts emphasize effective teamwork. (These need not be mutually exclusive, but the perceptions are a powerful disincentive to join up for some scientists.)

This step is all about making choices. But choices must be conscious and explicit and then followed by the action necessary to build and sustain appropriate integrated efforts to achieve the desired goals.

4. **Identify team members, at least the initial list.** Most of these efforts will be done within relatively small groups, perhaps reaching out to others for specific help on occasion.

Discuss the nature of the problem and requirements for team members. People who can devote substantial time to the work and who will not be distracted by conflicting priorities are preferable. This may require that ongoing projects are removed from their to-do lists, a difficult task indeed.

As noted earlier, some people are more suited to collaborative, team-oriented work than others. Not everyone can successfully work in a team environment, but not all the work will be done as a team. Traits or skills suggested as important include the following.

Personal:

- Self-confidence and expertise in a core disciplinary area as well as knowledge of legacies from past research. Critical thinking, lateral thinking, and creativity are valued for both individuals and teams.
- Tolerance for uncertainty and ability to operate in the face of ambiguity.
- Being adept at defining problems from a holistic or multidimensional perspective. This will require the ability to embrace a variety of disciplines, worldviews, gender differences, cultural backgrounds, and thinking and learning styles.
- Ability to dig more deeply into educational training (we all had some humanity courses, some biology, etc.) and become more adept at defining problems from a holistic or multidimensional perspective.
- Humility—there is rarely only one way to do things effectively. All participants need to be honest with themselves and others in the group. Everyone walks the talk and models integrative behavior.

Relative to others:

- Individuals must be team-oriented as well as self-oriented. Individuals must be able to fill multiple roles and have the ability to both teach and learn.
- A "power with" vs. "power over" philosophy is essential. This is not about who is right or who is more powerful. Rather, integrated work is about learning together in ways that cannot be accomplished by individuals no matter their position in the organization.
- Individuals must be able to embrace a diversity of disciplines, worldviews, gender, cultural backgrounds, and thinking and learning styles.

5. **Negotiate expectations and conditions that must be met to be successful.** These include other commitments (Some must be dropped or people will be unable to immerse themselves in the project!); incentives and disincentives for both individuals and the team; ways to resolve apparent barriers; immersion in the project, particularly early on; support from supervisors; and desired outcomes and outputs. (Note: this must be done both internal to the team and between the team and organizational managers.)
6. **Conduct initial problem framing.** The goal here is to **begin** to identify components and elements of the system of interest and to gain a sense of the scope of the problem and resources (e.g., time, money, expertise, skills, technology) required for the project. This is an ongoing, iterative process. Participants must avoid withholding fundamental disagreement about the

problem and introducing it later in the process. Thorough documentation is essential and must be formalized.

The mantra in such efforts should be to **answer the right questions, solve the right problems!** This seems simple, but we often tend to confuse means with ends, solutions with problems, and questions with answers. There must be agreement on the problem before agreeing on the solution. What are the drivers—science gaps or policy? A formal analysis may be needed to help to sort out the relative importance of questions. State the problem so it can be solved—in the short and long term. The trick is to not state a problem too generally while not overdefining it at this point. Avoid solving a solution (e.g., how to build a complex computer simulation model). This may help us gain a more holistic understanding of complex interactions, but such models can become the tail wagging the dog.

7. **Identify new team members** based on disciplines and skills needed to grapple with the problem as defined in step 6. This will likely be repeated several times during the project. In fact, this entire enterprise can be envisioned as a spiral moving through time.

   The leader and team members share responsibility to ensure that the effort is not bogged down as adaptive changes are made either to team composition or the focus of the project. A tension exists here that leaders must skillfully manage.

8. **Conduct team building.** Although this is presented as a separate step, it is an ongoing process. This should be focused on the substance of the work and not simply interactive games sometimes employed as team-building exercises. Mutual learning is the goal; often this can be fostered with self-discovery. This is often where a group begins to build an accord about the problem and people begin to "join up." Negotiate expectations and conditions that must be met to be successful.

   An important outcome of effective team building is that a shared vision, language, and expectations emerge. Members begin to understand the content of all segments of the Venn diagram.

9. **Begin formal problem framing.** The approach taken and results must be thoroughly documented here to aid in later steps. In addition to the suggestions described in step 6, there are some additional considerations:
   - Define the scope of the project and what falls outside the scope.
   - State specific objectives and questions by using the Venn diagram as an aid to ensure that all aspects of systems are considered.

- Identify basic biophysical and social system components and their subordinate elements, and postulate how components and elements may interact.
- Based on the above, reframe into a "new" set of integrated propositions, questions, issues, etc.
- Determine the general approach and roles of the team and team members.
- Identify the outcomes and results desired (interim and final).
- Gain further clarity on the skills and resources needed to meet stated goals and objectives.

10. **Do the "work" per above.** One important outcome of the problem framing is clarity about what is needed to do the work (i.e., the research and development). The first step is to codify the initial plan of attack and roles and responsibilities of members. Negotiate specific timeframes, operating rules, roles, and responsibilities. Formal efforts may be needed to clarify and document the roles, relationships, and responsibilities of each member.

    Some work may be done by the team or subgroups and some by individuals. Ensure that all team members have enough in common to allow them to work as a team or subset of a team focused on integrated questions. In any case, the work is driven by the objectives and questions that the team has developed as part of problem framing. The work may include major and minor syntheses of current knowledge about the problem under study.
11. **Reconvene the entire team periodically.** This should be driven by needs, not a calendar. Maintenance of continuity where people are scattered and busy on many other projects is difficult but essential to success. This will foster mutual learning and highlight needed changes. Such efforts will be intense and are aided by field discussions.

    When new team members join, there will be a need to "start over" at some level, or they will have difficulty joining up and contributing in any integrated way. The full team will need to deal with transition management issues (Bridges 1980, 2003) for both the existing team and new members. One must be careful not to confuse issues of efficiency with effectiveness.

    Make adaptive management (learning) a key component. This will require ongoing documentation (Stankey et al. 2005, in press).
12. **Reframe the project** (goals, objectives, approach, etc.) as needed. Teams must be ready to deal with surprises and be supportive of individual needs

that may unexpectedly surface—issues about the process as well as the substance of the project. The need to reframe will be a function of the learning that is going on as the project evolves.

Going "backward" may actually move the effort forward.

Adapting expectations and approaches may require that some work be redone. Going "backward" may actually move the effort forward. Progress can be impeded if reframing is too frequent, but a project that is never reframed along the way is likely not to meet desired goals. The trick is to be sensitive to critical times when a change is required to move forward. Reframing generally will be ongoing and involve the entire team in some capacity. This is another one of the areas where one can easily confuse concerns about efficiency with effectiveness.

It may be necessary to involve and renegotiate the terms of the project with hierarchical leaders if substantial modifications are required.

13. **Complete research tasks.** Producing interim products is important while on a long journey with what may be ambiguous outcomes. Focus on workflows not just on task assignments.
14. **Conduct reviews** (internally and externally). Although this occurs here as a formal requirement, review is really done throughout and should be focused on the process as well as the outcomes. There should be a combination of internal review by members of the team, reviews by hierarchical leaders, and technical reviews by external experts.

    The results of reviews should lead to revision of documentation (substance and process) with formal reconciliation. This is a responsibility of the entire team although individual members may do most of the work. This process of review and reconciliation will often reveal where additional linkages and knowledge are needed.
15. **Complete the project.** It is important that this is done before new assignments take over. Completion may include many things. What this entails should be negotiated up front.
16. **Celebrate successes.** Make sure that there are real endings even if the team will begin new projects. Individual, team, and organizational successes need to be acknowledged in a significant way.
17. **Disband or take on a new topic.** Manage the transition from both organizational and personal perspectives (Bridges 1980, 2003).
18. Formally **evaluate** both the substance and the process when the project is completed. This should be a written record that helps others convene and conduct future projects.

Manage conflicts throughout the process. As the steps above are implemented, a variety of issues or problems may emerge that will need to be resolved as projects progress. Some likely questions include the following.

- What if there is not support from hierarchical leaders? How to address changing demands and timelines imposed by external and unexpected forces?
- When and how to involve external scientists, managers, citizens in integrated projects?
- How to best foster mutual learning to create a common understanding or language?
- What to do with people who won't play? How to control the negative effects of prima donnas and saboteurs? (Research organizations often have an array of eclectic and sometimes eccentric personalities in them. This is a good thing, a very good thing. Some of the best and most creative ideas emerge from such people, but working with them can be challenging and disruptive in team environments.)
- How can the effects of systemic incentives and disincentives be better understood and managed? This is particularly challenging when these are not under the team's direct control.

We address some of these questions in the next section.

In sum, when putting together and implementing integrated research projects:

Do	**Avoid**
Lead	Micromanagement
Empower self and others	
Manage inevitable tensions	Unresolved conflicts
Be flexible and adaptive	Inflexibility
	Compartmentalization
Clarify expectations (frequently)	Confusing means with ends
Take risks	Mixed visions, expectations
Let go of assumptions	
Be patient	Premature closure
Produce desired outcomes	Waiting too long to produce

Barriers to Integrated Research

There are numerous systemic barriers that make integrated efforts difficult to conduct or the results difficult to use (Clark et al. 1999, Margerum 2001, Margolis 1993, Socolow 1976). Support for integrated research approaches is conditional on eliminating or mitigating these perceived barriers and threats. We summarize some barriers compiled from the literature and during workshops, surveys, and interviews in this section.

Some barriers stem from worldviews. Worldviews color perceptions and values. The barriers arise not from individuals holding certain worldviews or ideological beliefs, but from projecting them onto others or using them to constrain dialog and action in order to achieve personal agendas. It can be difficult for some people to accept that they are operating from an ideology or worldview; they believe that their perspective is "truth" and wonder why others do not see things as clearly as they do.

Other barriers stem from individual personalities. Not everyone has the personality, skills, or interest for working on integrated efforts. That is all right because not all problems require integrated approaches. The problem is a pervasive reluctance to talk about individual ability, capacity, or interests, thereby setting up situations where individuals and groups fail.

And yet other barriers stem from the group or team. For instance, lack of common vision, poorly defined expectations, and failure to establish agreements and protocols are common. Defensive efforts by team members to hold on to power and protect their "turf," their ideas, or data, are other barriers that create a competitive rather than collaborative environment. The resident "expert" may be the most dangerous person on an integrated team that is attempting to define a new problem if he or she asserts (either verbally or through behavior) that his or her knowledge, experience, and insight is superior. "Experts may see new problems as just like an old one, thereby overlooking the unique aspects of the new problems" (Kaplan and Kaplan 1982) (box 10).

Worldviews, individual characteristics, and team dynamics are not inherent barriers; rather, lack of effective leadership and poor communication is usually the culprit. Different disciplines use different vocabulary and work with different temporal and spatial scales. A successful integrated team develops a common vocabulary and agrees on the agenda. Effective leadership builds a team from individuals with the needed skills and propensity for systems thinking and integrated efforts.

Box 10: All too often, teams in business tend to spend their time fighting for turf, avoiding anything that will make them look bad personally, and pretending that everyone is behind the team's collective strategy—maintaining the appearance of a cohesive team. To keep up the image, they seek to squelch disagreement; people with serious reservations avoid stating them publicly, and joint decisions are watered-down compromises reflecting what everyone can live with, or else reflecting one person's view foisted on the group. If there is disagreement, it's usually expressed in a manner that lays blame, polarizes opinion, and fails to reveal the underlying differences in assumptions and experience in a way that the team as a whole could learn. (Senge 1990: 24)

Even when individuals and groups are capable of being effective, organizational barriers can make progress and success problematic. For instance, a limited or lack of shared vision within an organization hobbles integrated efforts. Conflicting missions or goals can make it difficult for some people to participate. The inability or unwillingness of organizations to meet the time demands of integrative projects can be fatal. Similarly, the inability or unwillingness to commit financial resources or to permit their expenditure on some endeavor can effectively constrain the most committed integration team. Rigid boundaries within and between institutions or between research programs or disciplines can also paralyze effective integration. Addressing the following questions will help prevent barriers from becoming permanent blockades. Is anyone in the organization responsible for ensuring that integrated efforts are successful? Whose knowledge is valued within the organization? Are integrated efforts valued by the organization and supported with funding and training? If integrated efforts are attempted, is the process documented so it becomes a learning tool for future efforts? Lack of clarity about what integrated research really is and what is expected of those who undertake and manage it make it difficult to know exactly what should be done, by whom, how, and why.

Rigid boundaries within and between institutions or between research programs or disciplines can paralyze effective integration.

Organizational structures and management practices can impede development of sustainable integrated research (Clark et al. 1998). For example, many research programs are funded and managed as separate entities (e.g., disciplines). Such "stove-piped" organizations result in expectations and accountability tightly tied to funding. Some argue there is little flexibility in such organizations to address

complex problems. Integration projects may require more time, require longer term budgets or commitments and a different set of expectations about outcomes and products.

Our guiding rule for resolving barriers to integrated research is that systemic problems require systemic solutions.

Potential participants (at any organizational level) may not have (or be willing to take) time required to make integration a reality. As a result, efforts often lead to stapling bits and pieces together at the end and frustration about how the work was done and what is missing. There are many disincentives and few incentives to encourage participation and commitment. Training to develop the skills for integrated research is seldom offered. Furthermore, impatience from the top of hierarchical organizations leads to reticence to engage at the bottom. Risk taking may not be valued, and fear of failure can limit the engagement and productivity of individuals and teams.

Lack of resources (funding, time, skills) make substantial progress unlikely, at least in the short term unless changes are made. Changing course and building capacity for sustained integrated research will take time, and organizational leaders are impatient and often risk averse (Stankey et al., in press).

Finally, we must also acknowledge that not everyone will be interested in or accepting of the results of integrative work. At times, the results of such efforts will conflict with the interests and values of different institutions, disciplines, or policymakers and will be viewed as threats rather than new, useful information. When this situation prevails, results of integrative projects can face censorship or simply be ignored.

Many barriers have been identified; they might not pertain to every situation, but organizational structure and management practices make integrated efforts difficult at best. Systemic constraints thwart the best intentions. With all the barriers in place, it is no wonder few examples exist of integrated research particularly on complex ecological and social issues. A question that was often asked while we wrote this report was, “Given the number of barriers, many of them of a systemic nature, can we possibly achieve a high degree of integrated research?”

Does it matter if barriers are real or perceived? In the final analysis it may not make much difference; perceptions are reality for those who hold them and ultimately affect their actions and performance.

Suggested Solutions for Critical Barriers

Our guiding rule for resolving barriers to integrated research is that systemic problems require systemic solutions.

Systemic barriers include constraints that are imbedded in the fundamental beliefs and values of an organization. Often, they are difficult to discern or recognize; this makes their effects particularly troubling. They can significantly constrain the range of choices and methods of inquiry. If groups or organizations attempt to tinker around the edges when confronted with what are truly systemic issues, at best, little headway is made, and at worst, problems are confounded. The cumulative effect of ineffective remedies is the belief that there is no hope. Making systemic change is difficult because it confronts the status quo founded on tradition and power relationships that are hard to change.

Our guiding rule is to integate from the beginning.

Clarify Expectations

The key for a new, integrated effort is to provide the transition time needed for startup and getting the work done. The initial period will be characterized by uncertainty, surprises, and false starts. Avoiding premature closure is critical. Expect things to go slowly in the preparatory stages and accelerate later. This is particularly true for new groups who are assigned complex problems. Persistence and patience are needed for an effective integrative process. Work toward overcoming barriers as they occur. In many ways, the environment for people on such teams is akin to living in a foreign culture; they are faced with learning a new language, acknowledging new beliefs and norms, and recognizing that other people hold different values, worldviews, and expectations. They do not have to accept these different views, but it is critical they accept their legitimacy and importance in integrative deliberations.

Developing a deep understanding of a problem requires focusing on that problem. A meeting or two, a few conference calls, and memos just won't do. Bringing people together in the same place at least at the beginning of complex projects and periodically thereafter is key to success. Without both focused time and face time, mutual learning is difficult if not impossible to achieve.

Integrate from the beginning; this is a simple and powerful rule, but it is often violated. There is a need to foster some different thinking in scientists and managers about what integrated efforts entail and require and what they will produce. Not all problems need to be addressed from an integrated perspective, but understanding the links (the web of interconnectedness) is an important step for developing solutions or taking action.

Do not underestimate the resources necessary—time and money. It may be appropriate to tap into ongoing efforts in some cases; in other situations new efforts may lead to better results.

Recognize that putting diverse disciplines on a team is not the same as integrating them. Integrated team efforts work only with effective processes and relationships. Integration means focusing on the logic and flow of the work to be done, not just on discrete tasks. It means managing interdependencies between people, functions, and entities. It is a challenge of the first order.

Enhance Leadership Skills

Leadership is needed, not only at the organizational level, but perhaps more importantly at the team and scientist level to show that integration has the potential to achieve better, more holistic understanding of key issues. Leadership must make a visible commitment (in terms of budget, time, etc.) to integrated research if it has any hope of succeeding. Integrated efforts may be more time consuming and more costly, but the payoffs will likely be worth the investment.

Many believe that there is a significant lack of the "right kind" of leadership associated with integrated research at all organizational levels. For example, at several workshops and in interviews with others, participants stressed the need for clear authority, responsibility, and accountability; diminished fiefdoms; and far less micromanagement (a frequent complaint about hierarchical leaders). Command and control approaches often exhibited by organizational leaders tend to inhibit or stifle creativity and enthusiasm. Suggestions included replacing people, recalibrating expectations, and training managers and supervisors to be better coaches and facilitators.

The roles and responsibilities of leadership may need to be redefined or refocused. For example, redefine research managers' role to encompass the integration process, in particular, efforts requiring cross-discipline and cross-program collaboration. This will require that managers create and maintain an environment conducive to science, integrated or not (box 11).

Recruit, Train, and Support the Right Mix of People

Achieving critical mass (expertise, time, and resources) is necessary for complex integrated research projects. Recruiting the right people for the right job is critical; it is equally important to provide training as needed on how to work on teams. This includes developing forums where it is "safe" for scientists and others to discuss the status of efforts and what is being learned along the way (Yankelovich 1999).

Knowledge and skills must be appropriate to the problem, and this may change as the problem framing progresses. If people critically needed for integrated

Box 11: It is abundantly clear that rigid authoritarian hierarchies thwart learning, failing both to harness the spirit, enthusiasm, and knowledge of people throughout the organization and to be responsive to shifting business conditions. Yet, the alternatives to authoritarian hierarchies are less than clear...

Others have failed because they *did* give up the control, and then found that enthusiastic committed local decision makers did not necessarily make good decision makers. Still others made attempts at involving people more in decision making, but failed to go far enough in letting people develop their own visions, design their own strategies and structures, and assume responsibility for their own learning.

While traditional organizations require management systems that control people's behavior, learning organizations invest in improving the quality of thinking, the capacity for reflection and team learning, and the ability to develop shared visions and shared understandings of complex business issues. It is these capabilities that will allow learning organizations to be both more locally controlled *and* more well coordinated than their hierarchical predecessors. (Senge 1990: 289)

research will not join up, find out why. Give teams time to become immersed, facilitate continuity, clarify expectations, provide incentives, and deal with barriers of concern to them explicitly.

Provide adequate resources (money, people, and time), continuity of resources, and organizational commitment to better understand complex resource management problems. If people are oversubscribed, new integrated efforts may just represent another discrete task on an already-full plate. All participants must reevaluate existing assignments, revisit priorities, and let some things go.

Provide the time to transition into new efforts. Often the time necessary to prepare for and move to new ventures is underestimated. During this lead-in time, the groundwork can be laid to start a new effort and organize the support and enthusiasm needed. Guilt and pressure are not sufficient incentives, but opportunities for growth and cooperation might be. Insist that there be time for incubation, creativity, and play. Relationships are important. It takes time to build and nurture relationships that enable people to work closely together.

Pay special attention to communication at all organizational levels and with

other key players and institutions. A common understanding among participants of the scope of the problem is a fundamental requirement. Even if everyone does not work on every aspect of a problem, they need to understand their niche. One never knows when that understanding may lead to new ideas and breakthroughs. Develop and maintain effective relationships with hierarchical leaders.

Facilitate processes that enable an environment conducive to shared learning. Integrating includes dealing with participants' visions and cultures. Respect and value the input of others; people must feel open to express their ideas without ridicule. Build effective working relationships among the participants. Make sure that everyone's expectations and worldviews are transparent. Diverse perspectives are the grist for new ideas. Disciplinary and worldview differences must be honored and embraced; this is where the true creative opportunities lie for integrated work.

Collaboration is essential to success; competition is not. There should be a willingness to work together, to share knowledge and ideas and other resources, and to share responsibility for processes, relationships, and outcomes.

Avoid burnout. Organizations seem reluctant to acknowledge and confront this; often, the answer to any challenge is, "We can do more and more with less and less." The logical extension of this is that we can do everything with nothing! In the face of major challenges, there will often be a need to ease into new ventures, entice and support people, and be patient. Integrative problems often require time to think and reflect. The workaholic lifestyles of some leaders and supervisors should not be seen as meritorious, as these are poor role models.

Finally, with all the apparent difficulties to integrated research, some seriously question if it is possible to move toward this goal in any significant degree within current research environments, at least in the short term. Overall, a number of conditions seemed to prevail in those integrated efforts that worked better than others.

There were good relationships—inclusion of diverse experts up front; time for groups to form around good problem framing, a clearly understood goal and expectations for the overall effort and for the individual, and people joined up.

There were effective processes—formal problem framing, appropriate information to get things started, time taken for necessary mutual learning and understanding, time and support from the top to do the problem framing, and continuity of effort. There were also reasonable efforts on the part of organizations to provide the necessary resources—time, money, leadership—to undertake the effort.

Several groups found that **integration cannot be accomplished in the abstract**. It requires a specific situation or place to integrate around. Sometimes this meant taking advantage of ongoing work that may have initially been narrow.

When efforts come from the ground up and are supported from the top, many people with diverse skills and expertise jump in.

Facilitating Successful Integrated Research Efforts

In this section, we discuss ways to facilitate success in general terms. During our research, we observed several barriers that repeatedly seemed to thwart integrated research. One barrier is ineffective methods for managing conflict and fostering communication within the team (box 12).

Part of effective problem resolution is managing inevitable conflicts among team members. These conflicts result from competing worldviews or from members or the hierarchical leaders trying to control the outcome and solutions as well as the process. Paying close attention to development and maintenance of effective relationships and processes is critical for achieving the goals of an integrated effort. The key idea here is that conflicts are accepted as part of the integrative process; the focus is not on trying to eliminate them but to manage them as effective components of the overall process.

Dialog among team members, and between team members and hierarchical leaders, is critical for success (Wondolleck 1998, W

Box 12: Team learning also involves learning how to deal creatively with the powerful forces opposing productive dialogue and discussion in working teams. Chief among these are what Chris Argyris calls "defensive routines," habitual ways of interacting that protect us and others from threat or embarrassment, but which also prevent us from learning. For example, faced with conflict, team members frequently either "smooth over" differences or "speak out" in a no-holds-barred, "winner take all" free-for-all of opinion—what my colleague Bill Isaacs calls "the abstraction wars." Yet, the very defensive routines that thwart learning also hold great potential for fostering learning, if we can only learn how to unlock the energy they contain. (Senge 1990: 237)

Box 13: Positions are what people have decided on, which means they have already defined the problem and established a solution. To counter this, emphasis is placed on exploring the interests—the needs and concerns—that lay behind these positions. . . .Thinking about the problem in terms of satisfying those interests changes its definition. . . .and pulls people back from solutions. (Bardwell 1991: 608)

People engaged in integrated research must be able to suspend their assumptions and treat one another as colleagues. This is often made easier with a facilitator who is responsible for the process and outcomes (Senge 1990).

As suggested above, tension and conflict among team members are not necessarily bad. Tension is helpful when it challenges our worldviews and leads us to new ways of thinking and acting. But if not carefully managed, tension can become conflict and result in confusion, distrust, wasted effort, and unmet goals.

Often we tend to focus on outcomes and outputs while relationships or processes are ignored or receive inadequate attention.

Relationships, Processes, and Outcomes

Successful integration requires attention to the relationship-process-outcome (R-P-O) triad. Underlying this simple framework is the premise that for any human enterprise to be effective, it must foster effective relationships, develop and sustain fair and effective process, and result in desired outcomes. These components are not mutually exclusive, nor is proficiency in one sufficient to success. These components cannot be considered sequentially; they must all be attended to in real time for success. This is the major responsibility of people who organize and lead integrated efforts. Furthermore, attention is needed to ensure that intentions are explicit and that the effects are clearly understood. One outcome of the R-P-O focus is that it leads to insights and conclusions not otherwise possible.

Often we tend to focus on outcomes and outputs while relationships or processes are ignored or receive inadequate attention. The folly lies in that the impact of poor relationships or ineffective processes can negatively affect the desired outcomes. The R-P-O framework is about how people are governed and govern themselves to get desired results. Workshop participants and others with whom we talked strongly felt that successful integration required more attention to relationships and processes. They also believed that too much emphasis is placed on outputs or products, particularly in the short term. The relation among interests, rights, and power must also be considered. Effective, integrated efforts focus on the interests of individual team members. Inappropriate or untimely exercise of power can

Figure 2—Intended actions and their effect on relationships.

Your intent when acting		Effect of action on me: Negative	Effect of action on me: Positive
	Negative	1. Convergence—Agreement We are in conflict	2. Divergence—Disagreement I am confused
	Positive	3. Divergence—Disagreement You are confused	4. Convergence—Agreement Healthy relationship

1 = We agree but the outcome is negative. You meant to deliver a negative message and I received it as negative. We know we are in conflict, and the relationship suffers.

2 = We disagree but I do not know it. I think everything is OK because I misunderstood your negative intent. The relationship suffers but I do not know why.

3 = We disagree and I am hurt. Your intent was positive but I misinterpret it, I judge you as being negative. The relationship suffers but you do not know why.

4 = We agree and we are aligned. The relationship is healthy and prospers.

stifle or otherwise inhibit team progress and productivity. In hierarchical organizations, however, inappropriate use of power is often at the heart of many conflicts.

In an enterprise where creativity and new ways of approaching old problems is valued, power can thwart rather than facilitate. We find that power once had is hard to give up, even when it jeopardizes individual and collective performance and success. The R-P-O framework and the relation between power, rights, and interests are useful tools to prompt questions such as, Where are we now and where must we be to be effective integrators? And whose responsibility is it to make needed changes?

The Best of Intentions

Major confusion or conflicts often occur when someone's actions have unintended negative effects. This mismatch between intent of the action and its effect causes unnecessary conflict (e.g., trust levels may be dramatically attenuated). Figure 2 illustrates the relation between intent and effect.

To be more effective, the link between intent and effect must be improved. The conditions of cell 3 (fig. 2) were common in some integrative projects we examined. Here, sincere, well-meaning efforts were made by different scientists to communicate with others, but shortcomings, for many different reasons, only led to confusion among other team members. The lesson is clear: only **you** can validate

The integrative process requires that both intent and effect become an explicit part of the discussion.

the intent of your message or behavior. Only **I** can tell you the effect of your message or behavior. The problem is that we rarely articulate either perspective. In the absence of effective communication, we judge one another independently leading to misunderstanding. To be effective, the integrative process requires that both intent and effect become an explicit part of the discussion.

For integrated efforts to be more effective, those who lead and those who participate must help maintain effective relationships and processes. By doing this, the outcomes that hierarchical leaders and team members desire are more likely to accrue in both the short and long terms. Trust levels will improve vertically and laterally in the organization. And most importantly, such efforts will be sustainable.

Assessing Progress

How will we know integration is working toward the desired end? We argued earlier in this paper that effective integrated research must have an adaptive component. So what signals should we look for that will tell us if we are on course? What measures of success exist or are needed to determine whether integration has happened? In this section, we summarize some of the things that have been suggested to look for as evidence of integrated research.

We believe that successful integrated research requires attention to relationships, processes, and outcomes. Stronger relationships among team members and the organization enable more effective integrative processes, which lead to more substantive outcomes. Below, we take each of these topics in turn and pose some questions that could be used to evaluate change and monitor progress in these three areas.

Monitoring Changing Relationships

Questions:

- Are people operating outside their traditional roles in appropriate ways?
- Is discord within the group increasing or decreasing? The amount of discord within a group could serve as an indirect measure of the lack of integration. Discord could be measured by the number of participants that leave a group.
- Is more discussion happening among participants about the effects of proposed actions on others?
- Is there a formally recognized need to use the integrative aspects of a pending project?

- Do the people involved feel they are part of the project? Do project reports include all contributors and their contributions? Do project reports favor the results of a particular discipline or scientist without justifying the apparent bias?
- Is there ownership in the process? Ownership leads to increased acceptance of processes and outcomes.

Improved relations among team members and the organization may lead to the following:

- A common understanding of what is meant by integration is developed. Steps are identified to further integration.
- We learn by doing. With practice it will become clearer when integration is appropriate and what it means to think and act integratively.
- People who would like to be involved in an integrative project are identified.
- Worldviews become transparent and help rather than hinder.
- Power relationships do not intrude and stifle the creativity of participants.
- Trust among participants and hierarchical leaders improves.

Monitoring the Effectiveness of Integrated Research Processes

Questions:

- Is problem framing effective?
- Does communication facilitate learning within and between teams?
- Effectiveness of communication could serve as one proxy measure for respect.
- Do participants communicate with each other regarding substantial aspects of the project throughout its duration?
- Did experts work outside their areas of expertise?
- Are methods and results easily understood, and can all participants communicate them?

If the integrated process is effective, the following may result:

- Energy is reallocated from narrow and deep efforts to those of a more integrative nature.
- Budgeting is responsive to new questions and emergent opportunities.
- Incremental progress toward removing barriers to integration is noted as real issues and problems are solved.
- Synergy is achieved in the group so that the whole is greater than the sum of the individual contributions.

- Communication is improved about the complexity of biophysical and social systems.
- A better sense of the benefits of integration and the costs of not doing it is gained.
- Mutual learning leads to new knowledge and respect among team members, which will aid later efforts.

Evaluating Outcomes

Questions for monitoring substantive outcomes:

- Are the new questions, processes, and products integrative and holistic? Are they contextual? Do they involve both sociocultural and biophysical or environmental components? Do they involve multiple perspectives? Are people from diverse backgrounds collaborating in the process and product development?
- Are needs fulfilled? Does each component rely on or build on the others? Can the integration respond to change?
- Can predictions be made? Can new situations or problems be readily recognized?

Substantive outcomes might include:

- Concepts and principles that were not evident in individual disciplines.
- New knowledge about complex systems and functions that would not have been possible by simply adding one discipline to another.
- New methods, concepts, frameworks, and theory drawn from a combination of disciplinary perspectives.
- A synthesis of what is known about the topic and a better sense of priorities for future work.
- Sustainable answers to complex natural resource issues that satisfy a broader range of interests.

Questions for monitoring process outcomes:

- Do the questions cut across boundaries? Questions should be more complex than any one group might define.
- Can one categorically distinguish or separate one discipline or subject from another?
- If there is distinct disciplinary work, is it in the context of adequate problem framing and done in context of integrated questions?

Process outcomes might include:

- The emergence of previously unasked questions.
- Mutual learning.
- Interactions that can be traced throughout the planning process to see how proposed actions and decisions were affected as a result of exchanges with others.
- Work that is broad and integrated as well as narrow and deep.
- Teams that demonstrate the whole is greater than the sum of the parts.
- Diverse technology transfer efforts such as symposia, fieldtrips, workshops, and software to translate and transfer results of integrated research and development to diverse managers, the public, and researchers.
- A published conceptual framework to facilitate integration of biological, physical, economic, cultural, and social knowledge.
- Conceptual frameworks and technology that consider information about diverse needs and the development of multiple resources that enable decisionmakers to more effectively plan and implement management options.
- Improved knowledge and tools for understanding and managing complex relations both within and between forest resources and uses.
- Improved processes for integrating diverse physical, biological, social, economic, and cultural components of natural resources with research, resource decisionmaking, and management at multiple scales and through time.

Conclusions

This paper has been grounded in substantial literature; intensive experience, discussions, and debates among scientists; and efforts to seek input from people both in agency research organizations and academic institutions.

This effort was only partially successful. The very same barriers to integration described in this paper made it difficult to achieve our intent. In particular, competing priorities (both individual and those of people needed to support the work) made getting it done difficult. In addition, a growing feeling of skepticism about the outcome among many of the people contacted during the course of this project, made keeping an enthusiastic frame of reference difficult at times.

A major conclusion from this effort is that organizations or groups must get serious (or not) about whether to pursue a course of doing comprehensive integrated research. More purposeful decisions are needed followed by actions that

Fundamental changes may be needed in organizational structure, leadership, and management approaches to enhance organizational capacity for integrated research.

match the rhetoric. Clear language and explicit expectations about what integrated research is and is not are required for success. The assertions that we are, or intend to be, integrative without a concomitant commitment of organizational will, leadership, and resources will prove ineffective at best and dishonest and self-deluding at worst.

Fundamental changes may be needed in some areas to enhance organizational capacity for integrated research. These include organizational structure, leadership, and management approaches (Clark et al. 1998). Decisions about structural and management changes are needed to facilitate such work within and across academic and agency research organizations and programs.

We have discussed several attributes that are associated with effective integrated efforts. Some of the most important are briefly summarized below.

Introduce integration at the beginning. Integration will not work if it is an afterthought or seen as occurring after the research is completed. The integrative process requires a holistic appreciation of the problem from the outset. How we perceive a problem often portends how well it will be integrated.

Integrated work must rest on a clear vision, a shared definition of the problem, and mutually-agreed-upon expectations. Some argue that expectations should be kept low because institutions are imperfect and evolving. We take a contrary view; low expectations are the reason we have so far to go. A decision to change to integrated efforts is relatively easy. Managing the transition is more difficult and will take time and leadership (Bridges 2003).

Leadership is vital to sustain and focus efforts. Power and control relationships between leaders and team members are often cited as reasons why integrated efforts go awry; this leads to lack of trust. Success is facilitated by leaders willing to share power. Integration requires effective leadership and management from the top, bottom, and middle of the organization. Leaders at all organizational levels must be careful when "managing" such efforts so as not to stifle them. The following attributes have been identified for effective leaders: nondirective, facilitative, participative; "power with" vs. "power over" philosophy and approach; and patience—lots of patience (Bennis 1989, Depree 1989, Goleman 1998, Kim 1995, Lee 1997).

Prioritizing work is an essential part of an integrated approach. Limits as well as opportunities must be recognized. Organizations with limited resources cannot work on everything at once; priority-setting processes are needed as well as ways to take things off the already full schedules of scientists. Access to needed

Box 14: Simply put, integration is the process of bringing together the parts into a whole; it is linking and combining largely independent bodies of knowledge about complex issues, questions, or problems into a more holistic framework. Knowledge and processes in individual science disciplines, management functional areas, institutions (research, management, and regulatory), and research management problems have been typically segregated over time making it difficult to respond to complex, interrelated problems and issues. We need new approaches that merge biological, physical, economic, social, and cultural aspects of natural resource management to address present and future management and policy issues. An integrated approach is only recently taking hold in the research community and represents a major challenge to traditional research theory, methodology, and organizations. (Clark et al. 1999)

skills and expertise is fundamental to success. If they do not exist internally in an organization, they may be obtained from collaborators.

Teams must be grounded on mutual learning and understanding as well as respect. Participants must be both able learners and teachers (Capezio 1996, Kasl and Elias 2000). All participants must be open to alternative perspectives and worldviews; they are the grist of new ways of thinking, creating, and acting. All team members must be able to constructively challenge ideology imbedded in disciplines and thereby in us as individuals. Team members also must recognize that thinking and acting integratively will prove uncomfortable. That is okay and comfort will increase with experience. The primacy of the group over the individual is central to effective integrated work; however, individual roles and contributions must be appreciated and rewarded.

Any process chosen must be adaptive. Integrated approaches represent a learning process that needs to be flexible enabling change in course as the situation changes. Learning and adaptation can be facilitated through appropriate documentation (Stankey et al., in press).

Sustained productivity is needed from the beginning to the end of a project. Athough work may be conducted over a long period, there must be a flow of short-term products to gain and sustain support. Work must be completed in a reasonable time.

Above all, any organization attempting to do integrated research will need the will and capacity to create, implement, and sustain integrated work over the long term (box 14).

The single biggest limitation to achieving fundamental integration is inadequate attention of leadership and commitment of managers from top to bottom of research organizations.

Some Lessons

Based on the literature and our experience, we submit that the single biggest limitation to achieving fundamental integration is inadequate attention of leadership and commitment of managers from top to bottom of research organizations. There is an abundance of direction and management from all quarters, but some integrated efforts suffer from limited vision and follow-through necessary for a creative environment conducive to integrated research. Furthermore, there is a widely held perception that traditional management smacks of control, aversion to risk, and micromanagement.

Language confuses and divides us as we discuss integration. There are too many divisive false dichotomies: short vs. long term, integration vs. reductionism, top-down vs. bottom-up, and individual vs. team. All of these (and what is in between) need to be embraced to gain the diversity needed for integrated efforts to be creative and successful. Integrated research is a means to an end; the basic goal of integrated research is a better understanding of complex interactions within and between biophysical, social, economic, and institutional systems. The hope is that this holistic understanding will help create more sustainable resource management processes and outcomes thereby reducing conflicts among competing values and uses for increasingly scarce natural resources.

Credit has been taken for rudimentary efforts at integrated research. In our view, most attempts at integration are relatively limited and narrow rather than comprehensive. If integration is occurring, it tends to be narrowly defined, and critical components are often left out and then appended at the end of what has been labeled an integrated effort. Initial problem framing to develop integrated questions and approaches is generally not done or is inadequate. Ongoing work, at best, appears to be more multidisciplinary rather than transdisciplinary and often lacks any rigorous attempt to reframe the problem along the way. Tight timeframes and due dates often appear to impede effective integrated efforts. These observations, if true, do not mean the work is without merit; it only means that more can be done.

Systemic problems often snare teams attempting integrated research and those attempting to use holistic understanding in resource management. These problems include ineffective organizational structures and management approaches; ineffective problem definition, problem framing, and problem solving; and the lack of will or capacity to make changes needed to enhance integrated efforts. In spite of expressed commitments, organizations and scientists often revert to old and comfortable ways of doing business. The goal often becomes one of just getting it done.

People are often reticent to participate because of perceived disincentives. Many scientists are currently oversubscribed, which impedes the opportunity, let alone enthusiasm for new projects, however interesting and useful they may be. Furthermore, in spite of more than 50 years of literature and experience about what it takes for new ideas to take hold (Rogers 1995), organizations do not seem capable of staying the course long enough for seeds of integration to germinate, take root, and thrive. The combination of a short-term focus and shifting priorities makes participation in integrated efforts risky for many scientists.

Constant pressure for short-term products undermines and can stifle enthusiasm and creativity and impede rather than accelerate production in an integrated environment. This is not to say a continuous flow of products is not needed. They are. But improvement in achieving short-term objectives is needed while maintaining a longer term perspective.

There are liabilities to pursuing integrated research—lots of uncertainty; many barriers; inadequate or even poor leadership; and lack of people with requisite skills. But there are also liabilities if attempts are not made to improve integrated research—limited understanding of complex, multisystem interactions and continued difficulty resolving the big, complex issues. Improved integrated research would benefit both research and resource management. We must acknowledge the growing public and political dissatisfaction with science that proves unable to address the pressing problems confronting society. As we have suggested, many of these problems are integrative at their core, and science must undertake renewed and revitalized efforts to organize itself in ways that better address such issues.

Problem framing is a critical first step in developing and implementing integrated research and management strategies and knowledge (Bardwell 1991, Wondolleck and Yaffee 2000). If the problem framing is done well, not only will the questions be properly specified, but the people expected to do the integrated work will have been transformed from an assortment of isolated, individual disciplinarians to a team whose members have learned from and about one another sufficiently to act as part of an integrated team even when working independently.

Ultimately, integrated research is a process rather than a specific outcome. Clark et al. (1999) identified some short-term and long-term components of the process, which we summarize here. In the short term, integrative processes establish the context for the work by defining the vision and goals of future actions. In that same vein, specific evaluation criteria are developed so improvement can be measured and adjustments made as needed. The essential elements of adaptive management—evaluate, learn, and adjust—are practiced. The assumptions, expectations, and logic underlying the process are explicit and available for review. The

process solicits and values multiple forms of knowledge and points of view. It becomes an integral part of the planning process rather than a separate phase.

The type of involvement essential to integration is not easy and will likely be resisted. There is no room for hidden agendas because an integrated approach requires specificity and exactness. By validating multiple forms of knowledge and viewpoints, the authority and power normally given to experts will be challenged. The way problems are framed influences how and which resources (money, time, expertise) are used. This means problem definition is basically a reformation in how power is shared and directed (Clark et al. 1999).

In the longer term, attention is needed to the continuing constraints to integration. Although there is history of interest in the topic, there are not many examples of success. By addressing three structural problems, some of the barriers may start to shrink. (1) Education programs for researchers are still mainly organized along disciplinary lines. (2) The institutions of resource management (laws, policies, budgeting processes, professional societies) are also organized along disciplinary lines and bound by administrative, political, or legal limits. (3) A general unwillingness of individuals, groups, and organizations to share power and cooperate (Clark et al. 1999).

Recognizing the need for integration is necessary but is not sufficient for success. Our more cynical and disheartened colleagues believe breaching the many barriers that prevent or limit integrated efforts is a hopeless task and not worth the time and energy. They submit that without a serious commitment (i.e., time, resources, and patience) the disincentives seem to far outweigh the benefits for many scientists.

The desired outcome of integrated research is not in doubt—a more holistic understanding of complex biophysical and social systems fostering more effective resource management options. Results of integrated research are essential to a more complete understanding of choices facing society about natural resource values and uses. This knowledge should lead to more integrated management approaches to dealing with this complexity in values and uses.

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