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Strengthening Syntheses on Fire: Increasing Their Usefulness for Managers

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Abstract

A synthesis for fire managers summarizes and interprets a body of information, presents its meaning in an objective, unbiased way, and describes its implications for decisionmakers. Following are suggestions for ways to strengthen syntheses on fire and on other natural resource issues:

- Include managers, scientists, and science delivery specialists in planning, developing, and delivering syntheses.
- If a synthesis has unique regional components, include someone from each region in the planning team and consider these needs in writing and packaging.
- Use managers as authors, co-authors, or reviewers to ensure management implications are fully developed and clearly explained.
- Use existing communication networks within the management community for marketing and delivery.
- Include syntheses in education and professional development.
- Improve use of technology to provide syntheses, research and monitoring results, and other information so managers can easily find the information and apply it to resource management decisions.

Keywords: fire, synthesis, communications, science delivery, technology transfer.

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Cover: All photos except lower left are taken from the covers of syntheses on fire provided by the Joint Fire Science Program and available at https://www.firescience.gov/JFSP_publications.cfm. Top left: Bison in a Yellowstone National Park meadow with the 1988 North Fork Fire in the background (Jeff Henry, National Park Service). Top center: Large, old tree with deep duff mound (Sharon Hood, USDA Forest Service, Rocky Mountain Research Station). Top right: Ahorn Fire, July 2007 (Rick Trembath). Middle left: Harvester operation (Jeremy Fried, USDA Forest Service, Pacific Northwest Research Station). Middle center: Longleaf pine (Joe O'Brien, USDA Forest Service, Southern Research Station). Middle right: Dialog, Shultz Fire 2010 (Sarah McCaffrey, USDA Forest Service, Northern Research Station). Bottom left: Author and others looking into once-burned landscape (Jim McCallum). Bottom center: Streambed after fire (Charlie Luce, USDA Forest Service, Rocky Mountain Research Station).

Summary

Fire managers rely on syntheses for concise, objective information that they can apply to questions about management. However, syntheses do not always meet this goal. In this report, I describe ways to create more useful syntheses for fire managers. I focus especially on identifying management implications, describing them clearly, and making them easy for readers to find. While I worked mainly with syntheses on wildland fire, my suggestions may apply to syntheses for managers of other natural resources as well.

To write a useful synthesis for fire managers, the authors need help from a team of professionals. An effective team usually includes managers who want the synthesis done; they can identify the important questions, find relevant field reports, and help describe how information applies to management. An effective team also includes scientists; they will find information in the scientific literature, ensure that information is presented in an unbiased way, and describe the certainty and limitations of the information. Finally, the team must include members who will ensure that the synthesis is organized and written so managers can use it easily; these members may be scientists, managers, or specialists in science communication (science delivery specialists).

Before beginning a synthesis, the team needs to see if it is feasible. What do managers need to know? Is enough information available to answer their questions? Then the team must decide what kind of synthesis would work best. Qualitative syntheses cover a broad variety of information. They usually provide conceptual background and incorporate extensive information from the literature, and they often include examples from management. Quantitative syntheses (systematic reviews and meta-analyses) are based on rigorous selection of information that enables the authors to re-analyze the data and present conclusions with a known level of certainty. A combination of qualitative and quantitative approaches may be ideal if enough quantitative information is available.

The fire managers, scientists, and science delivery specialists whom I interviewed for this project suggested dozens of ways to make syntheses more useful. Here are six points that were emphasized by many interviewees and seemed to me most important:

- Include managers, scientists, and science delivery specialists in planning, developing, and delivering syntheses.
- If a synthesis has unique regional components, include someone from each region in the planning team; then consider regional needs in writing and packaging.
- Use managers as authors, co-authors, or reviewers to ensure management implications are fully developed and clearly explained.
- Use existing communication networks within the management community for marketing and delivery.
- Include syntheses in education and professional development.
- Use information technology to provide syntheses and supplement with results from recent research and monitoring, so managers can easily find the information.

As we gather more and more information on wildland fire, syntheses will become increasingly important resources for busy fire managers. When we write useful syntheses and get them to those who need them, we help ensure that management decisions will be based on our full, rich legacy of knowledge from both research and management.

Acknowledgments

I am very grateful to the Joint Fire Science Program (JFSP) for supporting this work under Project 11-S-2-4. JFSP has been the nation's leader in developing syntheses for fire managers. JFSP sponsored the development of "Wildland Fire in Ecosystems," a series of publications on fire effects to be used by fire managers nation-wide. JFSP provides these publications and more than 20 additional syntheses on a web page dedicated to syntheses. In addition, JFSP has encouraged innovation in synthesis by sponsoring systematic reviews of specific fire management questions.

I am also grateful to the Fire Modeling Institute and the Fire, Fuel, and Smoke Science Program of the Rocky Mountain Research Station for supporting my work on the Fire Effects Information System and other synthesis projects for many years. Thank you to Kris Zouhar for helping me locate literature from many disciplines to improve this report. I am especially grateful to the Fire Modeling Institute for a sabbatical in which to reflect on comments from reviewers, analyze new literature, and complete the report.

Very warm thanks to everyone who offered suggestions, provided documents or photos, or made time for an interview. These include Alan Long, Alan Watson, Alexander Evans, Bob Gillaspy, Brett Williams, Caroline Noble, Charlie Luce, Chris Mallek, Christel Kern, Chuck McCallum, Dan Mindar, Dave Campbell, Dean Simon, Diana L. Olson, Elizabeth Pickett, Eugénie MontBlanc, Geoff Babb, Helen Mohr, Ilana Abrahamson, Jamie Barbour, Jeff Henry, Jeff Rose, Jennifer Northway, Jeremy Fried, Jerry Williams, Jessica Miesel, Jim McCallum, Jim Thinnes, Joe Marschall, John Barborinas, John Cissel, Kris Zouhar, Kristine Lee, Lane Eskew, Loa Collins, Mary Taber, Michael G. Ryan, Mike Rauscher, Nan Christianson, Nancy Chadwick, Nate Fayram, Paul Langowski, Penelope Morgan, Pete Fulé, Rachel White, Randi Jandt, Rhonda Mazza, Richard F. Miller, Richy Harrod, Rick Trembath, Robert Ziel, Robin Innes, Sarah McCaffrey, Sherry Leis, Tami Parkinson-Whitford, Tim Swedberg, Vita Wright, Wayne Buck, William T. Sommers, Zach Prusak, and Zoe Hoyle. Thanks also to past students in technical writing and biostatistics classes, and to all writers who have suffered my review comments throughout the years. Without your help, this report would have been much poorer and less interesting. If I missed your name, I am very sorry.

Contents

1.0 Introduction: Deciding on Synthesis

Syntheses analyze the past to prepare for the future (adapted from Webster and Watson 2002). Syntheses summarize a body of information and describe patterns, inconsistencies, and information gaps. Wildland managers use them to inform decisions and plan management actions. Students and newcomers to a field of knowledge use them as "primers" with which to master basic vocabulary, learn fundamental concepts, and see how the concepts can be applied. Scientists use them to survey fields outside their specialties, locate key literature, and assess information needs. Legislators and policymakers use them to develop new laws and regulations. Members of the general public use them to gain background information and understanding.

In this report I focus especially on syntheses developed for managers of wildland fire and natural resources influenced by fire—syntheses that aim to give managers not only a summary of current knowledge, but also an understanding of how this knowledge, gleaned from a wide variety of studies and reports, forms the basis for insights that can be applied to management. While the examples used in this report are mainly from the fire literature and most interviewees are involved in fire management, the concepts presented here can be applied to any synthesis for natural resource managers.

Key points about syntheses for fire managers:

- A synthesis for fire managers is most likely to be useful when managers, scientists, and science delivery specialists are all involved in planning and producing it.
- A credible, defensible synthesis examines a well-defined body of information, describes pattern or lack of pattern in the information, and clearly identifies management implications.
- A synthesis is feasible when the information available is sufficient to meet the needs of the managers who will use it. Both amount and type of information should be considered.
- Managers must contribute to identifying and explaining management implications.
- The most useful kind of synthesis (qualitative review, systematic review, and/or meta-analysis) depends on its objectives and the information available.
- A short, concise synthesis is not necessarily quick and cheap to produce.

Syntheses have often been requested by fire managers[1], and increasing numbers have been published by scientists and science delivery organizations in recent years (Figure 1). However, they do not always reach their intended audience or meet managers' expectations (Chen and others 2013). This is not to say that syntheses are failures. Managers do find them relevant and helpful. Most of the fire professionals who responded to a survey evaluating Joint Fire Science Program (JFSP) publications (Smith and others 2013) indicated that JFSP syntheses "sometimes or always" enhance their understanding. However, fewer than half of respondents agreed that JFSP syntheses state management implications clearly, and many respondents have found them "sometimes biased" and difficult for managers to find; thus, there is room for improvement. In the fall of 2011, JFSP managers asked me to develop guidelines for improving syntheses for

[1] Three of the JFSP Regional Knowledge Exchange Consortia identify syntheses as a top priority or desired product: the Northern Rockies Fire Science Network (http://nrfirescience.org/needsassessment), the Northwest Fire Science Consortium (http://www.nwfirescience.org/plan-of-work), and Great Basin Fire Science Delivery (http://www.gbfiresci.org/about/).

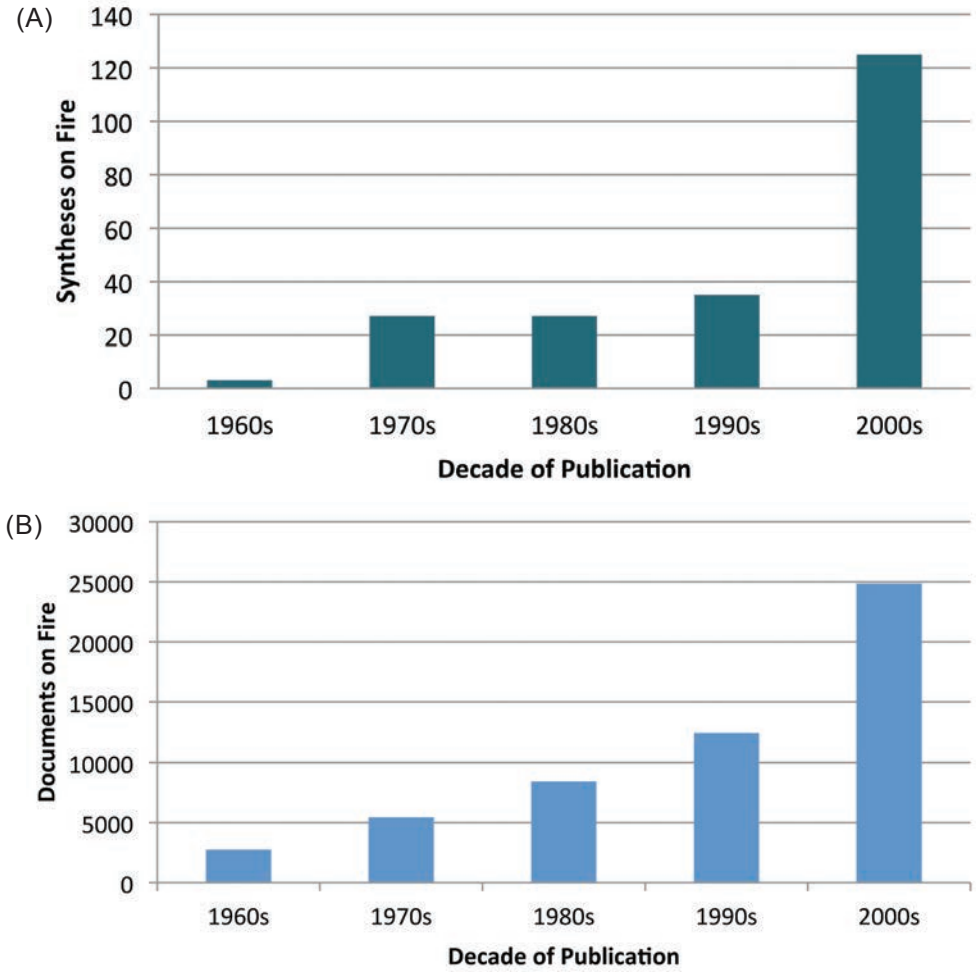

Figure 1—Growth in the number of syntheses about fire (A) is even more rapid than growth in the number of documents about fire (B). Search criteria and dates are described in Appendix A.

fire management. To do so, I have explored the literature on synthesis, science delivery, and informatics; examined syntheses on wildland fire; interviewed numerous fire and resource professionals; and relied on my own experience as an author, instructor of technical writing, and manager of the Fire Effects Information System (FEIS) for the past 20 years. Appendix A provides a detailed description of the methods used for this report.

It is common for fire managers to request a synthesis on a given topic and for scientists or science delivery specialists to write it, more or less in isolation from managers. While this approach may seem objective and an efficient use of everyone's time, it may also produce a synthesis that does not meet the needs of those who requested it. According to interviewees, the most important thing to do, to ensure that a synthesis is useful for managers, is to include managers in the process of developing it—especially in planning the synthesis and addressing management implications. The second most important thing is to ensure that the synthesis is packaged, advertised, and delivered so managers can easily find and use it. Interviewees noted that scientific credibility is essential, but they did not focus on this issue; their emphasis was on making sure that syntheses are useable for management and that they get used. Interviewees indicated that success is most likely when

- The synthesis is planned collaboratively by a team that includes managers, scientists, and science delivery specialists;

- Planning includes discussion of the kinds of information to use and the potential benefits of using case studies, examples, and anecdotal reports from managers;
- Management implications are developed fully and presented clearly with input and/or authorship from managers;
- The synthesis is carefully reviewed by scientists, managers, and science delivery specialists;
- The synthesis is organized, formatted, and packaged so managers can easily locate management implications and identify their scientific basis; and
- The synthesis is advertised and distributed to the field through the entire community of fire professionals.

Development of a synthesis can be conceptualized in five stages. Synthesis planners should consider a series of key questions for each stage (Figure 2 and Appendix B).

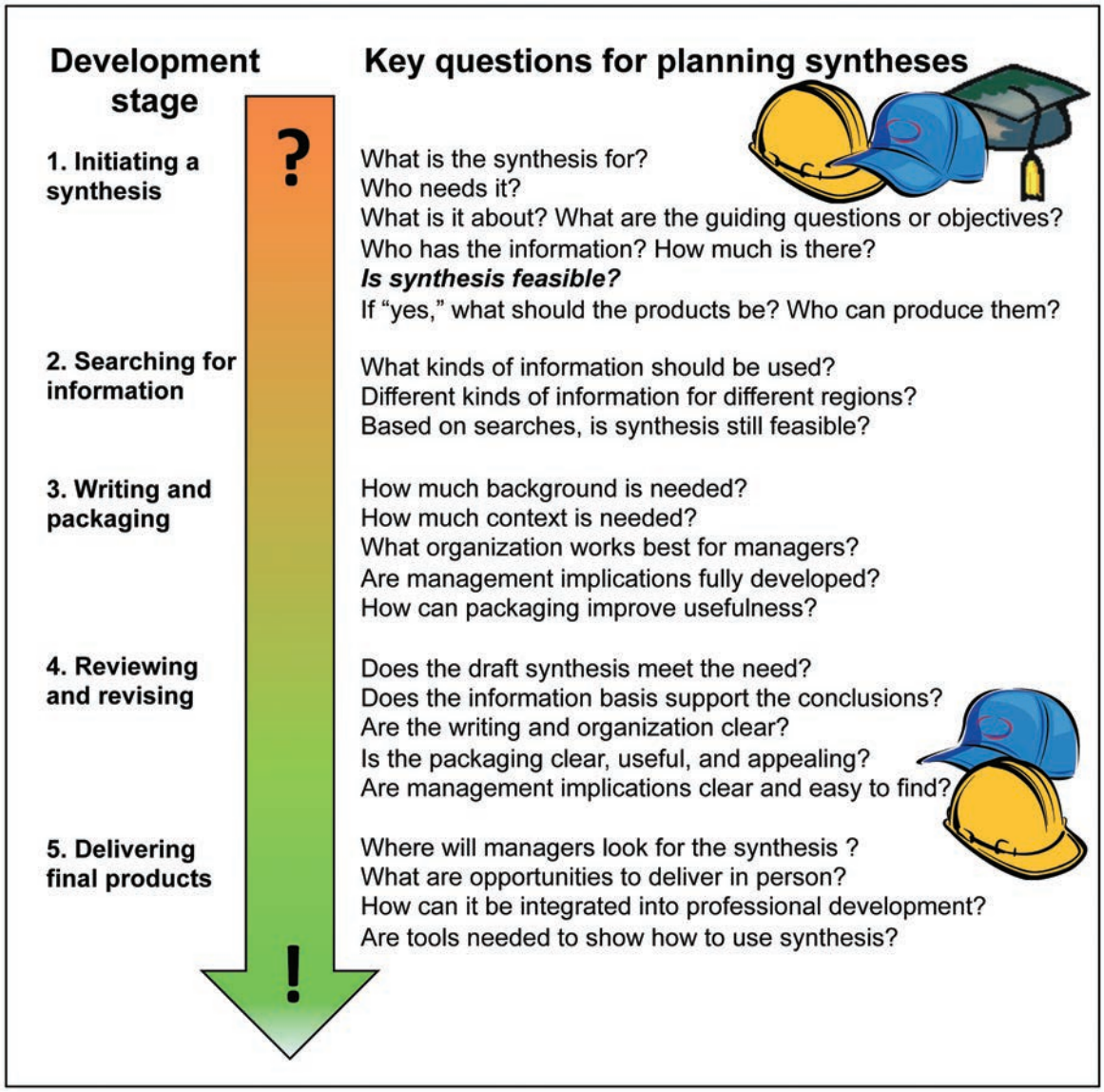

Figure 2—Integrate scientists (mortarboard), managers (hardhat), and science delivery specialists (baseball cap) in planning and developing a synthesis. All three roles are needed throughout the process, although scientists may be less important than others in product delivery. Appendix B breaks down each of the questions in this figure into a list of more detailed questions and guidelines.

1.1 Objectives and Structure of This Report

The objectives of this report are

1. To provide criteria for determining if a synthesis for fire and resource managers is feasible; and
2. To describe an effective process for planning and developing a useful synthesis on a fire management topic.

I hope this "synthesis on syntheses" is helpful to those who plan and fund syntheses, those who write and package and distribute them, and—most of all—those who need them to make wise decisions and take wise actions in managing fire and other resources affected by fire. While the details of any given section may be of greater interest to one or another of these audiences, I encourage readers to become familiar with all parts of the report, since isolation of specialists in different roles contributes substantially to frustration with synthesis efforts and products.

I heard often during interviews for this project that a synthesis must state management implications clearly and make sure they are highlighted in both format and delivery. I have applied that principle in this report. Key points are identified for each major section. Callouts bring the reader's attention to points that have been stated particularly well by an interviewee or author. Figures are used to highlight key processes described in the text and to vividly capture supplemental concepts and examples. Footnotes are used where documentation is needed but would obscure the flow of ideas. The Literature Cited section of the electronic version contains links to many of the source documents for this report, including all documents that are published in Treesearch, the Forest Service's online document library (http://www.treesearch.fs.fed.us).

In this report I refer to three groups of professionals in the wildland fire community who have a strong interest in improving the usefulness of syntheses: managers, scientists, and science delivery specialists. I use "managers" inclusively to represent decision makers, planners, and field practitioners who work directly in fire, and also specialists who deal with fire in other natural resource fields. Managers describe the need for synthesis, provide insights on the kinds of information to include, and contribute to the information base through monitoring reports and case studies; their input is essential for full development of sections on management implications. I use "scientists" to refer to professionals who conduct research—that is, those who produce new information and publish it in refereed journals[2], dissertations, theses, and other peer reviewed documents. They are major contributors to the information base and are often the authors of syntheses. I use "science delivery specialists" as defined by Ferguson and others (2014) to refer to professionals who have a broad understanding of both scientific and management perspectives and can act as translators or mediators between scientists and managers. They have also been called "technology transfer specialists," "knowledge brokers," and "boundary spanners." Many science delivery specialists have been educated as scientists, but they take on the unique role of connecting the users of science with scientists and science-based information. They may work for research organizations, distributing new information and condensing research findings into newsletters, web pages, and fact sheets. They may be the authors of syntheses. They may also work in

[2] I use "refereed" as it is commonly used in science, that is, to indicate a document that has been examined by anonymous peer reviewers and approved for publication in an academic journal. This is also called "blind review." Many documents in the "grey literature" also receive peer review, though not from anonymous reviewers. For example, all research papers and general technical reports published by the U.S. Forest Service are reviewed by at least two scientists, an editor, a program manager, and often a statistician before they are accepted for publication.

"boundary organizations" (Guston 2001) such as the JFSP Knowledge Exchange Consortia, which bring managers and scientists together to select research topics, develop methods, articulate applications, disseminate research, and assess the results of applying science on the ground (Kocher and others 2012).

Syntheses of information on fire management are of interest to many people outside the community of fire professionals, including students, legislators, policymakers, and the general public. While a single synthesis cannot be a perfect fit for everyone, it should present principal findings so they can be understood by a variety of audiences, and it may form the basis for supplemental documents that serve specific audiences.

1.2 What Is a Synthesis for Managers?

Syntheses for managers should be long-lasting, widely used, foundational documents that provide sound information that can serve as a basis for management decisions. I did not find a clear definition of synthesis for managers in the literature. Based on thoughts from Krueger and Kelley (2000), Thomas and Burchfield (2000), JFSP (Anonymous 2013), dictionary definitions, and comments from interviewees, I offer the following:

"It's not just collecting all the papers and see what happens. You need a guiding question, a point of view."

—Mike Ryan, Research Ecologist (retired), Rocky Mountain Research Station

A synthesis for managers in fire and related natural resources

- Examines, summarizes, and documents a well-defined body of information on fire and related topics;
- Describes pattern or lack of pattern in the information, thus creating new knowledge;
- Explains what is known, what is known but uncertain, and what is not known; and
- Describes implications for and applications to fire management.

Interviewees for this project listed many characteristics of syntheses, and they have much in common with dictionary definitions (Table 1). All require a search for information, integration to produce new knowledge, and identification of implications for management—that is, identification of ways to use the knowledge for wise management choices (Figure 3).

A synthesis is much more than a summary of information or an annotated bibliography because it emphasizes patterns, consistencies and inconsistencies in evidence, and creation of new understanding. The heart of any synthesis is the author's "disciplined scientific perspective" on what the compiled information means (Derish and Annesley 2011).

Table 1—Comments from interviewees and dictionary definitions describe similar features of syntheses: obtaining and integrating information, developing new understanding, and identifying applications.

Features of natural resources syntheses described by interviewees	Dictionary definitions of synthesis
• Based on thorough search for information • Provides a framework for understanding the topic or issue • Provides a balanced, unbiased report of what is found • Identifies sources of information • Identifies what is not known as well as what is known • Explains the level of certainty about information and knowledge • Explains the meaning of what is found, including its application to management	• The combining of often very different ideas into an ordered whole (Merriam-Webster 2012) • The action of proceeding in thought from causes to effects, or from laws or principles to their consequences (Murray 1971) • The dialectic combination of thesis and antithesis into a higher stage of truth (Merriam-Webster 2007)

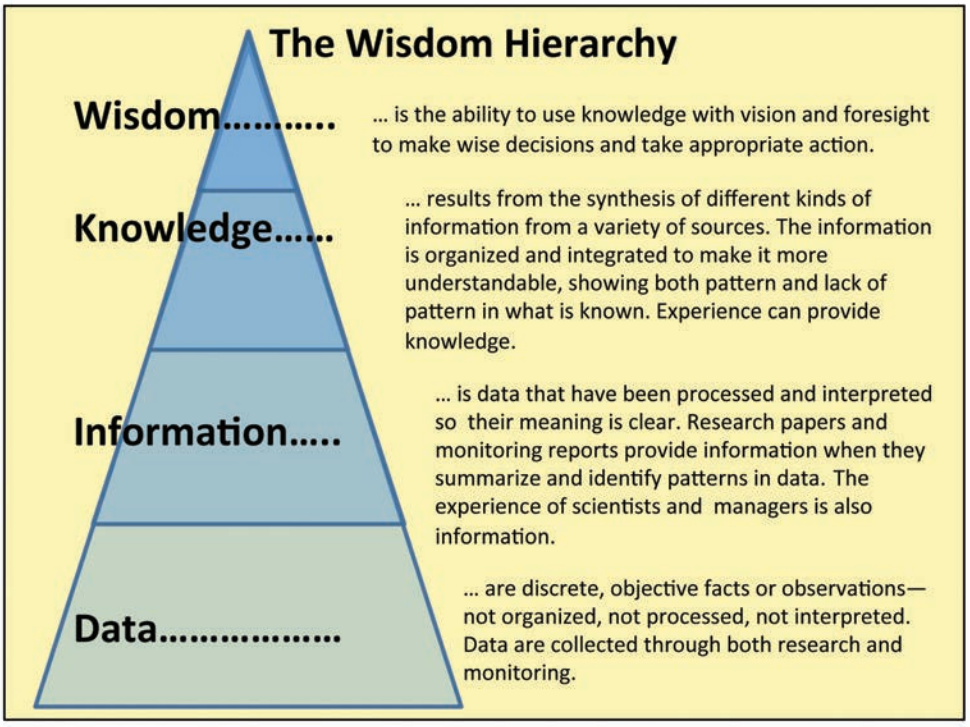

Figure 3—The "wisdom hierarchy," adapted from Rowley (2007), shows a progression of understanding from discrete pieces of information (data) to the ability to make wise decisions and take action on them (wisdom).

This is very different from an annotated bibliography. An article on literature reviews written for *Psychological Bulletin* provides this analogy: "Authors… are at risk for producing mind-numbing lists of citations and findings that resemble a phone book—impressive cast, lots of numbers, but not much plot" (Bern 1995). Instead of creating a list, a synthesis weaves a logically sound, well documented narrative from the information base. A synthesis for fire managers describes the management implications of the information available, just as a synthesis for healthcare providers describes appropriate medical practice (Grant and Booth 2009).

1.3 When Is a Synthesis for Managers a Good Idea?

"A synthesis product is not useful unless it functions within a network of people, all of the stakeholders."

—Mike Rauscher, Managing Editor, Forest Encyclopedia Network

What criteria can be used to decide if a synthesis is feasible and will be useful for managers? The answer depends on the need, the audience, and the available information. It should emerge from discussion among members of a team (managers, scientists, and science delivery specialists) who will help plan the synthesis and guide its development. Ideally, the team should come together initially having given some thought to the issue, networked among potential users, and conducted preliminary searches for information.

The planning team should:

1. List the objectives and scope of the synthesis. Objectives may range from increasing understanding to evaluating a specific management technique.
2. Identify the audience(s) and weigh their current understanding of the topic. This report assumes the primary audience will be professional managers in fire and related natural resource fields, but the needs of potential secondary audiences should also be considered. A variety of audiences may require a variety of products (Perelman and others 2001).

3. Describe the topic or central question of the synthesis, which may range from relatively simple to complex and may be highly controversial.
4. Discuss the type and amount of information available. There may be no history of management interventions or a rich legacy of case studies, no published literature or thousands of articles, data from only a handful of sites or from a wide geographic range.
5. Discuss whether the amount of information available is sufficient to support the kind of synthesis that will best meet managers' needs (Table 2).

If the planning team decides to go ahead and develop a synthesis, they can move on to discuss guiding questions about each stage in its development (Figure 2 and Appendix B). To help keep the project on track, they should review the guiding questions periodically, at least at the start of each stage. If the managers who request a synthesis are not thinking of the same product as those who develop it, and if the partners do not understand each other's needs and limitations, the project will frustrate the developers and disappoint the managers.

Table 2—A guide to deciding whether or not to produce a synthesis for managers in fire and related resource management. The left column follows a gradient from little information to abundant, empirically based information. The synthesis techniques mentioned (qualitative review, systematic review, and meta-analysis) are described in the text.

Amount and kind of information available	Main objectives	Recommendations
Limited anecdotal and field-based information, few or no publications	Any	Do not attempt to synthesize or provide statistically defensible argument. Provide for sharing of information among managers and researchers, especially results from monitoring. Provide ways to locate the relevant literature. Encourage research.
Mostly anecdotal information and field-based case studies, some published literature—likely inconsistent or only marginally relevant	Any	Consider qualitative review, but note its limited generalizability. Do not attempt to provide statistically defensible argument. Provide for sharing of information among managers and researchers, especially results from monitoring. Encourage research.
Mix of case studies and quantitative research that uses a variety of methods	Any	Consider qualitative review. Do not attempt to provide statistically defensible argument.
Mostly quantitative research that uses a variety of methods	Describe how to think about topic, describe patterns and management implications	Qualitative review
	Address effectiveness of specific management technique	Systematic review
Mostly quantitative research, preponderance of which uses same methods	Describe how to think about topic, describe patterns and management implications	Qualitative review with meta-analysis
	Address effectiveness of specific management technique	Systematic review with meta-analysis

1.4 What Kind of Synthesis Is "Best"?

I use three categories to describe the main kinds of synthesis likely to be produced for fire managers: qualitative review, systematic review, and meta-analysis. These categories are based on an extensive classification and analysis of health science reviews by Grant and Booth (2009), although my terminology is slightly different. Each kind of synthesis has strengths and weaknesses and is best suited for particular purposes. Some of the weaknesses may be overcome by combining features from more than one kind of synthesis.

Qualitative Review

Qualitative reviews are based on an extensive search for information and a critical assessment of its content and quality. They present fundamental concepts and define important terms. They provide conceptual background to help readers learn how to think critically about a topic. Qualitative reviews may report the quantitative outcomes of primary research (averages, ranges, correlations, etc.) but seldom include further statistical analysis, often because the information base comes from research that uses a variety of measurement methods. This feature is both a strength and a weakness. It allows the author to consider a broad range of information sources but limits the author's ability to state conclusions with a known level of confidence.

"Syntheses should show readers how to think about a topic, so they gain ability to make inferences, extrapolate, and assess new information."

—Penelope Morgan, Professor, Department of Forest, Rangeland, and Fire Sciences, University of Idaho

In the past, most syntheses published in academic journals were qualitative reviews, as were most of the stand-alone syntheses published for managers by government organizations. It is important to understand the differences between academic and manager-oriented syntheses, because scientists and managers may be thinking of two different things when they come together to plan a synthesis.

Academic literature reviews provide comprehensive analysis of a topic and are published as individual articles or as parts of theses, dissertations, proposals, and research papers. When based strictly on peer-reviewed science and published in a refereed journal, a literature review has high scientific credibility, so it could be a very useful form of synthesis on a topic where the science basis is likely to be questioned. However, it has some disadvantages as a tool for managers:

- Managers may not find or read it.
- It may not include valuable information from outside the refereed literature.
- Because journals require concise writing and discourage the presentation of information available elsewhere, it may provide limited background.
- The writing style is likely to be dense and technically specialized.
- Potential management implications may be presented briefly and conservatively.
- Since most journals are less likely to publish a review than an article on primary research, the potential for publication is limited.

"Don't put syntheses [only] in journals. If you do, you will limit your audience to a rare few."

—Bob Gillaspie, State Rangeland Management Specialist, Oregon State Office, Natural Resource Conservation Service

When I asked managers for examples of syntheses, they most often mentioned qualitative reviews published as stand-alone government documents. The content and format of these reviews are relatively unrestricted, so they can include extensive conceptual background, detailed graphics, numerous examples, and supplemental material such as glossaries and tables of information sources. While background information may not seem essential in a synthesis for managers, it can help them understand how to think about the subject and how to integrate their own experiences and new information—skills that remain relevant even as the content of the synthesis becomes out-of-date. Extensive

background information is provided in all of the national syntheses in the "Wildland fire and ecosystems" series[3].

Stand-alone qualitative reviews have these shortcomings:

- They do not have the authority that characterizes literature reviews in refereed journals.
- They do not quantify the level of certainty associated with conclusions.
- They are not as likely to be located by scientists through online reference databases as reviews published in refereed journals.
- They are often long, which can put readers off and make it difficult for them to find exactly the information they seek.

Systematic Review

A systematic review is based on a rigorous, repeatable search for information on a specific application of science, followed by objective appraisal of the quality of the information and quantitative analysis of the evidence. Systematic reviews originated as guides for practitioners in the health sciences (Egger and others 2001a), but they are now widely used to address environmental issues, following the guidelines provided by Pullin and Stewart (2006) and the Centre for Evidence-Based Conservation (CEBC), a nonprofit international organization at Bangor University, Wales (http://www.cebc.bangor.ac.uk/). Systematic reviews are usually published in refereed journals and may also be available in the database of the international Collaboration for Environmental Evidence (http://www.environmentalevidence.org/index.html). Fire-related systematic reviews include Fulé and others' (2012) assessment of the effectiveness of thinning and burning to alter subsequent fire behavior and Peppin and others' (2010) analysis of the effectiveness of post-fire seeding practices in western forests.

One challenge in writing a systematic review is deciding which studies to include in analysis and which to exclude. The synthesis planning team must agree on criteria for inclusion, since there may be tradeoffs between scientific rigor and coverage of the issue. Pullin and Stewart (2006) describe a hypothetical example where authors might choose to include a small-scale study that uses a classic randomized, controlled design but exclude a study that uses less rigorous methods—even though it is more relevant to the management issue, covers a larger geographic area, and applies over a longer time frame. If the authors apply strict criteria for including research, they might miss seminal research that used outdated methods and new research that contradicts conventional wisdom. One way to address this problem is for a systematic review to use both a quantitative approach, such as meta-analysis, and a qualitative approach, which provides context, helps describe the full range of evidence, and may help the authors resolve conflicting reports.

A major benefit of systematic reviews is that, by definition, they are directly applicable to management. Their use of a clear, repeatable search strategy and well-defined analytical methods gives them high credibility in the scientific community and can make them particularly helpful for addressing controversial management practices. However, they also have limitations:

- They work only for topics that can be formulated as a precisely focused question on a specific science application.

[3] Chapter 2 in the volume on flora (Miller 2000); Chapter 1 in the volume on fauna (Lyon and others 2000); Chapter 3 in the volume on air (Sandberg and others 2002); Chapter 1 and the introductions to Parts A and B in the volume on soils and water (Neary and others 2008); Chapters 2 to 4 in the volume on invasive plants (Zouhar and others 2008c); and Chapter 2 in the volume on archaeology and cultural resources (Ryan and Koerner 2012).

- They may provide little background information, vocabulary, or conceptual framework, so they may have limited usefulness in helping readers develop the ability to assess information for themselves, including information published after the review is completed.
- Strict adherence to a predetermined search strategy may prevent authors from consulting additional sources that could provide a deeper understanding (Boell and Cecez-Kecmanovic 2010).
- If they are published only in refereed journals, managers may not find them.

Meta-Analysis

Meta-analysis refers to a kind of synthesis and also to the technique used in these syntheses to compare the results of multiple studies that all test the same hypothesis by measuring the same variables (Harrison 2011). The scientist pools data from numerous studies, weighs their influence depending on sample size, and estimates the overall effect of the experimental treatment, its magnitude, direction, and variability. A major strength of meta-analysis is the ability to quantify confidence in the conclusions. Meta-analysis is commonly used within systematic reviews. Because this technique is objective and quantitative, it has high scientific credibility and can be particularly useful for controversial management issues.

Meta-analysis can be used to address a management question only if numerous studies are available that use the same approach. Given enough studies, the main limitation of meta-analysis is its potential to exclude many sources of information. The criteria for including information are strict. Not only must every study included use random sampling and valid methods, but it must also measure exactly the same variables and provide either the raw data or enough information to calculate data variability. The danger is that, if substantial insights from our scientist-elders are excluded based on methodological differences, the synthesis may lose conceptual background and historical knowledge. It could even lead future fire managers to "reinvent the wheel" by applying techniques already shown to be ineffective.

Fortunately, new techniques for meta-analysis are constantly under development by such groups as the National Center for Ecological Analysis and Synthesis (http://www.nceas.ucsb.edu/). At what point are enough studies available to represent what is actually known about an issue? This subjective decision should be made by the synthesis planning team. If a shortage of appropriate studies severely limits the usefulness of a meta-analysis for managers, then meta-analysis should be abandoned or combined with other synthesis techniques. In medical research, Egger and others (2001b) suggest examining possible sources of heterogeneity instead of pooling the data in search of a single, statistically tested answer. In ecology, Lajeunesse (2010) suggests that a synthesis is actually stronger if it includes studies with varying methodologies. The more inclusive approach enables the authors to look for consistencies and inconsistencies, a process he calls "triangulating" results, which should reduce the likelihood of reaching conclusions that are artifacts of a particular methodology.

Other Synthesis Products—What Kind? For Whom?

Many managers regard management guidebooks or handbooks as synthesis products. In fact, some managers whom I interviewed identified guidebooks as the kind of synthesis they use most often. Since a synthesis for resource managers must describe implications for and applications to field management, a guidebook is a logical endpoint of the synthesis process. While guidebooks have many appealing features, such as a streamlined design, concise writing, and abundant graphics, they may not include these features of synthesis:

- Conceptual background,

- Documentation of information sources,
- Description of overall patterns and lack of patterns, and
- Identification of knowledge gaps.

The addition of this information could make a guidebook too cumbersome for practical use. A good alternative might be to offer two products: a synthesis containing the overview and documentation, and a more practical, field-based guidebook. A pair of publications on western juniper (*Juniperus occidentalis*) demonstrates this approach: "Biology, ecology, and management of western juniper" (Miller and others 2005) is a synthesis that describes the distribution, life history, ecological relationships, and restoration potential for this species, while the 11-page "Western juniper field guide" (Miller and others 2007) addresses specific management questions.

Through most of this report, I discuss syntheses as single documents. However, a synthesis may be most useful—and most used—if it is the foundation for a suite of products, each using a specific format to deliver needed information to a specific audience. Production of a supplemental guidebook from a foundational synthesis is only one example. Every synthesis should be supplemented by a one-page summary and possibly by other documents (e.g., newsletter articles, briefing papers, fact sheets) and products in other media (e.g., webinars, podcasts, Facebook posts, and tweets). Supplemental products are appealing because they can be short and address specific informational needs, but they must be carefully connected to the foundational synthesis. If not, they are dead-end resources for readers: Readers may find a useful statement in them, but they cannot find out "Who says so and why?" and thus obtain more information or defend the statement. This problem is discussed in more detail under "Packaging Multiple Products" (p. 33).

1.5 Challenges

"Synthesis is very hard. It took longer and more work than I expected…. But I got perspective from this work to help my science be more productive and pertinent."

—Charlie Luce, Research Hydrologist, Rocky Mountain Research Station

Syntheses help managers make the most of the science we already have. They may be especially helpful with regard to controversial issues and issues where the science has produced conflicting results. Sometimes funding for new research on controversial issues is limited because of political considerations (Ruggiero 2013); this is all the more reason to synthesize the existing information and make it readily available to managers. Recent syntheses have addressed several complex issues in fire management, such as the effectiveness of fuel treatments (Evans and others 2011; Fulé and others 2012; Hudak and others 2011; Jain and others 2012), fire effects on riparian and aquatic resources (Dwire and others 2011; Luce and others 2012), and the effectiveness of post-fire rehabilitation practices (Peppin and others 2010; Robichaud and others 2010). Creation of these products is challenging. Even if science-based information is available, it may not fit the untidy world of management, where treatments are combined and long-term predictions are needed (Chen and others 2013).

Many interviewees mentioned the need for conciseness in syntheses and expressed the hope that they could be brief and produced quickly. However, brevity and speed are very hard to achieve if the authors are to develop sound conclusions and provide the background that makes them defensible (Grant and Booth 2009). Oversimplifying will misrepresent the science. The best way to develop a brief synthesis is to complete a detailed, thorough one and then write a short summary linked to the larger document (see "Packaging Multiple Products," p. 33). If time and budget limitations make it necessary to curtail the information search, planners should develop a systematic way to do so—covering only recent literature, for instance, or narrowing the topic—and weigh the advantages of this strategy against the potential to introduce bias and reach incomplete or incorrect conclusions.

2.0 What Makes a Synthesis Useful for Managers?

This section integrates information from interviewees with information from the literature to offer guidelines for developing useful syntheses and getting them into managers' hands. Prior to 2000, little guidance was available on developing syntheses for managers in fire and related natural resource fields. Most syntheses were qualitative reviews modeled on the academic literature review. Discussion of synthesis techniques has increased in recent years with the development of meta-analysis and systematic reviews. The guidelines in this report apply to all three kinds of synthesis. More detailed instructions for systematic reviews are available from the CEBC (2010), and those interested in meta-analysis should consult the extensive literature on that subject; they may also be interested in new, collaborative techniques for data synthesis, such as those developed at the National Center for Ecological Analysis and Synthesis (http://www.nceas.ucsb.edu/).

What makes a synthesis useful for managers?

- Complete, unbiased information base
- Objective assessment of information
- Clear description of main points
- Clear discussion of management implications
- Clear writing
- Clear organization and easy ways to navigate
- Effective marketing and delivery

2.1 Complete, Unbiased Information Base

The managers, scientists, and science delivery specialists whom I interviewed agreed that a high-quality synthesis must be based on a thorough, unbiased search for information. This concept is so ingrained in the world of scientists that few sources actually discuss it, but excellent guidelines are provided by the CEBC (2010, pp. 24–25, 31–36). I use "complete" to describe the information rather than "scientific" because the synthesis planning team may decide that information from case studies, monitoring, or management experience is just as important for a synthesis as information from research studies.

The information base for a synthesis depends on what is available and what the synthesis is for. If the topic is highly controversial, synthesis planners may decide it should include only refereed literature or only materials with quantitative, statistically tested results. In contrast, if information is sparse and variable, they may welcome reliable reports from all sources, knowing that a more restricted search could lead to a shallow or even biased interpretation (Figure 4). Use of the academic literature review as a model for synthesis has probably limited the use of case studies and examples from managers in the past, but this practice may not produce the most useful synthesis. Both scientists and managers have valuable knowledge; either can take the lead in developing new

Develop a complete, unbiased information base:

- Find out what kinds of information are available (research, experience, monitoring, etc.) and how much there is.
- Determine what kinds of information will best meet managers' needs, including the need for scientific defensibility.
- To avoid bias, develop an information search strategy, apply it consistently, and document it for readers.
- If the synthesis covers many geographic regions, consider the possible need for different search strategies for different regions.

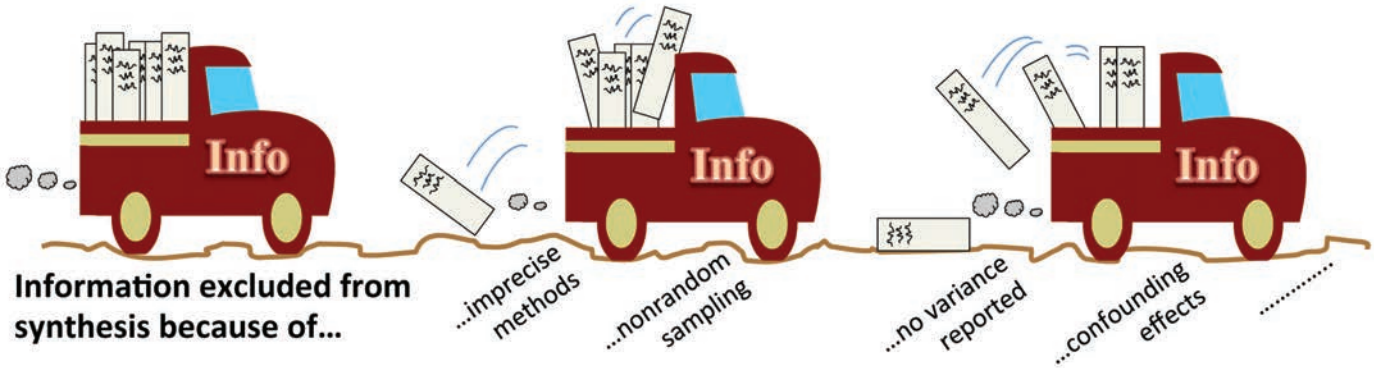

Figure 4—Decisions about the information to include in a synthesis depend on the objectives and the information available. Highly inclusive criteria may admit information that is unreliable or has limited generalizability, while highly exclusive criteria may leave valuable information by the wayside.

"The questions that come to me are things that have been in managers' minds for awhile. They come to me and say, 'I think I'm seeing this—what does the science say?'"

—Christel Kern, Research Forester, Northern Research Station

understanding, and there may be synergy in the "coproduction" of knowledge through collaboration over time (Kocher and others 2012; Russell-Smith and others 2003). For example, in their analysis of fuels management in riparian areas of the western United States, Stone and others (2010) found that the state of the practice preceded the state of the science; thus they chose to base their synthesis largely on input from managers. Marshall and others (2008) combined anecdotal information with information from the literature in their synthesis of information on fuel treatments in loblolly pine (*Pinus taeda*) forests. Evans's (2008) synthesis on biomass removal is based on 45 case studies from throughout the United States. Case studies have been used in the field of operations management as an empirical basis for developing new hypotheses (Eisenhardt 1989; Eisenhardt and Graebner 2007).

The information search may be especially challenging for syntheses that are national in scope but also cover regional variability. Some geographic areas, particularly the western states, seem to be "richer" in fire research than others (Kocher and others 2012). Regions also vary in land ownership patterns and the heritage of aboriginal and other traditional knowledge. Interviewees from several regions commented on the paucity of fire research in their areas and mentioned that, as a result, managers rely heavily on the long-term experience of local experts. Thus the planners of a national synthesis are likely to find that some of the questions in Figure 2, such as "What is the synthesis for?" and "Who has the information?" are answered differently from one region to another. To address this problem, they may decide that a suite of smaller syntheses would be more useful than a single, large product, or they may decide to organize the synthesis by region and use different search techniques for different regions. The decision should be guided by asking what product(s) will be most useful to managers. Search strategies that are used to obtain information should be documented so readers can understand the information base used for each region.

"Avoid being West-centric. Look for regional balance in treatment. If regions differ, can we have recommendations at the regional level?"

—Caroline Noble, Fire Ecologist, Southeast Region, National Park Service

Since most syntheses are based primarily on published information, the following recommendations may be helpful for obtaining a comprehensive literature search:

1. Use a variety of electronic search engines. Currently, no single source provides comprehensive coverage of fire and fire management issues. Coverage varies especially in regard to documents published decades ago.
2. Use library catalogs and specialized databases to search for books and proceedings, which are not covered as well as journal articles in leading science databases (Boell and Cecez-Kecmanovic 2010).

3. For resources on wildland fire, consult the Fire Research and Management Exchange (FRAMES) Resource Catalog (which also covers the E.V. Komarek Fire Ecology Database), the Citation Retrieval System for FEIS (http://feis-crs.org/), and the Fire Research Institute.[4]
4. "Chase" articles backward in time (Jahangirian and others 2011); that is, look up the primary research and other materials cited in references. This is a good way to locate seminal works, which may help you understand and describe patterns in the information you find. This technique is also called "reference tracking" and "snowballing" (Boell and Cecez-Kecmanovic 2010).
5. See how the ideas presented in key articles are later developed or refuted by "chasing forward" in the literature—using the citation analysis functions in electronic reference databases to find references that cite the original article (Jahangirian and others 2011).
6. Cite the primary source for each fact and idea that you report, and always read the materials you cite (Figure 5). If a secondary source misrepresented the study, you do not want to perpetuate the error. At the very least, it is embarrassing. It is also a disservice to managers and reflects poorly on your scholarship.

Informing Readers About the Search Strategy

A complete, defensible synthesis includes an explanation of the search strategy. This is analogous to the "Methods" section of a research paper because it allows readers to assess the information search for themselves—how broad or narrow the search was, what information was included and excluded, and where there may be potential biases.

[4] These fire-specific reference databases are described in Table 9, p. 43.

Check the source!

Whether working with field data or research reports, it is important to find and verify the original source of information. Tufte (1997) reports an error in map making that was repeated for more than a century: A 1622 map (right) showed California as an island, an error that was reproduced in 182 subsequent maps. The last one was published in 1745, "after which California cartographically rejoined the mainland."

Don't think that no one will find out if you didn't check the source. Simkin and Roychowdhury (2003) used misprints in citations to estimate the proportion of writers who cited a particular article *and had also read it*; they concluded it was about 20%.

Map of North America from Nicolas Sanson, *Cartes generals de toutes les parties du monde* (Paris, 1658), according to Tufte (1997). (I did not check the original map.) Moll Map detail courtesy of the Lilly Library, Indiana University, Bloomington, IN.

Figure 5—Do not cite a source unless you have read it. Check it to see if it makes sense and then quote it accurately. This anecdote illustrates how errors persist if no one checks the original source and data.

"It is difficult to argue that a review has usefully contributed to a field… if the review itself does not have a firm basis in a defined methodology for identifying, including and extracting information from the sources reviewed."

—Freya Harrison (2011). Methods in Ecology and Evolution. 2: 1-10.

Few qualitative reviews on fire explain their information search well enough for readers to make such a judgment, but some examples can be found. For instance, Kennedy and Fontaine (2009) explain clearly that their synthesis on fire-wildlife relationships is based only on peer-reviewed literature, and they give details on each source; Werth and others' (2011) synthesis on extreme fire behavior explains the rationale for including non-peer-reviewed literature; and Robichaud and others (2010) explain the rationale for limiting their report on post-fire hillslope stabilization to recent literature. Detailed descriptions are more often included if the search was somewhat unconventional, such as in three syntheses on fuel management that are based, at least in part, on information from managers (Evans 2008; Jain and others 2012; Stone and others 2010).

Documentation of search techniques is required for publication of systematic reviews by the Collaboration for Environmental Evidence and demonstrated by reviews on post-fire seeding effectiveness (Peppin and others 2010) and the effects of thinning and burning on wildlife (Kalies and others 2010). Qualitative reviews may not require this much detail, but the authors should at least answer these questions:

- What techniques were used for the literature search? What databases and other sources were consulted? If the goal was a comprehensive search, how did the authors know when they were finished?
- Did the search include published sources other than refereed literature, such as theses and dissertations, books, and conference proceedings? If so, how were these located?
- Did the search look for case studies, reports from managers, or anecdotal information? If so, how was this information obtained?
- Did the search cover only recent information, or did it reach back into older research? If so, how was that done?

"One episode of biased reporting just turns off receptivity to science."

—Elizabeth Pickett, Coordinator, Hawaii Wildfire Management Organization

Without this explanation, readers cannot assess the thoroughness and objectivity of the information base, and credibility may be questioned. Furthermore, if future researchers attempt to extend or update the synthesis, they cannot base their work on an understanding of the original information search. The search strategy used for this report is documented in Table A.1, p. 52.

2.2 Objective Assessment of Information

In searching for patterns, synthesis authors weigh evidence from a variety of sources and consider how it contributes to understanding of the whole. The terms used to describe confidence in information sources are not completely consistent (Table 3), so synthesis authors should define the terms and explain their criteria for evaluating information. While statistical results are often used to express levels of certainty, they usually address only one kind of uncertainty—the likelihood of finding an effect in the sample when there was actually no effect in the population. The likelihood of *not* finding an effect when there really *was* one may be just as important to managers, but it is much less likely to be measured (Underwood and Chapman 2003).

The generalizability of information (research, monitoring results, case studies, etc.) is also important for applying results appropriately to management: How broadly can the findings be applied? Are they relevant to the entire range of a species or only parts of it? Do they apply at both the stand and landscape scales?

Assess information objectively:

- Develop objective criteria through discussion among managers, scientists, and science delivery specialists.
- Apply them consistently, and document them for readers.

Table 3—Questions and terms that address confidence in the applicability of research results to management.

Questions about information and generalizations	Applicable terms
Do the observations address the question being investigated? Do the sampling scheme and data analysis support the explanation?	Internal validity (CEBC 2010), reliability (Popay and others 2006)
What is the likelihood that a hypothesis is false? What is the likelihood that a similar experiment would produce a substantially different result?	Certainty, probability, confidence interval (Dytham 2011)
How widely can the findings be applied? How strong is the basis for generalization?	Generalizability, external validity (CEBC 2010; Popay and others 2006), scope of inference (Puettmann and others 2009)
How likely is the explanation or conclusion to be correct?	Confidence (Solomon and others 2007), reliability (Fazey and others 2004)

Case study and anecdotal information are best presented as examples or "snapshots" of a situation (as used in Evans 2008), since their generalizability to a larger area or more diverse conditions is unknown.

The criteria used to evaluate information vary depending on the type of synthesis and its goals. For meta-analyses, the criteria are objective and clear. For systematic reviews, the criteria are usually more complex but still objective. CEBC guidelines (2010, pp. 39-43) suggest developing a procedure for ranking the "quality of evidence" of each information source, then testing the procedure with more than one person evaluating each source, and finally reviewing the procedure with stakeholders. This process may be laborious and time-consuming, but it can improve the credibility of the final product and may also lead to important findings. For example, Peppin and others' (2010) review of the effectiveness of post-fire seeding to reduce soil erosion indicated that higher-quality studies generally did not show post-fire seeding to reduce erosion effectively, while the majority of lower-quality studies did show the practice to be effective.

Qualitative syntheses usually use hedging (see "Explaining the Basis for Generalizations," p. 20), rather than strict objective criteria, to inform readers about the quality of information. Nevertheless, application of consistent, objective criteria should be considered. A few papers in the ecological literature suggest methods for ranking information quality. Krueger and Kelley (2000) suggest a classification based on the nature of the information source—documented case history, experimental research, professional resource knowledge, and scientific synthesis. An analysis of the information available on fire effects in bird communities (Leidolf and Bissonette 2009) uses direct observation as the criterion for information with high reliability. All reports based on direct observation (experimental studies, observational studies, and "naturalist observations") are classified "original research," as opposed to conceptual reviews, methodological reviews, meta-analyses, and bibliographies. An analysis of knowledge gaps in the information on fire and invasive plants in the eastern United States (Gucker and others 2012) also ranks information based on direct observation as "highest quality" for use in synthesis, whether the reports came from experiments, observations, or field experience.

Informing Readers about Evaluation Criteria

Criteria for evaluating information should be described in the synthesis methods. This is standard practice for meta-analyses and systemic reviews. In qualitative reviews, evaluation criteria are often integrated into the body of the synthesis with hedges and explanations, but any application of consistent, objective criteria should be described in the methods section.

2.3 Clear Description of the Main Points

A useful synthesis gives managers both a summary of current knowledge and an understanding of how this knowledge, gleaned from a variety of studies and reports, forms the basis for new insights that they can apply to management. The heart of synthesis is to provide greater insight than what is available from individual information sources—to "tell a trustworthy story" about what has been found (Popay and others 2006). Interviewees described this task in several ways:

- Identify the main ideas: "Put an umbrella over the information." "Boil it down." "Give us the bottom line."
- Describe the scope of what is known: "Explain what we know and what we don't know." "Describe the state of the knowledge."
- Weigh evidence: "Tell us what things are more similar than different." "Tell us what most of the evidence suggests."

"[E]xpert judgment is precisely what the reader should expect from the reviewer—otherwise a simple computer would do the job as well! Subjective evaluation is part and parcel of the special insight which the expert can bring to the discussion…. "

—H. J. Eysenck (1995). Journal of Evaluation in Clinical Practice. 1(1): 34.

Synthesis authors identify patterns and develop generalizations by thoughtful reflection on the meaning and limitations of the information available. While they offer insights and generalizations, they also need to keep their conclusions free from bias and explain how the limits of current knowledge constrain the story they tell. This section describes a few techniques for accomplishing this feat.

Describe the main points clearly:

- Describe pattern and lack of pattern in the information.
- Describe what is known, what is known but uncertain, and what is *not* known.
- Document statements so readers can answer the question, "Who says so and why?"
- Explain the bases for any inferences you have made.

Use of Information Source Tables

Synthesis authors often use tables of information sources to compare results across studies, look for patterns, and seek possible explanations for inconsistencies. These tables can help authors reach balanced, unbiased conclusions. Authors should be cautious about using information source tables for "vote counting"—that is, for drawing conclusions from the number of studies showing positive vs. negative or no significant effects (CEBC 2010; Gates 2002). Vote counting fails to weigh the quality and generalizability of the various sources, which is likely to bias the interpretation.

Information source tables used to develop syntheses are usually complex, containing many study attributes and extracted data. For example, a systematic review of the effects of thinning and burning on wildlife in conifer forests of the southwestern United States (Kalies and others 2010) recorded 16 descriptors of each information source (citation, species, taxonomic class, foraging guild, vegetation type, treatment, study design, time since treatment, variables measured, density estimation method, peer-reviewed or not, replicated or not, area of treatment, area of controls, experimental mean, control mean), and details were added as the sources were further analyzed. While extensive information source tables are important documentation, they could unnecessarily clutter the text of a synthesis, so authors often include pared-down versions in the final publication. These enable readers to examine patterns for themselves and access primary literature when additional understanding is needed. The following questions can be used to develop information source tables for publication (adapted from Irland 1995):

1. Does the table include all relevant information sources, thus giving a balanced view and avoiding bias?

2. does the table show the important information without oversimplifying?
3. Do the caption and notes clearly identify the purpose of the table and the nature of its content?
4. Is the table set up so readers can easily follow the logic and find the most important patterns?
5. Does the selection and order of rows and columns emphasize relationships?
6. If the table seems too long or too complex to include in the text, should it go into an appendix?

A synthesis of fire regime information on Alaskan tundra (Innes 2013) demonstrates the use of information source tables. The synthesis includes four such tables, each covering a different variable or a different time period. The table on paleoecological research (Table 4) includes qualitative information on study locations and methods, which may be useful for readers to understand the studies' applicability to specific management questions; and quantitative information on fire return intervals, which suggest a relatively consistent pattern across the time periods and plant communities represented. An information source table in Ryan and others' (2012) synthesis on fire and cultural resources directs readers to literature that can be used for specific purposes (information, further literature search, and modeling/monitoring). An eight-page information source table is included as an appendix to Kennedy and Fontaine's (2009) synthesis on fire effects on wildlife. Its express purpose is to provide access to original research, so it is limited to study attributes (citation, time since fire, season, type of fire studied, class and size of animals studied, and six others) and does not include results. Managers can use the table to obtain the sources most relevant to local management; they may choose to rely most heavily on "nearby" studies in making decisions.

Use of Inference

Another technique for developing a "trustworthy story" is inference, that is, the process of drawing a logical conclusion about something *unknown* based on something that *is* known (Merriam-Webster 2007). Extrapolation, the process of estimating the value of

Table 4—Information source table for a qualitative review of fire regimes in Alaskan tundra. Illustrates inclusion of qualitative information to show the geographic scope and methods of each study and quantitative information (mean fire return intervals) to show patterns in results. Adapted from Innes (2013), Table 4.

Location	Plant community	Mean fire return interval or range (years)	Methods	Reference
Kenai Lowlands	Shrub-herb tundra during late Pleistocene and early Holocene (13,000 years BP)	138	Pollen, plant macrofossils, and sedimentary charcoal from 3 lakes	Anderson and others (2006)
South-central Brooks Range	Bog birch (*Betula glandulosa*) and/or dwarf birch (*B. nana*) shrub tundra during the late Pleistocene and early Holocene (13,300–10,300 years BP)	137–150	Fossil pollen and stomata and sedimentary charcoal from 4 lakes	Higuera and others (2011)
	Forest-tundra during the mid-Holocene (8,500–5,500 years BP)	131–238		

a variable outside the range observed, is a form of inference. Inference is a powerful thought process that extends the usefulness of observed information. When statistical inference is used, authors use probabilities to indicate their confidence in the repeatability of results. For example, a synthesis on fuel management in dry mixed-conifer forests of the northwestern United States (Jain and others 2012) notes, in several instances, how sample size and geographic distribution limit the strength of generalizations based on the evidence. When extrapolation is used, synthesis authors should explain its logical basis to the readers. Several good examples are available: A national synthesis on fire and nonnative invasive species (Zouhar and others 2008a) points out that "cautious inferences" can be made about a plant species' response to fire based on morphological traits such as presence of dormant buds and ability to sprout. "However, fires and mechanical disturbances alter a site in different ways, so biological responses cannot be assumed to be equivalent." McIver and others (2012) point out that, even though the Fire and Fire Surrogate study (based on 15 years of experimental treatments at 12 study sites) demonstrated that mechanical treatment may reduce forest canopy cover to the same extent that fire does, "one cannot infer that the responses of most ecosystem components will be similar."

Explaining the Basis for Generalizations

Synthesis readers may ask, "How do you know?" "How sure are you about this pattern?" The first question is addressed mainly by in-text citations. It is important to put the citation close to the information itself so readers can follow up if they need details (Figure 6). A bibliography at the end of a synthesis (or related summary or fact sheet) is no substitute for in-text citations because readers cannot connect an assertion in the text with a specific source. If the synthesis planning team decides that author-date citations embedded in the text are likely to be an obstacle to readers, they might decide to use a citation numbering system instead. This practice, shown in Figure 6, is followed in the 1,100 syntheses published in FEIS (http://www.feis-crs.org/feis/).

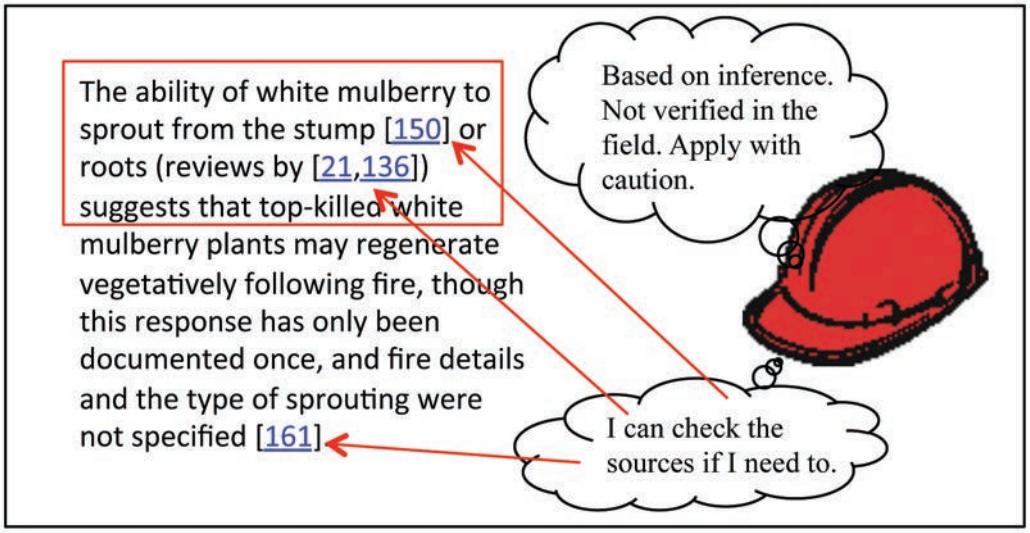

Figure 6—A synthesis should tell the reader when inference is used and identify sources of specific information. In this example from Stone (2009), it would be more difficult for the reader to find documentation if the citations were all listed at the end of the sentence, as follows: "The ability of white mulberry to sprout from the stump or roots suggests that top-killed white mulberry plants may regenerate vegetatively following fire…. [21, 136, 150, 161]."

"Researchers' world is to hedge, but managers' world is to apply, usually in the face of uncertainty. Help us figure out how to bring the science to a piece of ground. Sometimes field people need to understand extrapolation; they think 'if research wasn't done on their piece of earth, it doesn't apply.'"

—Jim Thinnes, Regional Silviculturist (retired), USDA Forest Service

The question "How sure are you?" is more difficult to answer except in meta-analysis, where statistical analysis is used. Conclusions in qualitative reviews and the narrative portions of systematic reviews are based on many information sources, each with its own uncertainties—already considered by authors when they decided what sources to include in the synthesis. Do generalizations based on these sources compound the uncertainties, or does the information base taken as a whole provide stronger evidence than the individual sources? Synthesis authors need to make this judgment and communicate their level of confidence in the generalizations they present. This is commonly done with "hedging"—placing a verbal boundary around a statement (Figure 7). Hedges lengthen a synthesis and make it more complex, so they are best used to communicate specific limitations of the information given—for example, to show the geographic scope of a study or identify a lack of published research (Figure 8). Hedges let the manager make decisions with awareness of uncertainty (Reckhow 1994) and can prevent reports based on anecdotal information from taking on the appearance of experimental evidence simply by being cited (Marlow 2000).

There is nothing wrong with uncertainty—it is in the nature of most knowledge, and it is the context in which most land management decisions are made (Brewer and Gross 2003; Fazey and others 2004; Reckhow 1994; Thompson 1986). Hedges should not prevent managers from using the knowledge presented; they should simply inform the managers about the basis for that knowledge.

Synthesis authors use short, vague hedges to tell readers that a generalization is not likely to apply in every case. While these hedges are important for accurate communication, they are imprecise and hence not very useful for readers: Does "is likely to happen" mean the same thing as "probably will happen" or "could potentially occur"?

Figure 7—Hedges in technical writing are analogous to hedges in landscaping: they place a verbal boundary around a statement, indicating a study's limitations or the authors' level of confidence in an assertion. Hedges should be used to help the reader avoid "straying" outside the limits of the information base in applying the information to management.

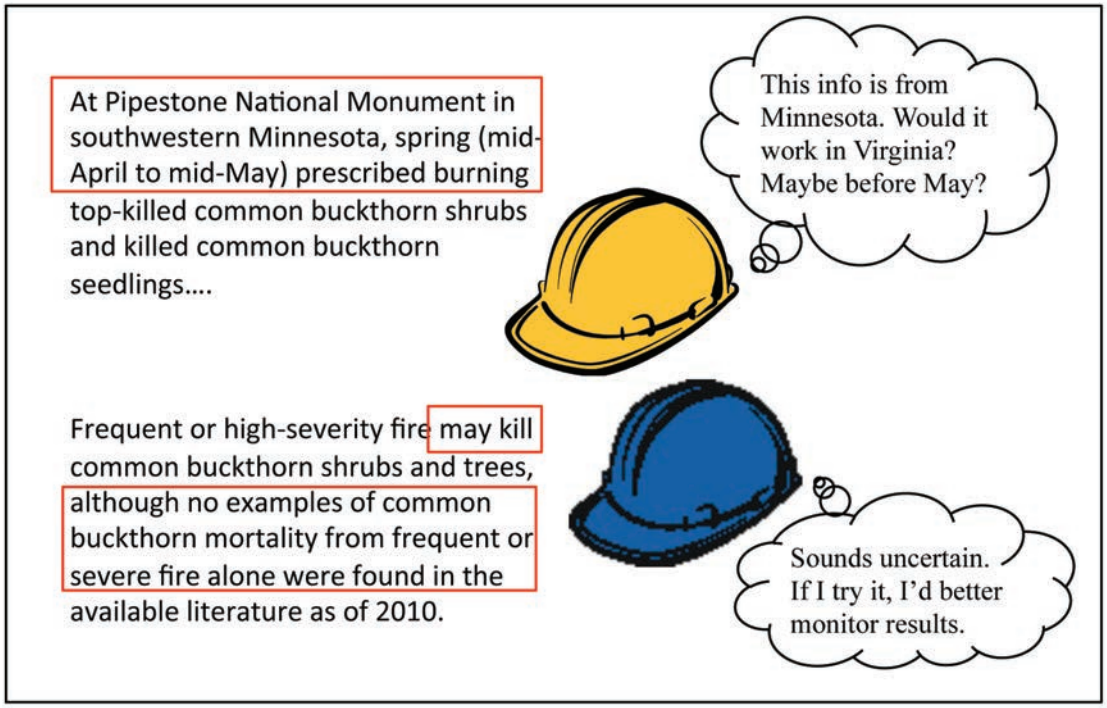

Figure 8—Hedges can tell the reader about a study's scope of inference (top—indicates geographic limits) or an author's level of confidence (bottom—indicates an inference but no basis in observations). Examples are from Zouhar (2010).

How much more probable is "very likely" than "likely"? The Intergovernmental Panel on Climate Change Technical Summary (Solomon and others 2007) uses a more precise way to express confidence in conclusions. The authors use one set of terms to express their level of confidence in a conclusion based on expert judgment of its scientific basis (Table 5A) and another set to express the likelihood of an event based on statistical analysis (Table 5B). This technique enables the authors to "… express high confidence that an event is extremely unlikely (e.g., rolling a dice twice and getting a six both times), as well as high confidence that an event is about as likely as not (e.g., a tossed coin coming up heads)." Because the authors express their confidence in conclusions with consistent terminology, readers of the report can compare various conclusions and apply the findings with appropriate caution. I have not found this technique used in any syntheses on wildland fire, but it could be considered in the future.

Describing Information Gaps

A synthesis must explain what is *not* known as well as what *is* known (with varying levels of confidence). Information gaps are often expressed in hedges and concluding sections of syntheses. Systematic analysis of information gaps is unusual, but it could help ensure that future research and monitoring efforts target the greatest needs and "deliberately provide data for synthesis" (Chen and others 2013). The literature on wildland fire provides two quantitative analyses of information gaps, both examining information on relationships between fire and invasive plants (Gucker and others 2012; Zouhar and others 2008b). The authors identified the topics most relevant to fire management, noted the number of information sources available for a synthesis in FEIS on each topic, and ranked the information quality depending on the source (in Zouhar and others 2008b) or whether it was based on direct observation or not (in Gucker and others 2012). The results describe the amount and quality of information available for each synthesis ("Species Review") on each topic (Figure 9). This kind of analysis can be used by scientists and research sponsors to prioritize future studies and by managers to prioritize monitoring on topics where information is most needed.

Table 5—Verbal descriptions of confidence in conclusions (A) and probabilities of outcomes (B) used in the Technical Summary (Solomon and others 2007) and Summary for Policymakers by the Intergovernmental Panel on Climate Change (Intergovernmental Panel on Climate Change 2007).

A. Levels of confidence in conclusions, based on expert judgment of science basis by authors.

Confidence terminology	Degree of confidence in being correct
Very high confidence	At least 9 out of 10 chance
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

B. Verbal labels for likelihood of outcomes, based on quantitative estimates of probability.

Likelihood terminology	Likelihood of the occurrence/outcome
Virtually certain	> 99% probability
Extremely likely	> 95% probability
Very likely	> 90% probability
Likely	> 66% probability
More likely than not	> 50% probability
About as likely as not	33 to 66% probability
Unlikely	< 33% probability
Very unlikely	< 10% probability
Extremely unlikely	< 5% probability
Exceptionally unlikely	< 1% probability

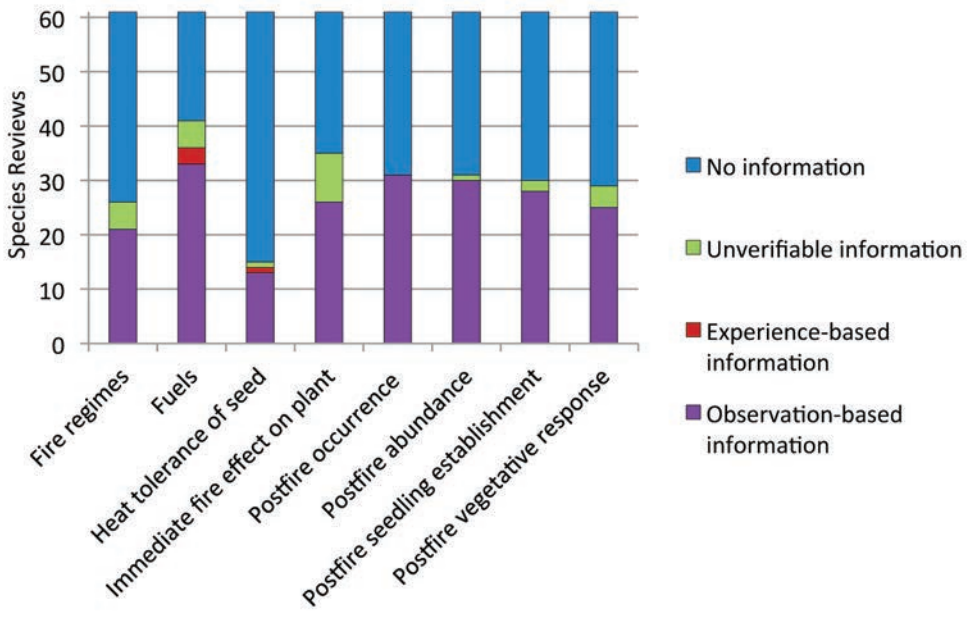

Figure 9—Quality of information available for each fire topic in 61 FEIS species reviews covering fire and invasive plants in the eastern United States (Gucker and others 2012). Bars are divided to show the highest quality of information available in each review: observation-based, experience-based, unverified, or no information at all. For example, information on fire regimes (leftmost bar) was available for less than half of species reviews.

Two kinds of information gaps are mentioned frequently in syntheses on fire effects: lack of long-term information and the limited geographic scope of research. Long-term studies of fuel treatments, for instance, are "scarce" (Jain and others 2012), which limits the usefulness of research for management and the reliability of fuel modeling over long periods. Hood (2010) refers to 41 studies on old- or large-tree mortality after fire; all but 3 of these studies reported results from less than 10 post-fire years. Peppin and others' (2010) systematic review of the effectiveness of post-fire seeding notes a lack of information from more than 2 years after fire. Of 43 syntheses covering fire effects on nonnative invasive plants written for FEIS between 2001 and 2006, only 30% contain information from more than 1 year after fire (Zouhar and others 2008b). This means that 70% of the reviews could provide no insight on whether populations of invasives are likely to increase or decrease with time. Wildland management plans are used for decades and public wildlands are to be managed for generations to come. The paucity of long-term studies is a serious problem for managers that cannot be addressed reliably by extrapolation from short-term measurements.

The applicability of a fire study to a particular management problem depends partly on the spatial scale of measurements and partly on the similarity between the ecosystem studied and the ecosystem being managed. Despite the breadth of information on fire-wildlife relationships collected in the Fire and Fire Surrogate program, Kennedy and Fontaine (2009) note that plot-level data from these studies cannot easily be applied at landscape scales. The need for information from a greater range of ecosystems has been identified in syntheses on climate change (Ryan and Vose 2012) and invasive species (Gucker and others 2012). Gucker and others' analysis of 61 FEIS species reviews noted that most observation-based reports came from a small fraction of the area in which the species occurred. In the synthesis on white mulberry (*Morus alba*) (Stone 2009), for instance, the only observation-based information about fire came from one state (New Mexico), even though the species occurs in 48 states. To apply the information appropriately, managers in areas outside New Mexico need to know about the limited geographic scope of the information base.

2.4 Clear Discussion of Management Implications

Managers' greatest source of dissatisfaction about syntheses comes from their need to apply information to specific, local management issues. Interviewees commented:

- Tell us the information means this and not that. Use it this way but not that way.
- Tell *us* how this relates to *us*.
- Clearly identify the "so what."
- Often the only thing in there for managers is little tiny management implications at the end.

Managers also described the discussion of management implications as "weak," "hesitant," and "too generalized to be useful." Differences between the professional "worlds" of managers and scientists can create a tension between the desire for readily applicable results and the desire for scientific defensibility. It is crucial for the synthesis planning team to consider how to address this tension—how to

Present management implications clearly:

- Write clear management implications that address the objectives of the synthesis.
- Connect management implications with their foundations in the information base.
- Consider having managers write or co-author management implications.
- Include examples or case studies that make implications concrete and vivid.
- Package the synthesis so management implications are highlighted and easy to find.

"There is no point in conducting reviews if ... the implications of the reviews for conservation management are unclear."

Ioan Fazey and others (2004). Environmental Conservation. 31(3): 194.

highlight potential applications without obscuring the extent, quality, and limitations of the information base. These decisions will affect every aspect of the synthesis, so the participation of managers, who represent the primary audience, is essential.

Many syntheses on fire are developed through dialogue between managers and scientists. Examples include Bartuszevige and Kennedy (2009), Evans (2008), Evans and others (2011), and Foltz and others (2009). It would be difficult to quantify the extent of these dialogues and I did not attempt to do so, but I suspect that the more isolated the authors are from managers, the less likely it is that the final product will meet managers' needs. Dialogue requires a commitment from all partners but also benefits everyone, as described by Charlie Luce, lead author of the synthesis on climate change, forests, fire, water, and fish (Luce and others 2012). Luce explained that development of this synthesis began with extensive discussion of management questions, including a full-day planning meeting with line officers. Line officers might not easily recognize the importance of explaining their decision processes and dialogue with the public to scientists, Luce noted, but these insights were critical for scientists to make the synthesis relevant to real-world decisions. The dialogue also helped scientists begin "boiling everything down" for presentation to managers. Luce pointed out that the section on management actions and decisions in the synthesis was the most challenging section but also helped him grow and influenced his research career. "It helped my science be more productive and pertinent." He also emphasized the importance of collaboration among authors, such as asking colleagues, "Can you please write this better than I can?"

Nearly a third of interviewees suggested having managers write or co-author sections on management implications. While scientists may find it difficult to describe practical applications of knowledge in the complex management arena, managers may be able to do so directly and concisely. Several qualitative reviews feature managers as authors. For example, Rebecca Timmons, Forest Archaeologist on the Kootenai National Forest, Montana, is lead author of the "Implications of Fire Management" chapter in a synthesis on fire effects on cultural resources (Timmons and others 2012). Becky Estes, Province Ecologist on the El Dorado National Forest, Placerville, California, co-authored a synthesis on effects of prescribed fire season (Knapp and others 2009). Fred Pierson, Range Hydrologist with the Agricultural Research Service, co-authored a pair of synthesis documents on western juniper (Miller and others 2005, 2007).

"Management implications are the most important part. If researchers hesitate to write these, why not partner with a practitioner who has experience in applying similar research in the field?"

—Mary Taber, Fire Ecologist (retired), National Interagency Fire Center, Department of the Interior, Bureau of Indian Affairs

At the very least, managers should review the synthesis thoroughly ("not just to rubber-stamp it") and offer ways to improve its relevance to management. Questions for manager-reviewers might include:

- Does the synthesis address the most important management questions?
- Does it capture the most important management implications?
- Are the implications presented clearly?
- Are practical examples included, so readers can understand how to apply the findings? (Examples of failure may be just as important as examples of success.)
- Does the synthesis describe fundamental concepts, so readers can grow in ability to interpret information for themselves?

Case studies from managers can form the basis for a synthesis, as Evans's (2008) synthesis on biomass removal illustrates. Case studies can also be used to demonstrate management applications. For example, a case study is used to demonstrate each management principle described in Hunter and others' (2007) guide to fuels treatment for ponderosa pine (*Pinus ponderosa*) forests. The case studies give a sense of concrete reality and practicality to abstract concepts such as "integrating ecological principles," "encouraging innovative approaches," and "collaboration to improve results."

"Tell me early on why I should care."

—Jennifer Northway, Coordinator, Alaska Fire Science Consortium

Scientific and technical writers often fail to recognize that even objective, scientific writing must be persuasive, in that the author must persuade the reader to continue reading. It is important to show, at the very beginning, how a synthesis will be useful—what kinds of questions it addresses and what kinds of problems it may help solve. Many syntheses isolate management implications at the end of each chapter or at the end of the document. Three of the six publications in the "Wildland Fire and Ecosystems" series do so (Brown and Smith 2000; Ryan and others 2012; Smith 2000). However, this may be exactly the reverse of what will appeal to readers. The synthesis planning team should consider presenting management implications early in the document, integrating them throughout, or possibly organizing the whole document according to management issues— using, for example, questions from stakeholders or topics required for NEPA documents as the organizational basis. The synthesis on public perceptions of fire management (McCaffrey and Olsen 2012a) addresses "eight essential questions" that evolved out of discussions among managers, policy makers, and scientists (McCaffrey, personal communication 2014). The systematic review of the effectiveness of post-fire seeding answers three management questions: Does seeding reduce soil erosion? Does it reduce invasion by nonnative species? Does it affect the recovery of native plant communities? Miller and others (2007) produced a field guide to describe appropriate management applications of their synthesis on western juniper ecology (Miller and others 2005). The guide addresses 29 questions that must be answered for a rapid, qualitative assessment of a field site.

"Organize the whole synthesis according to the applications, so they are clear and easy to find but substantiation for them is also easily available."

—Bob Gillaspie, State Rangeland Management Specialist, Oregon State Office, USDA Natural Resource Conservation Service

While a synthesis for managers must discuss implications for practical decisions, it may not be able to offer unambiguous guidelines. Management issues and the social context for decision-making vary from place to place and time to time, so different decisions could be based on the same evidence (CEBC 2010). Because of the complex, dynamic nature of ecosystems and management issues, managers need to bring their own experience together with all other evidence—from syntheses, the primary literature, monitoring programs, and other sources—so they can make wise decisions and take appropriate actions (Figure 3). The description of fundamental concepts provided by a synthesis can give managers a basis for thinking through this maze of information. The conceptual framework may be based on biological principles, as described in the "Fire Autecology" chapter in "Effects of Fire on Flora" (Miller 2000); or it may be based on management considerations, such as the five "general principles" offered by Luce and others (2012) to guide aquatic-terrestrial planning for fire:

"Keep in mind that managers are paid to pull ideas together—to synthesize and apply."

—Jeff Rose, Associate District Manager, Department of the Interior, Bureau of Land Management

1. Holistic approaches are required
2. Spatial arrangement has relevance
3. The system is dynamic
4. Sustainable solutions are needed
5. Timing may be critical

The fundamental concepts described by syntheses can suggest perspectives and processes for approaching problems with no precedents, a limited information base, diverse stakeholders, and dynamic, interacting causes—the kind of problems that often characterize the world of fire and resource management.

Many of the points described in this section and the next two—on clear writing and organization—are illustrated in syntheses already published on fire management issues (Table 6). These examples were chosen to demonstrate a variety of approaches for meeting the challenges that authors face in writing, organizing, and packaging a synthesis. Of course, there are many other effective ways to meet these challenges. Synthesis planners and authors would benefit from searching for ideas in a wide variety of syntheses and other documents.

Table 6—Examples of effective writing, organizational, and packaging features in syntheses for fire management.

Synthesis	Illustrates these features of effective synthesis:
1. Birds and burns of the Interior West (Saab and others 2007) (http://www.treesearch.fs.fed.us/pubs/27925)	• Abstract presents findings concisely • Conceptual background is set off and highlighted in colored boxes • Examples are highlighted in colored boxes
2. Climate change, forests, fire, water, and fish: building resilient landscapes, streams, and managers (Luce and others 2012) (http://www.treesearch.fs.fed.us/pubs/41932)	• Informative title (tells us it is interdisciplinary and lists the topics covered) • Definitions in callouts (p. 7) • Pictorial definitions (p. 44)
3. A comprehensive guide to fuel management practices for dry mixed conifer forests in the northwestern United States (Jain and others 2012) (http://www.treesearch.fs.fed.us/pubs/42150)	• Key messages from all sections presented early on, all in one place (pp. 5–7) • Structure consistent among sections • Definitions and supplemental information in callouts
4. Do thinning and/or burning treatments in western USA ponderosa or Jeffrey pine-dominated forests help restore natural fire behavior? (Fulé and others 2012) (http://www.sciencedirect.com/science/article/pii/S0378112711007729)	• Title is a management question • Conclusions section provides clear summary • Review is systematic, with clear criteria for including and assessing information
5. Ecological effects of prescribed fire season: a literature review and synthesis for managers (Knapp and others 2009) (http://www.treesearch.fs.fed.us/pubs/33628)	• Cover graphic gives information on both topic and organization • Findings shown as bulleted lists early in document (p. 4) and in each regional section • Graphics illustrate relationships between different kinds of information (p. 10, 30, 44)
6. Effects of climatic variability and change on forest ecosystems: a comprehensive science synthesis for the U.S. forest sector (Vose and others 2012) (http://www.treesearch.fs.fed.us/pubs/42610)	• Executive summary thorough, direct, well organized. • Implications discussed by geographic region within executive summary
7. The effects of forest fuel-reduction treatments in the United States (Stephens and others 2012) (http://www.treesearch.fs.fed.us/pubs/40902)	• Title clear • Abstract informative, easy to read • Clear graphic illustrates results of meta-analysis (p. 554)
8. Mitigating old tree mortality in long-unburned, fire-dependent forests: a synthesis (Hood 2010) (http://www.treesearch.fs.fed.us/pubs/35004)	• Vivid photos and graphics with clear labels and captions • Management options discussed by scale (landscape, site, individual tree)
9. Post-fire treatment effectiveness for hillslope stabilization (Robichaud and others 2010) (http://www.treesearch.fs.fed.us/pubs/35691)	• Clear explanation of relationship to previous work • Concise case studies, written by managers and shown as side bars, illustrate individual points • Detailed results placed in appendices
10. Post-wildfire seeding in forests of the West: an evidence-based review (Peppin and others 2010) (http://www.treesearch.fs.fed.us/pubs/36515)	• Abstract easy to read, states findings clearly • Discussion organized according to management questions • Review is systematic, with clear criteria for including and assessing information
11. Research perspectives on the public and fire management: a synthesis of current social science on eight essential questions (McCaffrey and Olsen 2012a)	• Organized as list of questions about topic • Clear summary at end of each section
12. Synthesis of knowledge from woody biomass removal case studies (Evans 2008) (https://www.firescience.gov/projects/07-3-2-02/project/07-3-2-02_Biomass_Case_Studies_Report.pdf)	• Each section begins with bulleted list of findings • All findings linked to numerous case studies • Case studies represent ecosystems throughout continental United States
13. Synthesis of knowledge of extreme fire behavior: volume I for managers (Werth and others 2011) (http://www.treesearch.fs.fed.us/pubs/39553)	• Graphs clean, uncluttered (Chapter 4) • Callouts (p. 25) highlight key concepts
14. A synthesis of the science on forests and carbon for U.S. forests (Ryan and others 2010) (http://www.treesearch.fs.fed.us/pubs/35006)	• Clear, appealing graphics with stand-alone captions. Readers can learn much about content by reading the pictures.

2.5 Clear Writing

Clear writing is so important that it is required by law in federal documents.[5] Skilled authors respect the reader's time and attention by making the document as easy to follow as possible or, as Blum and others (2006) express it, by providing "unfailing courtesy to the reader." However, clear writing is difficult in a synthesis because it brings information together from many disciplines and dozens to hundreds of sources. In this arena, as in other aspects of synthesis production, collaboration can help. The authors can be scientists, science delivery specialists, managers, or technical writers—or any combination—as long as they produce a clear document, easily readable by managers.

Write clearly:

- Write for the main audience—managers in fire and related natural resources.
- Consider other potential readers to avoid creating an "inside story" accessible only to professionals.
- Include summaries and lists of key points.
- Get reviews from managers, scientists, science delivery specialists, and any other audience whose understanding is crucial to success. Then use their comments to fine-tune the document.

Follow Principles for Good Writing

"Good writing doesn't come automatically for everyone, if ever. It has to be practiced over and over," according to Lane Eskew, Director of Publishing Services at the Forest Service's Rocky Mountain Research Station (Eskew, personal communication 2014). In my own writing and in editing syntheses for managers, I have found five principles especially important:

1. Begin by describing the most important findings and why they matter. This applies to organization of the whole document and also to the sentences that begin paragraphs and sections ("topic sentences"). I provide a few examples, good and bad, from my own writing (Table 7). The "effective" examples all contain a single kernel of information that is further explained throughout the section, while the "ineffective" examples either give no substantive information at all or emphasize something unimportant to readers, rather than an important idea to be developed in the rest of the section.
2. Minimize technical language, agency-specific language, acronyms, and other jargon. These features exclude readers (Thompson 1986) when the point of a synthesis is to include everyone who can use the information—the primary audience (fire managers) and also policy makers, professionals from other disciplines, students, and members of the public.
3. Emphasize the meaning of research findings, not the person or group who did the research and not the details of methods and statistics.

[5] The Plain Writing Act of 2010 requires that federal agencies use "clear government communication that the public can understand and use" (http://www.plainlanguage.gov/plLaw/). The Agricultural Research Service provides these directions for implementing the National Environmental Policy Act of 1969: "Environmental documents should be concise, written in plain language, and address the issues pertinent to the decision being made" (http://www.ecfr.gov/cgi-bin/retrieveECFR?gp=1&SID=0eddda6100d2d2d5480cf28b8b568077&ty=HTML&h=L&r=PART&n=7y6.1.2.1.8). Forest Service research papers are included in the USDA guidelines for compliance (U.S. Department of Agriculture 2011).

Table 7—Examples of effective and ineffective synthesis statements.

Statement function	Effective example	Explanation	Ineffective example	Explanation
Introduce paragraph ("topic sentence")	Physical properties of a fire, if known, are logical descriptors of fire severity (Smith and Fischer 1997).	Makes a clear assertion and suggests that details and documentation follow.	Several studies report declines in bird abundance or species diversity in the first year or two after stand-replacing fire, but few reports are available for the months immediately following fire (Lyon and others 2000).	Focuses on research woes rather than results. Is the paragraph about the many or the few? What do the few studies actually say?
	Two landscape-related aspects of fire, size and homogeneity, influence colonization and populations of small mammals on recent burns (Lyon and others 2000).	Indicates that two items will be discussed and tells the reader what they are.	Many strategies for evaluating and addressing potential postfire invasions by nonnative species are described in this volume… (Smith and others 2008).	Suggests that information is forthcoming but does not actually give any. It would be better to give a key idea about the many strategies or to say that they show no consistent pattern.
Introduce section	Fires may directly reduce populations of invertebrates that reside in or deposit eggs in the surface vegetation or the forest floor (Smith and Fischer 1997).	Makes a clear assertion and suggests that details and documentation follow.	Permanent alder communities in northern Idaho… have been described by Daubenmire and Daubenmire... (Smith and Fischer 1997).	Emphasizes the reference rather than what was learned. It would be better to report the findings and document them with the citation reference.
			The amount of fuel in seral lodgepole pine stands varies… (Smith and Fischer 1997).	Suggests that information is forthcoming but does not actually give any.
Introduce research results	If basal scorch occurs, or if 30 percent or more of the crown is scorched, growth is likely to decrease (Smith and Fischer 1997).	Emphasizes fire effects in the field rather than measurement methods or statistical results.	Duff depth reduction was positively correlated with preburn duff depth and negatively correlated with preburn duff moisture (Smith and Fischer 1997).	Emphasizes the statistical result, not biological results. The mixture of "ups" (positive correlation) with "downs" (reduction and negative correlation) makes it hard to follow.

4. Find exactly the right word or term for an idea and use it consistently; do not try to make the writing "more interesting" by using synonyms. Consistency tells the reader exactly which idea is being discussed, and it is essential for readers who will use electronic searching to track a concept's development.
5. Use a direct quote if an author said something better than you can. Summarize the thought in your own words (and cite the author) if you need to place it in context or show how it applies to your topic. If several authors have made the same point, capture the idea in your own words (that is, *synthesize* their thoughts) and cite all of the authors.

The subject of technical writing is much too large for this report, and excellent resources are available to help authors improve their skills. These four sources have been especially useful for me:

- "Notes on Writing Papers and Theses" (Lerzman 1995), a short article written for science students, provides clear guidance on use of concise, direct language: "Do not use more words where fewer will do."
- "Writing a Review Article for *Psychological Bulletin*" (Bern 1995) obviously does not focus on synthesis for resource managers, but it describes the nature of synthesis very well. It is written with a sense of humor and good examples.
- *Writing Science in Plain English* (Greene 2013) is a small, concise book that provides 12 guidelines for scientific writing, explains the reasoning behind each guideline, demonstrates effectiveness with real examples, and gives exercises in which the reader can revise an example and then compare it with the author's version.
- *The Mayfield Electronic Handbook of Technical and Scientific Writing* (Perelman and others 2001) is a comprehensive, well organized guide available at http://www.mhhe.com/mayfieldpub/tsw/home.htm. It is written concisely, provides excellent navigation aids, and covers dozens of kinds of technical documents.

Include Summaries

Readers use summaries to decide if they want to look for more details or move on. Therefore, summaries must be clear, concise, and focused on managers' information needs. By the time the authors have finished a draft and are ready to write summaries, they may be worn out and feel that this is just repetitive work. However, this is not the time to dash something off carelessly, because summaries are essential persuasive and navigational tools.

If a synthesis will be published in a journal, the only summary will probably be a one-paragraph abstract at the beginning of the article. Abstracts for research articles usually cover all aspects the project (Perelman and others 2001), which often jams them full of ideas and makes them difficult to read. This approach will not answer the needs of managers, who need quick access to important findings. An abstract for a synthesis should present the most important findings concisely and clearly. A good example is the abstract for a systematic review on fuel reduction treatments published in *BioScience* (Stephens and others 2012). It is just 147 words long, yet it states the conclusions and management implications clearly without oversimplifying this complex subject (Figure 10).

If the synthesis will be published as a stand-alone document, the authors may have flexibility in the number and format of summaries. They can use short paragraphs, bulleted lists, or a combination; they may even include important graphics or tables. Syntheses

The Effects of Forest Fuel-Reduction Treatments in the United States

The current conditions of many seasonally dry forests in the western and southern United States, especially those that once experienced low- to moderate-intensity fire regimes, leave them uncharacteristically susceptible to high-severity wildfire. Both prescribed fire and its mechanical surrogates are generally successful in meeting short-term fuel-reduction objectives such that treated stands are more resilient to high-intensity wildfire. Most available evidence suggests that these objectives are typically accomplished with few unintended consequences, since most ecosystem components (vegetation, soils, wildlife, bark beetles, carbon sequestration) exhibit very subtle effects or no measurable effects at all. Although mechanical treatments do not serve as complete surrogates for fire, their application can help mitigate costs and liability in some areas. Desired treatment effects on fire hazards are transient, which indicates that after fuel-reduction management starts, managers need to be persistent with repeated treatment, especially in the faster-growing forests in the southern United States.

Stephens and others (2012) in *BioScience* 62(6): 549.

Figure 10—Concise, informative abstract from a systematic review on the effectiveness of fuel reduction treatments (Stephens and others 2012).

often provide an executive summary at the start of the document. If this summary is fairly long, it should include headers to help readers find the topics they are looking for and page numbers or electronic links to help them find the details on any topic. An alternative may be to provide a short summary or a list of key points with every section. Table 6 (p. 26) contains several examples of fire syntheses with well-written summaries and lists of key findings.

Use Reviewers and Editors

Good reviewers and editors can help improve content, clarify the writing, and make the synthesis fit the audience. Since many of us writers become a little defensive when we receive criticism, Bern's (1995) comment about reviews is worth considering: "If your colleagues find something unclear, do not argue with them. They are right: By definition, the writing is unclear. Their suggestions for correcting the unclarities may be wrongheaded, but as unclarity detectors, readers are never wrong."

If a synthesis is written for managers, then managers should review it carefully. They can identify language that readers will stumble on and places that readers will find hard to navigate. They can point out content areas that need more (or less) explanation. Managers can also identify ideas in the synthesis that seem inconsistent with conventional wisdom and thus might require extra explanation, examples, and more thorough documentation, since readers usually compare new information with what they already believe (Lupia 2013).

2.6 Clear Organization, Easy Navigation

Few fire professionals read syntheses from cover to cover; most scan them or look for specific topics (Smith and others 2013). Thus it is critical that authors organize syntheses and select navigation tools that will help readers find the information they need quickly and easily. The document's organization is not about all of the hard work that the planning committee and authors did to get it done. It is not about subject-matter

"To read anything, I have to be convinced right away that it will save me time over the use of other resources. "

—Randi Jandt, Fire Ecologist, Alaska Fire Science Consortium

Organize clearly and package for easy navigation:

- Base organization and navigation on the ways in which managers seek information. Consult managers and science delivery specialists.
- If possible, organize according to management questions or issues.
- If the synthesis covers many geographic regions, seek ways to answer unique regional needs.
- Look at successful documents to find ideas for effective navigational tools and packaging techniques.
- Consider producing summaries, fact sheets, and other documents from the synthesis to reach diverse audiences and meet diverse needs. Use cross-references or electronic links to ensure that readers can always find the basis for assertions—"Who says so and why?"—in the synthesis.

viewed as isolated concepts, but rather about concepts viewed in the context of management. In this section I suggest ways to solve organizational problems, help readers find information, and package multiple synthesis products. Table 6 (p. 26) lists syntheses that demonstrate many of the features discussed here.

Solving Organizational Problems

Clear writing and clear organization are two sides of the same coin; neither serves readers well without the other. A logical, predictable structure helps readers follow the "trustworthy story" (Popay and others 2006) being told by the synthesis. If readers are lost among topics and details, they are not likely to read the story or find it trustworthy. The goal is to present information in discrete, relatively small pieces and offer it in an order that makes sense—usually by building understanding from start to finish or by making assertions at the start and explaining them in subsequent sections. If management questions can be used as the basis for organization, they probably should be.

Syntheses are usually interdisciplinary and highly integrated, so an author could place many "bits" of information in one of several different places. A guiding principle should be to put the information where it will be most useful to managers and cross-reference it, if necessary, from other locations. (Printed documents can use page references, and electronic ones can use links.)

Nearly half of interviewees commented that managers need easy ways to find region- and ecosystem-specific information in syntheses. Syntheses on ecological issues tend to be organized by region and ecosystem (for example, Evans and others 2011; Zouhar and others 2008c), but perhaps this is not sufficient. Some interviewees suggested writing region-specific syntheses rather than national ones. Others suggested producing national syntheses as a series of small, region-focused documents, possibly searchable from a map. However, one interviewee noted that, if geographic boundaries are "too strict," the reader will not benefit from information on neighboring areas or related topics. The many challenges inherent in developing a synthesis with national coverage should be discussed by the synthesis planning team and resolved early in the process of development.

Knapp and others' (2009) (http://www.fs.fed.us/psw/publications/documents/psw_gtr224/psw_gtr224.pdf) analysis of the ecological effects of prescribed fire season demonstrates several techniques for organizing and packaging a synthesis with national coverage. Even the cover graphic is well designed. A map shows the contiguous

48 states divided into three sections, a clever way to show the reader how the document is organized. The document's "Overview" explains the exclusion of Alaska and Hawaii, describes general concepts, and ends with a callout containing five key points that apply to management in all regions. Each section that follows applies these concepts to a single geographical region and begins with a graphic that integrates information on climate, prescribed fire season, and historical fire season; all of these graphics are based on the same template. Each section ends with a bulleted list of 5 to 7 key points. It is easy to move from one section to another because they all follow the same outline. The document's organization would also make it easy to repackage into smaller, region-based publications or online products.

Many readers access syntheses online, so each section should be relatively self-contained and "screen friendly."

- Write each section so it can stand alone as much as possible.
- Give readers a general idea of where you are going before you plunge into the details (Perelman and others 2001). Introductions and topic sentences (Table 7) serve this purpose, as does the practice of listing the topics to be covered at the beginning of a section (called "road mapping," "forecasting," or "signposting"). An example of a road mapping sentence is in the first paragraph of this section: "This section suggests ways to solve organizational problems, help readers find information, and package multiple synthesis products." The subsections that follow address these tasks in the order listed.
- Use parallelism. It is a friend to understanding. If several sections cover the same topics (as in regional syntheses), use the same structure in each.
- Provide information in small, "bite-sized" pieces. Keep paragraphs short enough to fit completely on a small computer screen. Limit sections to 5 or 6 paragraphs, each with an explanatory header.
- Use cross-referencing (linking in electronic documents) to help readers find background or details located in another section.

If authors or reviewers think a section is unclear or disorganized, it probably is. An "after-the-draft" outline can help authors fit the pieces together better. When I think I have finished a section or a manuscript, I often outline what I have written—paragraph by paragraph, sometimes sentence by sentence—to see if the ideas are in a logical order and each paragraph covers its topic fully. This helps me revise to improve organization and flow.

Helping Readers Find Information

"Make [the synthesis] an inviting document, a place they'll want to visit."

—Jamie Barbour, Program Manager, Focused Science Delivery and Goods, Services, and Values Program, Pacific Northwest Research Station

Navigating a synthesis can be like navigating a wilderness watershed: lots of interesting places, connected in subtle ways, easy to get lost. Navigational aids help readers know where they are and get from place to place easily to find the information they need. Effective layout, art work, and other packaging details help readers navigate and make the information more vivid and thus easier to grasp. These features also allow readers to browse through the synthesis for general impressions and ideas, even if they don't have time (right then) to read the details.

Publishers, editors, advertisers, and marketing specialists know much more about packaging information than I know or could learn in this project, as do science delivery specialists, such as the coordinators of the JFSP Knowledge Exchange Consortia. I suggest that authors examine many types of publications from various disciplines for appealing, effective ideas. Any tools selected for improving navigation and readability should be used consistently throughout the document so the reader knows what to expect from a given color, format, or other detail. These tools should enhance readability and navigation without cluttering the document and obscuring important points. Here are

11 suggestions based on interviewee comments and supplemented by information from the literature. Refer to Table 6 (p. 26) for examples.

1. Use bullets and numbered lists. They stand out from the text, so they are easy to find. If they are about management, emphasize them with color or feature them in a text box.
2. Use examples that illustrate the point clearly. If they would interrupt the text too much, put them in boxes.
3. On web pages, keep an outline in view that shows the reader's location. In printed documents, put the chapter and/or section header at the top of every page.
4. Use visually appealing features for emphasis: color, headers, font changes, white space.
5. Put supplemental information (concepts, definitions) that would clutter the text into boxes, footnotes, or appendices.
6. Make graphics "richly informative" (Henebry 2011). If text labels would help readers see the point of a photo, use them. If color would make graphs and diagrams easier to follow, use it. Use "colorblind safe" color schemes for any graphics where color differentiation is essential for interpretation[6].
7. Use photos to show readers what "the literature" looks like in a real place.
8. Use tables not just for data but also to organize concepts and information sources.
9. Write captions for tables and graphics so they explain the meaning rather than only identifying content, axes, and variables. Readers may examine these features to see if they want to read the section for more detail.
10. Use callouts to make concepts seem more real, draw the eye, and let readers know what is going on in a section.
11. Consider various ways to provide documentation. Papers in the fire management literature usually use author-date style to identify citations, but readers may find it difficult or annoying to "read around" them. In electronic documents, links could be used instead. In printed documents, a numbered-citation style, footnotes, or endnotes could be used.

"Pay attention in e-design to making sure the reader can get back to the original spot. We tend to wander within links and don't always keep track of what we started out to seek."

—John Barborinas, Wildland Fire Management Planner, National Interagency Fire Center, Bureau of Indian Affairs

Packaging Multiple Products

Syntheses for managers are usually envisioned as single documents, but most of them eventually form the basis for a family of related products because of diverse information needs. I have treated "managers" in this report as if decision makers, advisers, and field practitioners were one homogeneous group, but obviously they are not (Davis and others 2013). Furthermore, a synthesis for managers usually has important secondary audiences such as policy makers, students, and the general public. A variety of products based on the full synthesis can be used to

- Help advertise a new synthesis: "spread the word";
- "Translate" findings so they will make sense to a nontechnical audience (Chen and others 2013);
- Meet the needs of readers with a variety of learning styles (Davis and others 2013);
- Divide information into smaller modules to make it more "digestible"; and
- Highlight the information most pertinent for a particular purpose or region.

[6] Readers who cannot easily distinguish the colors in your tables and maps will be unable to interpret your findings and apply them to management. Why not be as inclusive as possible by using a "colorblind safe" color scheme? For guidance on map and graphic colors, see the National Science Foundation-sponsored website http://colorbrewer2.org.

"[Isolated] fact sheets are not good enough; provide the path to more detail. JFSP is good at publishing something and then creating a family of products around it."

—Richy Harrod, Deputy Fire Staff Officer, Okanogan-Wenatchee National Forest

The need for multiple products is not usually addressed in synthesis planning, but if it were, the entire suite of information might be packaged and delivered more effectively and efficiently.

Research organizations and science delivery specialists produce many products to advertise new information (for example, newsletters, briefing papers, fact sheets, and email messages). While these products are effective for directing readers to individual research papers, their effectiveness for lengthy, complex syntheses may be limited unless they direct readers to specific locations in the full synthesis. Suppose a newsletter article lists seven findings from a 200-page synthesis. The reader who looks at the fourth one and wants to know "Who says so?" must search the full synthesis for the explanation. Why not use the newsletter article to tell readers not only what the major findings are but also exactly where to find them in the full synthesis? This can easily be done with page numbers and/or electronic links.

A family of cross-referenced documents can be crafted from a foundational synthesis so each document stands on its own but can also lead readers to the other documents and, ideally, to the primary sources as well. The two examples below show how publications could be packaged to take readers from a short message or summary to more and more complete explanations and documentation:

1. A set of layered, cross-referenced documents (Figure 11). Readers could learn about a synthesis through a short message such as an email or tweet that lists a few key findings (top layer in the figure – purple). These findings would be described in a short, attractive summary document that is easy to find from the initial message. For example, a message about fire and forest carbon would lead readers to the *Fire Science Brief* (Frame 2010) that summarizes research on that topic (second layer in the figure – yellow). But the summary document

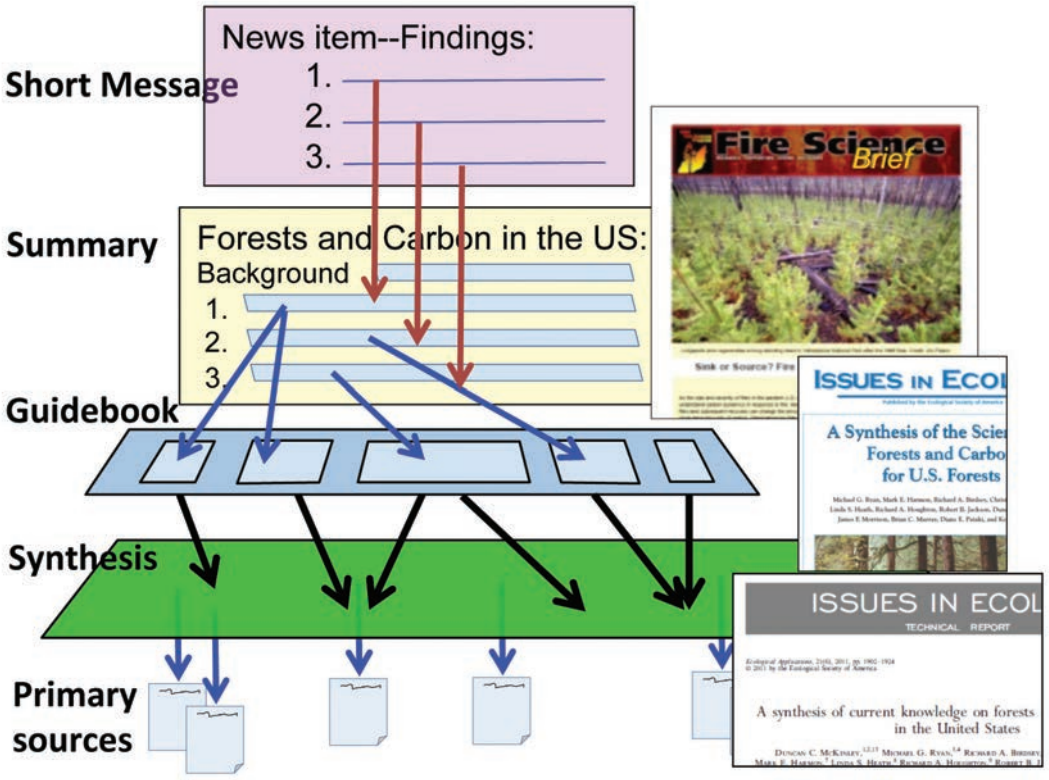

Figure 11—How a family of cross-referenced documents could be used to disseminate synthesis results.

would not simply list sources in a bibliography. To avoid being a dead-end for readers, the summary would cross-reference each major point with discussion and applications in more detailed, foundational documents. In this example, each key finding in a summary of information on fire and forest carbon would refer to discussion in a synthesis for general readers, such as Ryan and others (2010) (blue layer). The main points in the synthesis for general readers would refer to more rigorous explanations and further documentation in a synthesis published in a refereed journal, such as McKinley and others (2011) (green layer). The journal article is, of course, based on primary sources.

2. An expandable electronic document (Figure 12). This example refers to two documents on the social science of wildland fire – a full synthesis (McCaffrey and Olsen 2012a) and a 3-page flyer, which was released a few months before the publication was released to help readers "pick up a few morsels that may be of immediate use," and make them "generally aware of the research synthesis" (McCaffrey and Olsen 2012b). The webpage would open with a list of the 8 questions answered by the synthesis (top layer – green). When the user clicks on a question, the site would open excerpts from the synthesis regarding that specific question, as listed in the 3-page summary flyer (second layer, with question in red). When the user selects one of these questions, the site would open the section in the full synthesis that contains details and documentation (third layer, with question in gray header).

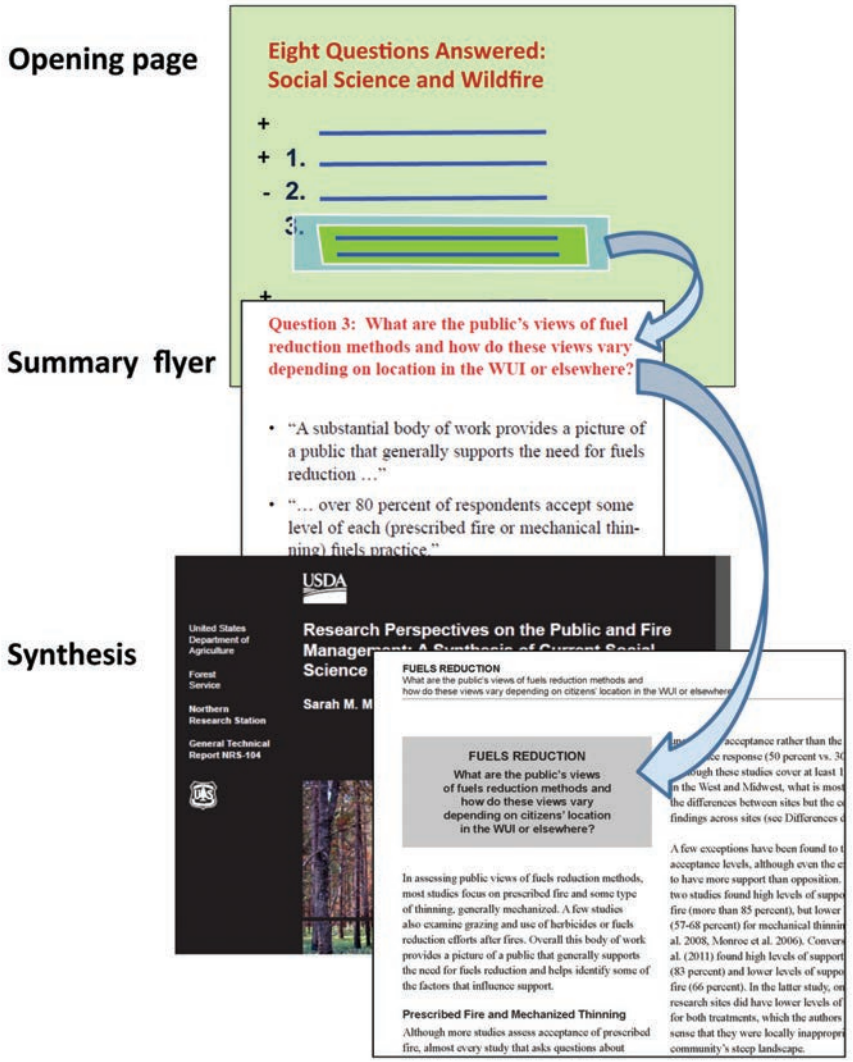

Figure 12—How an expandable structure in an online document could be used to package a family of synthesis documents.

2.7 Effective Marketing and Delivery

"[S]cience communication needs to be explicitly considered early in the project planning cycle, and … funding needs to also be dedicated to the movement of knowledge."
—Gussai Sheikheldin and others (2010). Environmental Management. 45: 920.

Managers will not use a synthesis until they know about it and can find it. Marketing and delivery require planning, networking, persistence, attention to detail, and fiscal support. Participants in a conference on national park management suggested 11 ways to improve the communication and use of science (Figure 13); nearly half of them require understanding the "world" of the audience, including their values, culture, responsibilities, and interest in learning. The synthesis planning team should work with science delivery specialists and use existing communication networks to deliver finished products. Principal fire management networks currently include the JFSP Knowledge Exchange Consortia, the Nature Conservancy's Fire Learning Network, the Coalition of Prescribed Fire Councils, the Fire Modeling Institute, the FRAMES Fire Research and Management Exchange System, the International Association of Wildland Fire, and the Association for Fire Ecology. Information on any these can be obtained with a simple Internet search.

Market and deliver effectively:

- Work with groups that are already delivering science successfully, especially those with strong participation from managers.
- Produce a 1-page summary cross-referenced to the full synthesis. Distribute it electronically and in person.
- Plan to market over many months or a year, so managers' "busy seasons" do not keep them from learning about the synthesis.

Fire managers currently prefer email to receive information on fire ecology and management, but other media should be explored as younger professionals enter the field of fire management (Smith and others 2013). Interviewees for this project offered the following suggestions, which I have supplemented with thoughts from the literature:

1. Always produce a one-page summary and circulate it widely. Emphasize management applications, preferably in bulleted lists. Make sure the summary refers readers to the discussion of each major point in the full synthesis.
2. If the synthesis is a JFSP product, publicize it in a *Fire Science Digest* report, as suggested by Smith and others (2013). If not, consider writing a short article on it for a fire trade journal such as *Wildfire* or *Fire Management Today.*
3. Get a manager to write a "book review" and circulate it through fire communications networks.
4. Advertise the synthesis ahead of time. Months elapse between having a document ready for publication and getting it out. Use the time in between to let people know it is coming. During the time I was conducting interviews for this project, McCaffrey and Olsen's (2012a) "Research Perspectives on the Public and Fire Management" was in press, and a three-page summary (McCaffrey and Olsen 2012b) was circulating among fire managers. Several interviewees had seen the summary and were watching for the final publication, anxious to get their copies.
5. Send advertising, the summary, and the full synthesis to everyone who asked for the synthesis, helped develop it, or reviewed it, and ask them to help get the information to managers.
6. Give the synthesis and its underlying science a "human face" (Sheikheldin and others 2010):
    - Use webinars and teleconferencing. Try podcasts and short video clips. When using nonprint media, find ways to highlight the location of the summary and the full synthesis so the audience can easily find them.

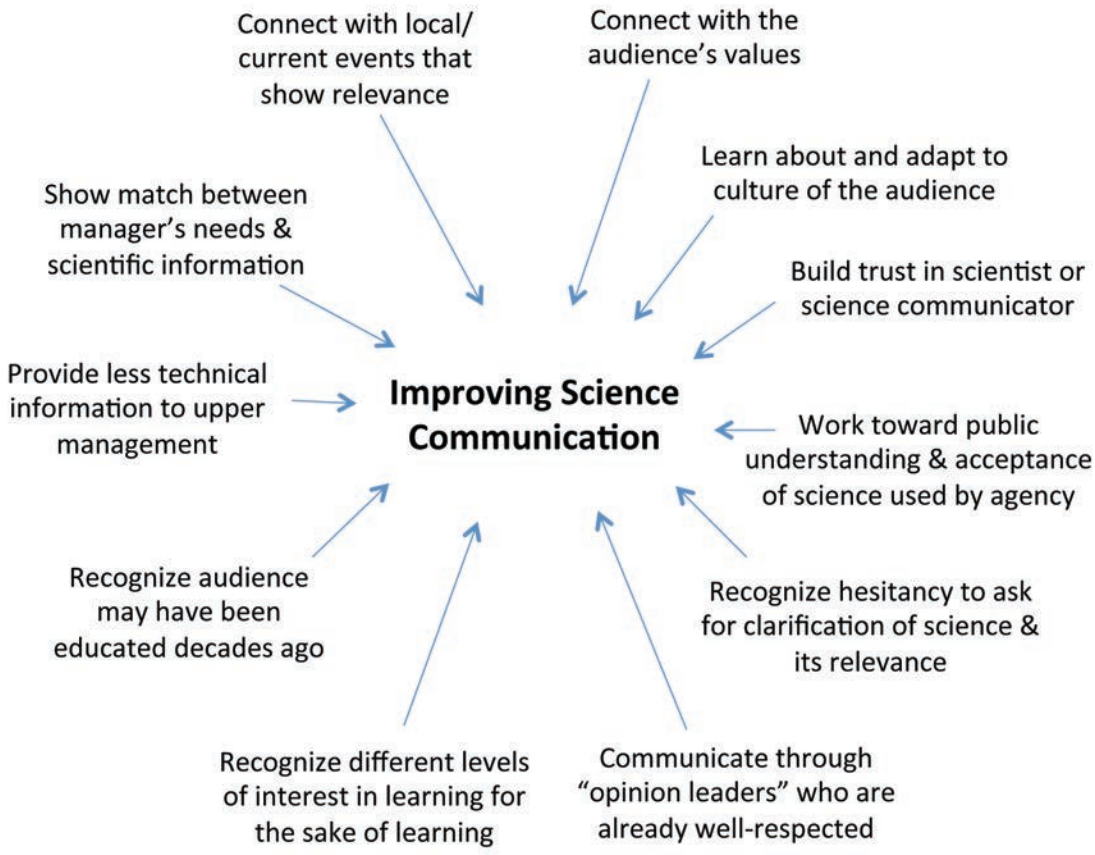

Figure 13—Suggestions from National Park Service participants at the 2005 George Wright Conference for communicating science more effectively (Wright 2006). Participants were discussing general use of science, but the suggestions also apply to delivery and use of syntheses.

- Participate in field trips to discuss important regional findings. Hand out copies of the summary.
- Go to meetings for managers. Hand out copies of the summary.

7. Consider developing demonstrations or experiential learning activities to increase understanding of fundamental concepts and show how they are related to real-world issues.
8. Consider using catchy terms or a sense of humor to appeal to potential readers, but not to the extent that it makes the content seem trivial or unprofessional. Jerry Cox (1993), from the Texas A&M Agricultural Research and Extension Center, commented, "If our [*Rangelands*] papers were fun, ranchers, land managers, and even scientists might actually read an article…."
9. Since the Internet will ultimately be the "home" for all synthesis products, consider placement carefully. Put them in—and link them from—locations that managers already use. Make sure that these locations are available to nonfederal partners and that the Internet addresses are stable, "places that will last." Science is disconnected from post-fire management, according to Chen and others (2013), partly because it is unavailable or inaccessible.
10. Work with those who plan and present professional education and development opportunities, including university and National Wildfire Coordinating Group courses. Integrate syntheses into the presentations and materials for the appropriate classes (see "Do Readers Need Guidance on How to Use Syntheses?" on p. 40).

"Put stuff where it's available to more than government people. Retired people, private land owners, and managers of nonprofits need these tools too. "

—John Barborinas, Wildland Fire Management Planner, National Interagency Fire Center, Department of the Interior, Bureau of Indian Affairs

Timing and persistence are important for marketing and distribution. Managers may lose track of information that arrives during their busiest time of year, and yet every time of year is busy for someone. Joe Marshall, Coordinator of the Oak Woodlands and Forests Fire Consortium, whimsically recommended using webinars, "but schedule them for a rainy day!" It may be wise to be flexible in scheduling and to spread out advertising for several months so the information will reach as wide an audience as possible.

3.0 After Distribution—Finding, Using, and Updating Syntheses

After a synthesis has been published, the scientists involved generally move on to other projects while science delivery specialists and managers work to deliver it and get it used. The aim is to integrate the synthesis with other management tools so it becomes a long-lasting, widely used foundation for decision-making. This section explores what happens after a synthesis has been published and distributed, when it is no longer news. How can managers easily find the syntheses relevant to a management issue? Do they need guidance on how to read and apply syntheses? As the information base on the topic continues to grow, how does the relevance of a synthesis change—and what might be done to keep it relevant?

When syntheses are no longer news, continue to help managers find and use them:

- Provide an Internet "home" for fire syntheses, analogous to a library's reference section, where managers can easily find them and identify the most recent information.
- Incorporate syntheses with other online information on specific fire management issues.
- Incorporate syntheses into education and professional development for fire managers.
- Include instruction in reading both research papers and syntheses in education and professional development.
- Seek ways to supplement existing syntheses with recent research and monitoring reports.

3.1 How Can Managers Find Syntheses on Fire?

This question came up many times in interviews. If syntheses are to serve as authoritative, foundational documents that fire managers can rely on, they should be easy to find. However, as of 2014 there is no single location dedicated to providing syntheses on fire. In fact, the Internet location of a synthesis depends more on who funded and wrote it than where managers might look for it. Treesearch (http://www.treesearch.fs.fed.us/) and GeoTreesearch (http://www.fs.fed.us/research/products/geotreesearch/), for example, catalog only publications produced by the Forest Service and do not provide a way to filter for syntheses. The National Forest Service Library (http://usfsdc.vtls.com:4080/vital/access/manager/Index) allows the user to search by topic and also filter for syntheses, but the collection is currently limited to publications published since 2005 and, like Treesearch, contains only those with Forest Service Research authorship. Similarly, the JFSP website provides a list of syntheses (20 of them as of May 2014—see https://www.firescience.gov/JFSP_publications.cfm#tab5) but includes only publications funded by JFSP and published as stand-alone documents; syntheses published in refereed journals, including systematic reviews, are not included.

Managers should be able to find fire-related syntheses both within a collection of fire reference documents and also within collections of documents on specialized topics. A "home" on the Internet for all fire syntheses would be analogous to the reference section in a library, where a newcomer can see the variety of topics covered and select specific documents for learning about fundamental concepts, vocabulary, and management issues. Supplemental products, such as summaries and guidebooks, could be associated with the foundational syntheses.

Some specialized topics within fire management already have Internet homes of their own, but there has been no systematic effort to make them complete or show relationships among documents. For example, at least five syntheses and one guidebook have been published on post-fire rehabilitation and restoration (Table 8). They are published by two different government offices and in two different journals; one of the journal articles is also available online from the Collaboration for Environmental Evidence. No single resource provides all of these documents in one place and helps readers figure out how they are related. Do the more recent ones completely replace the earliest one? How can someone using the guidebook know if some of its recommendations are outdated? The Burned Area Emergency Response Tools webpage (http://forest.moscowfsl.wsu.edu/BAERTOOLS/) directs readers to two of these syntheses and also to related models, field guides, and catalogs. A more comprehensive website would include all of the syntheses and additional BAER tools and would indicate which documents have the most recent information on individual subtopics.

Even with imprecise methods of counting, it is clear that increasing numbers of syntheses are being produced (Figure 1). They represent a tremendous information resource for managers, but their increasing abundance introduces the new challenge of guiding readers to the most recent, most pertinent synthesis on a topic or issue. FRAMES is one potential home for fire syntheses, and its Resource Catalog (https://www.frames.gov/about/resource-cataloging-system) could provide the mechanism. However, it is currently difficult for a visitor to distinguish syntheses from other documents in FRAMES.

Table 8—A family of interrelated syntheses on the effectiveness of post-fire rehabilitation and restoration treatments, listed by publication date. No single resource tells managers about all of them or how they are related.

Authors	Publication type	Title
Robichaud and others (2000)	Government publication (Rocky Mountain Research Station)	Evaluating the effectiveness of post-fire rehabilitation treatments
Napper (2006)	Government publication (Washington Office)	The burned area emergency response treatment catalog (BAERCAT) (contains guidelines and instructions)
Foltz and others (2009)[a]	Government publication (Rocky Mountain Research Station)	A synthesis of post-fire road treatments for BAER teams: methods, treatment effectiveness, and decisionmaking tools for rehabilitation
Robichaud and others (2009)	Journal article—*Fire Ecology*	Emergency post-fire rehabilitation treatment effects on burned area ecology and long-term restoration
Robichaud and others (2010)[a]	Government publication (Rocky Mountain Research Station)	Post-fire treatment effectiveness for hillslope stabilization
Peppin and others (2010)	Journal article—*Forest Ecology and Management*	Post-wildfire seeding in forests of the West: an evidence-based review

[a]These two publications are featured on the Burned Area Emergency Response Tools webpage (http://forest.moscowfsl.wsu.edu/BAERTOOLS/).

An internal query of the database, provided by Project Manager Diana Olson, retrieved 263 references with "synthesis" or "review" in the title; a search using the "public" side of the database retrieved 1,883 references. (See Table A.1 for search criteria.) Both searches retrieved many documents that are not syntheses, including proposals and after-action fire reviews. Managers and others interested in fire management need more comprehensive, straightforward ways to locate syntheses.

3.2 Do Readers Need Guidance on How to Use Syntheses?

Not everyone working in fire management is familiar with scientific literature and syntheses, and not all syntheses are written or packaged with managers in mind. Existing syntheses could be refurbished, if necessary, by writing a manager-oriented summary and highlighting key findings. Supplements could be written to present the implications more clearly and provide examples from the field.

Not everyone knows how to read syntheses and apply their information to management. Some guidance can be provided within a synthesis. For instance, the authors might provide a sidebar entitled "How to Use This Document," in which they explain whether the synthesis provides definitive guidelines or more open-ended suggestions. They might also identify sections intended as background for someone new to the field versus sections that apply to particular specialties, subtopics, or geographic regions. Technical terms can be explained within the text or in a glossary. If a technical term has been misunderstood, controversial, or poorly defined in the past, a callout could be used to draw attention to the definition. For example, the guide to fuels treatments in dry mixed conifer forests of the Northwest (Jain and others 2012) uses a callout to define "resilience."

Relevant syntheses should be provided and discussed as part of professional development for fire managers, such as university courses and classes coordinated by the National Wildfire Coordinating Group. Instructors can improve participants' critical reading skills if they take a few minutes to discuss how to find and use information in the synthesis. A few other concepts could also be discussed:

"People need to know they can't write a whole document just from a synthesis. In fact, does the synthesis encourage them to take shortcuts? Our agency culture should make it OK to read science. You should never feel bad about (a) reading or (b) going into the field just to look around."

—Jeff Rose, Associate District Manager, Department of the Interior, Bureau of Land Management

1. A synthesis usually presents examples and case studies to demonstrate a concept, not as a prescription for action. Medical practice provides a useful analogy. Kranke (2010) suggests that medical healthcare givers ask these questions about applying meta-analysis results to patient care:
   - Are the patients in the trials like my patients?
   - Are the inclusion criteria sensible?
   - Do the outcomes make sense?
   - Are the outcomes useful and do they matter to my patients?

   Perhaps fire managers should replace "patients" with "stands" or "landscapes" and ask the same questions.
2. Reports in a synthesis from the primary literature should not be cited without consulting the original document. Check the source to avoid misrepresenting the original research and propagating errors (Figure 5, p. 14). Everyone makes mistakes—even the author of this synthesis.

While interviewees did not support adding formal instruction in critical reading to the already full training load for managers, some suggested improving this skill in professional preparation, especially university classes. Upper-division classes often discuss how to read scientific papers. It may be worthwhile to add discussion on how to read and use syntheses and to supplement the discussion with examples and field experiences.

A report on learning from escaped prescribed fires (Black and others 2012) points out that experiential learning is not just a nod to diverse learning styles; it is also a way to simulate the ways in which decisions are made, in which learners "…can experience the same uncertainty and equivocality that creates new perspectives and high impact learning but with low risk."

3.3 How Can Syntheses Stay Relevant as the Information Base Grows?

Even the most recent, most complete synthesis does not provide *all* of the science-based information needed to address a fire management issue. As noted above, before a manager decides to rely heavily on an example given in a synthesis, he or she should check the source. Furthermore, the information base used in the synthesis is probably incomplete by the time the manager consults it. That does not make the synthesis irrelevant, but it should be considered as the manager moves from accumulating information to choosing a wise course of action. As the information base on a topic grows, how does the relevance of a synthesis change? What might be done to keep it relevant? When has it outlived its usefulness? This section summarizes insights from the literature with suggestions from interviewees.

When Has a Synthesis Outlived Its Usefulness?

If a synthesis provides a sound conceptual background and is based on reliable information, it remains useful even as the information base grows. The conceptual background helps readers learn how to think about the topic so they can integrate new information and their own experience into management decisions. For this purpose, a synthesis published as a stand-alone document may have longer-lasting usefulness than one published in a journal that constrains the scope and length of the article.

Syntheses become less useful when fundamental concepts change substantially, novel ecological conditions emerge, or new research provides substantial new insights. For example, the 1981 "state-of-knowledge" review of the effects of fire on flora (Lotan and others 1981) describes fire regimes mainly in terms of return intervals, gives little attention to the influence of nonnative invasive plants, and does not mention climate change. By the mid-1990s, understanding of these factors had become essential for understanding fire's influence on plant communities. A new review, organized around the fire regime concept, was published in 2000 (Brown and Smith 2000); another, focused on invasive plants and examining their influence on fire regimes, was published in 2008 (Zouhar and others 2008c)[7]. Both of these syntheses also address the potential for fuels altered by climate change to alter fire regimes. Another example is provided by the family of syntheses on post-fire rehabilitation and restoration (Table 8). The 2010 synthesis on post-fire hillslope stabilization (Robichaud and others 2010) "builds on" a more general synthesis on post-fire rehabilitation published in 2000 (Robichaud and others 2000) but has a narrower focus (erosion barriers, mulching, and chemical soil treatments). It also directs readers to recent syntheses on related topics.

Syntheses become outdated when substantial new information conflicts with the patterns they report. For example, the 2000 synthesis on post-fire rehabilitation referred to above (Robichaud and others 2000) cited several studies showing that post-fire seeding

[7] These are two of the six syntheses in the "Wildland Fire in Ecosystems" series, which replace the five published in the early 1980s. The more recent series covers not only plant communities and invasive plants but also wildlife (Smith 2000), air (Sandberg and others 2002), soils and water (Neary and others 2005), and cultural resources (Ryan and others 2012).

reduced erosion, while also expressing reservations about this practice. A 2010 systematic review of the subject (Peppin and others 2010) concluded that, while the majority of studies published before 2000 reported that post-fire seeding reduced erosion, they used less rigorous methods than recent research—and all of the more recent studies reported the practice to be ineffective.

The data analyses in systematic reviews and meta-analyses could potentially be updated as new studies and monitoring data become available. If the new results diverge significantly from those reported in the original document, it may be time for a new one.

How Can New Information Be Associated with Existing Syntheses?

As long as the conceptual background in a synthesis remains sound and new findings are consistent with its conclusions, it does not need to be replaced. Nevertheless, managers do need to locate more recent findings and integrate them into decision making. Nearly half of interviewees suggested ways to provide new information related to topics covered by fire syntheses. Some of their suggestions would require either use of innovative information technology or more systematic education and professional development for managers in the use of existing tools:

"Used to be you'd just call a scientist and say, 'What have you been up to?' but it's harder now to stay up-to-date."

—Jeff Rose, Associate District Manager, Department of the Interior, Bureau of Land Management, Burns, OR

- Improve electronic searches for new publications on fire and provide downloadable documents along with citations.
- Develop ways to electronically associate new research with existing syntheses.
- Develop ways to find monitoring results and associate them with syntheses.
- Publish short supplements to original syntheses.
- Develop procedures and/or provide tutorials to help managers filter citation databases for new information.

The first three of these are described more fully below.

Several interviewees mentioned the need to search more efficiently for fire research publications and download documents easily. Four large fire reference databases are currently available (Table 9), but as of 2014 none of them offers a precise way to search for syntheses. The Northern Rockies Fire Science Network is filtering reference databases to produce a list of region-specific references for its website, and other JFSP Knowledge Exchange Consortia are using other approaches to provide citation lists for managers. The ability to download documents varies between and even within databases, in part because of copyright protections. The current situation is complex and varies from one region to another. Would it help managers to have better nation-wide search/download capabilities? What investment would be needed to substantially increase efficiency? These questions merit further discussion as the fire information base grows.

A synthesis could form the foundation for a family of documents on a fire-related topic, to which new publications are added as they become available. The Burned Area Emergency Response Tools website (http://forest.moscowfsl.wsu.edu/BAERTOOLS/) could serve this function for postfire restoration and rehabilitation documents. The Fire Effects Information System (FEIS, http://www.feis-crs.org/feis/) user interface offers another approach. "Fire studies" (research publications, summaries of research projects, and summaries of monitoring projects) are published in FEIS and linked to species reviews. Fire studies either provide details on research described in the review or summarize research published after the review was completed. When a user finds a species review in FEIS, he or she automatically has access to a list of associated fire studies (Figure 14). Fire studies are currently created only when new research is located for a species review, but this functionality could be used to add new information more systematically and associate it with all relevant species reviews.

Table 9—Searches for syntheses in four reference databases on fire produced many "hits," but results were imprecise. The FRAMES Resource Catalog and the E. V. Komarek Fire Ecology Database (http://www.talltimbers.org/fedb-intro.html) are searchable simultaneously through FRAMES[a]. See Appendix A (Table A.1) for search dates and algorithms.

Database name and location	Web address	Total number of citations	Search by…			Products and services available
			Topic	Region	Search results for reviews & syntheses	
FRAMES Resource Catalog + E.V. Komarek Fire Ecology Database	http://www.frames.gov/search/	~16,000	All wildland fire topics and numerous media. Filters provide searches by medium, topic, etc.	All, with filters to search by region	Search of full records for documents: 1,883 hits. Retrieved after-action fire reviews, proposals, and other reports.	Citation and description. Links to Internet location for some recent publications.
Citation Retrieval System (CRS) for the Fire Effects Information System	http://www.feis-crs.org	~60,000	Fire effects and related ecology for organisms in the United States	All, with keywords to search by state and/or Forest and Range Ecosystem (Garrison and others 1977)	Search using keywords: 518 hits. Retrieved syntheses that address fire as a minor influence but do not focus on fire.	Citation and keywords, including "review"
Fire Research Institute Library	http://www.fireresearch-institute.org	~122,000	All wildland fire topics, all kinds of documents and media	All, including international	Search of titles: 1,572 hits. Retrieved after-action reviews, proposals, etc.	Citation and abstract. Functionality to obtain a copy, contact author for a copy, and/or receive monthly list of new publications.

[a]Users can search the FRAMES and Komarek databases separately by making a selection in the "Source" filter, the last option in the list of filters on the search page. A search of FRAMES alone yielded 1,213 hits, and a search of the Komarek database alone yielded 817 hits.

The same functionality could be used to associate monitoring reports with syntheses. Managers use monitoring results to inform local decisions, but these results could also be used to inform broader discussions of fire management if summarized and associated with syntheses. Monitoring results may be especially helpful for understanding the long-term effects of fire, since research studies tend to focus on the first few post-fire years. Robichaud and others (2010) emphasize the importance of long-term post-fire monitoring: "If we want to avoid today's solutions becoming tomorrow's problems, we must also evaluate longer term ecological consequences … and ensure that they are included in the treatment decision-making process." Improved information systems that connect syntheses with recent research and monitoring results could help managers "get the most out of" monitoring data (Chen and others 2013). Insights about database design might be gained from regional and national databases for other environmental management issues, such as the stream management projects database described by Jenkinson and others (2006).

Just as a new synthesis requires effective marketing and delivery before it will be integrated into practice, any innovations that provide updates, supplement syntheses, or improve managers' ability to find information should be widely publicized.

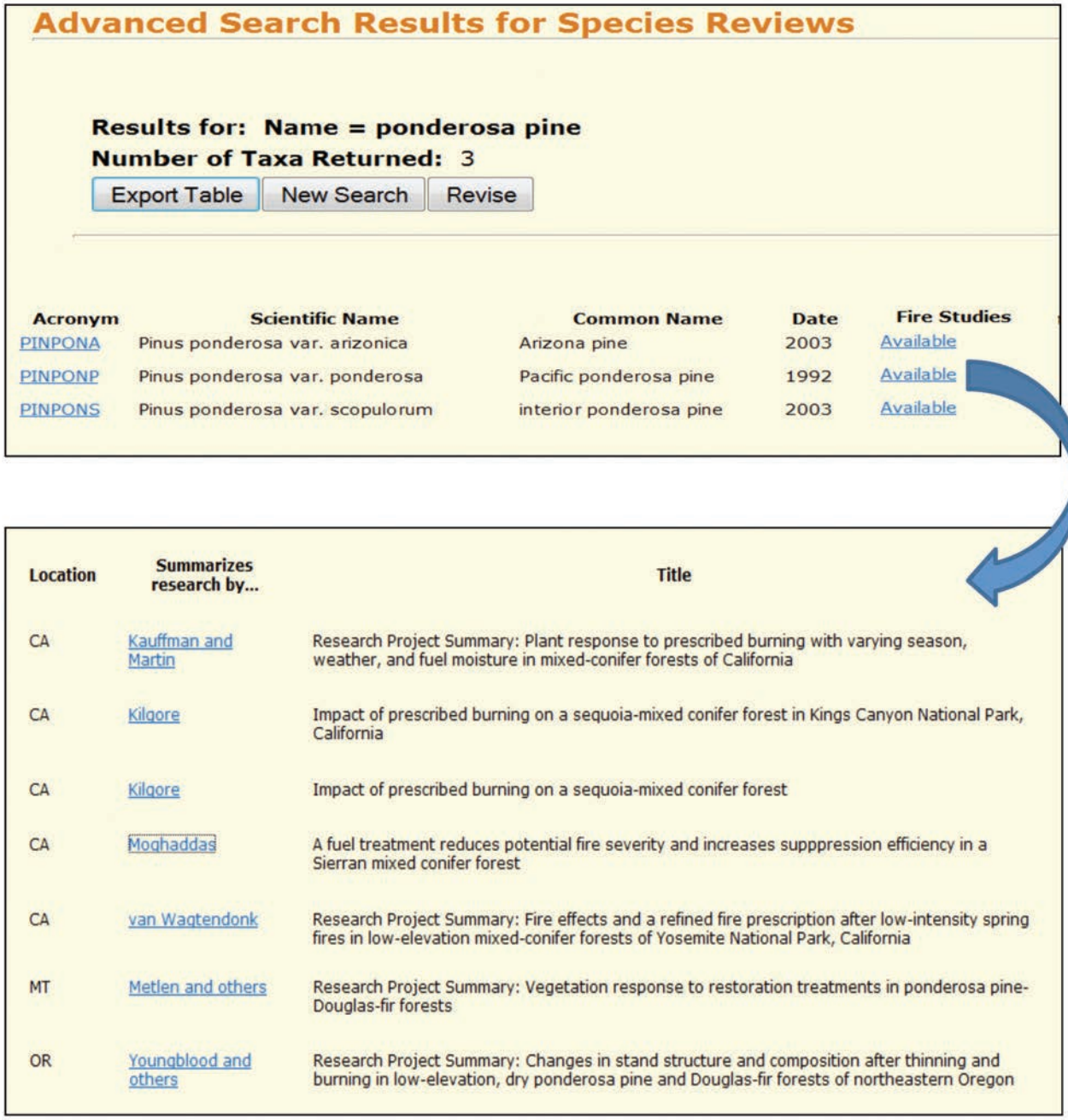

Figure 14—The user interface for the Fire Effects Information System (FEIS) provides a way to associate recent research studies and monitoring reports with previously published syntheses. In this example, the species review for Pacific ponderosa pine, published in 1992, is supplemented by seven fire studies. Four of these became available after the review was published.

4.0 Conclusions—The Future of Synthesis for Fire Managers

Fire management has a deep, valuable legacy of knowledge in the research and management communities, and hundreds of new publications become available each year. With more research, an increasing number of journals, and limited budgets for learning at meetings and conferences, the need for synthesis is more important than ever. In a management environment that makes more demands on fewer people, the need to locate information and objectively assess its management implications is increasing as well. The need to manage wisely in a world where information is available to all increases the need for syntheses to be clear, defensible, and easily accessible.

This challenge is not insurmountable. Fire management is far from alone in needing high-quality syntheses, so the tools for meeting these needs are either available or being developed. Ecologists and other environmental scientists have become international leaders in assembling diverse information from diverse disciplines and cultural perspectives to address environmental issues. Centers of expertise now bring researchers, decision makers, and other stakeholders together to find ways to answer difficult management questions with rigorous analysis of information. Information specialists are providing new, sophisticated tools for compiling and managing huge volumes of information.

Conclusions—To meet managers' growing need for syntheses and integrated information…

- Continue to produce syntheses that harvest information from science and management to address fire management issues.
- Explore new techniques for managing syntheses, references, research results, and monitoring data.
- Encourage use of research and monitoring techniques that produce data with potential for pooling and meta-analysis.
- Explore the potential for integrating syntheses with models.
- Learn more about "what works" in disseminating syntheses and getting them used to inform management decisions.

So what attitudes and actions will help us provide high-quality information syntheses for fire managers in the future? I suggest the following:

- Continue to synthesize information for fire managers. The information base and managers' needs for synthesis will continue to increase.
- Update or replace existing syntheses when they become out-of-date.
- Explore the potential for information technology to help managers harvest more knowledge from existing information. Specific areas where innovative technology could help include (1) providing locations where managers can easily find fire syntheses and see the relationships among syntheses on similar topics; (2) associating recent research and monitoring reports with already published syntheses; and (3) accompanying each synthesis with supplemental products such as flyers, summaries, webinars, and guidebooks. In addition, new technology may be needed to manage citations and documents and to archive data for possible meta-analysis.
- Encourage researchers to design studies with potential for future data-pooling and meta-analysis in mind. At the same time, do not let the drive for "poolable data" limit exploration of innovative research methods or the potential for managers and scientists to "coproduce" knowledge.

- Do not underestimate the value of qualitative reviews and qualitative sections in systematic reviews and meta-analyses. They provide a conceptual framework for thinking about a topic, and they can integrate historical research with more recent work. Statistical analyses cannot substitute for having well-informed minds consider all the information available and analyze its management implications.
- Look for synergistic relationships between syntheses and models, since both of these tools are based on past research. Would a synthesis of the science basis for a model help users understand how to apply it appropriately? Can model results be incorporated more often into syntheses? Can results from syntheses be used to validate models?
- Foster relationships and improve communication networks among researchers, science delivery specialists, and managers. Collaboration is essential for producing a high-quality synthesis, delivering it to managers, and getting it used appropriately. Science delivery specialists are good at this, but do not leave it all up to them.
- Use regional and local networks to learn more about how syntheses are disseminated and used. Which ones are most used, in which regions, and why?

Syntheses represent a substantial investment of time and energy for those who develop them, a sizeable investment by research sponsors, and a huge information resource for fire managers. They need to be well written, widely distributed, and wisely used to make sure that our rich legacy of information about wildland fire contributes to effective management on the ground. While it is always challenging to provide support for developing and maintaining information resources such as syntheses, wildland management organizations should weigh the cost of providing current, high-quality information syntheses against the cost of managing without it.

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Appendix A—Methods

This report is based on information in the literature, examination of syntheses on fire management topics, informal interviews, and personal experience.

I used two broad-based citation databases (Scopus and Web of Science) and one forestry database (FS Info) to search for literature on reviewing and synthesizing information. These were searched on keywords such as "literature review," "synthesis," and "writing" (Table A.1). The searches generated long lists of citations that were further refined by searching within results and limiting subject categories. From the refined searches, I examined references covering information management, literature reviews, meta-analysis, systematic reviews, and science delivery (also called "technology transfer," "science brokering," and "boundary spanning"). Many of these references focused on information management and synthesis in general. Others focused on specialized fields, mostly in the health sciences or natural resource management. I "chased backward" from these documents to find background references and "chased forward" from those that seemed conceptually innovative to see if their thoughts had been further developed or their suggestions had been implemented. For a description of "chasing" techniques, see Items 4 and 5 (p. 14) in Section 2.1, "Complete, Unbiased Information Base."

To find syntheses on wildland fire, I examined all JFSP-sponsored syntheses, whether published as stand-alone documents (listed at https://www.firescience.gov/JFSP_publications.cfm#tab5), in refereed journals, or by the Collaboration for Environmental Evidence (http://www.environmentalevidence.org/). I chased backward from these to find earlier syntheses on fire in the United States. I examined all syntheses mentioned as examples by interviewees.

Table A.1—Criteria used for citation searches in this report.

Location of information	Database or search engine	Date of search	Search criteria
Appendix A. Methods	FSInfo	Nov 2013	Searched for subject and/or keyword including the following in various combinations: applied science, literature review, literature reviews, literature search, literature survey, synthesis, technology transfer, writing.
	Scopus	Nov 2013	Searched for title, abstract, and/or keywords including the following in various combinations: article, ecological synthesis, information retrieval, learning, literature review, methodology, publication, reading, research, review, science communication, synthesis, teaching, writing. Limited to English-language literature.
	Web of Science	Nov 2013	Searched for topics that include "literature review." Searched for results that include "writing." Limited categories to communication, education, forestry, information science, and related terms.
Figure 1, Section 3.1	FRAMES Resource Catalog	27 Nov 2012	Internal search provided by Diana Olson: Searched for titles containing ((synthesis or review) + fire).
Figure 1	FRAMES Resource Catalog	11 May 2014	Counted documents containing each year from 1960 through 2009, then calculated totals per decade.
Section 3.1, Table 9	FRAMES Resource Catalog	13 May 2014	Searched documents for synthesis, then review, then added them and subtracted (synthesis + review) to remove duplicates.
	Citation Retrieval System (FEIS)	13 May 2014	Searched for keywords (review + fire).
	Fire Research Institute	13 May 2014	Searched for synthesis in title, then review in title, then added them.

For insights about writing syntheses and applying them to management, I sought help from those most closely involved: scientists, managers, and science delivery specialists. I invited 69 people to be interviewed. Of those, 40 responded. I interviewed 35 (Table A.2) and received helpful correspondence from several others. Interviewees were selected based on field of expertise, geographic location, agency or employer, and recommendations from other interviewees. The resulting group was diverse (Figure A.1).

Table A.2—Interviewees for this project.

Interviewee	Position, agency, location
John Barborinas	Wildland Fire Management Planner, National Interagency Fire Center, DOI Bureau of Indian Affairs, Ignacio, CO
Jamie Barbour	Program Manager, Focused Science Delivery and Goods, Services, and Values Program, USDA Forest Service, Pacific Northwest Research Station, Portland, OR
Dave Campbell	District Ranger (retired), West Fork District, Bitterroot National Forest, Darby, MT
Nan Christianson	Assistant Station Director, Communications, USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO
Nate Fayram	Project Coordinator, Tallgrass Prairie and Oak Savanna Fire Science Consortium, Madison, WI
Bob Gillaspy	State Rangeland Management Specialist, Oregon State Office, USDA Natural Resource Conservation Service, Portland, OR
Richy Harrod	Deputy Fire Staff Officer, Okanogan-Wenatchee National Forest, Wenatchee, WA
Christel Kern	Research Forester, USDA Forest Service, Northern Research Station, Grand Rapids, MN
Paul Langowski	Regional Branch Chief, Fuels and Fire Ecology, Rocky Mountain Region, USDA Forest Service, Golden, CO
Sherry Leis	Program Leader, Great Plains Fire Science Consortium, Springfield, MO
Alan Long	Administrative Director, Southern Fire Exchange, Tall Timbers Research Station, Tallahassee, FL; Professor Emeritus, University of Florida, Gainesville, FL
Charlie Luce	Research Hydrologist, USDA Forest Service, Rocky Mountain Research Station, Boise, ID
Chris Mallek	Fire Ecologist, Great Basin Science Delivery and California Fire Science Consortium - Sierra Nevada Region, University of California, Davis, CA
Joe Marschall	Coordinator, Oak Woodlands and Forests Fire Consortium, University of Missouri, Columbia, MO
Rhonda Mazza	Science Writer/Editor, editor of Science Findings, USDA Forest Service, Pacific Northwest Research Station, Portland, OR
Richard F. Miller	Professor Emeritus, Range and Fire Ecology, Oregon State University, Corvallis, OR

(continued)

Table A.2—(Continued.)

Interviewee	Position, agency, location
Dan Mindar	Fire Application Specialist, DOI National Park Service, Rocky Mountain Research Station, Luna, NM
Helen Mohr	Director, Consortium of Appalachian Fire Managers and Scientists, Clemson, SC
Eugénie MontBlanc	Coordinator, Great Basin Science Delivery, Reno, NV
Penelope Morgan	Professor, Department of Forest, Rangeland, and Fire Sciences, University of Idaho, Moscow, ID
Caroline Noble	Fire Ecologist, Southeast Region, National Park Service, Tall Timbers Research Station, Tallahassee, FL
Jennifer Northway	Assistant Fire Ecologist, Alaska Region, National Park Service, Fairbanks, AK
Tami Parkinson-Whitford	Fire Application Specialist, USDA Forest Service, Rocky Mountain Research Station, Boise, ID
Elizabeth Pickett	Executive Director, Hawaii Wildfire Management Organization/ Pacific Fire Exchange, Kamuela, HI
Zach Prusak	Florida Fire Manager, Florida Chapter Office, The Nature Conservancy, Altamonte Springs, FL
Mike Rauscher	Managing Editor, Forest Encyclopedia Network, Leicester, NC
Jeff Rose	Associate District Manager, DOI Bureau of Land Management, Burns, OR
Michael G. Ryan	Research Ecologist (retired), USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO
Dean Simon	Fire and Forest Management, North Carolina Wildlife Resources Commission, Lawndale, NC
William T. Sommers	Research Professor, George Mason University, Fairfax, VA
Mary Taber	Fire Ecologist (retired), National Interagency Fire Center, DOI Bureau of Indian Affairs, Boise, ID
Jim Thinnes	Regional Silviculturist (retired), Rocky Mountain Region, USDA Forest Service, Golden, CO
Rachel White	Science Writer/Editor, USDA Forest Service, Pacific Northwest Research Station, Portland, OR
Brett Williams	Fire Ecologist, Wildland Fire Center, Eglin Air Force Base, Niceville, FL
Robert Ziel	Program Coordinator, Lake States Fire Science Consortium, Marquette, MI

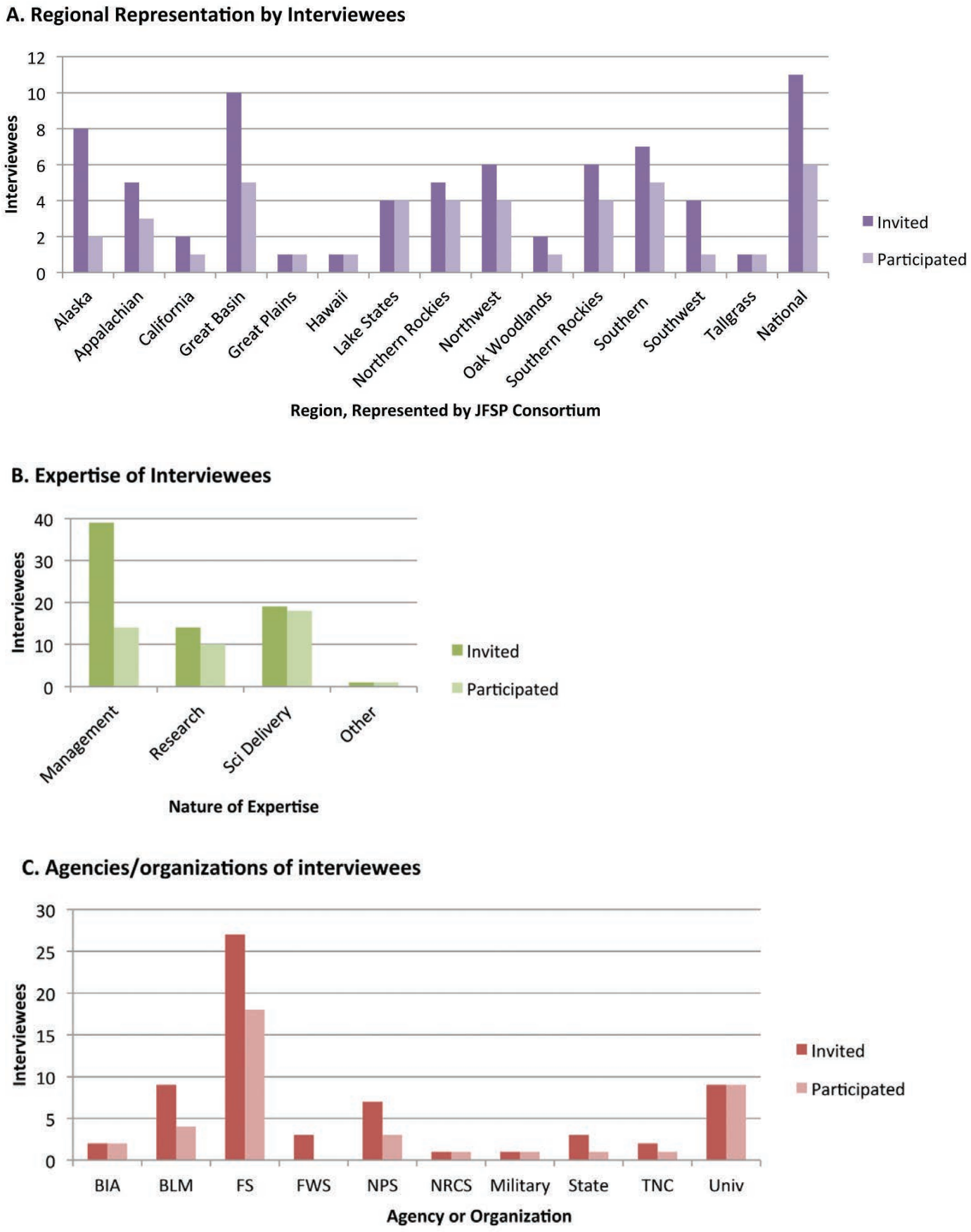

Figure A.1—Participants in interviews.

This was a convenience sample rather than a random or systematic sample, but I noted that few major new concepts emerged after about 10 interviews. On the other hand, every person I spoke with provided unique insights about practical aspects of synthesis for fire management: how to produce better syntheses, how to deliver them more efficiently, and how to get them used appropriately. Every interviewee, without exception, gave my questions full attention and offered new ideas. I am deeply grateful for their time, consideration, and expertise.

Interviews were conducted as informal conversations. Each lasted 30 to 60 minutes and covered the following questions, whether they were asked explicitly or arose from the flow of conversation:

1. What makes a scientifically defensible synthesis? Do you have any examples (good or bad)?
2. What makes a synthesis especially useful to field practitioners? Do you have any examples (good or bad)?
3. Is "outdatedness" a problem for syntheses? If it is, how can it be addressed?
4. Do you have suggestions on how to help practitioners use syntheses more efficiently and effectively?

While this report is based on the content of many documents and reflections from many experts, it is also based on my own convictions. I have taught technical writing at the undergraduate and graduate levels, and I have been writing syntheses on fire and teaching about wildland fire for nearly 40 years. For the past 20 years, I have edited syntheses on fire effects for the Fire Effects Information System (http://www.feis-crs.org/feis/) and other publication outlets. I hope this experience has infused the project with insight rather than bias, but I am responsible for the content either way.

Several citation databases were searched to produce tables and figures in this report, and the search logic is documented in Table A.1.

Appendix B—Guiding Questions for Planning a Synthesis

This detailed list can be used to guide synthesis planning. The topics below correspond to the "development stages" in Figure 2 (p. 3) but offer more detail in regard to each question. The items under "Initiating a Synthesis" must be addressed before work can go forward. Questions and statements in the next sections should be considered in the planning process and again at each development stage. These guidelines are not intended to be prescriptive or all-encompassing but rather to offer a starting point for synthesis planners.

1. Initiating a Synthesis

1.1. What is the potential synthesis for? Write clear objectives.

1.2. Who needs it? Identify the audience(s) and weigh their needs for information.

1.3. What is it about? What are the guiding questions or objectives?

- 1.3.1. Is it a topic, an issue, or a question about a management practice? List examples of questions that managers should be able to address using the synthesis.
- 1.3.2. Develop a clearly focused topic statement or question. This could be a broad topic like "climate change and fire regimes," a broad question like "How does fire affect invasion by nonnative plant species?" or a very specific question like "Does postfire seeding reduce the spread of invasive plants in the western states?"[8]
- 1.3.3. Develop the focus further, making it clear enough to help determine the breadth of the search for information, the criteria for including information, and the type of synthesis to be produced.
- 1.3.4. Is the potential synthesis national or regional in scope? If national with regional variation, include managers from different regions to figure out how regional needs can be addressed.

1.4. Who has the information, and how much is there?

- 1.4.1. How much information is available from various potential sources—academic journals, theses and dissertations, government publications, monitoring data, management case studies, management experience?
- 1.4.2. If information is needed from managers, who can furnish it?

1.5. Is synthesis feasible? (Also see Table 2, p. 7.)

- 1.5.1. What kind of synthesis would best serve managers' needs—qualitative review, systematic review, or meta-analysis? An approach that combines these techniques may serve managers best.
- 1.5.2. Is there enough information from the desired sources to produce the kind of synthesis needed? For example, if a rigorous systematic review or meta-analysis is needed, is enough quantitative information available to create a credible product? If management case studies are needed, are enough available to illustrate the range of treatments or outcomes that the synthesis needs to cover?

1.6. What should the final products be, and who can produce them?

- 1.6.1. Who can write the synthesis or various parts of it? Who has the right background, the time, the interest, the writing ability? Should different people (scientist, manager, science delivery specialist) take the lead for different sections?

[8] In fact, all of these have been the subject of syntheses sponsored by the JFSP. See Sommers and others (2011), Zouhar and others (2008c), and Peppin and others (2010).

1.6.2. Are different products needed for different audiences and purposes? Should different people take the lead for the main synthesis and any fact sheets, handouts, or summaries that are produced from it?

2. Searching for Information

2.1. What kinds of information should be used? (Build on the discussion from questions 1.4 and 1.5 above.)
  2.1.1. Develop a list of potential electronic search engines and databases. Then develop a search algorithm to use for each. It is likely to take iteration to get the search algorithms right. Document the algorithms finally adopted.
  2.1.2. Develop a list of other potential information sources and a procedure for systematically obtaining information from each. Document procedures.
  2.1.3. If management input is needed, refine the procedure for obtaining it with a small, willing group. Optimize the use of their time. Minimize iteration.

2.2. Does the topic have regional variation? If different kinds of information are needed from different regions, develop ways to address the varying needs.

2.3. Revisit question 1.5.2 again: Is the available information adequate for the products desired?

3. Writing and Packaging

3.1. How much background information should be provided? Base decisions on how the synthesis will be used, both by managers and by other audiences.

3.2. How much context should be given, and where should it be placed?
  3.2.1. Would information source tables be helpful? Should they be placed in the text or in appendices?
  3.2.2. Is the information hedged appropriately and as precisely as possible?
  3.2.3. Are information gaps identified clearly?

3.3. What organization scheme will work best for managers?
  3.3.1. Should the synthesis be organized by topic and subtopic? By region? By issue or management question?
  3.3.2. What navigation aids (page references, electronic links, etc.) would be helpful?

3.4. Are management implications fully developed?
  3.4.1. What is the best role for managers in regard to implications? Should they be authors? co-authors? reviewers?
  3.4.2. Are management implications written as clearly and directly as possible?
  3.4.3. Is the relationship between the information base and management implications clear, so readers know what the authority is for the implications?

3.5. How can packaging improve usefulness? What features make documents easy for managers to use?
  3.5.1. Look at tables, graphics, fonts, use of white space, and other features.
  3.5.2. Consider use of color, callouts, and other ways to emphasize important points and make the document visually appealing.

4. Reviewing and Revising

4.1. Does the draft synthesis meet the need as stated in the objectives (1.1 above)? Obtain review comments from a variety of potential users, especially in regard to management implications.
  4.1.1. If the synthesis has different information for different regions, obtain reviews from all regions.
  4.1.2. If reviewers and authors disagree substantially, bring them into a discussion so they can learn from one another and improve the synthesis.
4.2. Is the information basis clear, and does it support the conclusions and management implications?
4.3. Is the writing clear? Is the organization clear and useful?
4.4. Is the packaging clear, useful, and appealing?
4.5. Are the management implications clear, highlighted, easy to find?

5. Delivering Final Products

5.1. Where will managers look for the synthesis and associated products? Managers and science delivery specialists already have communication networks and know what kinds of products and techniques appeal to those who need this information. Encourage creativity and variety in advertising, marketing, and training. Encourage sharing of materials and techniques.
  5.1.1. Do different products (the full synthesis and associated summaries, fact sheets, etc.) need different distribution strategies?
  5.1.2. Are different strategies needed to reach different audiences, both within and outside the fire management community?
5.2. What are the opportunities for delivering in person—meetings, conferences, webinars?
5.3. How can the synthesis be integrated into education and professional development?
5.4. Are any tools needed to help managers figure out how to use the synthesis?

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