Looking into Syntheses:
Improving relevance and usefulness for managers

Draft General Technical Report
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Jane Kapler Smith (jsmith09@fs.fed.us)

Fire Modeling Institute
Fire, Fuel and Smoke Science Program
Missoula Fire Sciences Laboratory, Rocky Mountain Research Station, Missoula, MT

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Comments are welcome. Send to Jane Kapler Smith, jsmith@fs.fed.us by April 1, 2013.

Photo courtesy of Jim McCallum

Abstract

What constitutes a high-quality synthesis for wildland managers? Syntheses are often requested by managers, and many have been produced by scientists, but they may not always hit the mark. This project integrated guidelines from the literature with reflections from interviews with natural resource professionals (scientists, managers, and science delivery specialists) to develop guidelines for increasing the usefulness of syntheses for managers.

Different kinds of syntheses can serve different needs. Narrative syntheses are the most common form published for wildland managers. This format allows the author to include background information and incorporate detailed explanations and case studies. Peer-reviewed literature reviews and systematic reviews are more rigorous formats, which may be especially useful in resolving specific management questions; however, these formats may be more constrained than narrative reviews in regard to length, extent of background information, and information sources used.

The most important thing to do, to ensure that a synthesis is useful to managers, is to include managers, science delivery specialists, and scientists throughout the development process. The planning stage requires thorough discussion among all stakeholders. Managers may be particularly helpful in fully developing the management applications. Science delivery specialists have a great deal to offer in regard to format, content, packaging, and delivery of syntheses.

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Section I. Introduction and Summary

The Joint Fire Science Program has supported publication of more than 30 syntheses for managers on fire-related issues. However, these documents may not be well known or widely used, and they may not meet managers' needs as well as they could. In fall of 2011, I was asked to look into this issue and develop guidelines for improving syntheses for managers. To do so, I have explored the literature on synthesis and interviewed numerous managers, scientists, and science delivery specialists. I am especially grateful for the help of interviewees: Every person I spoke with was generous with time and reflections and offered new insights. **The message that I heard most often was that a synthesis must articulate its applications to management as clearly as possible and highlight them in the products.** I have applied that principle in formatting this report, so it describes the main lesson learned here, at the beginning, and follows with discussion of key questions. I hope that this "synthesis on syntheses" is useful for those who plan and fund syntheses, to those who write and package them, and—most of all—to those need them to inform management decisions.

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

The most important thing to do, to ensure that a synthesis is useful to managers, is to include them in the production process. The second-most important thing is to include science delivery specialists as well. Managers usually have at least some involvement in the development of syntheses for their use, and science delivery specialists are usually involved in delivery. But the most successful syntheses, according to the scientists and managers I interviewed, are those that

1. are based on extensive dialogue with managers and science delivery specialists in the planning stage
2. include consultation with managers during the information search, particularly if their information will be included
3. incorporate management input in the writing stage, especially in regard to management applications
4. use expertise from science delivery specialists in formatting and packaging
5. obtain comments from managers and science delivery specialists on review drafts
6. and rely on the entire network of scientists, managers, and science delivery specialists for getting products to the field and getting them used.

Figure 1 illustrates the process of collaborative synthesis development. Appendix A elaborates on the process.

While collaboration is crucial for developing syntheses useful to managers, several other aspects of the process are important as well. They are phrased as questions in the sections that follow—similar to the questions used in interviews for this project:

II. What is a synthesis? What kind is best?
III. What makes a synthesis scientifically defensible?
IV. What makes a synthesis useful to managers?
V. Is "outdatedness" a problem? If it is, how can it be addressed?
VI. What are some techniques for helping practitioners use syntheses more efficiently and effectively?
VII. What syntheses are available, and how can I find them?

I found sufficient information to fully develop a discussion of the nature and kinds of syntheses (Section II), features that make a synthesis scientifically defensible (Section III), writing and packaging techniques for making a synthesis useful for managers (Section IV). I found less information and fewer suggestions on keeping syntheses up-to-date (Section V) and increasing readers skills in using syntheses more effectively (Section VI), so these discussions are very brief. A question that arose repeatedly in interviews was "Where can I find these syntheses?" I found it difficult to answer, so Section VII addresses the issue. Appendix B describes the methods used to develop this report. A list of JFSP syntheses is in Appendix C.

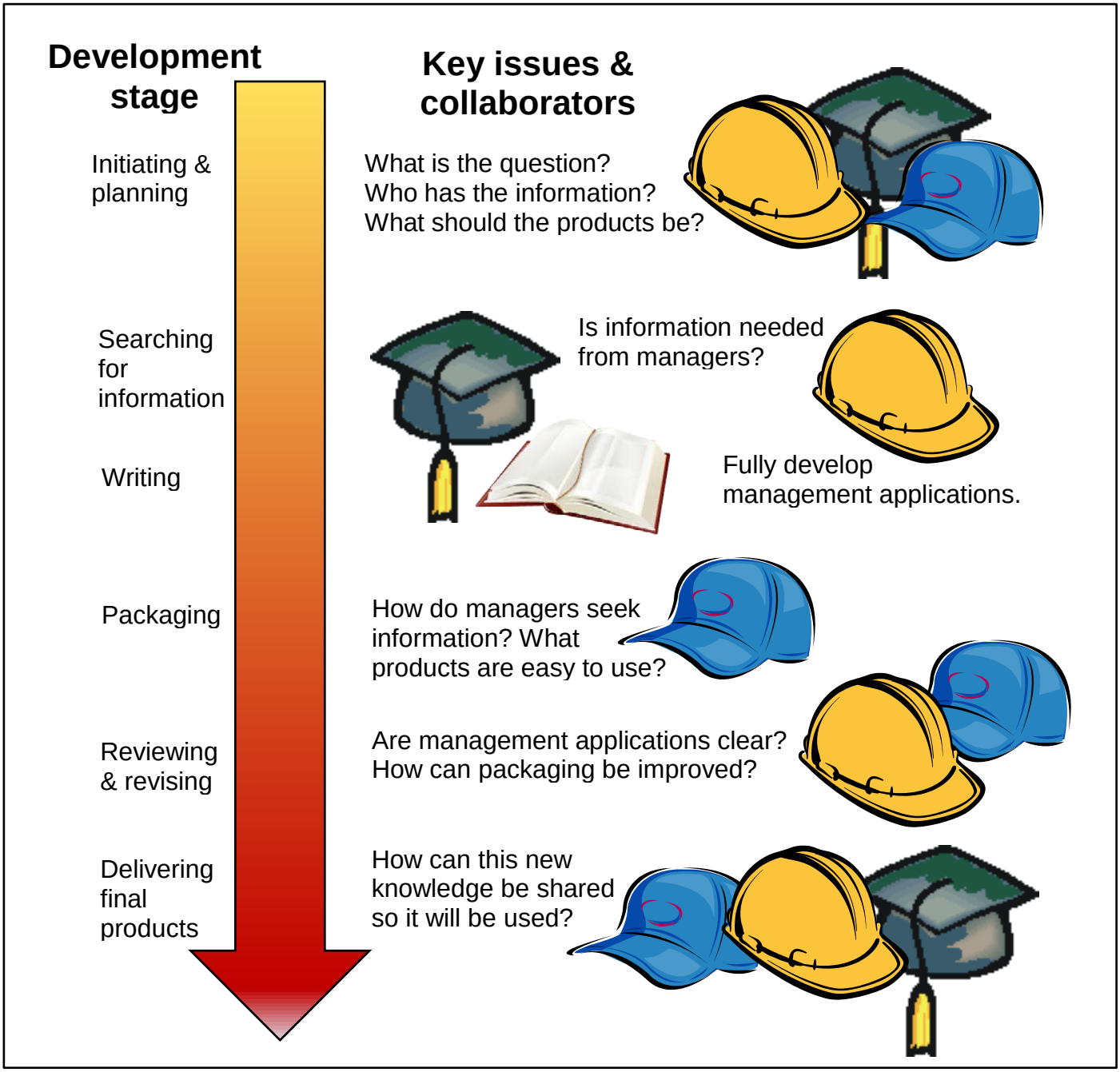


Figure 1. Integrating scientists (mortarboard), managers (hardhat), and science delivery specialists (baseball cap) throughout the process of producing a synthesis. For more details, see Appendix A.

Looking into Syntheses:
Key Findings

Section I. Introduction

The most important thing to do, to ensure that a synthesis is useful to managers, is to include them in the production process. The second-most important thing is to include science delivery specialists as well.

Section II. What is a synthesis? What kind is best?

- A synthesis for managers
    - examines and summarizes a body of information
    - describes pattern or lack of pattern in the information
    - explains what is known and what is not known
    - describes applications
- **Literature reviews** may be most appropriate for syntheses covering controversial issues on which published studies are relatively abundant, especially if the studies are so diverse that it is impossible to compare results directly.
- **Meta-analysis** is most appropriate for issues in which most of the evidence has been collected using similar techniques, and either raw data or complete descriptive statistics are available.
- **Systematic reviews** may be most appropriate for focused management questions, especially if they are controversial.
- **Narrative syntheses** may be most appropriate for topics that are relatively new or highly interdisciplinary, topics that vary regionally, and issues that are best addressed with examples and case studies.
- **Guidebooks and handbooks** may be appropriate vehicles for synthesis if they link to thorough background and documentation.

Section III. What makes a synthesis scientifically defensible?

- The basis for a high-quality synthesis is a thorough, unbiased search for information. The search should be carefully discussed in the planning stage and documented for the reader.
- Information should be evaluated based on scope of inference and reliability of findings.
- Synthesis authors use many tools to search for patterns, but all should lead to the authors telling the readers what the information *means*. That is the heart of synthesis.
- The authors should communicate their level of confidence in the patterns described and explain what information is *not* known.

Section IV. What makes a synthesis useful to managers?

- The science should be presented accurately with use of tools such as hedges, identification of inferences, and use of links and in-text citations.
- Management applications should be fully developed via dialogue with managers in the planning stage, review of drafts by managers, and possibly by including managers as authors of management sections.
- Layering of information may be a fruitful technique for packaging synthesis products so a concise summary is available but it provides easy access to full explanations and documentation.
- Packaging and delivery of syntheses should be addressed in the planning stage and completed just as carefully as preparation of the foundational synthesis document.

Sections V, VI, VII

- Store syntheses systematically and let managers know how to find them.
- Package supplements and key new research together with original syntheses.
- Embed pedagogy within syntheses: “how to use”, “how to read”, “how to think about this issue”.

Looking into Syntheses:
Applications

For proposed syntheses:

- In the planning stage, include scientists, managers, and science delivery specialists. If the synthesis has unique regional components, include someone from each region.
    - Develop a well-defined focus question, issue, or topic
    - Determine the nature and scope of information sources
    - Determine the kind of synthesis product(s) that will best address the need
- In the writing stage, include managers to help fully develop management applications. Consider having managers author or co-author these sections.
- Use expertise from science delivery specialists to plan packaging in ways that will make the product most accessible and efficiently used by managers.
- In the review stage, include scientists, managers, and science delivery specialists. Emphasize carefully review of management applications.
- Include all parties in advertising and delivering the final products. Rely especially on science delivery specialists' understanding of communication networks in the management community.

For existing syntheses:

- Consider repackaging with a "layered" structure that presents management applications up front in a 1- or 2-page summary, with links to details, further discussion, and documentation in the full synthesis. Include managers and science delivery specialists to address:
    - Are the management applications fully developed in the original synthesis? If not, collaborate with scientists to develop them now.
    - Are two layers (the short summary and full synthesis) enough? Is an intermediate layer needed—an in-depth guide for managers?
    - If the synthesis has unique regional components, should they be broken out into separate, smaller products?

For storing and updating syntheses:

- There is currently no one way to locate the >100 syntheses available on fire. Even if you search several sources, you can't be sure you've found them all. Develop a systematic way to store syntheses, a "reference library" of foundational information on fire management.
- Package supplements and key new research so they are associated with original syntheses. Thus the background and history of the research is available through the original synthesis, but key new findings can be found in the same place.
- Let managers know what is in the reference library. Focus especially on communicating with staff who are new to the field of fire management.

For more effective, efficient use of syntheses:

- Embed pedagogy within syntheses: "how to use", "how to read", "how to think about this issue".
- Consider whether direct teaching tools are needed, especially for staff new to fire management. If anything is developed, it should be short. Consider a podcast or YouTube presentation (15 minutes or less), downloadable PowerPoint (15 slides or less), online tutorial, or 15-minute segment in the S and/or Rx training series.

Section II. What is a synthesis? What kind is best?

I did not find any single, clear definition of synthesis for natural resource management in the literature. Therefore, based on thoughts from Krueger and Kelley (2000), Thomas and Burchfield (2000), and interviewees, I have developed the following:

> *A synthesis created to contribute to science-based management of wildland ecosystems is a product that*
>
> - *examines and summarizes a body of information*
> - *describes pattern or lack of pattern in the information, thus creating new knowledge*
> - *explains what is not known as well as what is known*
> - *describes applications to wildland management*

The term *synthesis* originated in the Greek word for a collection. But a synthesis for wildland managers is more than a collection of information; it creates something new from the information that is found, while also enabling readers to locate the source of the information. Just as an aerial view of a landscape shows both detail and pattern (Figure 2), a synthesis not only provides information but also describes patterns in the information, thus producing new knowledge.

Figure 2. Like an aerial view of a landscape, a synthesis shows patterns in information. Mosaic fire pattern in Madison Canyon. NPS photo by Jim Peaco, July 24, 1989.

Interviewees for this project listed many characteristics of syntheses, and they are similar in many ways to dictionary definitions. All require a search for information, integration to produce new knowledge, and identification of practical applications (Table 1).

Table 1. Comments from interviewees and dictionary definitions describe similar features of syntheses, including 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 or uncertainty 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, *Word Central online*) • the dialectic combination of thesis and antithesis into a higher stage of truth (Merriam-Webster 2007, *M-W online*) • the action of proceeding in thought from causes to effects, or from laws or principles to their consequences (Murray 1971, *Oxford English Dictionary*)

The "Wisdom Hierarchy"

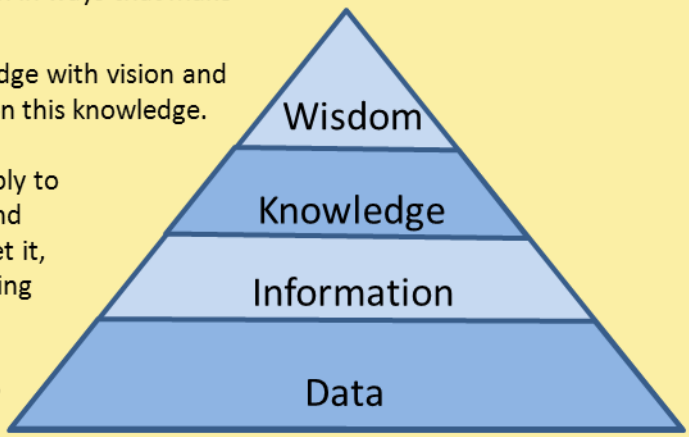
This report uses the following terms to describe kinds of information in the "wisdom hierarchy", adapted from Rowley (2007):

Data are discrete, objective facts or observations—not organized, not processed, not interpreted.

Information is data that have been processed so they are meaningful .

Knowledge results from the synthesis of many sources and kinds of information. Knowledge organizes and integrates information in ways that make it more understandable.

Wisdom is the ability to use knowledge with vision and foresight and act practically based on this knowledge.



How does the wisdom hierarchy apply to resource management? Research and monitoring collect *data* and interpret it, providing *information*. Syntheses bring *information* together from many sources to provide *knowledge*. Managers who integrate *knowledge* with understanding of other factors can act with *wisdom*.

In natural resource management and wildland fire, many different products can fit the definition of a synthesis: It could be a peer-reviewed document constructed with rigorous scientific standards or a guidebook based on scientific findings and other observations. Different kinds of syntheses have different strengths and weaknesses, as described below. This is why it is crucial for managers, scientists, and science delivery specialists to discuss the content, format, and delivery of any synthesis project in detail at the outset, and to collaborate as needed throughout the project (see Figure 1 and Appendix A). If the managers who request a synthesis are not thinking of the same product as the scientists who produce it, the project will frustrate the scientists and disappoint the managers.

Several kinds of synthesis have been produced by JFSP (Appendix C), and they typify the kinds of syntheses produced for natural resource managers in general. Here is a brief description and comparison:

The **literature review** is perhaps the best-known and most widely accepted form of synthesis for research scientists, since it is used in theses, dissertations, and research papers to place new information in the context of existing knowledge. When based strictly on peer-reviewed science[1] and

[1] I use "peer-reviewed" here as it is commonly used in science, that is, to indicate a document that has been reviewed and approved for publication by anonymous reviewers. However, it is important to note that many documents in the grey literature also receive peer review, though not necessarily from anonymous reviewers. For

published in a peer-reviewed journal, a literature review has high scientific credibility. However, it has some disadvantages as a tool to inform management: First, it is may not include valuable information from outside the peer-reviewed literature (Figure 3). Second, because journals require concise writing and discourage the presentation of information available elsewhere, it contains very limited background information. Third, the writing style is likely to be dense and technically specialized. Finally, potential management applications may be presented briefly and somewhat conservatively.

A literature review may be most appropriate for syntheses covering controversial issues on which published studies are relatively abundant, especially if the studies are so diverse that it is impossible to compare results directly by using meta-analysis.

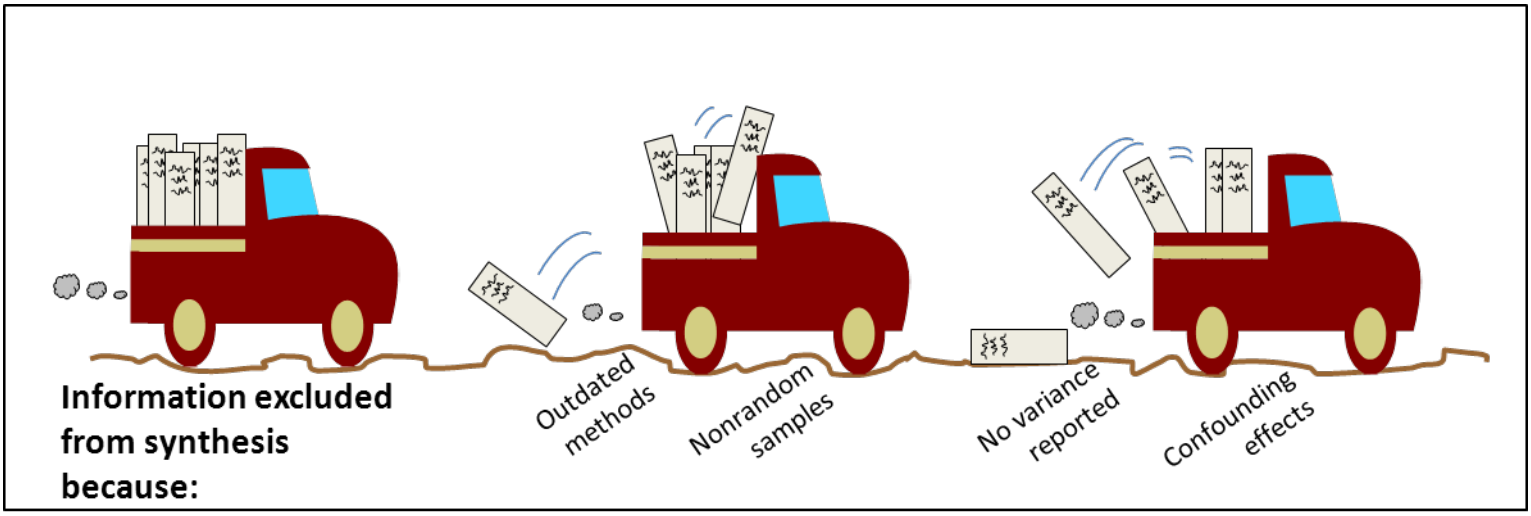


Figure 3. Decisions about the information to include in a synthesis are challenging. Highly inclusive criteria may admit information that is unreliable or has a narrow scope of inference. Highly exclusive criteria may leave valuable information by the wayside and leave the writer with little to synthesize.

Meta-analysis is not exactly a form of synthesis, but rather a statistical technique that can aid in synthesis. In a meta-analysis, data from several studies are pooled and analyzed for statistical significance (Merriam-Webster 2007). Because meta-analyses draw from a larger sample than any individual study, they can produce more precise results. However, if data are pooled inappropriately, the result may be precise but wrong; and if important evidence is excluded because of incompatibility in study design rather than flaws in the research, the result may poorly represent the actual state of knowledge. Egger and others (2001b) note that, in medical research, it may be more worthwhile to examine possible sources of heterogeneity than to pool data in search of a single, statistically tested answer. In natural resources, it would be sad and dangerous to exclude insights from our scientist-elders simply because they used a now-outdated study design or failed to report all of the information needed for pooling data.

Meta-analysis is most appropriate for issues in which most of the evidence has been collected using similar techniques, and either raw data or complete descriptive statistics are available.

The **systematic review** (also called "systematic evidence review") assesses a treatment's effectiveness by integrating information in an unbiased, systematic, repeatable way. This technique has been most

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example, all Research Papers, Research Notes, and General Technical Reports published by the US Forest Service are reviewed by at least two scientists before they are accepted for publication.

thoroughly developed in medical fields (see Egger and others 2001a), but its application to natural resource issues is increasing. Pullin and Stewart (2006) and the Centre for Evidence-based Conservation (CEBC) (2010) offer guidelines for systematic reviews in the environmental sciences. Systematic reviews can be published in the peer-reviewed literature and also in the Collaboration for Environmental Evidence (http://www.environmentalevidence.org/index.htm), hosted by CEBC. Systematic reviews differ from literature reviews and narrative syntheses in two important ways: First, they *require* that all stakeholders be included in the planning stage, when the focus question is developed and methods are agreed upon. Second, they are conducted with rigorous adherence to the agreed-on methodology so the product will be objective and free of bias. The methodology usually requires that two or more scientists examine each reference to determine if it should be included. While this approach increases the objectivity of the synthesis, it is likely to increase the cost and time required as well.

Systematic reviews have high scientific credibility, and they have some advantages over literature reviews: They generally include more studies because unpublished information and data from the grey literature are used; they are more likely to include research that produced nonsignificant results (Fazey and others 2004); and they clearly identify best management practices, since that is the whole point of the review. However, like literature reviews, systematic reviews usually provide the reader with little background information. Systematic reviews often use quantitative techniques (meta-analysis or tallies of research outcomes), they also admit qualitative discussion (Pullin and Stewart 2006). This flexibility allows them to avoid a major shortcoming of meta-analysis, that is, the exclusion of substantial high-quality information simply because the data were collected in ways incompatible with the quantitative technique to be applied.

> *A systematic review may be most appropriate for focused management questions, especially if they are highly controversial.*

Narrative synthesis is the term used in this report for syntheses published in the grey literature that survey a topic or the information applicable to a management question[2]. Narrative syntheses are usually published by universities or federal entities rather than in the peer-reviewed literature. When I asked interviewees for examples of syntheses, narrative syntheses were the kind most commonly mentioned. Unlike systematic reviews, narrative syntheses may address broad topics as well as focused questions[3]. Content and format are relatively unrestricted, so a narrative synthesis can include extensive background information, detailed graphics, numerous examples, and supplemental materials such as glossaries. But narrative syntheses also have drawbacks: They do not have the high credibility that literature reviews and systematic reviews enjoy in the scientific community. Because they lack strict rules for inclusion of evidence, they can produce biased results. And they are often long, which can in itself be a barrier to readers and can also make it difficult for readers to find exactly the information they're seeking.

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

[2] CEBC describes a "narrative synthesis" technique for systematic reviews; this report uses the term with a broader meaning.

[3] An example of the first is Werth and others' (2011) "Volume I" on extreme fire behavior; an example of the second is Hood's (2010) analysis of techniques for protecting old trees when fire is reintroduced.

A narrative synthesis may be most appropriate for topics that are relatively new, interdisciplinary, and thus not well understood by most field practitioners; for topics that vary regionally; and for issues that are best addressed by numerous examples and case studies[4].

Many scientists would not view a **guidebook** or **handbook** as a synthesis, but many managers do. In fact, some interviewees identified guidebooks as the kind of synthesis they use most often. If we recall that the definition of a synthesis requires that it include management applications, then a guidebook is the logical endpoint of the process. Guidebooks are published with field practitioners in mind and are usually organized so managers can find information quickly and easily. Vocabulary and writing tend to be direct and concise. Illustrations are many and may include decision trees or other tools for decision-making. But guidebooks also have drawbacks as vehicles for synthesis: Their scientific credibility may be limited; they may not provide background information that helps readers learn how to think about an issue; and they seldom provide details about or documentation of the science used.

Guidebooks and handbooks may be appropriate vehicles for synthesis if they either provide thorough background and documentation or can refer to other documents that provide this information and more comprehensive synthesis.

Short, **summary documents and briefing papers** may also be syntheses, but only if they identify information sources. Summaries and briefing papers are appealing because of their brevity and direct language. However, unless they are well documented or linked with detailed source documents, they are dead-end documents for readers; that is, readers may find an idea that sounds useful but, without documentation, they cannot figure out "Who says so?" and thus defend the statement or obtain more information. A bibliography at the end is only marginally helpful; instead, readers need a citation for major point set of information, so they can figure out if it applies to their particular management issues. (See "In-text links and citations" in Section IV.)

Summaries and briefing papers can serve as syntheses if they are based on a more complete synthesis and major points are linked directly to the appropriate sections in the full synthesis.

It should be obvious from this discussion that synthesis is a difficult, challenging endeavor. While automated searches and quantitative analysis can be helpful, ultimately the authors must assess the information they find and figure out what it means. Critical thinking, creativity, and flexibility play important parts in creating a scientifically valid, useful synthesis for managers.

> 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

[4] Examples of syntheses organized to accommodate regional variation include Brown and Smith (2000)'s *Effects of fire on flora*; Zouhar and others' (2008a) *Fire and nonnative invasive plants*; and Knapp and others' (2009) *Ecological effects of prescribed fire season*.

Section III. What makes a synthesis scientifically defensible?

Publications about science synthesis in natural resource fields were few before the 2000s. Discussion of synthesis has increased in the last decade with the development of systematic reviews, and ecologists are now asking if "synthesis ecology" should be recognized as a scientific discipline (see http://www.imachordata.com/?p=1178). This section explores some of the unique challenges of developing a high-quality, defensible synthesis.

The managers, scientists, and science delivery specialists whom I interviewed agreed that the basis for a high-quality synthesis is a thorough, unbiased search for information. This concept is so ingrained in the world of scientists that few sources actually discuss it. The Centre for Evidence-Based Conservation (CEBC) provides sound guidelines for systematic reviews, which I have adapted to apply to syntheses in general. Once information is located, it must be evaluated so its reliability and relevance are understood. Then the author must synthesize it, identifying patterns and noting what is not known or well understood.

> ***Short & concise ≠ quick & cheap***
>
> Many interviewees mentioned the importance of brevity and conciseness in a synthesis. That is very hard to achieve in a single document that also provides background and documentation. The "layering" approach may make this possible (Section IV).
>
> If readers want only a short synthesis, will it be quick and inexpensive to produce? Only if someone has already searched for information, analyzed it, and produced a full synthesis.

<u>Searching for information (CEBC pp. 24-25, 31-36):</u>
The information basis for a synthesis depends on what is available and what the synthesis is for. Scientists and managers should discuss these issues thoroughly during the planning stage (see Section I and Appendix A). If the topic is highly controversial, planners may decide the synthesis should include only peer-reviewed science or only materials with quantitative, statistically tested results; if information is sparse and variable, they may welcome reliable reports from all sources, knowing that a more limited search could lead to a biased or shallow interpretation. There is no strict divide between scientists and managers in terms of insight, experience, or even education, and managers may be the leaders in developing new knowledge. In regard to fuels management in riparian areas of the West, for example, Stone and others (2010) found that the state of the practice preceded the state of the science, so they focused their synthesis on input from managers.

> 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

Special challenges may arise when authors seek information for a synthesis that is national in scope and also covers regional variability. Some areas are "richer" in research than others. Regions also vary widely in land ownership patterns and the heritage of aboriginal and other traditional knowledge. Interviewees from several JFSP consortia commented on the paucity of fire research in their areas and mentioned managers' reliance on the long-term experience of local experts. Thus the planners of a national synthesis are likely to find that the questions in Figure 1, such as "What is the question?" and "Who has the information" are answered differently from one region to another. This challenge must be met if the synthesis is to serve all regions.

Find the source!

Whether working with field data or research reports, it is important to find the original source of information and verify it. Tufte (1997) reports an error in map making that was repeated for more than a century: A 1622 map (below) showed California as an island. Tufte reports that the error was reproduced in 182 subsequent maps. The last one was published in 1745, "after which California cartographically rejoined the mainland". And don't think that no one can tell if you didn't go to 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). Information from Tufte 1997.* Moll Map detail courtesy of the Lilly Library, Indiana University, Bloomington, IN.

Regardless of search strategy and regional challenges, three practices will improve the results:

1. Use a variety of search engines because no single source (currently) provides comprehensive coverage of wildland fire issues and some have greater coverage of documents published decades ago[5]
2. "Chase down" the primary research and other potentially helpful materials that are referenced in your sources. This is a good way to locate seminal works in the science legacy.
3. Cite the primary research, if you can possibly find it, and always read the materials you cite. If a secondary source misrepresented the study, you don't want to perpetuate the error. At the very least, it's embarrassing. It is also a disservice to your readers and reflects poorly on your scholarship.
4. Explain your search strategy in the synthesis, including the process of chasing articles. This explanation is analogous to the "Methods" section of a research paper because it tells readers exactly how you got the information that you have synthesized for them.

[5] Scientists usually begin with science search engines such as JStor (http://www.jstor.org/), Scirus (http://scirus.com/), and Web of Knowledge (http://wokinfo.com/). Resources focused on fire include the FRAMES Resource Cataloging System (https://www.frames.gov/about/resource-cataloging-system), which contains ~38,000 references on all wildland fire topics and includes the catalog of the E. V. Komarek Fire Ecology Database (http://www.talltimbers.org/fedb-intro.html); and the Citation Retrieval System for the Fire Effects Information System (CRS) (http://www.feis-crs.org/), which contains ~80,000 references on biology, ecology, and fire effects. The Komarek Library and Citation Retrieval System both contain articles and other materials that date back into the 1800s and early 1900s—resources not likely to be thoroughly covered by broader-based search engines.

Evaluating information (CEBC 37-42):

How "generalizable" is the information you have found? To use a statistical term, what is its scope of inference? This issue requires critical thinking and judgment on the part of authors as they select and weigh the information they find. Let's break it down into two questions:

> Better use of information technology is essential, but creativity abhors prescription and well-documented junk is still junk.
>
> Kurt Riitters (2011)

1. How much of the population has been studied? The importance of this question is evident when we think about syntheses that cover plant and animal species. If a species occurs in 20 states but the available information comes from only one, managers in the other 19 should probably apply the results with caution[6]. Scope of inference may be limited temporally as well as spatially, for example, when information on fire effects is available for only 1-2 years after fire. Finally, scope of inference is also an issue in regard to individual research projects. How should the results of two studies be presented to readers when one sampled a single prescribed burn using exhaustive field measurements and the other sampled 20 burns in 10 states using remotely sensed data? According to CEBC guidelines (p. 39), the first study has relatively higher internal validity and the second has higher generalizability. Managers may need the information from both.
2. How reliable are the results? In systematic reviews, two or more scientists assess each information source to determine if its results should be considered in further analysis. Authors of literature reviews and narrative syntheses use less rigorous, less time-consuming processes but still must assess the reliability of information, especially when sources disagree. Several authors suggest formal criteria for ranking the quality of information, including publication type (Krueger and Kelley 2000), publication outlet (Leidolf and Bissonette 2009), the rigor of the sampling design (see Peppin and others 2010a), and the report's basis in field observation (Gucker and others 2012).

Like the search strategy, criteria for including or excluding information should be documented in the synthesis methods or explained in the narrative as information is presented. You may exclude a study because it was poorly designed and you don't trust its results, but if you don't explain your standards, readers may see your choice as biased and dismiss the whole product.

> One episode of biased reporting just turns off the spigot for delivering science.
>
> Elizabeth Pickett

Synthesizing information: identifying pattern and lack of pattern (CEBC pp. 46-47):

This process is the heart of synthesis and what differentiates it from information summaries, annotated bibliographies, and grocery lists. Interviewees used the following descriptions of this task:

- Put an umbrella over the information
- Boil it down
- Explain the meaning and potential applications of the research—"It means this and not that, use it this way but not that way"

[6] Gucker and others (2012) report on the information available for syntheses recently written about invasive plants in the eastern states. In 27 of 61 syntheses, observation-based information on fire came from less than 5% of the states in which the species actually occurs. For example, white mulberry (*Morus alba*) occurs in 48 states, but observation-based fire information came from only one (New Mexico) (Stone 2009).

- Explain what we know and what we don't know
- What is the state of the knowledge?
- What things are more similar than different?
- Where is the preponderance of evidence?

Scientists use many tools for finding patterns in information, including meta-analysis, tallying results from studies or study sites, and constructing tables that summarize results. But these tools are only the path to synthesis; ultimately, the authors must tell the readers what patterns they found, what all of this information *means*. However, it's important to recognize that scientists may have a different view of "pattern" than managers, who must apply the new knowledge (see discussion on presenting management applications on p. 21). This points, once again, to the importance of collaboration on the design and content of the synthesis (Section I and Appendix A).

A synthesis usually brings together reports that contradict each other or seem to do so. It is important to examine differences among studies, seeking reasons for apparent contradictions (Eysenck, H. J. 1995). The author may also weigh the evidence on the basis of information quality and scope of inference and enumerate the studies that demonstrate one or the other conclusion. Peppin and others (2010a) combined these techniques in their systematic review of the effectiveness of postfire seeding in western forests. They found that research results were related to the quality of the research, which was related to the time of publication; more recent, higher-quality studies showed seeding was ineffective for preventing erosion. Finally, not every apparent contradiction can be explained. Authors should acknowledge this problem and may recommend ways to resolve it.

Synthesis is hard work and much needed, so the authors should put a bright spotlight on the new knowledge they create. There are many ways to package knowledge (Section IV), but the most important techniques are common to all good expository writing: Start paragraphs with clear topic sentences; start sections with thesis statements that capture the most important points; and begin the document with a description of the most important findings and why they matter. The examples in Table 2 are taken from my own writing. Under the "Ineffective" column, notice that no specific information is given, and there is no indication of why that particular information is worth knowing. Statements under the "Effective" column make assertions about patterns or relationships. Two helpful and entertaining articles on writing for natural resource fields are Carraway (2006) and Lerzman (1995).

<u>Identifying information gaps: the uncertain and the unknown</u>

Synthesis authors should not only describe patterns in information but also how much confidence they have in those patterns, and they must explain what is *not* known about an issue as well as what *is* known.

> [E]xpert judgement 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.
>
> Eysenck 1995

Table 2. What's the difference between effective and ineffective synthesis statements? Here are examples of topic sentences and theme statements.

Level	Ineffective	Effective
Paragraph	Many strategies for evaluating and addressing potential postfire invasions by nonnative species are described in this volume…[2] Stickney (1982) described the process of postfire plant succession following fire in Northern Rocky Mountain forests.[2]	Physical properties of a fire, if known, are logical descriptors of fire severity.[2] In areas near timberline, fire is less frequent and widespread than in contiguous forests below.[2]
Section or Chapter	The amount of fuel in seral lodgepole pine stands varies…[2] Permanent alder communities in northern Idaho… have been described by Daubenmire and Daubenmire (1968)….[2] This volume synthesizes scientific information about interactions between fire and nonnative invasive plants in wildlands of the United States.[3]	The literature shows that fire in many cases favors nonnative species over natives and thereby may lead to postfire invasions….[3] Many of the common shrubs and herbaceous plants that grow in northern Idaho forests can renew themselves from plant parts that survive fire.[2] Fires may directly reduce populations of invertebrates that reside in or deposit eggs in the surface vegetation or the forest floor.[2]

[1]Smith and others 2008a
[2]Smith and Fischer 1997
[3]Smith and others 2008b

Let's address the issue of confidence first: When a synthesis describes a pattern in information, the reader is likely to ask, "How do you know? How sure are you?" These questions may be about either the reliability of the research and its statistical significance or about potential application to a management issue. In any case, it is important to frame the basic information and the new, synthesized knowledge with enough detail that readers can assess its relevance to specific management questions. This is commonly done with "hedging"—placing a verbal boundary around a statement (Figure 4), such as the use of "commonly" in this sentence. Hedging is discussed further in Section IV. Hedges do not have precise meanings, so it's hard to use them to compare reports: Which is more certain, the "probable" outcome described for Study X or the "potential" outcome from Study Y? The International Panel on Climate Change addressed this problem by assigning simple English terms to levels of certainty (IPCC 2007). Terms relating to "confidence" are used for qualitative levels, and terms

Figure 4. Hedges place a verbal boundary around a statement. They can tell the reader about a study's scope of inference or the author's confidence in an assertion.

relating to “likelihood” are used for quantitative levels (Table 3). Use of this practice in syntheses for resource managers could improve the consistency and comparability of results.

Table 3. Standard terms used to describe qualitative (top) and quantitative (bottom) levels of confidence in patterns reported by the International Panel on Climate Change (IPCC 2007).

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

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

Second, let’s attempt to focus on ways to describe what is not known. If you have ever tried to look at the dark parts of the sky on a starry night, you know how challenging this can be: We gravitate toward knowledge just as we are attracted to light.

Almost every research paper ends with a description of what is not known and recommendations for future studies. But there will never be enough information to make management choices with certainty, and the most urgent questions may be the most difficult to investigate. Thomas and Burchfield (2000) caution that scientific analyses “…are often not about what is important, but what is easy to measure.” A synthesis must describe what is not known, placing these “knowledge gaps” in perspective—identifying the information most needed for present management and for emerging or future conditions.

A thorough analysis of information needed for management may help managers and scientists plan for the future. The staff of the Fire Effects Information System has conducted two such analyses in regard to relationships between invasive plant species and wildland fire (Gucker and others 2012, Zouhar and others 2008b). Both studies identified the topics that seemed most relevant to management decisions,

then quantified the information available and described its quality. The studies produced tables showing information gaps regarding fire for a total of 128 invasive species. Scientists and sponsors of science could use these results to help prioritize future research; managers could use them to note the species and topics for which knowledge is most uncertain and therefore monitoring may be most important.

One knowledge gap was mentioned repeatedly in interviews for this project and is mentioned throughout the fire effects literature: the lack of information on long-term effects of fire and management actions. There may be ample information on fire effects at a single point in time (usually the first year or two after treatment), but management plans are used for a decade or more, and public wildlands are to be managed for generations to come! The paucity of long-term studies is a serious problem for managers.

> "More research is needed" is not helpful. Give us information that helps us prioritize. Help us figure out how to bring the synthesis meaningfully to our landscapes, how to bring the science to a piece of ground.
>
> Jim Thinnes
>
> “More research is needed” is usually included because reviewers hammer you if your paper sounds like it's the end-all and be-all on the problem. It's a deferential statement, not "feed me".
>
> Charlie Luce

Section IV. What makes a synthesis useful to managers?

Consider again the wisdom hierarchy (p. 8), with *data* at its base, then *information*, then *knowledge*, then *wisdom* at the top. Section III discussed the integration of *information* to create new *knowledge*; this section describes ways to present, package, and deliver the information and knowledge so it can contribute to *wise management*. First, we look at technical aspects of the presentation. Second, we explore ways to fully develop and present management applications, based mainly on suggestions from interviewees. Then we look at a few techniques for packaging syntheses and getting them to the managers who need them.

<u>How should a synthesis present information and knowledge?</u>
No manager is likely to need the details of every assertion in a synthesis, so brevity and generalization are appealing. But readers often need just enough detail to decide if they should apply that information to a specific, local management question, disregard it entirely, or look up the source for more details. Here are three important techniques for presenting information and knowledge.

1. HEDGES: Section III discussed the need to evaluate the information available for a synthesis and describe its limitations, possibly with the use of "hedges" (p. 16). These may make a synthesis more complex and hence longer and possibly more difficult to read, but they have three important uses:
    - To help readers decide if the information applies to their specific management issues
    - To help readers understand the source of information and hence some possible limitations
    - To help authors communicate their level of confidence in the knowledge they present (Figure 5).

    Hedging lets the manager make decisions with awareness of uncertainty (Reckhow 1994). It can also prevent reports based on anecdotal information from taking on the appearance of experimental evidence simply by being cited, a risk identified by Marlow (2000).

> Hedge personal communications very carefully so they don't become "folk wisdom", accepted as if based on rigorous science.
>
> Mary Taber
>
> It's OK to use field knowledge, but explain the source and note the possible limitations.

2. INFERENCES: We use inference to make an educated guess about something we don't know, based on something we do know. It is common, for example, to infer a plant's response to fire based on its response to cutting or mowing (Figure 6). Inference is not as reliable as direct observation, however, so synthesis authors should tell the reader when they are using it. In the Fire and Fire Surrogate study, 15 years of experimental treatments on 12 study sites demonstrated that, while 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 (McIver and others 2012).

> Information must be verifiable. We need to help the reader understand the source and our level of confidence in it.
>
> Jamie Barbour

3. IN-TEXT LINKS AND CITATIONS: How can readers find the source if they need details about something referenced in a synthesis? This is easiest if they can follow links or citations embedded in the text (Figure 6). Like hedges, in-text references may make the text a little more difficult to read, but they can save a lot of time for managers who need the detailed information.

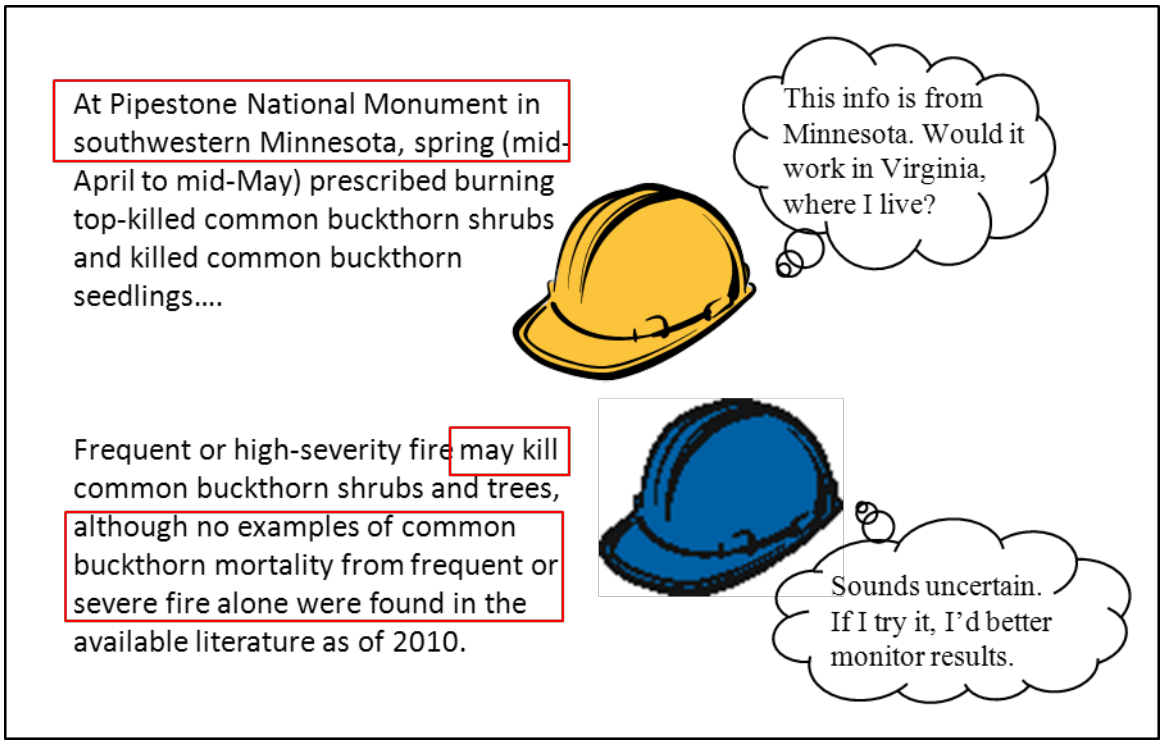

Figure 5. Hedges tell the reader about a study's scope of inference (top) or an author's confidence in a generalization (bottom). Examples are from Zouhar's (2010) species review of *Rhamnus* species in the Fire Effects Information System (www.fw.fed.us/database/feis).

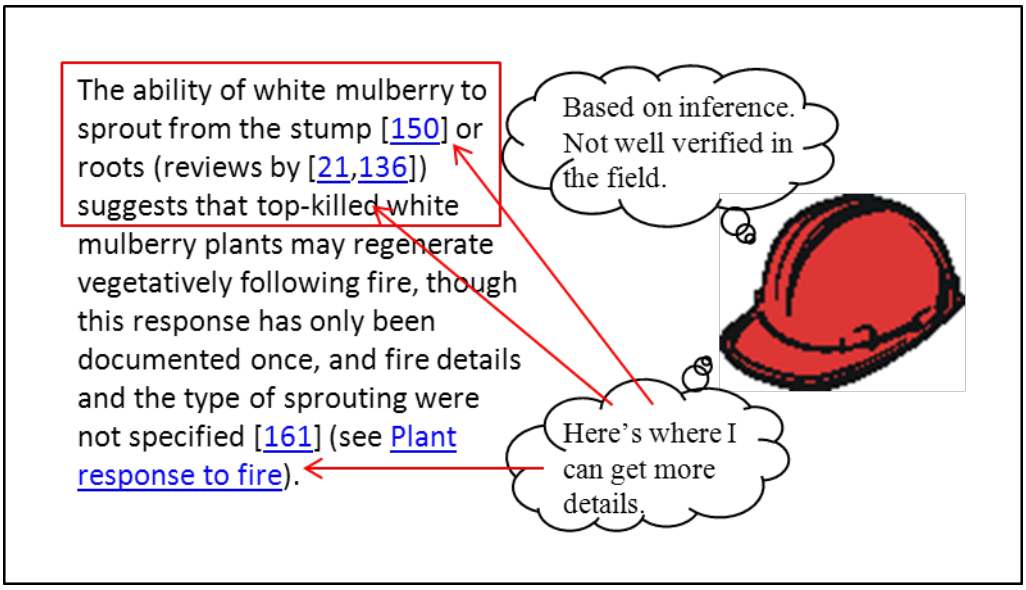

Figure 6. A synthesis should tell the reader if inference is used (top) and identify sources of specific information (bottom). Example is from Stone's (2009) review of *Morus alba* in the Fire Effects Information System (www.fw.fed.us/database/feis).

How can the knowledge in a synthesis be fully developed into management applications?
"There is no point in conducting reviews if they are not accessible to researchers and practitioners or if the implications of the reviews for conservation management are unclear" (Fazey and others 2004). I heard many discouraging descriptions of management applications from interviewees: "weak", "hesitant", "too generalized to be useful", comprised of "tiny little management applications" that are "buried in some obscure place". Surely the science-management community can do better. Those who plan a synthesis should address ways to develop and present management applications during the planning stage and revisit the issue several times during development (see Figure 1 and Appendix A). Interactions throughout the process are likely to be synergistic, increasing everyone's understanding of potential applications (van Kerkhoff and Lebel 2006).

Many interviewees suggested ways to highlight the relevance of a synthesis and fully develop its management applications. "Tell me early on why I should care," one interviewee commented. This may be difficult for scientists to articulate, while managers may do it directly and concisely—especially the managers who requested the synthesis in the first place! Syntheses can sometimes be organized according to questions that managers need to answer, possibly from stakeholders or NEPA and planning documents templates. The recently published synthesis on climate change, forests, fire, water, and fish (Luce and others 2012) was only begun after extensive discussion of management questions, according to lead author Charlie Luce. The planning workshop for the synthesis included a full-day meeting with managers ("real-live line officers"). Line officers might not easily recognize the importance of sharing their decision processes with scientists and explaining what they see and hear in dialogue with the public, but these insights added a great deal of value to the synthesis, according to Luce. In addition, the scientists gave 12-minute presentations at the meeting, which "prepared us for synthesizing because we had to boil everything down." Luce commented that the final section of the synthesis, "Management Actions and Decisions", contained the most applied information. "That's where I really grew," he added.

At the very least, managers should review the draft synthesis thoroughly ("not just to rubber-stamp it"). It is important that they consider whether the authors have described management applications in depth and captured all or most of the potential applications. But managers can have an even larger role if they are authors and co-authors of sections on management. This practice was suggested by numerous interviewees and has been used in several narrative syntheses. 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)[7].

How can syntheses be packaged so managers can easily find what they need?
Plan, write, package, and deliver syntheses with the audience in mind. It is not about what the planning committee or scientist had to go through to get it done. It is not about every detail discovered in the process. It is about managers, field practitioners, and land owners who need sound science to address management questions. Of course, this is complicated because the "audience" has diverse needs and

[7] Other examples: Fred B. Pierson, Range hydrologist with the Agricultural Research Service, is co-author of a pair of synthesis documents on western juniper (Miller and others 2005, 2007); James Morrison, from the Forest Service's Northern Region, is co-author of two syntheses on carbon in US forests (Ryan and others 2010, McKinley and others 2011); Becky Estes, Province Ecologist on the El Dorado National Forest, Placerville, CA, is co-author of a synthesis on effects of prescribed fire season (Knapp and others 2009).

Scientists' role in decision-making

Scientists can play a variety of roles in natural resource decision-making. Here are three viewpoints:

- Lach and others (2003) found that managers, interest groups, and members of the "attentive" public all preferred to have scientists help integrate research into management. Scientists supported this role but slightly preferred a more conservative, "interpretive" role.
- The CEBC (2010) describes systematic reviews as tools for "informing" managers rather than "advising" them.
- The Forest Service's code of ethics (U.S. Department of Agriculture, Forest Service 2000) forbids conflict of interest but places no specific limits on the scientist's role in applying research.

skills. I heard many suggestions about packaging syntheses. The most innovative of these is the idea of "layering" synthesis products to address different audiences and different needs.

Layering knowledge in syntheses: Most synthesis projects produce a single document, but many interviewees commented on the need for different products to meet the needs of different audiences. Some authors have already done this: An ecological synthesis is combined with a management guide for western juniper (Miller 2005, 2007), and a publication for decision-makers (Ryan and others 2010) complements a formal literature review (McKinley and others 2011) on carbon in US forests. Research organizations also produce short, attractive publications that summarize results of research or syntheses. JFSP has produced *Fire Science Briefs* and *Fire Science Digests* for this purpose. But while *Briefs* and *Digests* can increase awareness of a synthesis, their usefulness is limited because they don't connect readers directly from the summary to the full discussion of individual points. If readers want to know "Who says so?" or "Why would you think that?" they must obtain the full synthesis and search it for the explanation. This may not be a problem when a *Brief* discusses a single research project, but when it discusses a synthesis of more than 100 pages, the citation alone is not helpful.

A suite of carefully layered, linked products may be more effective than a collection of loosely connected publications because it could provide multiple levels for accessing knowledge. The more concise product could provide a gateway to in-depth knowledge. Here are two theoretical examples that refer to already-published documents as if they were designed for the purpose of layering information (with my apologies to the authors):

1. EXPANDABLE DOCUMENT: A 2-page summary of findings from the synthesis on public understanding of wildland fire (McCaffrey and Olsen 2012a) circulated a few months before the publication came out. Its organization is similar to that of the full synthesis (McCaffrey and Olsen 2012b), so it could be used as the entry level. Its short presentation of each section would be "expandable" into the full discussion (Figure 7A).

2. MULTIPLE, LINKED DOCUMENTS: JFSP has sponsored three publications on carbon in US forests (Figure 7B). The review published in *Ecological Applications* (McKinley and others 2011), the most rigorous product, could form the foundational layer. The synthesis for decision makers (Ryan and others 2010) would form the next layer, with each main point linked to details in the foundation layer, as needed. The *Fire Science Brief* (Frame 2010) could be the top layer—or perhaps only the four "Management Implications" within the *Brief* would be the top layer. Each of these points would be linked to explanations in the layer beneath. If feasible, the foundation layer could have a "ground floor" comprised of downloadable primary sources.

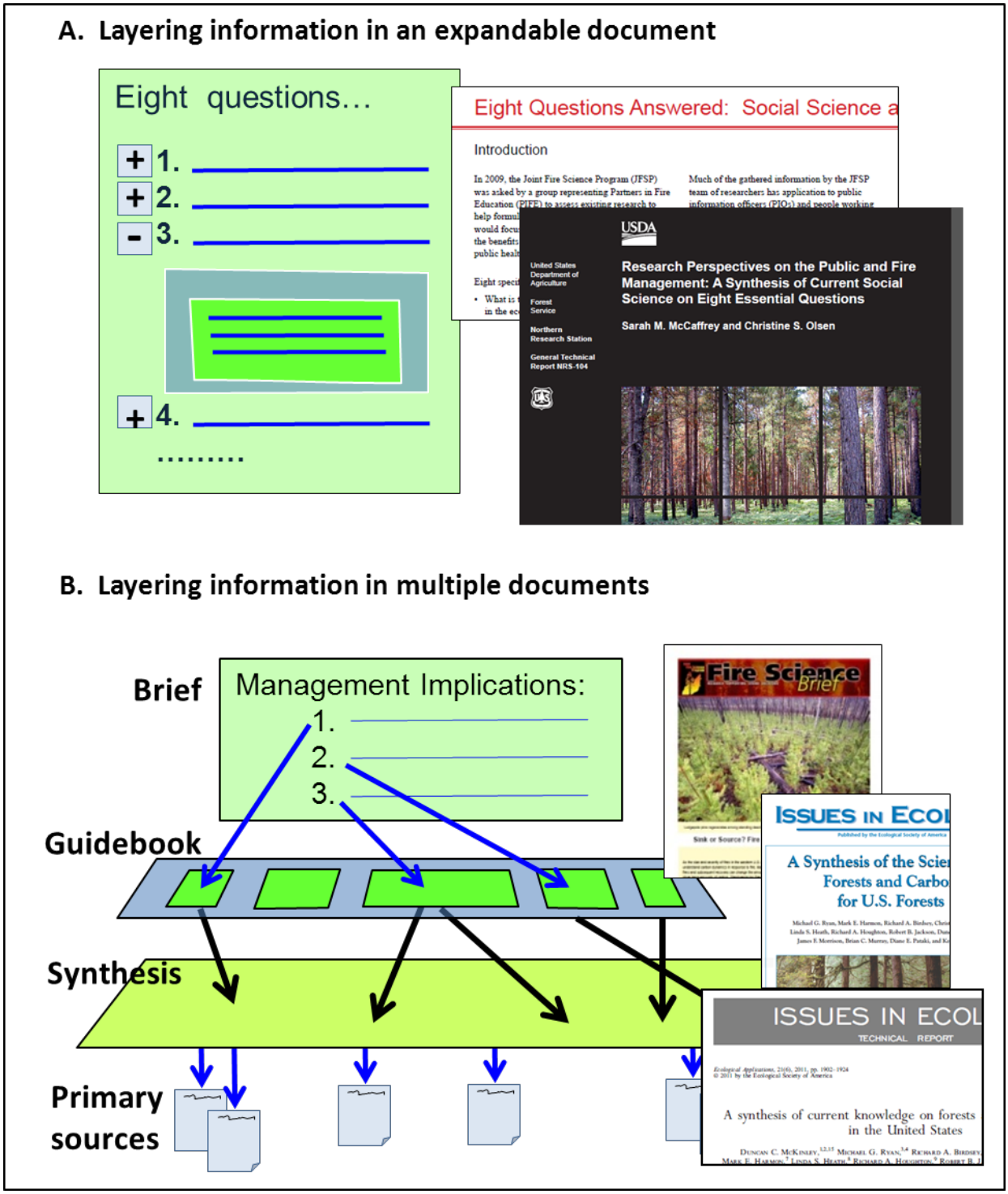

Figure 7. Possibilities for layering information. A. Expandable/collapsible structure for presenting layered information in a single document. The most concise, management-focused layer opens first. Each main point can be expanded to show detailed discussion and documentation. B. Linked structure for multiple layered documents. The detailed synthesis is the foundation (bottom); the concise, management-focused summary is at the top. Each layer links to more detail in the layer below. Links to primary sources could be provided beneath the foundational synthesis.

More packaging ideas: Publishers, advertisers, and marketing specialists know much more about packaging information than I could learn in this project. So do coordinators of the JFSP Fire Science Consortia, who function as "knowledge brokers", in the language of van Kerkhoff and Lebel (2006). Here are 12 guidelines based on interviewee comments, supplemented by information from the literature. Table 4 refers to a few examples from published syntheses. I suggest examining many publications for ideas.

> Make it an inviting document, a place they'll want to visit.
> Jamie Barbour

1. USE PLAIN LANGUAGE: Make it simple and straightforward. Highly technical language and jargon actually *exclude* readers (Thompson 1986), when the point of a synthesis is to *include* anyone who can use the information. Agency-specific language is also exclusionary. A helpful guideline comes from the director of the Science Writing Program at UC-Santa Cruz: Always provide "unfailing courtesy to the reader" (Blum and others 2006)[8].
2. PUT THE APPLICATIONS UP FRONT: Use a "punchy, conclusion-first" style (Pye and others 2007).
3. PROVIDE INFORMATION IN BITE-SIZED CHUNKS: Readers like short paragraphs that fit completely on a screen and short sections (3-5 paragraphs) with clear headers. Provide only the details needed for me to understand the point[9].
4. USE LISTS: Use bullets. Use numbered lists. If they're about management, emphasize them with color or in a text box.
5. USE GRAPHICS: Use "richly informative" graphics (Henebry 2011)—photos, diagrams, maps. Photos will tell us what "the literature" looks like in a real place. Write captions so they explain the meaning rather than just identifying axes or content. Use rich colors, but assign them carefully if they're essential for interpretation of graphs and maps[10].
6. USE TABLES—NOT JUST FOR DATA: Organize concepts with them. List studies in them so managers can easily find the information that fits their questions, geographic area, issues.
7. USE SUMMARIES: Provide lots of them—at the beginning and possibly at the beginning of each chapter. Mention the management applications first. Link them to content in the text. Abstracts seem harder to read than summaries. Why is that? Write them all in plain language.
8. ABOUT STATISTICS: It's more important to report the relevance of results than their statistical significance. For example, it is easier to interpret "Y increased with increasing X" than "There was a significant positive correlation between X and Y."
9. MAKE REGIONAL INFORMATION ACCESSIBLE: Make it easy to find, especially if the document is not organized by region.
10. HELP US NAVIGATE: Write each section so it will stand alone, since people won't read the synthesis from start to finish. Provide lots of road maps in the text and lots of other navigation tools so readers don't get lost. Put the chapter or section name on every page.

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[8]Plain language is required of federal agencies since enactment of the Plain Writing Act of 2010 (http://www.gpo.gov/fdsys/pkg/PLAW-111publ274/pdf/PLAW-111publ274.pdf). Forest Service research papers are included in the U.S.D.A. guidelines for compliance (US Department of Agriculture 2011).

[9] Readers of syntheses might agree with a newspaper editor who informed a teacher of science writing that his students "…are very smart, but if you ask them what time it is, they tell you how the watch works" (in Blum and others 2006).

[10] For guidance on map and graphic colors, se the National Science Foundation-sponsored website http://colorbrewer2.org.

11. USE EXAMPLES, CALLOUTS, BOX QUOTES: Examples can be real or made-up, as long as they illustrate the point clearly. If they would interrupt the text too much, put them in callouts or footnotes. Box quotes draw your eye and let you know what's going on in that section.
12. ABOUT CITATIONS: Readers need them but don't like them. It's distracting to have to read around them. Find a way to minimize or hide them, especially in electronic text. Consider links, footnotes, or endnotes instead.

Table 4. Examples of packaging techniques for improving syntheses. This is a very small set of examples relative to what is available in the literature; synthesis authors may benefit from examining a wide variety of examples.

Synthesis	Illustrates the following:
Birds and Burns of the Interior West (Saab and others 2007)	~Concise language. ~Examples (p. 8) ~Appealing photos—how could you miss with birds?
Climate Change, Forests, Fire, Water, and Fish: Building Resilient Landscapes, Streams, and Managers (Luce and others 2012)	~Title tells us it's interdisciplinary ~Definitions in callout boxes (p. 7) ~Pictorial definitions (p. 44)
A Comprehensive Guide to Fuel Management Practices for Dry Mixed Conifer Forests in the Northwestern United States (Jain and others 2012)	~Key findings from all sections in one place (pp. 5-7) ~Sections all use same structure ~Information from managers, field visits (p. 8) ~Table describes studies and regions (p. 49)
Ecological Effects of Prescribed Fire Season: A Literature Review and Synthesis for Managers (Knapp and others 2009)	~Cover design tells what it's about ~Findings are in a bulleted list early on (p. 4)
Mitigating Old Tree Mortality in Long-Unburned, Fire-Dependent Forests: A Synthesis (Hood 2010)	~Table of studies and what each measured (pp. 13-15)
Post-Fire Treatment Effectiveness for Hillslope Stabilization (Robichaud and others 2010)	~Detailed results presented in appendices
Research Perspectives on the Public and Fire Management: A Synthesis of Current Social Science on Eight Essential Questions (McCaffrey and Olsen 2012b)	~Organized as list of questions
Synthesis of Knowledge from Woody Biomass Removal Case Studies (Evans 2008)	~Based on case studies from managers in regions throughout continental US
Synthesis of Knowledge of Extreme Fire Behavior: Volume I for Managers (Werth and others 2012)	~Graphs are clean, uncluttered (see Chapter 4) ~Callout boxes (p. 25) highlight key concepts
A Synthesis of the Science on Forests and Carbon for U.S. Forests (Ryan and others 2010)	~Clear, appealing graphics with stand-alone captions. ~One could learn much of the content just by reading the pictures
Wildland Fire in Ecosystems: Effects of Fire on Cultural Resources and Archaeology (Ryan and others 2012)	~Table lists studies and nature of content (pp. 49-51)

What are effective ways to get syntheses to the managers who need them?

Interviewees considered the delivery of science syntheses a crucial step in getting them used. These suggestions came mostly from managers and science delivery specialists; I have added a few suggestions from the literature.

> … science communication needs to be explicitly considered early in the project planning cycle… and funding be dedicated to the movement of knowledge.
> Sheikheldin and Krantzberg (2010)

1. PRODUCE A 1-PAGE BRIEF: Emphasize management applications, preferably in bullet form.
2. ADVERTISE AHEAD OF TIME: Months elapse between having a document ready for publication and getting it out. Use the time in between for some advertising. Let people know it's coming. McCaffrey and Olsen's (2012a) 2-page summary of social science findings circulated for a few months before the publication came out. People were watching for it, anxious to get their copies.
3. GIVE THE RESEARCH A HUMAN FACE (Sheikheldin and others 2010). Use webinars (but "schedule them for a rainy day"!). Try VTC sessions, podcasts (call them "Fire Talk"?). Go to meetings and take flyers along. Put on a regional "research road show". Use field trips. A sense of humor might also put a human face on science. "If our papers were fun," Jerry Cox (1993) commented regarding scientific publications, "ranchers, land managers, and even scientists might actually read an article…."
4. PUT SYNTHESES WHERE MANAGERS WILL FIND THEM (Seesholtz 2008): Every group wants their own website to be the destination of choice. Get over that. Put products in places where managers already go. Make sure web postings have stable addresses—"places that will last". Advertise through channels that managers already use. Reach them at meetings they already go to. Don't put products in a place available only to government workers.
5. FOLLOW UP WITH PARTNERS. Who asked for the synthesis to begin with? Who provided reviews? Send copies to them.
6. PEOPLE LEARN FROM A VARIETY OF MEDIA. USE AS MANY AS YOU CAN. Try flyers, articles in trade journals (*Wildfire, Fire Management Today*), YouTube, Twitter. Use emails and newsletters. Try getting a manager to write a "book review". Be sure to link all of these to a 1- or 2-page summary focused on management applications. Link that to specific sections in the synthesis.

> There must be a sweet spot somewhere on the continuum between personal interaction and technological delivery.
> Elizabeth Pickett

Section V. Is "outdatedness"[11] a problem? If it is, how can it be addressed?

The short answer to this question is "yes, as a synthesis becomes out-of-date, it becomes less useful to managers". But how do we know if it's out of date? And if it is, what can we do about it? Those questions are harder to answer. I did not do extensive research on this issue, but this short section summarizes what I learned.

> 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

Syntheses, especially narrative syntheses designed to help readers gain a basic understanding of a topic, form a foundation for understanding, a "way to think about the subject", according to Penny Morgan. This foundation is not likely to change rapidly, but if and when it does, the document's usefulness becomes limited. Similarly, the emergence of information on the effectiveness of a new management technique may make a systematic review outdated. In these cases, the synthesis may be incomplete or misleading; it is time for an in-depth revision or a new product.

> You kind of have to reinterpret old research, see the old data with new eyes. For instance, take the old silvicultural research but consider extra measures like diversity. Also, due to invasives and climate change, research done in the 1950s was actually done in a different ecosystem than we have now.
>
> Christel Kern

While a completely new synthesis may not be needed for years or even decades, the details and documentation within a synthesis are likely to become out of date before it is even published, because new research is constantly emerging and managers are always refining and developing techniques. This problem might be addressed, at least in part, in these ways:

- Follow the model of the old encyclopedia yearbooks by publishing short supplements to original syntheses, as needed. This would also be a good way to add followup information on long-term studies.
- Don't produce syntheses just as stand-alone documents. Use them as the foundation of a "family" of documents that managers can consult to find the original synthesis and any updates or key new research.
- When something is updated or supplemental material becomes available, advertise—let managers know!

[11] It's a klunky word but yes, it is a word (Merriam-Webster 2012).

Section VI. What are some techniques for helping practitioners use syntheses more efficiently and effectively?

Many interviewees agreed that good critical thinking skills are needed to apply research to management. As Jeff Rose put it, “Keep in mind that managers are paid to pull ideas together—to synthesize and apply.” It may be worthwhile to encourage development of critical thinking and introduce strategies for efficient reading of research and syntheses.

Learning can come from direct instruction and also from subtle, indirect instruction. The latter was definitely favored by interviewees. “Embed pedagogy in the text,” Rick Miller suggested, “by using simple language, in-text definitions, and short explanations.” In contrast, direct instruction puts “more burden on the manager to find the time and then use it” (Eugenie Montblanc).

Direct instruction may also be useful. Content could be adapted from university classes that address how to read the scientific literature efficiently. A common strategy is to “spiral” through a scientific paper, going only as deep as necessary to meet the reader’s needs: Read the title and then the abstract or conclusions to see if the research might apply, then look at the graphics and discussion, then results… and read the methods last. Could this strategy be adapted for syntheses? Could a short, online tutorial be provided for syntheses in general? Or should each synthesis contain a short callout on “How to use this document”? These questions are worth considering in the development of future syntheses.

Section VII. What syntheses are available, and how can I find them?

This question came up many times as I was arranging and conducting interviews. Syntheses might be considered a key set of references in the manager's information library, but if this is the case, they need to be located in a place where they can always—easily—be found. Currently, storage and retrieval of syntheses are a little haphazard. The JFSP website lists 24 publications as "syntheses", but some important ones are not included (Appendix C). The situation is messier in general search engines. As of November 27, 2012, the FRAMES Resource Cataloging System (RCS, at https://www.frames.gov/about/resource-cataloging-system) listed 263 documents with "fire" and either "review" or "synthesis" in the title. These included fire season reviews and newsletter items, but most seem to fit the definition of *synthesis* given in Section II. Many are quite recent; nearly half have publication dates of 2000 or later (Figure 8). The Citation Retrieval System for the Fire Effects Information System (CRS, at http://www.feis-crs.org/) provides similarly abundant documents—196 with "fire" as a keyword and "review" or "synthesis" in the title. Obviously, syntheses are available—a huge resource for managers and a sizeable investment for research sponsors. Do managers need a more systematic way to find them? If they do, what's a good way to develop it? And how will field practitioners learn about it?

Several interviewees mentioned the desirability of ways to search efficiently for fire research publications and download documents. The topic of citation management is somewhat peripheral to this report, but here is a summary of a recent discussion with Alan Long, Diana Olson, Jessica Miesel, Wayne Buck, and Vita Wright. I thank them for their thoughts; if there are errors here, they are mine:

Three large fire reference databases are currently in existence (RCS, CRS[12], and the E.V. Komarek Library at the Tall Timbers Research Station). They have overlapping—but not completely redundant—content and keywording systems. The Komarek Library and CRS both have keywords for searching by geographic criteria, but FRAMES does not. RCS searches references in the Komarek database but does not currently connect to CRS. The Northern Rockies Consortium is developing an extensive list of region-specific references, partly by using the RCS and possibly CRS; other consortia provide short lists of citations or comprehensive lists on specific topics. The current situation is complex—maybe even messy—but it could lead to the development of more efficient ways to obtain information and increased accessibility of downloadable documents. How helpful would that be for managers? What investment would needed to increase efficiency substantially? I do not know, but these questions may merit further discussion.

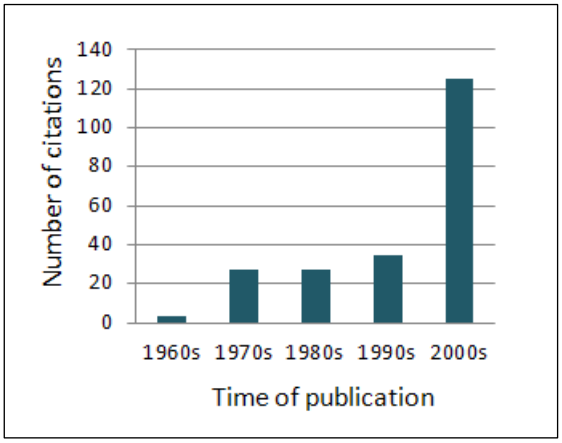

Figure 8. Synthesis development seems to be a growing field. Number of citations in the FRAMES Resource Cataloging System with "fire" and either "synthesis" or "review" in the title, as of 27 November 2012.

[12] Yes, it is true—the acronyms are almost identical, which does not help keep this discussion clear.

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Appendix A. Process for developing syntheses

These discussion points and questions should be addressed collaboratively, with participation from scientists, managers, and science delivery specialists. Stages correspond to those in Section I and Figure 1.

1. Initiating and planning:
   - 1.1 What is the topic of the synthesis? List examples of questions that managers need to address.
   - 1.2 Are the questions national or regional in scope? If national with regional variation, include managers from different regions to figure out how regional needs can be addressed in a balanced way.
   - 1.3 Develop a clearly focused question or problem statement. 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?"[13] *The focused question is very important*. It helps determine the breadth of the search for information, the criteria for including information in the synthesis, and the type of synthesis produced.
   - 1.4 What kinds of information are available, and is the information sufficient to address the management questions? If information from managers will be included, who will furnish it?
   - 1.5 What kind of synthesis should be produced? Should it be a textbook-like discussion, a handbook, a meta-analysis, a systematic review? Are multiple products needed for different audiences and purposes? Is a technical writer, editor, or other science delivery specialist needed?
   - 1.6 What kinds of information are available, and is the information sufficient to address the management questions? If information from managers will be included, who will furnish it?
   - 1.7 Discuss content and organization. Base decisions on how the synthesis will be used. How much background information is needed? Should it be organized by topic and subtopic? By region? By issue or management question?
   - 1.8 Discuss packaging and delivery. Who needs this knowledge? What format, graphics, and supplements will be most helpful? What's the best way to get the product to field practitioners and help them figure out how to use it?

2. Searching for information:
   - 2.1 Do any of the issues above need to be revisited as the authors search for information? In particular, does the information available seem adequate for the products desired? If the synthesis has regional components, address these questions for each region.
   - 2.2 Obtain information from managers based on their needs.

3. Writing:
   - 3.1 Does the product envisioned at the outset still seem the most useful for managers?
   - 3.2 Include managers in developing management applications so they can be as clear, direct, relevant, and wide-ranging as possible based on the information available. Consider having managers co-author sections on management applications.

4. Packaging:

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

4.1. Consult science delivery specialists about format, packaging, and distribution. They usually know how local managers obtain information and what kinds of packaging are most appealing and easy to use.

4.2 If management applications contradict conventional wisdom, should plans for packaging and delivery be revisited?

5. Reviewing and revising:

5.1 Obtain review comments from a variety of potential users, especially in regard to management applications. If the synthesis has different information for different regions, obtain reviews from all regions.

5.2 If reviewers and authors disagree substantially, bring them into a discussion so they can learn from each other and improve the synthesis.

6. Delivering final products:

6.1 Managers and science delivery specialists already have communication networks and know what kinds of products and techniques will appeal to those who need this information. Encourage creativity and variety in advertising, marketing, and training. Encourage sharing of materials and techniques.

Appendix B. Methods for developing this report

This report is based on literature regarding reviews and syntheses, examination of syntheses on wildland fire topics, informal interviews, and personal experience.

I examined references covering information management, literature reviews, meta-analyses, systematic reviews, and science delivery. Most of these focused on topics in ecology and natural resource management, but some were general in nature or focused on reviews in the health sciences.

I examined all of the JFSP-sponsored syntheses that I could identify (Appendix C), although this list may not be complete. To find a variety of techniques and examples, I examined all documents mentioned as examples by interviewees and some that were located through database searches. See Section VII about challenges with locating syntheses.

For insights about writing syntheses and applying using them in 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 and received informative correspondence from several others (Table 5). Interviewees were selected based on field of expertise, geographic location, agency or employer, and recommendations from other interviewees. The resulting group was diverse but not entirely balanced (Figure 9). Although this was a convenience sample rather than a random or systematic sample, I noted that few new concepts emerged after about 10 interviews. On the other hand, every person I spoke with provided valuable, unique insights about practical aspects of this issue: how to produce better syntheses and how to deliver information more effectively. 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 simply 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? Examples?
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 reflections from many experts and the content of many documents, it is also based on my own convictions. I have taught technical writing at the undergraduate and graduate levels, and I have been writing and teaching about wildland fire for nearly 40 years. For almost 20 years, I’ve been editing syntheses on fire effects. I hope this experience has infused the project with insight rather than bias, but I am responsible for the content either way. I hope the result is useful.

Table 6. Participants who helped with this project. **Many thanks** for everyone's time, attention, and creative suggestions.

Participant	Position
Geoff Babb	Fire Ecologist, Central Oregon Fire Management Service, Bend, OR
John Barborinas*	Regional fire planner, BIA, 3 regions
Jamie Barbour*	Program Manager, Focused Science Delivery and Goods, Services, and Values Program, Pacific Northwest Research Station
Wayne Buck	Content Specialist, FRAMES
Dave Campbell*	District Ranger, West Fork, Bitterroot NF, MT
Nan Christianson*	Assistant Director, Communications, Rocky Mountain Research Station
Nate Fayram*	Project Coordinator, Tallgrass Prairie and Oak Savanna Fire Science Consortium, Madison, WI
Bob Gillaspy*	Natural Resources Conservation Service, Oregon
Richy Harrod*	Deputy Fire Staff Officer, Okanogan-Wenatchee NF, Wenatchee, WA
Zoe Hoyle	Technical Writer, Southern Research Station
Randi Jandt	Fire ecologist, BLM, AK
Christel Kern*	Research Forester, Northern Research Station, Grand Rapids, MI
Paul Langowski*	Regional Branch Chief, R2 Fuels and Fire Ecology, Golden, CO
Sherry Leis*	Coordinator, Great Plains Fire Science Consortium, Springfield, MO
Alan Long*	Administrative Director, Southern Fire Exchange, Tall Timbers Research Station
Charlie Luce*	Research Hydrologist, Rocky Mountain Research Station, Boise, ID
Chris Mallek*	Fire Ecologist, California Fire Science Consortium, Sierra Nevada Region and Great Basin Science Delivery Projects
Joe Marschall*	Coordinator, Oak Woodlands and Forests Fire Consortium Coordinator, University of Missouri-Columbia
Rhonda Mazza*	Science writer, editor of Pacific Northwest Research Station *Science Findings*
Sarah McCaffrey	Research Social Scientist, Northern Research Station, Evanston, IL
Jessica Miesel	Research Associate, Lake States Fire Science Consortium
Richard F. Miller*	Professor emeritus, Range and Fire Ecology, Oregon State University, Corvallis, OR
Dan Mindar*	Fire Application Specialist, Rocky Mountain Research Station
Helen Mohr*	Coordinator, Consortium of Appalachian Fire Managers and Scientists
Eugenie Montblanc*	Coordinator, Great Basin Science Delivery Project Coordinator, Reno, NV
Penny Morgan*	Professor, Dept of Natural Resources, University of Idaho, Moscow, ID
Caroline Noble*	Fire Ecologist, NPS Southeast Region, Tall Timbers Research Station
Jennifer Northway*	Coordinator, Alaska Fire Science Consortium, University of Alaska, Fairbanks, AK
Diana L. Olson	Program Manager, FRAMES
Tami Parkinson-Whitford*	Fire Application Specialist, Rocky Mountain Research Station, Boise, ID
Elizabeth Pickett*	Coordinator, Hawaii Wildfire Management Organization, Kamuela, HI
Zach Prusak*	The Nature Conservancy, FL
Mike Rauscher*	Managing Editor, Forest Encyclopedia Netowrk, Leicester, NC
Jeff Rose*	Associate District Manager, BLM, Burns, OR
Michael G. Ryan*	Rocky Mountain Research Station (emeritus), Fort Collins, CO

Dean Simon*	Fire and Forest Management, North Carolina Wildlife Resources Commission
William T. Sommers*	Research professor, George Mason University, Fairfax, VA
Mary Taber*	Fire Ecologist (retired), BIA and National Interagency Fire Center
Jim Thinnes*	Regional Silviculturist, Denver, CO
Rachel White*	Science Writer and Editor, Pacific Northwest Research Station
Brett Williams*	Fire Ecologist, AFCEE AF Wildland Fire Center, Eglin AFB, Niceville, FL
Vita Wright	Principal Investigator, Northern Rockies Fire Science Consortium
Robert Ziel*	Coordinator, Lake States Fire Science Consortium, Marquette, MI
*Interviewees	

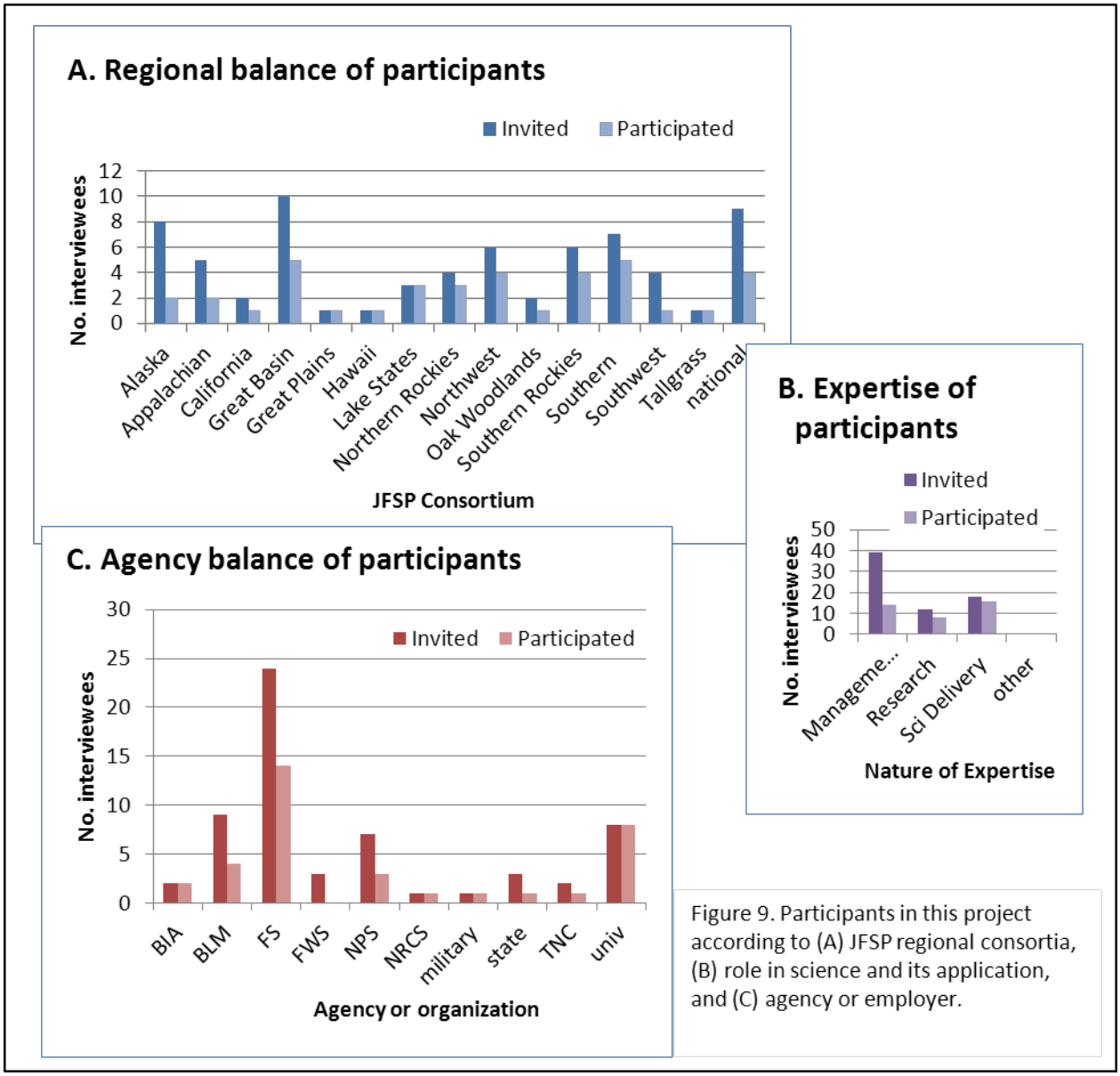

Figure 9. Participants in this project according to (A) JFSP regional consortia, (B) role in science and its application, and (C) agency or employer.

Appendix C. Syntheses produced by the Joint Fire Science Program

A. Results of searching http://www.firescience.gov/JFSP_research.cfm under "Syntheses" tab, 12/1/2012:
A Comprehensive Guide to Fuel Management Practices for Dry Mixed Conifer Forests in the Northwestern United States (Jain and others 2012)
Climate Change, Forests, Fire, Water, and Fish: Building Resilient Landscapes, Streams, and Managers (Luce and others 2012)
Research Perspectives on the Public and Fire Management: A Synthesis of Current Social Science on Eight Essential Questions (McCaffrey and Olsen 2012b)
Synthesis of knowledge of extreme fire behavior: Volume I for managers (Werth and others 2012)
Effectiveness of Fuel Treatment Mitigating Wildfire Severity: A Manager-Focused Review and Synthesis (Omi and Martinson [no date])
Wildland Fire in Ecosystems: Effects of Fire on Cultural Resources and Archaeology (Ryan and others 2012)
Post-Wildfire Seeding in Forests of the West: Trends, Costs, Effectiveness, and Use of Native Seed (Peppin and others 2010b)
Fire History and Climate Change Summary of Knowledge for Managers (Sommers and others 2011)
A Guide to Fuels Management in Riparian Areas of the Interior West (Dwire and others 2011)
A Comprehensive Fuels Treatment Practices Guide for Mixed Conifer Forests (California, Central and Southern Rockies, and the Southwest) (Evans and others 2011)
Characterizing Lessons Learned from Federal Biomass Removal Projects (Becker and others 2009)
A Comprehensive Guide to Fuels Treatment Practices for Ponderosa Pine in the Black Hills, Colorado Front Range, and Southwest (Hunter and others 2007)
Post-Fire Treatment Effectiveness for Hillslope Stabilization (Robichaud and others 2010)
Synthesis of Knowledge from Woody Biomass Removal Case Studies (Evans 2008)
Synthesis of Knowledge on the Effects of Fire and Fire Surrogates on Wildlife in US Dry Forests (Kennedy and Fontaine 2009)
Synthesis of Knowledge on the Effects of Fire and Thinning Treatments on Understory Vegetation in US Dry Forests (Bartuszevige and Kennedy 2009)

Mitigating Old Tree Mortality in Long-Unburned, Fire-Dependent Forests: A Synthesis (Hood 2010)
Ecological Effects of Prescribed Fire Season: A Literature Review and Synthesis for Managers (Knapp and others 2009)
Synthesis of Knowledge of Hazardous Fuels Management in Loblolly Pine Forests (Marshall and others 2008)
A Synthesis of Post-Fire Road Treatments for BAER Teams: Methods, Treatment Effectiveness, and Decisionmaking Tools for Rehabilitation (Foltz and others 2009)
Wildland Fire in Ecosystems: Effects of Fire on Soil and Water (Neary and others 2005)
Wildland Fire in Ecosystems: Effects of Fire on Air (Sandberg and others 2002)
Wildland Fire in Ecosystems: Effects of Fire on Flora (Brown and Smith 2000)
Wildland Fire in Ecosystems: Effects of Fire on Fauna (Smith 2000)
B. Additional JFSP syntheses:
Responses of amphibians to fire disturbance in Pacific Northwest forests: a review (Bury and others 2002)
Fire effects on water quality: a synthesis of response regulating factors among contrasting ecosystems (Elliott and Vose 2006)
Compiling, synthesizing and analyzing existing boreal forest fire history data in Alaska (Olson and others 2011)
Emergency post-fire rehabilitation treatment effects on burned area ecology and long-term restoration (Robichaud and others 2009)
Principal short-term findings of the national fire and fire surrogate study (McIver and others 2012)
Wildland fire in ecosystems: fire and nonnative invasive plants (Zouhar and others 2008a)