Describing and Categorizing Natural Resources Literature

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All of us as natural resources professionals can benefit from classification of our literature into categories that reflect the nature of the information reported. Effective resource decision making requires input from a variety of sources, some science and some experience. We will describe our view of what information is science and what is not science but rather professional resource knowledge based on experience and observation.

Within the natural resource disciplines, science is typically understood to be information gathered according to specified protocols, commonly called the scientific method.

To define the characteristics of the categories we propose, we need to first define science as we use it in this paper. The term science has been used in many ways, from a general understanding of nature and how nature operates to very rigid definitions that define science within specific disciplines. Within the natural resource disciplines, science is typically understood to be information gathered according to specified protocols, commonly called the scientific method. Consequently we have accepted the following definition for science. Science is knowledge covering general truths or the operation of general laws, especially as obtained and tested through the scientific method (Merriam-Webster, 1985). It is objective, without imposed social values, and should be the foundation upon which decisions are built. To understand cause and effect or the relationships among variables is an important aspect of science based decision-making.

When any of us makes management decisions, we try to operate from a scientific perspective using results from scientific research as a base of reference. A manager does not apply science to the ground but rather applies an understanding of science to the decision made. It is our view, that a classification of literature will help each of us focus on the nature of the work we are evaluating and consequently increase our understanding of the work and its applicability to decisions that need to be made. Sometimes science is the most useful information to assist decision making and sometimes the wisdom and experience within professional resource knowledge is the most useful information to assist decision making. Either way we need to know what we are using.

We are not inferring anything about the quality of information by our classification. There are both good and poor scientific experiments and reports as well as good and poor understanding of experience and observations. We have mechanisms to deal with quality but we do not have an accepted system of classifying literature. As resource professionals all of us have a strong scientific foundation, often with specialized training in a given aspect of resource management. Some professionals conduct fundamental or applied research to gather knowledge about basic relationships that exist among ecological processes, or study cause and effect relationships in nature. Other professionals blend this scientific information with social and political factors to formulate land use decisions. It is necessary to include non-scientific information in resource decisions, but science should be used as the foundation for making these decisions within the infrastructure of the complex field of land management. The literature used by scientists and managers includes a variety of reports. Some are scientific and others reflect knowledge derived primarily from experience. Currently scientific and experiential reports are frequently interchanged and treated like they have uniform applicability. We suggest that this is not appropriate and that each kind of literature has a specific area of utility. Using literature appropriately provides a strong foundation for making resource decisions that have predictable outcomes. We need to evaluate the specific attributes of each report we utilize. This study will increase our understanding of natural resources science and help us deal with the complexity of the driving factors in natural resources decisions. Because of the different contributions of research scientists and managers, success in the field of natural resources is contingent upon effective communication among them. Consequently each needs to understand the writings of the other. The first step is to discern whether literature is based on a scientific or experiential design. The purpose of this paper is to define a classification system for literature in the natural resources field. We explain how to differentiate between types of literature, and describe a system of reporting the literature. We suggest published reports should be classified and referenced as either professional resource knowledge or science and further classified as to whether the science is experimental research, a documented case history or a scientific synthesis, according to established criteria.

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Science

Experimental research and documented case histories comprise original research, which requires hypothesis formulation, experimental design, and statistical evaluation. Original research is information of verifiable technical quality. When the source is a peer reviewed journal you can be assured it has had intense review. Original research is sometimes published in documents where the level of the review is unknown. However, since the data and analysis are presented in the reports the reader can evaluate the quality of the work. Whether refereed or not, it is important to determine for yourself if the data and analysis presented support the author's conclusions. The strength of original research lies in the objectivity of the designs and the statistical analysis of the data collected.

Experimental research is characterized by replicated experiments and usually involves studies that allow definition of cause and effect. It can be used to generalize and predict cause and effect, as well as relationships, across a wide variety of environmental conditions. Conclusions from experimental research lead to generalizations that apply across varying ecological sites.

Documented case histories are non-replicated research. They involve either the study of cause and effect or relation-

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ships among parameters. Conclusions can only be drawn within the boundaries of the case. Interpretation of documented case histories is constrained by the conditions of the research. However, when a number of documented case histories have been completed across a wide variety of conditions, the ability to use this information to make more general predictions increases. When they include a variety of conditions, a series of documented case histories may be similar to experimental research. Evaluating documented case histories should be done from a different point of view than evaluating experimental research. To evaluate documented case histories you must understand the constraints of the case, as they are only directly applicable to areas that have the same environmental conditions. So, for the research to be of value, the constraints must be clearly identified in the paper. Documented case histories, e.g. exclosure studies, often involve only extremes of land use and consequently they are only useful to compare across the extremes rather than within the norms of good management. On the other hand they are often similar to management situations because they tend to involve studies of larger scales that are similar to management scales.

Both types of research are useful in providing a baseline to understand the resources being managed. However, research should not be a template for management but rather a basis to assist resource managers in improving the decisions they make. The reality is that management decisions involve a wider array of complexities than is dealt with in research. Managers need to use their skills as managers and not try to find mathematical models or constrained research predictions to replace the art of management.

Although not original research, scientific synthesis is an important type of science. Scientific synthesis is a specialized literature review that is based on original research with no technical dependency on non-researched hypotheses (viewpoints). A scientific synthesis integrates a broad spectrum of specific research to provide a holistic understanding of the area of science reviewed. They present a sufficiently representative body of data so that the reader can independently evaluate the author's conclusions. Properly done a scientific synthesis can be an excellent scientific base to use in formulating management strategies and for developing scientific theories.

Scientific syntheses have strong advantages since they draw broadly on original research and contain sufficient data to allow for independent evaluation. Typically senior scientists who bring significant experience, insight and an extensive understanding of research and literature to the topic write scientific synthesis papers. This comprehensive examination of a topic by a qualified, objective scientist can bring new perspectives to current and old studies. In addition this approach allows the scientist to compare and contrast research methods, temporal and spatial scales, and conclusions. For example Coutant (1987, SS) in his scientific synthesis included interpretable data sets from eleven different studies. This allowed the reader to see the original data and evaluate the quality of Coutant's synthesis. Coutant provided additional analysis of these data sets to draw generalizations that are appropriate across multiple environments. He also pointed out how the literature should be used to make management interpretations. And how the literature can be used to prioritize decision-making and to maximize the beneficial impact of management practices in order to help deal with very large-scale problems.

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Professional resource knowledge

Science is not the only information important for making valid natural resource decisions. Qualitative knowledge and experience of professional resource managers, scientists and others is widely reported through the natural resources literature. This literature base does not have experimental designs or statistical analysis of data, and is not science. It is not possible for the reader to look at the information presented and objectively determine if they would draw the same conclusions. This literature reports knowledge based on the skills and abilities of the authors. When coupled with a scientific foundation it can provide powerful insights to advise resource decision-makers. When interpreting professional resource knowledge, it is important to understand the intent of the authors; their skill levels and if value systems have influenced the conclusions. Much of the resource management literature is professional resource knowledge. It is similar in some ways to documented case histories but does not have a scientific aspect. These case histories are not written in a way that the results can be verified, so they require substantial judgement in application to different areas. The information presented ranges from excellent and insightful views based on quality experiences to viewpoints based largely on philosophy.

Classification of riparian literature

Although, the literature used by natural resource professionals to make decisions or develop environmental assessments is generally presented as science, in reviewing over 1500 riparian and stream ecology publications from a variety of sources, the majority (66%) of the "scientific" papers would not qualify as science (Larsen, et. al. 1997, PRK). Since a literature citation alone does not clearly state if the references used are scientific reports, it is frequently difficult to determine the use of science in management. This is especially true for riparian related literature since the majority of the literature is professional resource knowledge.

When we classified the literature into science and professional resource knowledge by areas of investigation, it was apparent that there was wide variation in the designs used to study or evaluate specific phenomena (Figure 1). Studies relating to stream flow had the highest proportion of scientific reports, over 60%. Similarly, more than half of the hydrology and riparian bird studies were classified as scientific. The reports about watershed attributes, environmental impacts, and riparian restoration were all less than 20% science reports. It is clear that a professional needs to evaluate every paper individually to determine how it can be useful to the issues being addressed.

Values in natural resource decisions

Everyone has personal values, often strongly felt, regarding specific uses of natural resources. Some favor commodity production and others favor environmental preservation. This tendency to orient our views toward values is moderated by ecological objectives, financial constraints, laws, protocols, policies and regulations. Values are an appropriate driving force in management decisions and need to be in-

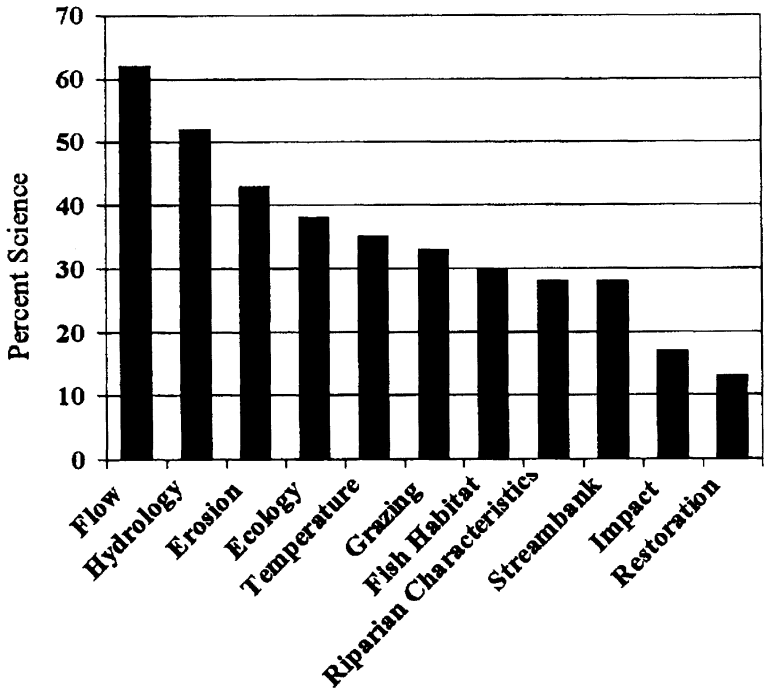

Fig. 1. ***Examples of the percentage of categories that were classified as science.***

tegrated into the decision-making process. These same factors have no place in science. Science must simply be the objective evaluation of cause and effect or other relationships. When research is oriented toward value system objectives it loses objectivity, violates the scientific method and is of little value to managers. Natural resource professionals need to be proficient at evaluating science and integrating it with other factors. As a society we trust science. To believe we are basing a decision on science when in fact we are not creates false confidence in the decisions made.

A system of reporting and using literature

To enhance the reader's understanding of natural resources literature and the use of each type of information, we have developed a system of reporting and referencing literature so that it is clear if information is derived from scientific research or professional resource knowledge. We suggest published reports should be classified and referenced as either professional resource knowledge or science and further classified as to whether the science is experimental research, a documented case history or a scientific synthesis, according to established criteria. Because papers published in scientific journals, like the *Journal of Range Management*, are usually science or defined as non-science (e.g. viewpoint) by the editor, it would not be difficult to classify papers into appropriate categories. Likewise, reports that are professional resource knowledge can be readily identified. The greater challenge will be to accurately classify the articles in popular journals and magazines (like *Rangelands*), and publications from institutions or agencies many of which are not science manuscripts. To facilitate classification and referencing, authors of papers in popular journals or institutional formats would categorize their work and provide this information to the reader. Writers referencing these articles would include the classification with the traditional citation in the body of their paper and in the full citation in the literature cited section. For example, a paper would be referenced as Kelley (200X, DCH) to represent an original researched documented case history or Krueger (200X, PRK) to represent professional resource knowledge. ER would represent experimental research and SS would represent scientific synthesis. This establishes a format to provide information on the type of literature being written and referenced allowing the reader to gain greater insight into the literature and more completely evaluate the appropriate level of generalization the reference supports. As a result resource professionals will be better able to discern the nature of the information being presented.

Adoption of this system will require the cooperation of research scientists, professional resource managers, editors, and institution and agency leaders. Although implementation of this system will require additional work, we believe that all professionals in the natural resource field as well as the communities they serve will derive benefits from the additional information available in the references. Knowing the nature of the literature used, either directly or as references in reports, allows for more thoughtful use of the information, and provides us with a substantial opportunity to learn and improve our critical thinking about the resources being examined. This enhanced clarity or understanding should lead to the proper use of the natural resources literature. Recognizing the limits of information in terms of science or professional resource knowledge can help focus monitoring on poorly understood areas. Ultimately, this approach should result in the increased effectiveness of adaptive management strategies, through improved understanding of the literature and how it relates to site specific land use practices.

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