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Forest Health From Different Perspectives

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Abstract.—Forest health is an increasingly important concept in natural resource management. However, definition of forest health is difficult and dependent on human perspective. From a utilitarian perspective, forest health has been defined by the production of forest conditions which directly satisfy human needs. From an ecosystem-centered perspective, forest health has been defined by resilience, recurrence, persistence and biophysical processes which lead to sustainable ecological conditions. Definitions and understanding of forest health are also dependent on spatial scale, with increasing ambiguity associated with increasing land area and numbers of trees.

INTRODUCTION

The term "forest health" is being increasingly used in the context of forestry and natural resource management. For example, the term has been the subject of several recent articles (e. g., Smith 1990, Burkman and Hertel 1992, Kessler 1992, Haack and Byler 1993, Sampson and Adams 1994) and a recent Society of American Foresters task force report, "Sustaining Long-Term Forest Health and Productivity" (SAF 1993). Forest health is also increasingly used in government mandates concerning forest management. For instance, the "Forest Ecosystems and Atmospheric Research Act of 1988" mandated the USDA Forest Service to develop surveys to monitor long-term trends in the health of forest ecosystems (see Burkman and Hertel 1992). Moreover, under new federal forest management operating philosophies, such as ecosystem management, forest health has emerged as a central objective for the desired future condition of forests that replaces, to some extent, management for sustained commodity output (USDA 1993a, SAF 1993).

Despite its widespread use, the term "forest health" is frequently used without a clear definition, making its application to forest management difficult. In cases where the term has been defined (e. g., McIntire 1988, Monnig and Byler 1992, USDA 1992, 1993a), alternative definitions and viewpoints of forest health have not been thoroughly discussed (however, see O'Laughlin et al. 1994). We feel that the overall concept of forest health needs to be more thoroughly examined given its growing use and importance as a management objective. Like it or not, foresters and other natural resource professionals are currently, and will continue to be, participants in public debates over land management where health analogies and metaphors are used. The potential for miscommunication in such debates is great. In fact, we believe that miscommunication about forest health is common in discussions between parties which have very different expectations from the forest. Therefore, it is essential that common definition and conceptual understanding of forest health be agreed upon each time it is introduced into the discussion. Moreover, the need for clarity is of considerable importance given that a healthy forest is viewed as a desired future condition and maintenance of forest health is viewed as a constraint that may limit forest uses on public lands in the future.

In this paper, we discuss different definitions of forest health, problems in scaling the concept of health from individuals to ecosystems, and the relationship between forest health and pest management, often using southwestern ponderosa pine, *Pinus ponderosa* var. *scopulorum*, forests as an example. A central point of this paper is that

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ambiguity should be minimized by defining the term when it is used, or at least by discussing the concepts included in the term.

FOREST HEALTH DEFINITION

Aldo Leopold

Although forest health is a relatively new term in forestry, notions of land health have existed for millennia (Norton 1991, Callicott 1992). Most contemporary views of forest health stem from the writings of Aldo Leopold (Leopold 1949, Callicott and Flader 1992). In several of his essays, Leopold decried widespread symptoms of land "sickness," such as reductions in vegetation cover and ensuing soil erosion, resulting from land abuse. He argued for the practice of land health in which practitioners would seek to maintain the sustainability of ecological conditions and processes by conserving the ecological integrity or coevolved diversity of the land. Leopold supported the restoration of sample native ecosystems present before industrialization of the American landscape. These restored areas were to serve both as laboratories and as standards for comparison in his practice of land health (Flader 1974).

Utilitarian Perspective

More recent definitions of forest health range between utilitarian (anthropocentric) and ecosystem (ecocentric) perspectives. The utilitarian perspective emphasizes forest conditions which directly satisfy human needs, while the ecosystem perspective emphasizes the maintenance sustainable ecosystems over the landscape. From a utilitarian perspective, a desired state of forest health can be considered "a condition where biotic and abiotic influences on forests (pests, pollution, silvicultural treatments, harvesting) do not threaten management objectives now or in the future" (McIntire 1988, USDA 1993a). That is, a forest is considered to be healthy if management objectives are satisfied, and unhealthy if they are not.

"Consistency with objectives" is a theme common to both utilitarian and ecosystem definitions of forest health. Failure to meet objectives, stated by either human uses or ecological conditions, indicates an unhealthy forest. The utilitarian perspective is perhaps more deeply rooted in the "consistency with objectives" theme in that pests are traditionally defined as organisms that interfere with intended uses of forests (Barbosa and Wagner 1989). The "consistency with objectives theme" in forest health definitions has been criticized in the context of ecosystem management philosophy (Wagner 1994). On one hand, a healthy forest depends on meeting management objectives, while on the other hand, a healthy forest is a management objective according to recent ecosystem management philosophy. This results in circular logic and creates a paradox where a desired state of forest health depends on the occurrence of a healthy forest! Solutions to this paradox include removal of the "consistency with objectives" theme from forest health definitions or removal of forest health as an objective of ecosystem management.

The utilitarian definition implies that a healthy forest can be described by many standards. A single forest condition could be viewed as healthy from one perspective or use but unhealthy from another. For example, a common component in southwestern ponderosa pine forests is dwarf mistletoe, *Arceuthobium vaginatum* sbsp. *cryptopodum*. Dwarf mistletoe is well-known to reduce the growth of ponderosa pine (Beatty 1982) and increase mortality (Hawksworth and Geils 1990) and would be viewed as being unhealthy from the perspective of wood fiber production. However, abundance and species richness of birds is higher when dwarf mistletoe is present (Bennetts 1991) and the northern spotted owl nests in witches' brooms caused by mistletoe in Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, (Martin et al. 1992). Consequently from a perspective of bird species habitat and diversity, the presence of dwarf mistletoe may constitute a healthy condition. Thus, dependency on objectives can create obvious problems in generating a definition of forest health, particularly when land management objectives are not static.

The utilitarian perspective of forest health is especially appropriate for those situations where management objectives are unambiguous and consist of a small number of complementary human uses. This situation is largely restricted to private industrial forest lands which emphasize the production of wood fiber, and wilderness areas which emphasize the preservation of natural processes (i.e., processes with minimal human influence). Application of the utilitarian definition of forest health to forest lands managed for multiple objectives, such as most of the National Forest System, is a problem because management for multiple objectives complicates the prioritization of objectives. Some authors have proposed a return to a land management philosophy that allocates land to categories of similar uses as a way to simplify the formulation of objectives and consequently the evaluation of forest health (Seymour and Hunter 1992, Wagner 1994).

Ecosystem Perspective

Difficulties in application of the utilitarian perspective of forest health to forest lands managed for multiple uses suggests the need for an ecosystem perspective of forest health that emphasizes basic ecological processes which characterize forest ecosystems whose presence on the landscape can be sustained over time scales of at least many decades. Some examples of forest health definitions from the ecosystem perspective are: "a forest in good health is a fully functioning community of plants and animals and their physical environment," and "a healthy forest is an ecosystem in balance" (Monnig and Byler 1992). These examples provide a starting point for thinking about forest health from an ecosystem perspective. Terms such as "balance" and "fully functioning" are effective in steering our thoughts towards ecosystem characteristics which appeal to many segments of the public, especially those who believe that nature has an inherent equilibrium, or balance. Unfortunately, most ecologists agree that ecosystems tend to be chaotic in behavior, and not "in balance," especially when viewed over long time periods.

Other ecosystem definitions of forest health include the idea of resilience. For example "a healthy forest is one that is resilient to changes.." (Joseph et al. 1991), "the term forest health denotes the productivity of forest ecosystems and their ability to bounce back after stress" (Radloff et al. 1991), or "forest health can be defined as the ability of a forest to recover from natural and human-caused stressors" (USDA 1992). A related idea is that a healthy forest is persistent on the landscape and recurs following disturbance (Botkin 1994).

While we agree that resilience to dramatic change at the landscape level may be a desired component of a healthy forest, measuring the degree of resilience of a forest is difficult. Although lack of resilience is evident a posteriori when a forest has been significantly altered by stress or disturbance, the a priori presence of resilience is difficult to quantify, especially in the absence of detailed monitoring of physiological and ecological characteristics which promote recovery following stress or disturbance. In other words, we really don't know the degree of resilience of a forest until it has been exposed to and changed by stress or disturbance. Resilience is a useful ecological concept in the context of ecosystem health. However, difficulty in quantifying resilience suggests problems in its use in defining and measuring forest health.

A more useful definition of forest health from an ecosystem perspective should include specific types and rates of ecological processes and numbers and arrangement of structural elements that lead to and maintain diverse, productive, forest ecosystems. This perspective is based on a mechanistic view of forest ecosystems where important ecological processes would be identified and objectively measured to assess the health of the system. An example is given by Haskell et al. (1992) who offer that a healthy ecosystem should be "free from distress syndrome." In this context, "distress syndrome" of an ecosystem is characterized by the following group of symptoms (Rapport 1992): reduced primary productivity, loss of nutrient capital, loss of biodiversity, increased fluctuations in key populations, retrogression in biotic structure (a reversal of the normal successional processes whereby opportunistic species replace species more specialized in habitat and resource use in the absence of severe disturbance), and widespread incidence and severity of disease. Unfortunately, quantitative information on rates of essential ecosystem processes, such as net primary productivity, nutrient cycling, or decomposition, and structural characteristics, such as snags and landscape corridors, that create and maintain diverse, productive, sustainable forest ecosystems is presently not available for many regions. This type of information may be available for some forest types in the future if efforts like the Environmental Monitoring and Assessment Program, administered by the US. Environmental Protection Agency, are adequately supported for at least the next several decades.

Of course, there are potential problems with this highly quantitative approach to defining and measuring forest health. One problem is the identification of threshold rates of important ecological processes which lead to degraded resource conditions. In most cases, knowledge of the "normal" range of temporal and spatial variation for rates of important ecological processes is lacking. Specification of "normal" rates and trajectories of succession is a problem in some regions. Techniques for understanding ranges of variability in ecosystem structure and processes in past times are being developed (Morgan et al. 1994). However, the degree to which these techniques can be used to determine past levels of all important ecological processes is uncertain. Some have suggested a pre-European settlement baseline of range of variability for pine-dominated forests which evolved under the influence of frequent, low-intensity fires (e.g. Monnig and Byler 1992). Whether a baseline patterned after pre-European settlement or other past forest conditions is appropriate for other forest types is unclear.

Another potential problem with the quantitative approach to defining and measuring forest health is the cost. Despite the public's willingness to support environmental protection in surveys, some of this apparent support may diminish when it is time to actually pay for this level of research and monitoring. Given our current knowledge of ecosystem ecology, long-term support for forest health research and monitoring will be required in order to implement a highly quantitative approach to defining and measuring forest health. Such an approach could yield scientifically defendable data on the health of forest ecosystems if previously identified problems could be surmounted.

In the absence of detailed quantitative information on desired rates of ecosystem processes, present definition of forest health from an ecosystem perspective should at least include qualitative statements of the types of processes, structures, and resources needed to support productive forests in the sense of satisfying at least some of society's objectives. For example, we consider a healthy forest ecosystem to have the following characteristics:

1) the physical environment, biotic resources, and trophic networks to support productive forests during at least some seral stages;
2) resistance to dramatic change in populations of important organisms within the ecosystem not accounted for by predicted successional trends;
3) a functional equilibrium between supply and demand of essential resources (water, nutrients, light, growing space) for major portions of the vegetation; and
4) a diversity of seral stages, cover types, and stand structures that provide habitat for many native species and all essential ecosystem processes.

Specification within these four criteria allow for definitions of forest health which span the gap between landscapes which are natural, e. g. near pristine (i.e., pre-industrial or presettlement characteristics) and landscapes which are artificial, e. g. intensively managed for industrial uses.

We believe that a useful ecosystem concept of forest health must consider patterns and rates of change in forest composition and structure, or succession. This recognition of the temporal variability of forest vegetation was noted by Leopold (1949) who offered that "health is the capacity of the land for self-renewal." Thus, a definition of forest health must consider the capacity for forest replacement within the timespan of succession. Acceptable rates and patterns of forest replacement following disturbance will vary widely among different ecosystems and climatic regions, but should reflect historical rates and patterns to the extent that these rates and patterns sustain desirable ecosystems. For example, a long succession to forest cover following disturbance is not necessarily an indication of poor forest health if slow succession is a historical characteristic of the ecosystem because of naturally harsh environmental conditions.

Our definition also recognizes that dramatic change in vegetation composition and structure following stress or disturbance is inevitable over portions of a landscape. For example, small openings in the canopy are common due to root disease, windthrow, and other factors. Such openings are not necessarily unhealthy because they can increase availability of resources to understory vegetation and tree regeneration and may enhance values such as wildlife habitat and aesthetics. However, dramatic change may be undesirable when it occurs at scales other than those experienced over the recent evolutionary development of an ecosystem. For example, many ecologists believe that fire suppression activities in the western United States have led to the development of dense, homogeneous conifer stands over widespread areas (e.g. Covington and Moore 1994). This is very different than the mosaic of stand ages, structures, and species mixtures which were likely maintained by fires prior to Euro-american settlement. Widespread, dense stands are particularly prone to attack by bark beetles and other biological agents which colonize heavily stressed trees.

The emphasis in our definition of forest ecosystem health on the balanced availability of resources for portions of the vegetation, instead of all the vegetation, recognizes succession as a process which can occur, at least in part, because of changes in resource supply to components of the vegetation. For example, the emergence of late-successional species is partially a consequence of the decline of early successional species resulting from their failure to acquire resources at levels sufficient to meet their high nutritional and metabolic demands. In other words, there are winners and losers when plants are competing for resources in a healthy forest. Thus, we should not automatically assume that all instances of decline by a single species, or groups of species with similar ecological characteristics (i.e., early successional or pioneer types), reflect poor forest health. Evaluation of forest health must be made within the context of successional processes and ecosystem dynamics.

THE PROBLEM OF SCALE

Much of the current ambiguity about forest health has arisen because of attempts to take a concept developed at the individual organism level and elevate it to describe a landscape process. Most dictionary definitions of "health" emphasize the condition or functioning of a single organism. Extension of this concept to a complex system, such as a forest, is based on the analogy between the functioning of an organism and an ecosystem. Kessler (1992), for example, makes an analogy between the health of a human and the health of a forest. This type of analogy is based on the Clementsian concept of community ecology (Clements 1916) where the ecosystem is viewed as a superorganism. Despite the apparent usefulness of the superorganism analogy for describing the status of ecosystems, Clementsian concepts have been discarded by most contemporary ecologists and thus are not recommended for discussions of forest health.

There are other problems with the use of the term "health" to describe the status of ecosystems (Ehrenfeld 1992). From a scientific perspective, it is difficult to determine a normal state for communities whose characteristics are often in flux because of disturbance. From a practical perspective, attempts to define health in rigorous scientific terms may diminish its present value as an intuitive, general concept. In fact, Ehrenfeld (1992) concluded that health is not a valid ecological concept, but does have value in communication between scientists and non-scientists regarding the production of values by ecosystems. Although the limitations of the term suggest that it should not be used in a rigorous ecological context, it is likely that "health" will continue to be used to describe and mandate management objectives for forests.

Health has been applied to forest ecosystems at several scales ranging from an individual tree to landscapes. The concept becomes more ambiguous with increasing complexity of the system to which it is applied. One definition of health, "absence of disease" (Haskell et al. 1992), actually leads to a precise definition for an individual tree because disease can be defined as a "deviation in the normal functioning of a plant caused by some type of persistent agent" (Manion 1991). Forest pathology is a long-standing discipline in forestry that some refer to as "the study of tree health" (Tattar 1978). In this context the health of a tree can be evaluated by such indicators as crown condition, growth rate, and external signs of disease-causing agents. A dead or dying tree is not healthy.

The health of a stand is complex and must consider many more dimensions than the health of a tree. The health of a stand relates to the management objectives for that stand (utilitarian perspective) and to the long-term functioning of the organisms and trophic networks which constitute the stand (ecosystem perspective). Tree mortality in a stand would not indicate an unhealthy condition as long as the rate of mortality was not greater than the capacity for replacement. Stand objectives such as wildlife habitat, soil and water protection, and preservation of biodiversity do not require a healthy condition for all trees in the stand. A dead tree is not healthy, but it may be part of a healthy stand! The health of a forest ecosystem (i.e. large watershed or landscape) is more complex than the health of a stand. The health of a forest ecosystem depends both on society's objectives for the forest (utilitarian perspective), and upon the interaction of biotic (including humans) and abiotic processes that produce the range of habitats required for continued existence of native species (ecosystem perspective).

A NEED FOR SIDEBOARDS

There is a clear need to place bounds on the concept of forest health. Many forest pest management specialists think of themselves today as forest health specialists. For example, the USDA recently formed a "National Center of Forest Health Management." The current emphasis of the center is on the development of pest management strategies and technologies (USDA 1993b). However, based on our definition of forest health, forest health specialists would require broad training in physiology, ecology and ecosystem science. Traditional pest management has primarily focused on the influences of insects and diseases on commodity outputs. The role of insects and diseases in ecological processes is frequently less emphasized in the traditional education of pest specialists, although entomologists and pathologists are not without appreciation for the ecological role of these organisms (Haack and Byler 1993, Clancy 1994, Schowalter 1994). We suggest restricting the term "forest health" to the examination of the role of biotic and abiotic agents in ecosystem level processes. Pest management would then be a subdiscipline of forest health with an emphasis on the influence of biotic and abiotic agents in the production of commodity outputs. Entomologists and pathologists would continue and hopefully increase their examination of the role of insects and diseases in ecosystem-level processes.

EVALUATING FOREST HEALTH—SOUTHWESTERN PONDEROSA PINE FORESTS

Given our definition of a healthy forest ecosystem, when is a forest considered to be unhealthy? The type of thinking needed to answer this question can be illustrated by using ponderosa pine forests in the southwestern United States as a case study. To address this question, we refer to the four essential elements in our definition of forest ecosystem health: 1) physical and biotic resources to support forest cover; 2) resistance to dramatic change; 3) functional equilibrium between supply and demand of essential resources; and 4) diversity of seral stages and stand structures. The physical and biotic resources are presently in place to support ponderosa pine forests in most areas of the Southwest that have historically supported them, except perhaps some riparian sites. Using this criterion, our ponderosa pine forests are probably healthy. However, for the other three criteria, it would be difficult to argue that we have a healthy forest.

A significant threat of dramatic change in forest composition and structure at the landscape level exists in much of the southwestern ponderosa pine forest due to pine bark beetles, *Dendroctonus* spp., *Ips* spp. These insects are well-known to reach outbreaks when forest stand density exceeds the carrying capacity of the site (Sartwell and Stevens 1971, Barbosa and Wagner 1989). Conditions are very favorable for pine bark beetle in northern Arizona and "it is probably only a matter of time before another large outbreak occurs" (Wilson and Tkacz 1994). Tree mortality associated with widespread bark beetle outbreaks often increases the risk of severe, stand-replacing wildfire over large areas.

Present high stand density and forest floor accumulations in many southwestern ponderosa pine forests compared with presettlement conditions (Covington and Moore 1992, 1994) has increased the destructive potential of wildfires to the degree where there is a significant risk of eliminating forest cover at the landscape level. These factors have also created an imbalance between demand and supply of water, nutrients, and growing space for major portions of the vegetation (Covington and Sackett 1986, unpublished data on file with T. E. Kolb in the School of Forestry, Northern Arizona University), especially herbaceous vegetation (Covington and Moore 1994). Nutrient cycling rates are likely low because of fire exclusion and the lack of compensating factors such as microbial decomposition. This creates a situation in which large nutrient reserves are found in forest floor material in a form unavailable to plants (Covington and Sackett 1990).

The relatively homogeneous nature of the southwestern ponderosa pine forest does not provide a balanced diversity of seral stages, cover types, and stand structures. Underrepresented types include native prairie vegetation, tree regeneration, and old growth (USDA 1993c). Forests tend to be even-aged with a dense, uniform canopy and little recent regeneration. These dense stand conditions were created by past grazing practices, fire exclusion, and other environmental conditions favorable for pine establishment in the early part of this century. Thus, many southwestern ponderosa pine forests fail to meet three out of the four criteria needed to satisfy our ecosystem definition of a healthy forest.

FOREST HEALTH SUMMARY

Although there are problems with the use of health concepts to describe the complex array of factors that influence ecosystems, the growing use of the term demands that natural resource managers understand health issues. It is also important to recognize that one's view of a healthy forest may vary considerably between utilitarian and ecosystem perspectives, as well as over spatial scales. One solution to the present dichotomy which exists between utilitarian and ecosystem-centered definitions of forest health is to combine elements of both viewpoints into a single definition. For example, O'Laughlin et al. (1994) offer that "forest health is a condition of forest ecosystems that sustains their complexity while providing for human needs." Moreover, the ecosystem perspective of forest health is not necessarily in conflict with the utilitarian perspective if both are applied to large landscapes composed of a mosaic of different stand ages, structures, and levels of management intensity appropriate for satisfying the range of demands placed on the landscape by society. Satisfaction of these demands will require maintenance over the landscape of many native species and all of the ecosystem processes that ultimately provide resources and habitat for their survival.

Current forest health problems were caused by past lack of understanding of the importance of disturbance in forest ecosystems and poor understanding of public values by forest managers. Forest health problems certainly exist in areas in the western United States where conditions have been altered over the past several decades by concentrated harvesting of early successional species or fire exclusion in fire-adapted ecosystems (McIntire 1988, Covington and Moore 1992, Wickman 1992, O'Laughlin et al. 1993, Covington and Moore 1994, Covington et al. 1994). However, we believe that present concerns over forest health also reflect failures in defining management objectives that are acceptable to society. In the absence of well-defined and widely publicized objectives for forest management which reflect the diversity of values held by society, forest health will continue to be a concern even with dramatic breakthroughs in our scientific understanding of forest ecosystem processes. On the other hand, public expectations must be tempered with the understanding that, in many cases, the range of values potentially delivered by forests is limited by biological constraints to insure sustainable forest ecosystems. Forest scientists and managers are obligated to clearly communicate these biological constraints to the public. In the current political system of the United States, identification of priority objectives for forest management within these biological constraints is a public decision which is often difficult and tedious and thus rarely achieved.

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