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From science to stewardship: Harnessing forest ecology in the service of society

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ABSTRACT

Knowing—experience from the past; understanding—investigation of structures, patterns and processes in the present; forecasting—prediction of possible future ecosystem states based on a combination of knowing and understanding. All are necessary, but none is sufficient for the achievement of sustainability and stewardship of forests. Both Occam and Einstein advocated that theory and explanation (and, by logical inference, policy and practice) should be as simple as possible, but as complex as necessary. Studies at any level of biological organization provide understanding, but prediction must be made at true levels of biological and physical integration—the ecosystem in the case of forest ecology. Reducing complexity to facilitate disciplinary hypothesis testing is a necessary part of ecological sub-disciplines, but for the products of reductionist, disciplinary science to be useful in society's quest for a sustainable relationship with forests, the pieces of the scientific jigsaw puzzle must be integrated into a complete picture, and the picture projected forward over time to create a "movie" of possible forest futures.

Ecosystem classification, chronosequence/retrospective studies and traditional knowledge all contribute to knowing. Disciplinary and experimental studies provide an understanding of individual mechanisms and structures and permit the rejection of incorrect ideas about them. Synthesis into conceptual models of appropriate complexity and their implementation as predictive computer or other types of model delivers the knowledge and understanding to society in the form of scenario and value trade-off analysis and decision support tools. These are a *sine qua non* for policy and practice in forest management and conservation, and for adaptive management, but to be useful in today's environment they should be ecosystem-level and deal with multiple values.

Our inductive, deductive and synthesis activities should be planned to facilitate a smooth integration with these decision support tools and other mechanisms for the delivery of our science to policy makers and practitioners, and to public groups whose political activities have become a major determinant of policy and practice. We must also learn to better integrate traditional knowledge with the methods and products of contemporary "western" science.

1. The increasing importance of forest ecology

The human mind is inquisitive and constantly seeks understanding. As a consequence, science can exist and be justified outside of any practical application. However, the pressure of climate change, population growth, urbanization, and the relentless human quest for an improved standard of living pose such threats to the world's forests that our science should increasingly satisfy our intellectual curiosity within the context of environmental issues. As Peters (1991) noted, the challenge for ecologists is to answer the pressing ecological questions of the time.

From 1960 to 2007, a period of half or less of the life span of most temperate/northern early successional tree species, the world's human population more than doubled, from 3 to 6.6 billion. It is expected that there will be an additional 3–4 billion people within a century if current trends continue. In 1900, an estimated 13% (220 million) of the world's population of about 1.6 billion lived in cities. By 2005 the urban population had grown to 3.2 billion or 49% of the total, and by 2030, 60% of the population is expected to be in cities (4.9 billion people; UN Population Division, 2005). This move to cities may reduce pressure on forest ecosystems if it leads to lower grazing pressure and reduced deforestation by firewood collection and farming, but increases pressure on many ecosystems when it leads to increased standards of living and per capita resource consumption.

Climate change alters disturbance regimes involving fire (e.g. Stocks et al., 1998; Flannigan et al., 2000; De Groot et al., 2003; Westerling et al., 2006), wind, drought, flood (e.g. Dale et al., 2001), forest disease (e.g. Woods et al., 2005) and insect epidemics (e.g.

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Volney and Fleming, 2000; Carroll et al., 2006); it changes soil processes (e.g. Trofymow et al., 2002) and hydrology (e.g. Stewart et al., 2005; Cleugh et al., 2007), and affects growth (e.g. Landsberg et al., 2003; Booth, 2005), reproduction and regeneration of trees and other forest plant species, all of which will alter habitat values for animal and microbial species. As a result of these many individual effects and their interactions, the geographical location of ecological zones will shift (e.g. Hamann and Wang, 2006) and individual species ranges will change. Understanding and forecasting the complexity of possible forest ecosystem consequences of current and predicted climate change poses the greatest current challenge to our science. For a recent summary of this biophysical complexity, see IPCC (2007).

These and other challenges to the world's forests require that the science of forest ecology increasingly supply governments and policy makers, resource managers, environmentalists and resource consumers with a much improved ability to forecast the possible consequences of changes in our relationships with forests (policy and practice), and changes in forests as a consequences of human activity and climate change. There is a responsibility to deliver our science in a way that facilitates the necessary and urgently needed transition to improved stewardship and sustainability, however these are defined (Kimmins, 2007a; Nemetz, 2007). This requires prediction, which Peters (1991) asserted is the major criterion of the success of our science. Prediction in the face of complexity is difficult, as illustrated by the complexity of climate change effects noted above and their interactions. It suggests that forecasts of climate change effects on ecological zone maps (e.g. Hamann and Wang, 2006) must include all the key determinants that are expected to change and not just climate and the geographical location of the "bioclimatic envelope".

2. Fundamental responsibilities of forestry and the science of forest ecology

Forestry can be defined as the art (skill), practice, science and business of managing forest stands and forested landscapes to sustain a desired balance of values that are ecologically possible over appropriate temporal and spatial scales. A major role for forest ecology is to provide the ecological underpinnings of this definition, and to develop systems by which to assess the potential sustainability of different biophysical values and ecosystem processes under a variety of "natural" and human-induced disturbance regimes—systems that provide a basis for comparative scenario and value trade-off analyses. This requires all three component of science—knowing, understanding and predicting.

Knowing is descriptive, inductive and deals with the past. Much of knowing is implicitly at the ecosystem level because the systems, issues or objects that we are describing are the product of all the key ecosystem processes that have acted collectively to produce them. However, this experience-based wisdom generally produces hypotheses that are implicitly complex, difficult to test or are un-testable. While it provides the basis for hypothesis generation and the subsequent deductive activities that provide understanding, Peters (1991) asserted that inductively derived explanations based on experience or inductive descriptions have negatively affected ecology by reducing the focus on prediction.

Understanding is generally deductive and involves testing of inductively derived hypotheses (Peters, 1991). However, the limitations of statistics, experimental design, and the spatial, temporal and resource requirements of complex hypothesis testing generally limit this component of our science to reductionist, disciplinary or sub-disciplinary hypothesis testing, and research in which the principle of parsimony has ruled. This is a *sine qua non* of science, without which rejection of incorrect disciplinary hypotheses and the advancement of understanding is not possible. However, it constitutes the "jigsaw-puzzle" phase of science (Kimmins et al., 2005) which is poorly equipped to resolve the complex issues (often referred to as "wicked problems"—Rittel and Weber, 1973) faced in forests and forestry today. Reassembly of the components of the ecosystem puzzle that were separated by reductionism during the hypothetico-deductive phase of science back to a complete picture of the ecosystem, and then linking all the snapshots of the ecosystem over time to make a "movie", should be the ultimate objective of our science.

Knowing and understanding are both necessary, but are insufficient on their own. Only when combined into systems of prediction has our science fulfilled its mandate (Fig. 1). Direct application of the products of "hard", reductionist, deductive science leads to ineffective "jigsaw puzzle" policy that fails society, just as policy based on poorly informed belief systems is generally ineffective. As Aldo Leopold (1966) noted in his essay 'The land ethic', *The evolution of a land ethic is an intellectual as well as emotional process. Conservation is paved with good intentions which prove to be futile, or even dangerous, because they are devoid of a critical understanding either of the land, or of economic land use.*

The definition of forestry given above creates two major responsibilities. First, forestry must change as society changes the balance of values it expects from forests, and secondly, forestry must reject existing and resist suggested new methods of management that are inconsistent with the ecology (and sociology) of the new desired set of forest values.

Forestry has always been changing as society changed the values it wanted. As unregulated exploitation created supply problems for a variety of values, "administrative" forestry regulations were developed. As evidence accumulated that regulations and practices which ignored ecological and biological diversity and the ecological basis for sustainability of desired values were ineffective, forestry increasingly adopted an ecological foundation. Ecological site classification, understanding stand and ecosystem dynamics, and recognition of key ecosystem processes have increasingly become a required component of forest stewardship. Unfortunately, because education, government and many other aspects of society are organized along disciplinary lines, ecosystem-based management (as the latest rendition of ecologically based forestry is often called) has generally been restricted in practice, if not in concept, to managing individual resources according to their individual ecologies. In public forests, different agencies frequently manage different values in relative isolation—forestry agencies manage mostly timber, wildlife agencies manage wildlife, fisheries agencies manage fish, etc. While timber managers have constraints imposed on their timber objectives to account for other values, generally there is no overall management of entire ecosystems under a single plan, no adequate value tradeoff analysis over time, and inadequate consideration of multiple spatial scales (Kimmins, 2007b).

Why is this the case? Is it solely because of the structure of society? Or is it also because our science has failed to provide ecosystem-level planning tools with which stand management can be integrated with landscape management, the dynamic nature of ecosystems accounted for, and the inevitable value tradeoffs that accompany management for multiple values examined? Both are probably involved, but the pressures for graduate students and junior researchers to conduct "jigsaw puzzle" research ensures that much of our science remains fragmented, something that has been referred to as "chaos in the brickyard" (Forscher, 1963). In fact it is difficult to remain an ecosystem-level ecologist. Career pressures, intellectual satisfaction, peer and publication pressures and the need to understand individual components and processes of ecosystems constantly encourages young forest ecologists to join one of the ecological sub-disciplines related to zoology, botany, microbiology, pedology, climatology, etc., rather than enlisting as an ecosystem level ecologist.