# Table of Contents

# Sustainability and Resilience in Boreal Regions: Sources and Consequences of Variability

*John Pastor*, *Steve Light*, *and* *Laurie Sovell*

***Minnesota Department of Natural Resources***



Boreal regions are, besides tundra, the globe's only circumpolar terrestrial biome, covering approximately 1.3 x $10^9$ ha in upland forest and 0.26 x $10^9$ ha in peatland (Olson et al. 1983, Apps et al. 1993). They constitute 20% of the world's forested regions, second only to moist tropical forests (Olson et al. 1983).

Boreal regions represent some of the last large remaining expanses of wilderness areas, where natural ecosystems remain essentially intact and unmanaged. However, in the past several decades, resource extraction in boreal regions has increased in order to meet growing global demands for fiber and to meet the demands of a growing local resident population. Furthermore, global climate changes are expected to be most extreme in high−latitude areas. Boreal regions, therefore, are substantially at risk from anthropogenic change, but also may represent the last great opportunity to build a sustainable economy based on properly functioning natural ecosystems.

The boreal forest is a biome of low taxonomic diversity, low functional redundancy in ecosystem properties, and low productivity (Hobbie et al. 1994, Pastor et al. 1996). It is also characterized by highly cyclic populations of plants and animals (Hansson 1979, Pastor and Mladenoff 1992, Hanski et al. 1993, Chapin et al. 1996, Pastor 1996) that interact in poorly understood ways with disturbance regimes (Heinselman 1973, Payette and Gagnon 1985, Payette 1992, Hobbie et al. 1994, Pastor et al. 1996). These properties of boreal regions challenge ecologists to develop general theories of how such a biome can sustain itself, in the face of wide oscillations of its constituent species. They also challenge managers to develop techniques of resource extraction that do not cause local extinction of a species or reduce productivity irreparably, and to maintain the properties and processes that underlie the resiliency of these ecosystems toward disturbance.

Chapin et al. (1996) conjecture that negative feedbacks in ecological systems keep oscillations within bounds, but positive feedbacks restore the system to its characteristic periods of oscillations. The important point of Chapin et al. is that the paper focuses not on the factors that control the mean, but on the factors that control oscillations. If these factors are the ecological underpinnings of resilience and sustainability, then a sustainable economy is one in which management interventions do not cause the system to move out of the range of natural oscillations.

Indigenous peoples appear to adjust their economy and culture to take advantage of the system oscillations, and direct and continuous management intervention by them is light (Nelson 1982, Berkes et al. 1994, 1995). The price paid for this is that indigenous populations are small and nomadic. In contrast, Western management seeks to control variation in the hopes that the mean value of an extracted commodity can be sustained, or even enhanced, to fuel a developing economy that supports much higher, non−nomadic population sizes than were ever obtained by indigenous peoples. Western management therefore attempts to minimize oscillations about mean values in these systems. However, the mean value is the least common and most ephemeral value of a naturally oscillating system. Therefore, Western management seeks to maintain the least probable state of the natural, oscillating system. It is an open question whether this is sustainable, especially if it decreases the structural and species diversity of boreal forests. Such a long−term decline in productivity and stability has been

documented, for example, in boreal forests of New Brunswick, Canada (Baskerville 1985, 1988, Regier and Baskerville 1986).

So what are the important ecological processes governing variability of boreal ecosystems and their inhabitants, and their resiliency from disturbances? How do we maintain resilience in boreal ecosystems and still maintain viable resource extraction industries? How have indigenous peoples such as Cree Indians and Laplanders managed themselves and their resources over hundreds of years? Do they provide some insights to how we might think and act in the future? How can we sustain the release of economic opportunity in boreal regions? How can we live with and profit from the natural variability that boreal forests require? What are the policy and management implications?

Researchers from Fennoscandinavia, Canada, and the United States came together to address these questions during an October 1997 workshop at Itasca State Park, northern Minnesota, under the auspices of the Beijer Foundation, the MacArthur Foundation, the Minnesota Department of Natural Resources, and the University of Minnesota−Duluth. Altogether, 10 papers presented at the workshop and included in this volume address one or more of these questions.

Six papers review the ecological sources of variation, resilience, and stability in boreal ecosystems, particularly in regard to silvicultural practices. Three of these papers (Frelich and Reich, Bergeron et al., and Host and Pastor) review disturbance regimes in boreal forests and their relationship with ecosystem properties. Two of the papers (Danell et al., and Niemi et al.) review the ecological processes underlying population variability in mammals and birds, respectively. Finally Dave Schindler reviews the current state of knowledge about boreal aquatic systems in a landscape context.

Frelich and Reich present a conceptual model of the variety of disturbances. Disturbances are classified according to whether they produce continuous, discontinuous (threshold), or cusp−catastrophe/multiple−stable−state responses of species composition in boreal regions. Frelich and Reich suggest that if management is done according to a different disturbance regime than the natural type or mix of types for the landscape in question, then it can cause major changes in species composition. Bergeron et al. review the arguments that silvicultural practices are a direct analogy of natural disturbances such as fire, and find them wanting. Natural disturbances vary greatly in return times, intensity, and compartments affected. Consequently, they maintain variability in species composition. Conversely, most forest management practices have far less variety, and consequently "homogenize" the landscape. Bergeron et al. suggest that we must develop silvicultural techniques that maintain a spectrum of forest composition over the landscape. Host and Pastor show that the successional development of sub−boreal forests after a disturbance is linked to the geomorphic control over soil water availability. This geomorphic control constrains feedbacks between species and the soil that control nitrogen availability and, hence, productivity. It is a major negative feedback keeping oscillations within bounds.

Danell et al. review the evidence for fluctuations of mammalian populations in boreal regions and include a valuable summary of much of the literature from Fennoscandinavia and the former Soviet Union that may be unfamiliar to many readers. Fluctuations of boreal mammals, such as the snowshoe hare−lynx cycle, are among the best known of any population oscillation. Danell et al. show that not all mammalian populations fluctuate so regularly or strongly, and discuss the implications of different temporal dynamics for game management for food and fur. Niemi et al. find little evidence for regular population fluctuations in boreal forest birds, but also suggest that this may be due to the lack of long−term records and a poor understanding of many bird species. Nonetheless, most bird populations are highly variable. Not enough is currently known about the effects of silvicultural treatments on boreal bird populations, particularly passerines, to make any generalizations now. Nonetheless, not managing to sustain bird populations could have adverse economic consequences, as many of the bird species are important predators on insects that inflict huge economic losses, such as the spruce budworm.

Dave Schindler shows how boreal aquatic systems are intimately tied to the dynamics of the surrounding landscape, including many of the disturbance regimes discussed by Frelich and Reich and Bergeron et al. He suggests that we must consider the cumulative effects of many changes to the landscape on boreal lakes and

streams, many of which may already be irreversible. Schindler concludes that the sustainability of boreal aquatic systems and their fisheries requires a much lower exploitation of the surrounding landscape than is currently happening.

So how to we translate these ecological theories and observations into practice? Doing this requires not only adapting management practices (reviewed by Graham and Jain), but also changing business and economic systems (reviewed by Chapin and Whiteman, and Leefers and Castillo). Ron Trosper offers a perspective on socioeconomic systems of First Nation peoples that allowed them to sustain a vibrant and prosperous culture in the face of ecological variability.

Graham and Jain review the suite of silvicultural practices used in boreal systems, from even−aged to uneven−aged systems, including their consequences for such ecosystem properties as coarse woody debris, forest floor mass, and other features underlying resiliency of boreal forests. They then show how silvicultural practices can be adapted to sustain not only timber yield from boreal forests, but also habitat for an important predator, the Northern Goshawk.

Sustainability of boreal regions requires not only sustaining the ecological systems, but also the economic systems that support whole societies. Chapin and Whiteman offer a conceptual framework for analyzing feedbacks in ecological and socioeconomic systems, which expands upon the feedback model of stability discussed by Chapin et al. (1996). Stability of ecological systems, including stable cycles of populations, are maintained by negative feedbacks between, e.g., predator and prey, vegetation and soil, and species composition and natural disturbance regimes and a great variety of ecological settings in the landscape. Many indigenous peoples also incorporate negative feedbacks and variety into their harvesting practices. For example, reviewing the work of Berkes et al. (1994, 1995), Chapin and Whiteman show that different Cree families, even in the same village, would often harvest different fish species using different net sizes, thus distributing the harvesting pressure over many populations and keeping harvesting of any one species at low levels. However, modern business practices often have degenerative positive feedbacks between harvest intensity and resource abundance, leading to collapse of a resource. For example, a typical pattern of fisheries exploitation by Western society is for everyone to exploit the same resource, driving abundance to low levels and raising prices, thus spurring even greater harvesting intensity. Chapin and Whiteman suggest criteria for sustaining the economy of boreal regions within the limits of natural behaviors of their ecosystems.

Trosper shows how First Nations often had social systems that distributed wealth. These act as a negative feedback on accumulation of wealth by a small group of individuals. In contrast, it is this accumulation of wealth, in many Western societies, by the powerful few that leads to the overexploitation cycle. A premier example of such a social system in the First Nations is the potlatch practiced among the Pacific Northwest Coast societies. In the potlatch, a chief maintained a position of authority by demonstrating how his decisions were made on behalf of all the people, and by periodically distributing his wealth. Trosper shows that we may adapt some of these practices if we view the resources managed and exploited by corporations as being in the public trust; the CEO of a corporation then functions as a chief entrusted by all members of the society, rather than simply reporting to the shareholders.

Leefers and Castillo discuss the idea of natural capital and a Natural Resource Accounting framework for keeping track of the key processes and properties of ecological systems underlying their sustainability. They then show how such a framework can be used to assess the sustainability and resilience of Michigan's lowland boreal conifer ecosystems.

Finally, although this workshop was great fun and intellectually stimulating, it does no good unless these ideas are put into practice. Whiteman concludes with a perspective on how ecosystem ecologists can learn a few lessons from business managers and better market our ideas. Although the idea of "marketing" may not appeal to many, Whiteman makes cogent arguments that if we are to sustain boreal ecosystems while harvesting resources − perhaps the last chance we have to sustain any managed ecosystem − we must learn from the business community good techniques of presenting our ideas. Otherwise, we may not have a boreal system that is recognizable by anyone.

We therefore invite you, dear reader, to browse and study these papers and see what thoughts they provoke in you. Observations, suggestions, and reasonable speculations abound, but hard conclusions are few. There is a vast gulf between knowledge and practice that must be closed in order for us to sustain not only the last large expanse of relatively untouched landscape, but also the great variety of peoples that depend on it.

---

## RESPONSES TO THIS ARTICLE

Responses to this article are invited. If accepted for publication, your response will be hyperlinked to the article. To submit a comment, follow this link. To read comments already accepted, follow this link.

---

## LITERATURE CITED


**Apps, M. L., W. A. Kurz, R. J. Luxmoore, L. O. Nilsson, R. A. Sedjo, R. Schmidt, L. G. Simpson, and T. S. Vinson.** 1993. Boreal forests and tundra. *Water, Air, and Soil Pollution***70**: 39−53.

**Baskerville, G. A.** 1985. Adaptive management, wood availability, and habitat availability. *The Forestry Chronicle***61**: 171−175.

**_____ ..** 1988. Redevelopment of a degrading forest ecosystem. *Ambio***17**: 314−322.

**Berkes, F., P. J. George, R. J. Preston, A. Hughes, J. Turner, and B. D. Cummins.** 1994. Wildlife harvesting and sustainable regional native economy in the Hudson and James Bay Lowland, Ontario. *Arctic***47**: 350−360.

**Berkes, F., C. Folke, and M. Gadgil.** 1995. Traditional knowledge, biodiversity, resilience, and sustainability. Pages 281−299 *in* C. A. Perrings, K.−G. Mäler, C. Folke, C. S. Holling, and B. O. Jansson, editors. *Biodiversity conservation.* Kluwer Academic Publishers, Dordrecht, The Netherlands.

**Chapin, F. S., M. S. Torn, and M. Tateno.** 1996. Principles of ecosystem sustainability. *American Naturalist***148**: 1016−1037.

**Hanski, I. , P. Turchin, E. Korpimaki, and H. Hettonen.** 1993. Population oscillations by rodents: regulation by mustelid predators leads to chaos. *Nature***364**: 232−234.

**Hansson, L.** 1979. On the importance of landscape heterogeneity in northern regions for the breeding population densities of homeotherms: a general hypothesis. *Oikos***33**: 182−189.

**Heinselman, M. L.** 1973. Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota. *Quaternary Research***3**: 329−382.

**Hobbie, S. E., D. B. Jensen, and F. S. Chapin, III.** 1994. Resource supply and disturbance as controls over present and future plant diversity. Pages 385−408 *in* E.−D. Schulze and H. A. Mooney, editors. *Biodiversity and ecosystem function.* Springer−Verlag, New York, New York, USA.

**Nelson, R. K.** 1982. A conservation ethic and the environment: the Koyukon of Alaska. Pages 211−228 *in* N. M. Williams and E. S. Hunn, editors. *Resource managers: North America and Australian hunter−gatherers.* AAAS (American Association for the Advancement of Science), Washington, D.C., USA.

**Olson, J. S., J. A. Watts, and L. J. Allison.** 1983. Carbon in live vegetation of major world ecosystems. *Oak Ridge National Laboratory Technical Report ORNL−5862,* Oak Ridge, Tennessee, USA.

**Pastor, J.** 1996. Unsolved problems of boreal regions. *Climatic Change* **33**: 343−350.

**Pastor, J., and D. J. Mladenoff.** 1992. The southern boreal−northern hardwood forest border. Pages 216−240 *in* H. H. Shugart, R. Leemans, and G. B. Bonan, editors. *A systems analysis of the global boreal forest.* Cambridge University Press, Cambridge, UK.

**Pastor, J., D. Mladenoff, Y. Haila, J. Bryant, and S. Payette.** 1996. Biodiversity and ecosystem processes in boreal regions. Pages 33−70 *in* H. A. Mooney, J. H. Cushman, E. Medina, O. E. Sala, and E.−D. Schulze, editors. *Functional roles of biodiversity: a global perspective.* Wiley Press, New York, New York, USA.

**Payette, S.** 1992. Fire as a controlling process in the North American boreal forest. Pages 144−169 *in* H. H. Shugart, R. Leemans, and G. B. Bonan, editors. *A systems analysis of the global boreal forest.* Cambridge University Press.

**Payette, S., and R. Gagnon.** 1985. Late Holocene deforestation and tree regeneration in the forest−tundra of Quebec. *Nature***313**: 570−572.

**Regier, H. A., and G. L. Baskerville.** 1986. Sustainable redevelopment of regional ecosystems degraded by exploitative development. Pages 76−100 *in* W. C. Clark and R. E. Munn, editors. *Sustainable development of the biosphere.* Cambridge University Press, Cambridge, UK.

---

**Address of Correspondent:**
John Pastor
Natural Resources Research Institute
University of Minnesota − Duluth
5013 Miller Trunk Hwy
Duluth, MN 55811 USA
Phone: 218−720−4271
Fax: 218−720−9412
jpastor@sage.nrri.umn.edu

---



---

Return to Table of Contents for Volume 2, Issue 2

Main | Issues | How to Submit | Subscription Benefits