Forests and Natural Resources in the 22nd Century Science Forum Proceedings*

August 31–September 1, 2005

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Popular Summary

Driving changes in the focus of natural resources research

John L. Innes[1]

Abstract

The International Union of Forest Research Organizations (IUFRO) World Congress ("Forests in the Balance: Linking tradition and technology"), which took place August 2005 in Brisbane, Australia, was deliberately designed to call attention to the uncertainties facing both forests and the forest sector. The Congress encouraged a problem-based and interdisciplinary approach to individual sessions. Ten Congress sub-themes representing the current directions of forest research emphasized the interactions between the natural and social sciences, and between forests and people. Considerable stress was placed on the roles of Indigenous peoples in forest management, reflecting the growing importance of this issue. A discussion of the drivers of change in forest research identified that research must now focus on increasing rates of environmental change, new kinds of problems, the global vision of and context to local problems, and the expectation that research will result in changes on the ground. A major feature of the World Congress was a number of sessions that looked at the nature of forestry education and the need to rethink curricula to meet the rapidly changing requirements of the profession.

KEYWORDS: *environmental change, forest policy, forest research, globalization.*

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Setting Priorities

The title of the International Union of Forest Research Organizations (IUFRO) World Congress, "Forests in the Balance: Linking tradition and technology," was deliberately designed to emphasize the uncertainties facing both forests and the forest sector globally. Many forests, especially in tropical countries, are under threat of conversion, and even in countries such as the United States conversion of forests to other forms of land use is a major issue. The forest sector is also "in the balance" at the current time, with power shifting very rapidly from the development of primary forests in the northern hemisphere to production from plantation forests in the southern hemisphere. The pulp and paper sector in countries such as Canada already has a very uncertain future, and it appears likely that lumber will follow the same pattern. To a certain extent, these changes have already occurred over much of Europe, where the primary objective of forest management is no longer the production of timber.

At the same time as these global trends are occurring, there is increasing recognition that the roles of Indigenous peoples will in future be given much greater attention in many countries. In countries such as Canada, Australia, and New Zealand, the colonial legacy is slowly being eliminated, and access to and ownership of traditional territories are being returned to the Indigenous peoples. For example, once treaty negotiations are concluded, as much as 40% of the land used for commercial plantation forestry in New Zealand could be owned by the Maori people. Similar trends are apparent elsewhere, as the rights of Indigenous peoples become enforced through national and international processes. These trends are also resulting in the gradual elimination of the colonial forestry model, typified by the granting of large timber concessions by central government without meaningful consultation with, or significant benefits to, local peoples (regardless of whether or not they are Indigenous), with the primary purpose of the concessions being the production of commodities for export.

These global changes are being superimposed on a number of other changes occurring both within and outside the forest sector, creating a complex and rapidly changing global context for forests. While it has been possible to ignore such changes in the past, increasing globalization is making a focus on local events increasingly irrelevant. Forest managers in British Columbia, Canada, and elsewhere would be unwise to continue to believe that the changes occurring outside their own jurisdictions are of no concern to them. Much the same applies to those managing research—a focus on local problems is resulting in a concentration on short-term issues, with the result that when unusual (but often predictable) events occur, such as a bark beetle epidemic or major fire season, decision makers are taken by surprise.

IUFRO World Congress Sub-Themes

The IUFRO World Congress went through a broad international consultation to identify the sub-themes of greatest interest to the research community. The following 10 sub-themes represent the interests of researchers globally, and reflect the current directions of forest research, defined broadly.

- Integrating approaches to achieve multiple goals: Intensive management, extensive management, or conservation?
- Utilizing genetic resources to further sustainable forestry.
- Meeting the challenge of climate change.
- Promoting development through improvements to the forest to wood and products chain.
- Involving Indigenous groups in forest science and forestry.
- Increasing the value of forests through innovative products and technologies.
- Demonstrating sustainable forest management.
- Sustaining forests: A duty for forestry and society?
- Realizing the environmental benefits of forests.
- Advancing the role of communication, education, and capacity-building in the future of forestry.

These themes differ markedly from those that featured in the 2000 IUFRO World Congress in Kuala Lumpur. For example, whereas in 2000 the climate change sessions focussed on the nature of future climate change, the 2005 Congress concentrated on the role of forestry in mitigating the impacts of climate change through its role in carbon sequestration. Much greater emphasis was given in 2005 to the interactions between the natural and social sciences—in fact, the entire World Congress was set up differently to encourage a problem-based and interdisciplinary approach to individual sessions. For the first time, considerable emphasis was given to the roles of Indigenous peoples in forest management, reflecting the growing importance of this issue.

Many sessions focussed on connections. For example, the session "Innovation and entrepreneurship, rural development and forest sector competitiveness" looked at the barriers to innovation in the forest sector and how these were related to rural development. Another session, "Decisions with long-term effects in forest management," looked at the role of uncertainty in investment decisions in the forest sector and how flexibility can be incorporated into the decision-making process.

Drivers of Change

In a session aimed at enabling research directors to compare experiences, the drivers of change in forest research were clearly identified. For Anne Bartuska, Deputy Chief of the U.S. Forest Service responsible for research, forest research must now be placed in the context of increasing rates of environmental change, new kinds of problems (a recurring theme in the Congress), the global vision of and context to local problems, and the expectation that research will result in changes on the ground. Research needs to move away from disciplinary issues and deal with multiple values, such as how to reduce the risk of catastrophic fire while, at the same time, maintaining other forest values such as biodiversity. She considered the primary drivers of forest science to include:

- the need to rehabilitate and recover forested ecosystems,
- the need to manage with disturbance (as opposed to managing disturbances),
- the need to capture the full value from forests,
- the need to link land use and water,
- the interactions between social dynamics and forest use,
- the rise in urban natural resource stewardship, and
- the increase in globalization.

She emphasized the growing need for forest biosecurity and protection, and the importance being placed on the quality of life, not only of humans but also of wildlife. This theme was picked up during several sessions dealing with forests, trees, and human health and well-being.

Other speakers pursued many of these themes, especially the changing nature of the problems facing forest research. Sessions on the role of forests in promoting human well-being, in the valuation of environmental services provided by forests, in the balancing of production and conservation, amongst others, emphasized the rapid shift in the focus of research away from forests as a source of timber to forests as a source of multiple benefits. Although the research community is adapting to these changing needs, one keynote speaker, Lisa Sennerby-Forsse, emphasized the barriers presented by the innate conservatism of academics. This criticism was, perhaps, a little unfair, since researchers are driven by funding opportunities and, in places such as British Columbia where the research agenda is largely driven by the short-term needs of industrial forestry concerns, it is almost impossible to engage in innovative or strategic research.

The Nature of Forestry

A major feature of the IUFRO World Congress was a number of sessions that looked at the nature of forestry education. One speaker prefaced his talk with a quote from Jack Westoby, formerly of the United Nations Food and Agriculture Organization: "Forestry is not about trees; it is about people; it is about trees only insofar as they meet the needs of people." These words were written in 1967, and forestry, as it has always done, has continued to evolve since then, yet forestry curricula have not co-evolved. Throughout the Congress, the links between people and forests were continuously emphasized, so it was disappointing to learn of the very slow progress made in adjusting the curricula of Canadian forestry schools to the "new" needs of forestry. The approach that is still being adopted is to tinker with the existing model, adding new material only when a decision is made that existing material can be dropped from the curriculum. Many speakers at the Congress emphasized the need for a radical rethinking of forestry curricula—when the existing skill sets are matched against perceived needs, the need for new curricula becomes clear. Ironically, the freedom offered to non-traditional schools that teach forestry is resulting in more and more students opting for the relevant and interesting curricula offered by such schools. While not gaining degrees that will make them professional foresters, they are gaining jobs in the forestry sector, weakening the role of more traditionally trained foresters.

Education, of would-be and existing foresters, of policy and decision makers, and of the general public, was featured in many presentations. The forestry sector has not been adept at this, and missed opportunities abound. Unlike proper professionals, professional foresters in many parts of the world are not required to participate in continuous education, despite the rapidly changing needs of the profession. This has been a source of frustration amongst policy-makers and researchers; very often, the answers to problems are available, but foresters are unaware of the solution. Each believes that their own problem is unique, yet throughout the Congress, it was the similarity of the problems facing forestry everywhere that was striking, not the uniqueness.

What is the nature of these problems? Many speakers stressed that the nature of forestry problems is changing, although the specifics rarely emerged. The general feeling was that problems are becoming more complex, bringing about the need to integrate between traditional disciplines. Speakers emphasized the need for interdisciplinary research approaches, but the problems facing this were considered substantial.

Conclusions

This was a large Congress, with 2700 papers submitted and 1700 ultimately presented (either as verbal or poster presentations). The quality of the presentations was predictably mixed, but generally higher than in previous IUFRO congresses. With so much going on (e.g., up to 20 parallel sessions at any given time), it was extremely difficult to cover every paper of potential interest, and this was a source of frustration for some delegates. However, all abstracts have been published as a special issue of the *International Forestry Review*, which is available for purchase or on-line to members of the Commonwealth Forestry Association.

Popular Summary

The forest science–policy interface: Time for a change

Chris Hollstedt[1]

Abstract

The application of policy is the largest change agent affecting people and the environment. A 40-year cycle from problem identification to solution may be too long for current sustainable development challenges. There is a compelling need for science, Indigenous, and experiential knowledge to inform sound sustainable development policies that transcend national boundaries. Both the research and policy sectors need to align their goals and develop mechanisms to contribute to science-based policy solutions that integrate across disciplines, biophysical scales, and bio-political boundaries. Solutions to enable and improve the science–policy interface require changes in institutional behaviour as well as establishment of knowledge networks, partnerships, funding arrangements, and intra- and international agreements.

KEYWORDS: *communication, forest policy, networks, science, sustainable development.*

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Science Influencing Global Policy and Key Policy Drivers

The historic influence of science on global policy decisions is well documented and was cited in various presentations throughout the recent International Union of Forest Research Organizations (IUFRO) World Congress, held in Brisbane, Australia. These policies, when implemented, are the largest change agents affecting people and the environment. Milestone agreements, such as the United Nations Convention on the Human Environment (1972), the Bruntland Report (1987), and the Rio Declaration (1992), set goals for sustainable development related to people and the environment. The Johannesburg Declaration (2002) reaffirmed a global agenda to address:

- the eradication of poverty,
- access to clean water,
- energy,
- health,
- improving agricultural productivity while reducing the rate of desertification and loss of biodiversity,
- reversing the degradation of natural resources,
- solutions relating to ozone depletion and pollution, and
- world trade.

Historically, the influence of science on policy follows a 20-year cycle, with management application often taking another 20 years. In 1967, scientists communicated the possible connection between sulphur emissions and acidification. The Convention on Long-range Transboundary Air Pollution was signed in 1985 and signing parties reported achieving the 30% reduction target by 1993. Scientists identified a possible link between aerosols and changes to the ozone layer in 1974. Although some nations moved quickly to ban the use of aerosols, the Montreal Protocol was signed almost 20 years later, and the issue is still far from resolved.

International agreements developed with advice from scientists continue to challenge regional and local governments in their attempt to develop local policies and guidelines for achieving goals related to human health and well-being, conservation, ecological function, and economic development. The need for science–policy interaction has thus increased at the regional and local level due to the development of international policies related to forestry and the environment, and the recognition of the cumulative impacts of local, regional, and national economic development activities on global social and ecological systems functions. Margaret Shannon, in her studies of forest policy development, suggested that although science often recognizes the need for an environmental policy, science rarely creates the means of policy to achieve this end. Policy problems are messy and complex and require attention. A cultural shift is required and only then can the emerging science–policy process create new institutional norms to enhance political ownership of the solutions, ensure scientific independence, and provide clear and transparent analysis and understanding of the consequences.

Ariel Lugo described challenges within the context of tropical forestry, but his reflections are very applicable in other forest regions. They included:

- increasing our understanding of biotic responses to environmental change;
- improving science outreach and expanding the focus of research;
- developing a new vision for coping with environmental change;
- increasing our understanding of the interactions between anthropogenic and natural disturbances;
- increasing our understanding of, and seeing the value from, emerging ecosystems; and
- increasing the number of research networks focussed on long-term and large-scale research across environmental gradients and gradients of condition.

The provision of ecosystem services specifically requires more science and more policy. A strategic and integrated approach to possible solutions is recommended rather than attempting to solve these locally, which could result in fragmented and not necessarily compatible systems for combining results at regional and global scales.

Several IUFRO World Congress presentations recognized the need to address questions at a landscape and watershed scale, and suggested that interdisciplinary studies (as opposed to multidisciplinary studies) are needed; however, it remains to be seen whether science will answer the following questions:

- Can we achieve landscape-level biodiversity and ecosystem-function objectives with our current silvicultural tool box?
- Will focussing on larger-scale interactions inform changes to stand-level practices?
- How will decision makers know what to adjust in this complex framework?
- Will science inform the refinement of Sustainable Forest Management (SFM) criteria so that we know we're asking the right questions?

- Will indicators developed and monitored at various scales inform us soon enough that we can adjust our strategies to avoid unpleasant results?

Big questions still surround decisions about which components of the environmental, social, Indigenous, and economic targets can be traded off against one another. This becomes more complex as decision makers make tradeoffs across multiple scales and political boundaries. Tools for making tradeoffs require local criteria developed by local constituents, and the science community can play a very important role in informing these selections.

The following policy issues continue to require research attention:

- Risks and benefits of intensive versus extensive forestry
- Management for biodiversity and other ecosystem attributes in plantations (or plantations as surrogates for natural forests)
- Monocultures versus mixed-species management
- Tenure and ownership models
- Zoning and Protected Areas
- Multiple goods and services, and valuation of these
- Wood quality in plantations
- Use of models: where's the true decision support?
- Scale
- Disturbance, including climate change
- Small-scale forestry versus industrial forestry
- Use of long-term research results to address short-term needs
- Genetics, bioengineering, bioenergy, biofuels, and nanotechnology
- Use of science to inform goal setting, monitoring, and decision making: the Criteria and Indicators debate
- Role of the First Peoples: Indigenous people, and experiential and Indigenous knowledge

Important Challenges and Issues

The value of good science in developing sound environmental policies that transcend national boundaries was not questioned at the IUFRO World Congress. The policy–science–management continuum is complex, however. If science-based policy is desired (and in some cases is the law), why does it still pose such challenges? Why is it perceived that science is not informing policy, or that research is not addressing the priority policy questions, or that policies are not based on the best available science? And what sector makes the first move? It is striking how all jurisdictions face similar challenges regarding the science–policy interface. These common challenges include, but are not limited to, the lack of:

- policy science or knowledge of the effects of science on policy,
- policy or regulatory requirements,
- human capacity,
- decision criteria and (or) cost-benefit data for tradeoff decisions, and
- supportive institutional and individual behaviour.

The largest challenge appears to involve the need to ensure a continuous dialogue among all players through multiple geographic and time scales and across disciplines, many of which are non-traditional in the forestry community.

In her IUFRO Congress presentation, Lisa Sennerby Forsse outlined the following important issues that must be resolved by the research and policy communities to meet this challenge:

- Academic conservatism
- Lack of research capacity in government
- Lack of ownership of the problem by both the research and policy community
- Reluctance of the political system to take risks
- Scarcity of fora for dialogue on key issues at national scales

Some Possible Solutions

In his opening address, IUFRO President Risto Seppala affirmed the need of a global focal point for science to enhance communications with policy-makers. It was emphasized that scientific, Indigenous, and experiential knowledge should be included to address issues of deforestation, illegal logging, poverty alleviation, social values, and management in new disturbance regimes. Lisa Sennerby Forsse suggested a holistic approach to science and the need for scientific syntheses, quality-assured research and research competence, and international co-operatives. She also stressed that research be recognized as an investment for the future and that international co-funding of facilities and global agreements are needed.

At the institutional level, Anne Bartuska's new vision for forestry science included the following suggestions.

- Get back to basics
- Embrace new disciplines

- Rejuvenate public–private partnerships
- Build on unique capabilities of your institutions
- Develop a comprehensive approach to monitoring
- Improve and continue to communicate science
- Implement adaptive management

At the inter-institutional level, I suggest aligning strategic goals and working in networks and communities of practice. Redefining strategic goals and objectives for the knowledge sector that align with the policy sector will reduce the potential for resistance and demonstrate an honest effort at understanding how the sector works, while reflecting the importance placed on the sector's ability to use the best available information to make decisions. Institutions need to work together with the decision makers through strategic networks. These networks can move beyond the typical information-flow hierarchies to focus on strategic relationships. Formal or informal networks should have a clear mandate, effective governance structure, and resources to accomplish their goals. They should focus on core values, principles, and the strength of the knowledge capital in the network. Focussing on goals and developing solutions through a learning process will result in a significant knowledge-based policy shift.

To address integration of science at a community level, Arne Skaugset suggested a "perfect partnership" where those most likely to implement the solution are engaged in the process, where information and data generated can be integrated directly into the decision process, and where there are adequate resources to address the issue. Juan Manual Torres Rojo cited institutional arrangements, internal rules, changes in decision-making processes and goals, and the scope of the problem as critical factors in successful integration. Bob Szaro thought that managing human needs and expectations is also critical. To enable learning and realize a long-term policy solution, Szaro suggested that a research partnership should:

- educate decision makers about the core elements of their research,
- uphold statistical credibility,
- keep things simple,
- devote resources to data management,
- have the capacity to sustain long-term studies, and
- provide leadership and continuity.

At the institutional and individual levels, the IUFRO Task Force on the Forest Science–Policy Interface developed a set of guidelines to help researchers work more effectively at this interface. These guidelines are organized into the following four categories:

1. Focussing research on questions that are relevant to policy issues
2. Conducting research in a communicative and collaborative manner
3. Understanding, serving, and engaging in policy processes
4. Creating organizational capacity and culture that enables and encourages research at the science–policy interface

Conclusions

The application of policy is the largest change agent affecting people and the environment. A 40-year cycle from problem identification to solution may be too long for current sustainable development challenges. There is a compelling need for science, Indigenous, and experiential knowledge to inform sound sustainable-development policies that transcend national boundaries. Both the research and policy sectors need to align their goals and develop mechanisms to contribute to science-based policy solutions that integrate across disciplines, biophysical scales, and bio-political boundaries. Solutions to enable and improve the science–policy interface require changes in institutional behaviour as well as establishment of knowledge networks, partnerships, funding arrangements, and intra- and international agreements. Aligning institutional goals and strategies, building on strengths and unique capabilities of institutions and people, improving research communications and enhancing extension capacity, ensuring adequate financial resources, and building recognition for engagement in a revitalized science–policy interface are recommended. Both the science and policy sectors must build momentum and co-lead a new era of working together to address the critical interdisciplinary, transboundary sustainable development solutions that can work locally.

*Abstract**

Research and resource-dependent communities: A world of possibilities

Robert Kozak[1]

The recent International Union of Forest Research Organizations World Congress held in Brisbane, Australia, showcased a wide variety of high-quality presentations related to forestry research from around the globe. Little of this research, however, can be extended to forest-dependent communities in British Columbia. Possible exceptions include opportunities to promote the value-added wood products industry, develop a meaningful non-timber forest products services sector, and incorporate innovative approaches into core business strategies and modes of operation. In this paper, I also argue that much of today's forestry research does not consider the "big picture," especially concerning sustainability issues and our current ecological footprint. We have come to a juncture in time wherein forestry researchers should take a leadership role with bold, innovative and interdisciplinary work that serves to benefit the environment, the economy, and society as a whole.

KEYWORDS: *forest products, forestry research, globalization, resource-dependent communities, sustainability.*

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Popular Summary

The growing role of Indigenous communities in the management of natural resources

Ronald Trosper[1]

Abstract

The 22nd IUFRO World Congress emphasized "Linking Tradition and Technology." The major themes of the conference addressed concerns shared with Aboriginal people, especially the importance of sustainability. Some subplenary speakers who gave presentations on non-Aboriginal topics raised Aboriginal issues as part of the discussion. The two resolutions announced at the final ceremony had some references to Indigenous peoples and to issues important to those peoples. The IUFRO has also organized a task force on linking science and traditional forest-related knowledge.

KEYWORDS: *Aboriginals, Indigenous peoples, resource management, sustainability.*

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Impressions of IUFRO World Congress

This presentation is a report on my impressions of the attention paid to Indigenous communities at the recent IUFRO World Congress in Brisbane, Australia. I was pleased that the conference theme emphasized "Linking Tradition and Technology." I wondered, however, how well this linkage would be implemented—world view differences between Western science and other knowledge systems are difficult to reconcile.

The opening ceremony raised the fear that Aboriginal people would be presented as "window dressing" rather than as an integral part of the society. Much as international visitors view Northwest Coast art as they arrive in Vancouver—while the people of Haida Gwaii are fighting to save their cedar—relegating Aboriginal people to the artistic part of life is always a danger. The ceremony began with Aboriginal music and dance. There was no formal welcome to territory, and the Master of Ceremonies talked more about the game of cricket than about the traditional owners.

It turned out that the land where the conference occurred had probably been jointly owned, and the traditional groups had competing claims over it. Hence, only a vague acknowledgement of the traditional owners was possible. Although Australia's judicial system has retreated from the idea that no people were in Australia when the settlers arrived, this idea meets resistance from other governmental units. That the conference organizers moved a small distance toward joining with the judiciary was good. They made an honest effort to have a full traditional welcome.

On the other hand, the plenary speaker claimed that management of tropical forests in the 1980s was "nil," as if Indigenous people did not exist and only others could provide "some kind of management." Later in the speech, he recognized that new ecosystems include people in them, thus retreating from the tradition in science of separating people and nature.

The major themes of the conference addressed concerns shared with Aboriginal people, especially the importance of sustainability. It reminded me that the Intertribal Timber Council in the United States often organizes sessions on "total resource management," meaning all features of forests, not just trees.

Very few Aboriginal scholars attended the conference, possibly because they would have had to pay their own way, possibly also because the image of forestry in Australia is dominated by the old, colonial approach of extraction and plantation. The in-conference tour I took featured a visit to a plantation of exotic trees, to visit the top clone on-site. That group of five trees was amazing as productive creators of fibre for 2 × 4's—a "40-year-old" tree that grew in 10 years, straight, hard, and with small branches. Hectare upon hectare of that clone are planted by the Queensland forestry department. Such an extreme investment of "all-ones'-eggs-in-one-basket" is contrary to the Aboriginal traditions I know of. Perhaps the fast growth reduces the risk—but one wonders.

The subplenaries featured speakers on non-Aboriginal topics who raised Aboriginal issues as part of the discussion, which I liked. A paper on community forests in Mexico and one on certification in New Zealand both stood out in this respect. I heard reports of other examples—the conference was too large for one person to cover. Wednesday's subplenary speaker was Joseph Gosnell from the Nisgaa Lisims Nation, and he was well received. I had thoughtful questions addressed in response to my presentation, as did Joe Gosnell.

The smaller sessions also had many related to Indigenous issues, and most I attended had substantial attendance by others at the conference. One featured an excellent study proving that moose hunters knew where the moose were in their territory in northern Quebec. While I liked the proof that the hunters had accurate knowledge, I was saddened that such proof is still required. Money would be better spent discovering knowledge new to both the hunters and the scientists.

The two resolutions announced at the final ceremony had some references to Indigenous peoples and to issues important to those peoples. That and the fact that IUFRO has organized a task force on linking science and traditional forest-related knowledge are good signs that more than window dressing is intended.

Popular Summary

Integrating ecological knowledge into forest planning for the conservation of forest-dependent species

S. Craig DeLong[1]

Abstract

Integrating ecological knowledge into forest planning is becoming an important strategy for the management of forest-dependent species. Our knowledge of natural disturbance and the role it plays in shaping landscapes and crucial forest habitat attributes is increasing and changes to forest policy are being guided by this knowledge. New policy for the management of seral stage distribution and patch size was recently developed in northern British Columbia based on studies of the temporal and spatial pattern of wildfire. In another project, a deadwood model developed on the basis of detailed field studies should help guide future deadwood management. Our conservation of forest-dependent species in the future will depend on how well we make use of our ecological knowledge of these forest ecosystems.

KEYWORDS: *conservation, deadwood model, ecological knowledge, forest-dependent species, forest planning, natural disturbances.*

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Introduction

Broad characteristics of natural disturbance dynamics, such as their spatial extent, frequency, severity, and heterogeneity, are increasingly used as a basis for forest management policies directed towards maintaining biological diversity in many forest types (Booth *et al.* 1993; British Columbia Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995). An underlying assumption of this management paradigm is that forest-dependent biota are adapted to the ecosystem characteristics and landscape patterns created by natural disturbance regimes (Hunter 1993; Bunnell 1995; DeLong and Tanner 1996; Bergeron and Harvey 1997; Angelstam 1998; DeLong and Kessler 2000). We expect that species and ecosystem functions should be more resilient to the ecological changes associated with forest management activities if the pattern and structure created by these activities resemble those of natural disturbance events. I discuss two projects, recently conducted in northern British Columbia, that have increased our understanding of disturbance in natural forest ecosystems. For both projects I will also discuss how this new information informs policy for the conservation of forest-dependent species.

Designing More "Natural" Landscapes

Since 1995, disturbance rate and patch size distribution have been examined for large landscapes within northern British Columbia (DeLong 1998). More recently, this knowledge has been incorporated into landscape-level guidance for forest management. Mapped estimates of the extent of old forests, in combination with other map layers of ecologically based information, were used to derive landscape units with similar natural disturbance rates, processes, and successional development. For each of these "natural disturbance units," natural disturbance rate and patch size distributions from the aforementioned research along with a simple landscape disturbance model were used to describe the natural range of variability (NRV) in landscape temporal and spatial pattern.

The estimated NRV for old forest (> 140 years of age), for each natural disturbance subunit (NDS), is shown in Table 1. As would be expected, the relative amount of old forest is much higher in wetter mountainous landscapes (e.g., 84–89% for the Wet Mountain) than in drier plateau landscapes (e.g., 17–33% for the Moist Interior – Plateau). In general, a large proportion of non-contributing forest occurs in the wetter units, which helps reduce the potential effect on the allowable

TABLE 1. Area of timber harvesting and non-contributing land bases, estimated percentage of total forested area in forests greater than 140 years old for natural forests, and final target (in brackets) for forests greater than 140 years old within natural disturbance subunits in the Prince George Timber Supply Area

Natural Disturbance Subunit	Timber harvesting land base (ha)	Non-contributing land base (ha)	NRV and final target for forest > 140 yrs (% of total forested area)
McGregor Plateau	217 807	78 325	43–61 (26)[a]
Moist Interior – Mountain	135 313	58 720	41–61 (29)
Moist Interior – Plateau	1 543 574	604 199	17–33 (12, 17)[b]
Northern Boreal Mountains	81 401	121 849	37–60 (37)
Omineca – Mountain	300 123	250 027	58–69 (58)
Omineca – Valley	593 672	186 942	23–40 (16)
Wet Mountain	552 936	221 903	84–89 (50)
Wet Trench – Mountain	97 997	212 637	80–88 (63)
Wet Trench – Valley	292 046	158 657	76–84 (53)

[a] In some cases, this is a blended number as the actual analysis and final values were based on smaller units (i.e., biogeoclimatic units within the NDS).

[b] Amount was 12% for some biogeoclimatic units and 17% for others.

annual cut (AAC) of conserving large amounts of old forest (Table 1). For some units (e.g., Wet Mountain), however, the proportion of non-contributing land base is relatively low (approx. 29%), but the estimated minimum for the NRV of old forest is high (i.e., 84%). To balance the ecological ideal (i.e., old forest within the NRV) against the potential effects on timber supply, a number of different scenarios for old-forest protection were estimated and a final scenario negotiated for implementation. The final negotiated percentages for old forest retention are shown in Table 1. In addition, the following general strategies were adopted.

- Larger rotating reserves of forest between 120 and 200 years of age for drier plateau units where very old forest was naturally rare and where older forest (i.e., > 150 years) is very susceptible to stand-replacing natural disturbance events (e.g, fire, mountain pine beetle).
- Fixed reserves of forest greater than 140 years of age for wetter units where very old forest (i.e., > 250 years of age) is common and where older forest is not susceptible to stand-replacing natural disturbance events.

Estimated patch size distribution for each NDS is shown in Table 2. In all cases except the boreal alluvial floodplains, the landscapes are dominated by large (100–1000 ha) or very large (> 1000 ha) patches. This is consistent with other studies within Canada that examined patch size for landscapes where fire is the primary stand-replacement agent (Andison 2003; Bergeron *et al.* 2004). Generally, it is difficult to manage landscapes to attain the estimated natural patch size distribution while also considering practical and social limitations. However, managing for a more natural patch size distribution, and in particular having a large proportion of harvested forest in patches exceeding 100 ha, is ecologically desirable. Apart from resulting in a more natural spatial age mosaic on the landscape, it slows the rate of new road-building, new stream crossings, and snag depletion (DeLong *et al.* 2004). Allowing some large patches also reduces fragmentation, which has been shown to have a negative effect on American marten in forested landscapes (Chapin *et al.* 1998; Hargis *et al.* 1999).

TABLE 2. Patch size distribution for natural disturbance subunits in northern British Columbia

	Patch size (% of total disturbance area)[a]			
Natural Disturbance Subunit	**> 1000**	**100–1000**	**51–100**	**< 50**
Boreal Foothills – Mountain	40	30	10	20
Boreal Foothills – Valley	40	30	10	20
Boreal Plains - Alluvial	0	0	40[a]	60[a]
Boreal Plains – Upland	70	20	5	5
McGregor Plateau	40	45	5	10
Moist Interior – Mountain	40	30	10	20
Moist Interior – Plateau	70	20	5	5
Moist Trench – Mountain	60	30	5	5
Moist Trench – Valley	70	20	5	5
Northern Boreal Mountains	60[a]	30[a]	5[a]	5[a]
Omineca – Mountain	40	30	10	20
Omineca – Valley	60	30	5	5
Wet Mountain	10	60	10	20
Wet Trench – Mountain	10[a]	60[a]	10[a]	20[a]
Wet Trench – Valley	10[a]	60[a]	10[a]	20[a]

[a] Based on expert opinion.

Managing the Deadwood Supply

As more forested area in British Columbia is harvested and subjected to intensive management, such as site preparation, planting, and thinning, developing strategies to maintain deadwood in forests is becoming of ever-greater concern. In Scandinavia, where forests have been intensively managed for decades, many species that rely on deadwood are now rare or endangered. In British Columbia, an estimated 150 wildlife species, including cavity-nesting birds, birds of prey, mammals, and amphibians, rely on various forms of deadwood.

A spatially explicit model for forecasting the long-term implications of forest management alternatives on amount of deadwood and habitat quality has recently been developed for wet forests in east-central British Columbia. The model is designed to examine changes in patterns of deadwood types and abundance over large landscapes, while also permitting operational rules specified at much smaller scales.

The model projects hybrid white spruce and subalpine fir snag densities and downed log volumes into the future in response to treatment scenarios specified by the operator. Densities and volumes are tracked by decay class, and remnant "stubs" (created by management or by snap-off of snags) are also tracked. The model simulates harvesting, road-building, snag-felling along road and block edges related to worker safety regulations, and the establishment of different types and amounts of within-harvest-block reserves. A cell resolution of 20 m × 20 m is used in an attempt to capture the finer-scale aspects of harvesting and access management activities and their effect on deadwood distribution across the landscape. Details of the harvesting, access management, and snag removal submodels can be found in DeLong *et al.* (2004).

The deadwood submodel represents deadwood in different "guilds," or groups of tree species with similar decay rates. For each guild and size class of deadwood (small: 17.5–27.5 cm DBH; medium: 27.5–47.5 cm DBH; > 47.5 cm DBH), the decay and dynamics of different types of deadwood (snags, "stubs," and downed wood) in each cell are modelled using a set of discrete stages that represent classes of increasing decay rates. For example, snags or stumps are tracked as a population of individuals and as a pool of volume, and their fates (decay or fall) are followed through time. Downed wood is tracked as volume in each decay class. To develop parameters for this submodel, a 2-year field study collected data on snag and downed wood amounts and dated year of death for snags and logs, and year of fall for logs in different stages of decay. Relationships between deadwood habitat quality, according to the classification of Keisker (2000), and snag or log attributes (i.e., size and decay state) were also developed to help interpret results regarding the effects on deadwood users.

Initial results indicate that average snag density remains reasonably stable across the landscape with some reduction of larger snags; however, downed log volumes are drastically reduced to levels of about 18% of those in the current test landscape, or approximately 10% of the level estimated to be present in an unmanaged landscape over just 50 years. Of particular concern are log habitats associated with freshly downed wood such as elevated runways. The volume of these habitats can be reduced to 10% of their present level in as little as 20 years.

The model is currently used to test various deadwood management practices that can be implemented at relatively low operational cost, but can help reduce long-term deadwood deficits.

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Popular Summary

Twenty-year site carbon budgets for broadcast burn plantations of north-central British Columbia

J. Marty Kranabetter[1] and Anne M. Macadam[2]

Abstract

Carbon storage and cycling in forests has generated considerable interest because of concerns over greenhouse gas emissions. Northern temperate and boreal ecosystems are of particular interest because of the relatively high accumulations of forest floor and coarse woody debris typical of these forests. An operational broadcast burn project was established in the early 1980s across the north-central Interior of British Columbia to examine the change in biomass and carbon content of logging slash, forest floors, mineral soils, and regenerating lodgepole pine (*Pinus contorta* var. *latifolia*) stands. The collection of year 20 data is nearing completion; a brief summary of the study and interim results are presented.

KEYWORDS: *biomass, carbon budgets, carbon storage, lodgepole pine.*

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Introduction

Carbon (C) storage and cycling in forests has generated considerable interest because of concerns over greenhouse gas emissions. A number of initiatives have been undertaken to predict forest C budgets with the expectation that forest management can offset some of the fossil fuel inputs of atmospheric carbon dioxide. Northern temperate and boreal ecosystems are of particular interest because of the relatively high accumulations of forest floor and coarse woody debris typical of these forests. Trends are difficult to generalize, however, because of the many factors influencing C cycles, such as climate, soil properties, plant species, and management regimes. More localized data sets are valuable in providing land managers with relevant information for the ecosystems of interest.

An operational broadcast burn project was established in the early 1980s across the north-central Interior of British Columbia. Six sites have been monitored from immediately after harvest through the broadcast burn (year 1), and then again at years 5, 10, and 20. We used this study to examine the change in biomass and C content of logging slash, forest floors, mineral soils, and regenerating lodgepole pine (*Pinus contorta* var. *latifolia*) stands. The collection of year 20 data is nearing completion and will be reported in detail, so only a brief summary of the study and interim results are presented here.

Methods

Six sites were established in the moist cold (mc) subzones of the Sub-Boreal Spruce (SBS), Engelmann Spruce–Subalpine Fir (ESSF), and Interior Cedar–Hemlock (ICH) biogeoclimatic zones in north-central British Columbia between 1982 and 1985 (Table 1). All sites had predominantly medium moisture and nutrient regimes, with typical vegetation and surficial materials for the given biogeoclimatic unit. Three plots were established at each site after the completion of logging. Each plot was 30 × 30 m, and was chosen for uniformity in surface shape and slash loading, without any significant soil disturbance (skid trails, ruts) from logging. The entire cutblocks were broadcast burned in the fall with appropriate fuel moisture codes for a light to moderate burn intensity. Lodgepole pine seedlings (2+0 bareroot stock) were planted at either 2- or 2.5-m spacing on the sites 1–3 years after burning.

Quantitative assessments of slash loading and consumption were based on line transect samples. Before burning, three 30-m transects forming a triangle

TABLE 1. Broadcast-burned plantation locations and site descriptions

Site	Logged	Burned	Latitude	Longitude	Elevation	BEC[a]	Soil description
Echo	Winter 1983–84	Fall 1984	54°19'25"	125°9'50"	1250 m	ESSFmc 01	Podzolic Gray Luvisol; morainal blanket with coarse loamy texture; Hemimor forest floor 6–18 cm deep
Helene	Winter 1981–82	Fall 1982	54°16'40"	125°3'45"	1050 m	SBSmc2 01	Brunisolic Gray Luvisol; morainal blanket with loamy skeletal texture; Hemimor forest floor 5–17 cm deep
Herron	Winter 1982–83	Fall 1983	54°20'25"	125°10'0"	1335 m	ESSFmc 01	Orthic Humoferric Podzol; morainal blanket with coarse loamy texture; Hemimor forest floor 8–22 cm deep
Kinskuch	Winter 1981–82	Fall 1982	55°33'22"	128°59'40"	270 m	ICHmc1 01	Podzolic Gray Luvisol; morainal blanket with sandy loam texture; Hemimor forest floor 3–10 cm deep
McKendrick	Winter 1984–85	Fall 1985	54°51'50"	126°43'45"	1075 m	ESSFmc 01	Orthic Humoferric Podzol; colluviated morainal veneer with coarse loamy texture; Hemimor forest floor 7–14 cm deep
Walcott	Winter 1981–82	Fall 1982	54°31'20"	126°55'0"	830 m	SBSmc2 01	Orthic Dystric Brunisol; morainal blanket with loam texture; Hemimor forest floor 6–20 cm deep

[a] Biogeoclimatic ecosystem classification

were superimposed on each plot. Forest floor depth was measured at four points along each 30-m transect. A metal depth-of-burn pin was inserted adjacent to each measurement. The sample transects were relocated and resampled within 10 days after burning. Slash loads were remeasured at year 20 with the same methods, although it was not possible to relocate the exact position of the original 30-m transects.

Soils were sampled immediately after harvest but before burning (year 0), the year after burning (year 1), and then at years 5, 10, and 20. Forest floor mass and depth were determined by excavating a 20 × 20 cm area down to the mineral soil interface. Mineral soils were sampled at 0–15 cm depth and 15–30 cm depth using a stony soil auger. Before burning, we determined mineral soil bulk densities by excavation and volume displacement to convert C concentrations to mass. Total C concentrations of the forest floor and mineral soil were determined using combustion elemental analysis.

A 0.02 ha circle (7.98 m radius) was located in the approximate centre of each plot to measure the regenerating stands. Sapling height, root collar diameter (RCD), and diameter at breast height (1.3 m) were determined on planted pine seedlings 5, 10, and 20 years after planting. Six trees from three sites that covered a range in tree height (6–10 m tall) were destructively sampled for biomass. Linear regressions of C content per tree as a function of root collar diameter and tree height were determined for the six sample trees, and this regression was used to estimate the carbon content of each tree in the 20-year-old lodgepole pine stands.

Results

Total C of the post-harvest sites averaged 137 Mg per ha, with approximately one third of site C (45 Mg per ha) contributed each by mineral soils (0–30 cm), forest floors, and logging slash (Figure 1). Together these components of the C budget declined by almost 50% over the 20-year measurement period, with no evidence yet of organic matter accumulation in soils (slash biomass was not estimated in years 5 or 10, so intermediate values between years 1 and 20 were used for the purposes of this comparison). Site C content

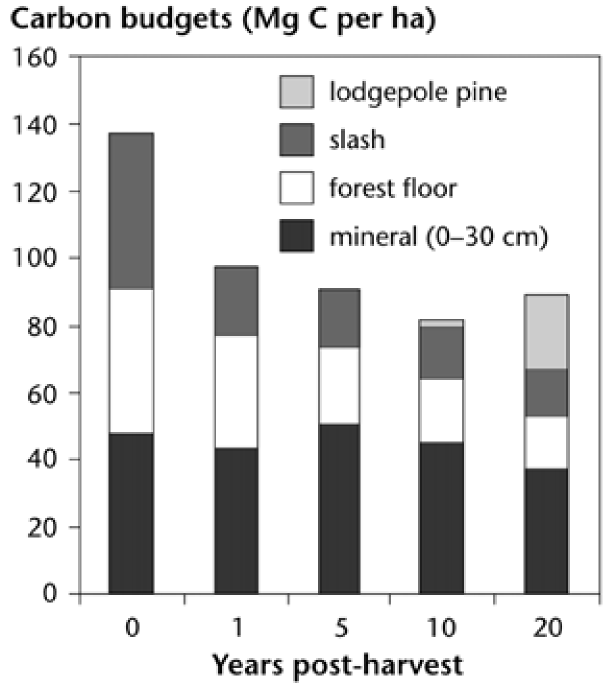

FIGURE 1. Carbon budgets (Mg C per ha) by mineral soil, forest floor, logging slash, and lodgepole pine (stem and branches only) across the 20-year post-harvest period.

increased after year 10, however, because of the increasing contribution of sequestered C by regenerating pine stands. Overall, the site C budget of these 20-year old plantations was approximately 65% of the post-harvest site C mass.

The sequestration of C by pine trees after year 20 will continue to be substantial, and should lead to a net increase in site C (compared to post-harvest levels) within a few decades. Ideally, the pools of C in forest floors and mineral soils will accumulate in the latter stages of the plantation rotation, rather than being continuously depleted under forest management. It is uncertain whether "rawplanted" plantations would have as substantial a loss in site C as these broadcast-burned plots, but at least we can expect that these patterns in C would not be more severe under alternative management regimes.

Operational-scale forest carbon accounting

Ed Banfield[1] and Werner Kurz[2]

Abstract

Forests play an important role in the global carbon budget. How these forests are managed can influence the carbon budget of Canada's forests at local, regional, and national scales. The Canadian Forest Service and the Model Forest Network are developing an operational-scale carbon budget model (Operational Scale Carbon Budget Model of the Canadian Forest Sector–CBM-CFS3) that will allow forest managers to assess forest carbon stocks and stock changes. This presentation briefly examines the role of stand- and landscape-level forest dynamics in the carbon budget and outlines the tools being developed for forest carbon accounting at the operational scale.

KEYWORDS: *biomass, carbon accounting, carbon budgets, carbon budget modelling, organic matter pools.*

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Introduction

Forests play an important role in the global carbon budget. How these forests are managed can influence the carbon budget of Canada's forests at local, regional, and national scales. With the increasing national and international awareness of the role that forests have in the contribution towards carbon sinks and sources, there is growing expectation that forest managers be able to assess the forest carbon stock changes on their land base. Several national and international processes, including forest certification, Criteria and Indicators, and the United Nations Framework Convention on Climate Change, recognize the importance of forests to the global carbon budget. In addition to assessment for reporting, forest managers have the opportunity to contribute to reducing carbon sources and enhancing carbon sinks through their forest management activities.

The Canadian Forest Service (CFS) Carbon Accounting Team and the Model Forest Network (MFN) are working together to develop and provide a tool that forest managers can use to assess forest carbon stocks and stock changes. This tool—the Operational Scale Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3)—builds on over a decade of research and work with the CBM-CFS2 (Kurz *et al.* 1992; Kurz and Apps, 1996, 1999). The model is continually updated to incorporate the best available science and to ensure consistency with international carbon accounting rules. The tool can be used in a monitoring role to account for past and current carbon stock changes, or in a projective role to conduct scenarios of future carbon stock changes.

The Role of Forests in the Carbon Budget

Forests take up carbon from the atmosphere through photosynthesis, and lose it through respiration, decomposition, and through emissions associated with disturbances like fire, insect mortality, and harvesting. The balance between carbon uptake and losses determines whether the forest is a net sink or source for a given period. This balance is influenced by factors at both the stand and landscape level.

Stand-level Dynamics

The net balance between uptake and losses varies over time within an individual forest stand. This is driven mainly by the balance between uptake of carbon through biomass growth, and losses from decay of dead organic matter on the forest floor and in the soil. For a stand to be a net carbon sink, the carbon uptake must be higher than the ongoing losses through decomposition. Since growth rates vary over time, a single stand can change between a source and a sink throughout stand development. In stand initiation (immediately following a disturbance), stands generally act as a carbon source until the carbon uptake exceeds the losses from the decay of dead organic matter, at which point the stand switches from a net carbon source to a net carbon sink. Forest management activities influence stand-level carbon dynamics. Activities that affect biomass growth rates and the timing of growth, such as site preparation, planting, and stand tending, will influence the carbon balance of a stand.

Landscape-level Dynamics

A forest landscape is composed of many stands, and the carbon dynamics of each is affected by the local conditions, stand development stage, and site history. Consequently, at a given point in time, a landscape will generally have a mix of stands that are acting as a source, and others as a carbon sink. The carbon balance of the entire forest can be estimated by summing the exchange in all the stands. At the forest landscape scale, the disturbance regime has a major impact on the carbon balance. Increasing disturbance rates generally result in a carbon source, while reductions in disturbances result in a carbon sink (Kurz *et al.* 1998; Kurz and Apps 1999; Apps *et al.* 2000). Management activities having an effect at the landscape scale, such as suppression of natural disturbances or changing harvest rotation lengths, will have a large impact on the forest carbon balance (Price *et al.* 1997; Kurz *et al.* 1998).

Forest Carbon Accounting at the Operational Scale

Managers who wish to include carbon-related indicators and goals will need tools that help them assess the effect of their activities on forest carbon stocks and stock changes. A carbon accounting tool needs to be applicable across the range of forest management activities and apply to all forests in Canada. The project initiated by the CFS Carbon Accounting Team and the MFN is designed to provide a tool that addresses this need. The objective is to develop, test, and implement a user-friendly forest carbon accounting tool that:

- incorporates our current understanding of ecosystem carbon dynamics,

- is compliant with international guidelines, and
- is available to the forest management community in Canada.

The approach builds on over a decade of research and expertise in the development of the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS2), which was primarily a research tool.

The core model (CBM-CFS2) was developed to assess past and future forest carbon stock changes in Canada. It has been used to assess carbon stock changes for all of Canada (Kurz and Apps 1999), both in the managed forests of individual provinces (Kurz *et al.* 1996a) and at the scale of operational units (Price *et al.* 1997; Kurz *et al.* 1998). Currently, the model is used to assess the impact of large-scale natural disturbances across Canada, as well as the effect of the recent mountain pine beetle outbreak in British Columbia.

The approach taken is to provide a model that builds on the existing knowledge base and data normally used by the forest management community. The model makes use of the same type of information that is used in timber supply analysis, augmented with additional data and simulation modelling to cover those aspects of ecosystem carbon dynamics that are not normally included in timber supply modelling. To facilitate the import of data, specific tools have been created. In addition to the standard tool for users to import their data into the model, two specific tools have been added: for Ontario's Strategic Forest Management Model (SFMM) and for the timber supply analysis tool Woodstock.

Biomass Carbon Estimation

A detailed forest inventory provides information on the area, age, and other indicators (such as site class, cover type, etc.) of the forest. Growth and yield information (volume over age) for each strata is used to describe the biomass dynamics over time in each stand. For most operational users, the growth and yield curves can also be empirically derived; however, these curves can also be supplied from yield models or process models. From the volume, conversions are used to obtain biomass and carbon estimates. Regional volume to biomass conversion factors used by the model are being developed to cover the entire country through a CFS project supported by the Federal Panel on Energy Research and Development (PERD). Belowground biomass in coarse and fine roots is estimated using previously developed equations (Kurz *et al.* 1996b; Li *et al.* 2003).

Dead Organic Matter Pools

Most forest inventories do not have information on dead organic matter pools, such as snags, coarse woody debris, litter, and soil carbon. The model uses a simulation approach to estimate the size of the dead organic matter pools (Kurz and Apps 1999). Regional comparisons between independent field observations of soil carbon and estimates by the CBM-CFS2 have yielded reasonable results (Bhatti *et al.* 2002). The CFS is currently using the recently compiled Forest Ecosystem Carbon Database (Shaw *et al.* 2005), and will also examine results from a long-term decomposition experiment (Trofymow and CIDET Working Group 1998) for validation and potential model revisions.

Summary

Forest management activities affect carbon sinks and sources in forests. The CFS and MFN are developing an operational-scale carbon budget model that will empower forest managers to assess and manage the effects of forest management activities. The model is currently in the final stages of Beta testing, with a planned public release in fall 2005. With such a tool, forest managers can begin to determine the effect of current practices, as well as potential practices on forest carbon stocks and stock changes. In addition, model users will benefit from the ongoing scientific and technical improvements to the model. The CBM-CFS3[1] is also at the core of Canada's new National Forest Carbon Monitoring, Accounting and Reporting System, which is being developed to meet international reporting requirements for national greenhouse gas sources and sinks (Kurz and Apps, in press).

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[1] For more information on the CBM-CFS3 see: *http://carbon.cfs.nrcan.gc.ca*

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Popular Summary

Climate model scenarios for impacts on forestry

Trevor Murdock[1]

Abstract

The context for application of climate scenarios to forestry impacts is presented as well as an overview of climate change scenarios for the region. Background information is provided about climate scenarios including information about climate variability, climate change, global climate models, construction of regional climate scenarios, and sources of uncertainty.

KEYWORDS: *climate change, climate models, forestry, uncertainty.*

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Canadian Institute For Climate Studies

The Canadian Institute for Climate Studies (CICS) was founded in 1993 by the Province of British Columbia and Environment Canada at the University of Victoria in order to:

> *further the understanding of the climate system, its variability and potential for change and to further the application of that understanding to decision making in both the public and private sectors.*

The CICS currently operates as a division of the University of Victoria's Centre for Global Studies (see *www.globalcentres.org*). Since its formation, the Institute has engaged in the following main areas of activity:

- Climate Research Network
- Seasonal Climate Predictions
- Climate Applications
- Climate Scenarios
- Science-based Policy

Climate Research Network

The Climate Research Network operated from 1993 until 2001. The Canadian Institute for Climate Studies co-ordinated the work of the Climate Research Network, managed the network, established an independent Scientific Advisory Panel, operated a Network Support Group, and reported the latest findings of the Research Network to decision makers through the *Climate Research Network Newsletter.*

Seasonal Climate Predictions

The CICS was created, in part, to inform and assist business to take advantage of climate information, past, present, and future, and to incorporate it in their decision making. One of the ways in which the CICS does this is by issuing predictions of seasonal temperature and precipitation for the three upcoming seasons. In addition to running our own predictions, we publish a quarterly *Seasonal Climate Bulletin* that summarizes the national predictions of our own and various other seasonal climate prediction methodologies from other centres. We also offer subscriptions to monthly updates, specific regions and stations, and custom weather elements (variables other than temperature and precipitation).

Climate Applications

The CICS has been available to consult on a large variety of projects to assist decision makers in making use of climate information. A list of selected projects is available at: *www.cics.uvic.ca/index.cgi?/About_Us/Climate_Applications*. This listing includes analysis of historical climate trends and indicators, custom seasonal climate prediction projects, downscaling of Global Climate Model (GCM) scenarios for specific applications, and presentation of climate science results for a decision-maker audience in various formats.

Climate Scenarios

The CICS managed the Canadian Climate Impacts and Scenarios project from its inception in 1999 until completion in 2004, at which time Environment Canada launched its Canadian Climate Scenarios Network to provide some of the same services on a national scale with regional offices. Since completion of the project, the CICS has been pursuing a regional focus in partnership with the Province of British Columbia. The scenarios project Web site has remained available while the software is being redeveloped to focus on needs of regional- and community-level users.

Science-based Policy

The CICS is housed within the Centre for Global Studies at the University of Victoria. When applications of GCM results require research on the policy implications of climate-change impacts, the Centre for Global Studies has capacity to carry out research in a wide variety of active policy research areas.

Climate Variability and Climate Change

Climate variability at the seasonal to decadal time scale in North America is related to strength, interaction, and frequency of atmospheric processes, such as El Nino–Southern Oscillation, Pacific Decadal Oscillation, North Atlantic Oscillation, and the Arctic Oscillation. Climate variability takes place on the scale of years to decades and can be thought of as the peaks and troughs about a long-term trend-line. Climate change is generally measured as long-term trends on the scale of centuries or more. Climate variability and change are ongoing due to natural processes, and more recently due to human perturbation of the global climate system, which means that what we consider as 30-year "normals" change. Therefore, there is an onus on us to consider climate variability and longer-term climate change in our resource and infrastructure planning. To do this, we need to look beyond the relatively short periods of observational data such as 30-year normals.

Analysis of climate trends and variability can lead to useful relationships between climate information and operations within various sectors. Long-term observed trends in British Columbia have been analyzed and are available at: ***http://wlapwww.gov.bc.ca/air/climate/indicat/index.html***

Furthermore, seasonal climate variability, in particular, is predictable with skilful use. For example, the Seasonal Climate Predictions made by the CICS for the Okanagan over 9 years were 46% correct compared with 26% correct using historical averages over the same period (three-category prediction).

To effectively study climate change, we recommend first identifying climate vulnerabilities (e.g., extreme winter cold for pine beetle, spring and summer drought, summer temperature for fires), then studying the potential effects by using projections of future climate. A range of scenarios from GCMs can be used to deal with uncertainty. Downscaling and Regional Climate Models (RCMs) are used to increase resolution for regional assessments. Finally, adaptation strategies may be developed to manage for current and potential future impacts of both climate change and variability.

Global Climate Models and Uncertainty

Global climate models are complex computer models that simulate weather patterns. These models include physical and chemical processes in the ocean, atmosphere, cryosphere (ice), and biosphere, and incorporate the effects of human input of greenhouse gases and aerosols. The statistics generated are useful tools for the analysis of global climate. Uncertainty arises from:

- unknown future population, energy consumption, and thus greenhouse gas emissions;
- how carbon cycle dynamics will convert greenhouse gas emissions emissions–carbon sequestration into atmospheric greenhouse gas concentrations (which is what drives climate);
- different parameterizations in the physics, biochemistry, and dynamics of the GCMs themselves;
- using GCM results to address regional- and local-scale effects; and
- application of GCM results to natural resource impact models with their own inherent uncertainties.

Scenarios

Scenarios are used to demonstrate uncertainty by presenting a range of results rather than a "best or average prediction." The CICS Scenarios (*www.cics.uvic.ca/scenarios/*) include several options for custom regions, dynamic map creation, user customization of many features, meta-information about map and region (min, max, median, area-weighted mean, SD), scatterplots, and other tools, as well as background information. The addition of RCM data, high-resolution baseline data, zoom features, and individual user preferences is in progress.

A scatterplot for spring temperature in Kamloops by the 2050s shows an increase of 0.9–1.8°C. The scenarios Web site can be used to produce similar projections for other seasons and parameters. A brief summary of such results for the region suggests moderate temperature increases throughout each season, slightly more total precipitation through most of the year, but slightly less in summer, increased extreme precipitation events, and reduced snowpack.

Applying Scenarios: Downscaling

"Downscaling" is a term that refers to various techniques used to overcome differences of scale between coarse resolution GCMs (roughly 400-km grids) and higher-resolution applications (both temporal and spatial scales). Various methods are available. See *www.cics.uvic.ca* for more information.

Dynamic methods retain internal physical consistency and include high-resolution atmospheric GCMs and RCMs. The results from RCMs are just beginning to become available. A major initiative, NARCCAP, promises to deliver a wide range of RCM results similar to those currently available from GCMs.

Statistical methods are less costly and less complicated. Examples include weather generators such as LARS-WG, and multiple linear regression such as SDSM. Each of these tools is available for download from the scenarios Web site. Statistical methods tend to be site (individual station) specific.

Numerical methods are also available for the application of climate model change fields from the larger spatial scale to the working scale. These methods are also less costly and less complicated, and allow for the application of GCM results by making use of high-resolution baseline information. Care must be taken during interpretation as these methods can introduce the appearance of false geographical precision. Numerical methods used in forestry include those of Price *et al.* (which uses the ANUSPLIN method), and those of Hamann *et al.* (i.e., ClimateBC, which uses elevation and other physical information through PRISM baseline).

Pacific Climate Impacts Consortium

The impacts of climate change in this region will be unique because of our complex geography. Natural resources are at risk (forest pest infestations, wildfires, drought) from climate change including extreme events. Expert capacity in British Columbia needs to be increased to address the complex multidisciplinary aspect of climate change in a way that can be used directly by stakeholders. The University of Victoria and CICS, in partnership with the B.C. Ministry of Environment, BC Hydro, and others, propose to establish a consortium—the Pacific Climate Impacts Consortium (PCIC; *www.PacificClimate.org*)—to address the emerging needs of stakeholders.

The consortium will bridge the gaps between research and applications, and will make practical information available to government, industry, and the public. The PCIC will be broad based and will draw on expertise from several universities including the University of Victoria and the University of British Columbia plus federal agencies and neighbouring jurisdictions. Climate science researchers will be encouraged to participate in addressing the needs of stakeholders. The focus will be on understanding the impacts of climate change in British Columbia and western North America.

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Popular Summary

Indigenous People's involvement in natural resource management: Lessons from the *Yinta*

S. Denise Allen[1]

Abstract

What will our forested ecosystems look like in the year 2100? To fully grasp the social context of natural resource management, benchmarks are needed that will help us better understand how the forested ecosystems look *today*—and how such perceptions may vary throughout the different communities involved in and affected by forestry activities. This becomes even more complicated in cross-cultural settings in which natural resource management regimes (e.g., traditional and industrial) overlap. Identifying social–ecological linkages is a potentially useful framework for improving the cultural sensitivity of forest management and understanding the contribution of natural resources to community sustainability. This presentation discusses experiences in collaborative research with the Office of the Wet'suwet'en Hereditary Chiefs on their traditional territories (the *Yinta*) in north-central British Columbia's Bulkley Valley. It also highlights some of their own local innovations in forest management and planning. Major conceptual distinctions in the Wet'suwet'en involvement in natural resource management planning activities include their use of social (cultural) boundaries, a planning approach that considers forest-related resources as one component within the matrix of natural resources on the land base, and extensive incorporation of traditional ecological knowledge, in both oral and text formats. Social boundaries play an important role in building understanding around the social–ecological linkages between the community and the landscape, and in developing tools that will allow for more effective translation between local Indigenous and industrial concepts of sustainable forest management in a manner that allows local innovations to be integrated and intellectual property rights maintained.

KEYWORDS: *concept mapping, criteria and indicators, social-ecological linkages, social sustainability, sustainable forest management, Wet'suwet'en.*

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Introduction

What will our forested ecosystems look like in the year 2100? This could be addressed as merely an exercise in prediction, or as a more open-ended question about the goals of sustainable forest management (SFM). Frequently, forest managers are asked to envision the desired future forest condition to provide a framework for forest management and planning goals. The dynamic and plural nature of social and political agendas evades prediction, and has led to a near-exclusive focus on the measurable ecological components in modelling exercises to this end.

To fully grasp the social context of natural resource management, benchmarks are needed that will help us better understand how the forested ecosystems look *today*—and how such perceptions may vary throughout the different communities involved in and affected by forestry activities. This problem becomes even more complicated in cross-cultural settings where natural resource management regimes (e.g., traditional and industrial) overlap. Can Indigenous communities identify which goods and services must be sustained in the natural environment in order for their cultures to flourish? Identifying social–ecological linkages (Berkes and Folke 1998) is a potentially useful framework for improving the cultural sensitivity of forest management and understanding the contribution of natural resources to community sustainability.

Sustainable Forest Management and Territorial Stewardship: Lessons from the *Yinta*

This short presentation discusses experiences in collaborative research on the measurement of socio-cultural impacts with the Office of the Wet'suwet'en Hereditary Chiefs (OWHC) on their traditional territories (the *Yinta*) in north-central British Columbia's Bulkley Valley and highlights some of the OWHC's own local innovations in forest management and planning processes.

Mapping Concepts of Sustainability

The investigation into local concepts of social sustainability was framed around three basic research questions:

1. What are the visions for SFM?
2. What are the perceived impacts of forest management?
3. What are the expected benefits of SFM?

Semi-standardized interviews using open-ended questions were conducted in the traditional territories over summer–fall 2004 and spring 2005 with all of the current House (*Yikh*) Chiefs and Wing Chiefs involved in land and resource management on the territories (Allen 2005). In addition to a manual (classical content) analysis, concept (perceptual) mapping software (CatPac II) was used to help capture definitions of SFM and identify themes and concept linkages (Woelfel 1974). This procedure made it possible to represent the attitudes and beliefs of the Wet'suwet'en chiefs about the impacts of forest management activities on their territories as a holistic picture or "map" in a three-dimensional graph. Colfer *et al.* (1996) suggest that capturing and communicating such indirect or unexpressed consequences of forest management in this manner may improve our awareness and management of human involvement in the forest. In the context of Indigenous participation in natural resource management planning, another benefit of concept mapping is that it allows for the detailed intellectual property of oral tradition and traditional ecological knowledge and wisdom to be protected while helping to articulate important concepts for better incorporation in dominant (formal) systems of forest management and planning (Allen 2005).

For the OWHC, expectations of SFM include provisions for maintaining their culture, co-dependent with access to the land and resources of their traditional territories (*Yinta*). Collaborative research on Wet'suwet'en concepts of SFM suggests that resource-related ecological impacts are strongly linked to cultural impacts, including traditional systems of governance (e.g., the Wet'suwet'en feast hall system or *bat'lats*) (Mills 1994; Allen 2005). The forest plays an integral role in providing cultural context, and traditional tenure institutions provide the social frame of reference for the Wet'suwet'en people to the land; however, within the Wet'suwet'en conception of territorial stewardship, the forest cannot necessarily be considered in isolation from the land, other resources, or even other plant communities. This understanding informs the Wet'suwet'en approach to involvement in resource management on their traditional territories, which is focussed around addressing issues of procedural justice and legitimate authority, and protecting the natural wealth on the land (Glavin 1998).

Local Innovations

The OWHC have embraced science and technology in an effort to learn from their long tradition of territorial stewardship in the Bulkley Valley. Using the traditional House (*Yikh*) and Clan (*Pdeek*) boundaries, the OWHC Lands and Resources Department has built an extensive data set, which includes predictive ecosystem mapping (PEM), GIS, and oral and written records of traditional ecological knowledge to develop a *Wet'suwet'en Territorial Stewardship Plan*, and accompanying *Wet'suwet'en Criteria and Indicators for SFM and Territorial Stewardship*. These planning activities are being used to carefully identify important environmental goods and services and articulate the perspectives of the hereditary chiefs on desired future forest conditions for the territories. The OWHC participates in formal natural resource management and planning activities, such as Land and Resource Management Planning (LRMP) processes and a joint venture processing facility with Canadian Forest Products Ltd. (KyahWood Forest Products Ltd.). The OWHC is also building on informal arrangements for direct involvement in forest management planning and harvesting activities through dialogue with local forestry companies (i.e., Houston Forest Products). Currently focussed on the harvest of timber threatened or damaged by mountain pine beetle (*Dendroctonus ponderosae*) in culturally significant areas, this kind of relationship requires more extensive dialogue, but also offers more flexibility for both the company and the First Nation and is more easily tailored to local issues, expectations, and needs.

Conclusions

When considering social aspects of SFM, perhaps it may be more appropriate to rephrase the research question and ask: What parts of society are going to flourish—or decline—from a sustained supply of particular goods and services from our forest environment? Researchers and communities need to identify which environmental goods and services are tied to social and cultural aspects of sustainability, whether critical thresholds exist, and monitor these for impacts. In the Wet'suwet'en case, major conceptual distinctions in the Indigenous approach to involvement in natural resource management planning activities include their use of social (cultural) boundaries, a planning approach that considers forest-related resources as one component within the matrix of natural resources on the land base, and extensive incorporation of qualitative traditional ecological knowledge, in both oral and text formats. Social boundaries play an essential role in building understanding around the social–ecological linkages between the community and the landscape, and in developing tools that will allow for more effective translation between local Indigenous and industrial concepts of SFM in a manner that allows local innovations to be integrated and intellectual property rights maintained.

From a research perspective, there is still a lot of room for improvement in involving Indigenous peoples in natural resource management. Research organizations and scientists have an important contribution to make by working to make research support (infrastructure, collaboration, and funding) more accessible to Indigenous communities, and emphasizing community-driven research objectives and local research protocols in their own work. Understanding how knowledge systems and local institutions for resource management overlap will help to improve the (cultural) sensitivity of forest management and forestry research. In this light, the path to 2100 should involve an evolution from trying to fit socio-cultural data into existing management frameworks (i.e., Aboriginal Criteria and Indicators) to the collaborative development of new frameworks based on knowledge partnerships.

Acknowledgements

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The role of traditional ecological knowledge and natural resources*

Stan Dixon[1]

* Editor's Note

Chief Stan Dixon kindly stepped in to present at the Science Forum when a scheduled presenter was unable to attend, and was therefore not obliged to provide a written Popular Summary. We appreciate Chief Dixon's contribution to the Forum dialogue.

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*Abstract**

Natural resources and community vitality: A rural perspective

Cindy Pearce[1]

British Columbia is uniquely blessed with a spectacular wealth of ecologically diverse natural resources. Beginning with First Nations societies long ago, these resources have been the foundation for the sense of place, quality of life, and economies of rural communities in the province. These communities, however, now face rapid, unprecedented change linked to natural resources—change which emanates from both from global and "made-in-BC" sources. Such change creates challenges and uncertainties, but also presents opportunities. A five-point framework used to assess the fate of societies shows that British Columbia's rural communities will continue to face challenges in areas crucial to their futures. This heightens the need to strengthen community capacity both to anticipate and deal with problems and to seize opportunities. Most rural communities are now committed to taking charge of their futures, and are seeking ways to thrive in this era of change. Although attention paid by science to community sustainability has increased significantly in recent years, much more research is needed. This paper outlines some change-related challenges and opportunities facing rural communities in British Columbia and offers suggestions for important research to help communities build local capacity.

KEYWORDS: *Rural community; community sustainability.*

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* Editor's Note

At the request of the Managing Editor, the author revised and expanded this Popular Summary for publication as a *JEM* Perspectives, which is presented on pages 63–69 of this issue.

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Popular Summary

Challenges in defining the disturbance regimes of northern British Columbia

Phil Burton[1], Steve Taylor[2], and Gurp Thandi[3]

Abstract

The British Columbia Natural Disturbance Database is analyzed for patterns of wildfires and insect outbreaks in northern British Columbia during the period from 1961 to 2000. In terms of annual area affected by these disturbances, forests are generally more likely to experience insect outbreaks than wildfires, but with distinctive differences among ecological zones. Multivariate analysis of 21 northern ecoregions reveals clustering along a gradient of maritime to continental influences, resulting in decreasing importance (from west to northeast) of western balsam bark beetle and increasing importance of eastern spruce budworm and fire. Existing data provide an incomplete picture of the disturbance ecology in most parts of the province, and the characterization of a suite of infrequent events is constrained by the size of sampling windows in space and time. Progress is being made in characterizing the individual and joint probabilities of disturbance by various agents at a variety of scales, which should improve the ability of policy makers and managers to manage risk.

KEYWORDS*: boreal cordillera, boreal forest, disturbance history, disturbance regime, ecological land classification, ecoregions, forest fires, insect outbreaks, risk analysis, wildfire.*

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Introduction

Throughout the history of forest management, efforts have been made to protect timberlands from the destructive forces of uncontrolled fires, insects, and other agents of tree mortality. It is recognized that the susceptibility of forests to damage from these various biotic and abiotic agents is largely under the control of climate, terrain, and current forest composition. Year-to-year variation in weather and the population levels of insects and fungi make the annual incidence of tree mortality difficult to predict. Yet over the long term, distinctive patterns of forest disturbance are evident in their legacy of forest age-class structure, patch size distributions, and species composition (Frelich 2002).

Considerable effort is placed on the control of some forest disturbances such as wildfire, while scant attention is paid to other less dramatic causes of tree death. Forestry practices can sometimes prevent or lessen the impact of some disturbances (e.g., by managing species composition and age through harvesting and silviculture, by designing roads and cutblock edges to minimize the risk of landslides and windthrow). Natural disturbances are also recognized as important generators of diversity in forest landscapes, creating open habitats at a variety of scales and initiating or releasing new growth that had previously been suppressed by mature trees (Van der Kamp 1991; Parminter 1998). The importance of natural disturbances to commercial fibre production and to biodiversity conservation, coupled with our limited ability to prevent them, compels forest managers to operate within the constraints of regional disturbance regimes. Indeed, the emulation of natural disturbances is considered an appropriate approach for protecting biodiversity at the habitat or coarse-filter level (Bergeron *et al.* 2002; Lindenmayer and Franklin 2002).

The purpose of the research described here is to explore broad disturbance patterns found in the forests of northern British Columbia, using existing data of mapped wildfires and insect outbreaks. We look at regional differences and examine some of the associated environmental factors and consequences of those regional differences. This analysis focuses on that portion of the Boreal Cordillera Ecozone found in British Columbia, and contrasts its attributes with those of neighbouring ecozones. We explore the disturbance spectra of northern ecoregions, and discuss alternative means of portraying, predicting, and mapping forest disturbance regimes.

The British Columbia Natural Disturbance Database

The Canadian Forest Service and the B.C. Ministry of Forests and Range have been collectively documenting the locations of forest fires and insect outbreaks since early in the 20th century. Delineated as mapped "events" each year on paper, linen, mylar, and eventually digital maps, these records constitute a immense, multidimensional database on the recent history of major disturbance agents in British Columbia's forests. This information has been recently compiled in a single digital database at the Pacific Forestry Centre (Taylor 2005). Coverage is understandably incomplete for some insect species and for remote areas, especially in past decades. So for the purposes of this exploratory analysis, we limited our examination to fire and the 15 most important forest insect pests, for the 40-year period from 1961 to 2000.

The British Columbia Natural Disturbance Database consists of separate "layers" of data in an ArcInfo geographic information system (GIS), each one mapping the area of forest affected by each disturbance agent in each year. These layers were intersected with various levels of ecological land classification and associated summaries of environmental attributes (Marshall *et al.* 1999), following the Canada-wide framework of ecoregion classification (Environment Canada 2005). The database file generated from the intersection of annual disturbance events and ecological classifications was then imported into the SAS statistical analysis system to determine mean annual disturbance rates for each agent. Values were converted from hectares per year to percent per year using the documented area of vegetated land cover for each region under consideration. Mean disturbance intervals (in years) were calculated as the inverse of mean disturbance rates in percent per year. These values were compared for different ecozones and ecoregions, and the combination of 16 disturbance agents was summarized using principal components analysis (PCA). The prevalence of individual agents and PCA scores was then correlated with environmental attributes at the ecoregion level.

Patterns and Correlations

Over the 40-year period under consideration, the area of forest annually affected by insect outbreaks typically has been greater than that affected by forest fires across most ecoregions of northern British Columbia. Nevertheless, distinctive differences exist in the prevalence of fire and outbreaks of various insect species in different parts of the broad region north of approximately 52° latitude. Fire (from both lightning and human ignitions) was most prevalent in the Boreal Plains Ecozone, where it burned 0.196% per year. In contrast, forest fires burned an average of only 0.015% of the northern portions of the coastal Pacific Maritime Ecozone every year, while the Montane Cordillera (0.059% per year) and the Boreal Cordillera (0.157% per year) ecozones were intermediate. The area of forest annually affected by insect outbreaks was similar to that of fire in the Boreal Cordillera (0.165% per year), but the cumulative effects of defoliators and bark beetles were much greater (in area annually affected) than that of fire in the Taiga Plains (1.664% per year) and Boreal Plains (0.289% per year) ecozones. The Montane Cordillera supports a wide diversity of insects capable of killing forest trees, at an average rate of 1.100% per year.

If the incidence of fire remains relatively uniform over time, and if all stand ages are uniformly susceptible to burning, then more than one third of a forest will consist of stands older than the calculated fire return interval (Van Wagner 1978). It is interesting to compare the mean return interval of insect outbreaks with that of wildfire in different ecological zones, as longer fire return intervals imply a greater likelihood that insects will attack stands before they burn. In the Taiga Plains Ecozone, the eastern spruce budworm (*Choristoneura fumiferana*) attacks large areas of white spruce (*Picea glauca*) and can be a more important agent of tree mortality than is fire. Similarly, the forest tent caterpillar (*Malacosoma disstria*) can repeatedly attack trembling aspen (*Populus tremuloides*), especially in the Boreal Plains Ecozone. No single insect species is more important than fire in the Boreal Cordillera, though collectively they are just as likely to affect forest stands as are fires. In the Montane Cordillera, on the other hand, stands are more likely to be attacked by 2-year cycle budworm (*Choristoneura biennis*), western balsam bark beetle (*Dryocetes confusus*), forest tent caterpillar, mountain pine beetle (*Dendroctonus ponderosae*), spruce beetle (*Dendroctonus rufipennis*) or western spruce budworm (*Choristoneura occidentalis*) than by fire.

Further differences in the combination of insect pests and the incidence of fire can be seen among individual ecoregions within ecozones. When British Columbia's boreal and northern sub-boreal regions are analyzed by PCA, the first axis is dominated by increasing amounts of eastern spruce budworm and fire, and decreasing amounts of western balsam bark beetle; the second axis is associated with increasing amounts of western balsam bark beetle and (to a lesser degree) eastern spruce budworm (Figure 1).

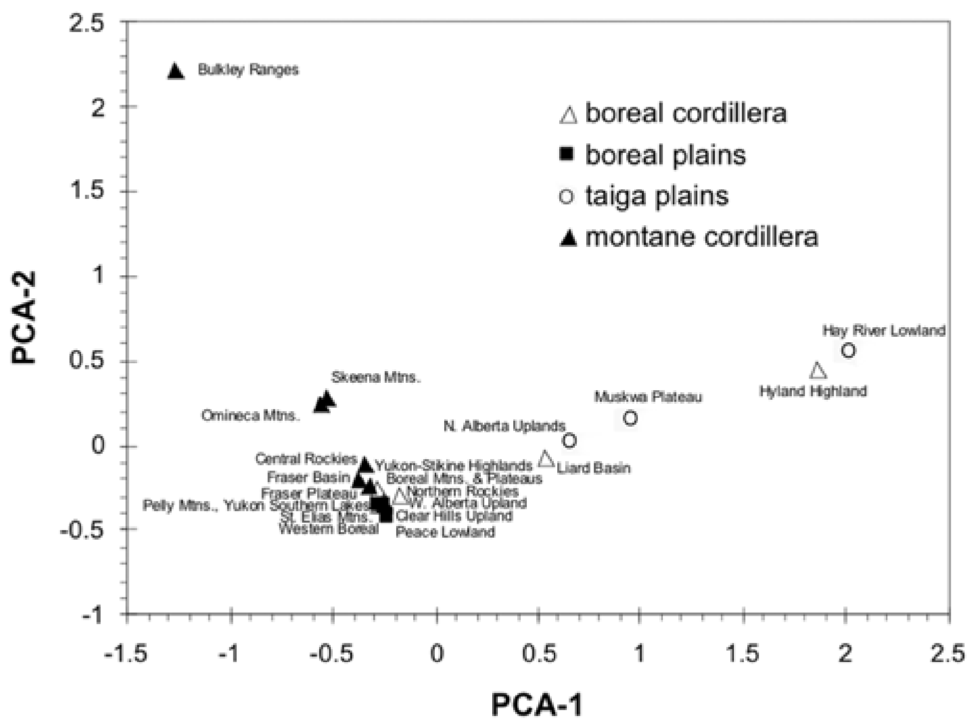

FIGURE 1. Principal components analysis of a 40-year history of wildfire and insect outbreaks in the ecoregions of four interior ecozones in northern British Columbia.

The first PCA axis is significantly correlated with lower mean winter temperatures, lower elevations, and higher growing degree-days above a 15°C threshold, indicative of a general gradient of increasing continentality; we found no significant environmental correlates with the second PCA axis. Plotting the first and second PCA scores of 21 northern ecoregions results in clusters that cross ecozone affinities. For example, the Bulkley Ranges Ecoregion in the west stands out as characterized by western bark beetle outbreaks and a general absence of fire, forest tent caterpillar or spruce budworms. The Liard Basin and Hyland Highland ecoregions, though part of the Boreal Cordillera Ecozone, behave much more like part of the Boreal Plains Ecozone, with frequent wildfires and outbreaks of eastern spruce budworm. Although most (13 of 21) northern ecoregions can be mapped as experiencing a similar spectrum of disturbances, others are clearly more extreme in their coastal or continental affinities (Figure 1).

Challenges and Implications

We recognize that this is an incomplete picture of the disturbance ecology of northern British Columbia. We have been trying to classify the disturbance spectra of ecodistricts and smaller geographic areas independent of ecological land classification, but such areas are often too small to have experienced the full range of natural disturbances (over the 40-year period under consideration) expected from the regional ecology. This is a limitation of working with mapped data of historic events, in that the calculation of disturbance rates is sensitive to the size of the window used. Another problem is that information on many natural disturbance agents is missing, notably the extent of damage from windstorms, landslides, avalanches, and floods. Although insect outbreaks have been mapped according to several levels of severity, we have no such stratification of fire severity. It is well known that different intensities of disturbance determine not only the species and sizes of trees that may die or survive, but also influence the trajectory of post-disturbance successional recovery (Frelich 2002). Older fire maps are especially uneven in the degree to which they portray islands and fingers of unburned forest within the polygons describing large fires.

Few disturbance rates have been stable over the last several decades, with fire and insect outbreaks decreasing in some ecoregions and increasing in others. Wildfires have a strong human-caused component, even in remote northern areas. Insect outbreaks, particularly bark beetles, are strongly driven by forest age dynamics and so may be somewhat controllable to the extent that management can manipulate forest age structure. Timber harvesting is relatively minor in much of the north, and one might argue that most forests in northern British Columbia are essentially unmanaged in that the amount of timber lost to natural mortality exceeds the amount harvested (Clutter *et al.* 1983). Thus, managers have to work within and react to the natural disturbance regime when forests are in a transition from a natural to managed state. The recent province-wide eruption of mountain pine beetle is particularly unprecedented (see ***http://mpb.cfs.nrcan.gc.ca/biology/introduction_e.html***), suggesting that an historic approach to the analysis and emulation of natural disturbance regimes can take us only so far in our efforts to understand and sustainably manage our forests.

At some point, process models of disturbance agents and their combination will provide more useful information than historical analysis. For example, Taylor *et al.* (2005) have recently developed logistic regression models for predicting the incidence of wildfires (started by lightning, people, or both) in 1-km^2 cells across the province. Drawing on prevailing fire weather index norms, terrain attributes, lightning density, road density, and descriptions of forest type and land cover, a similar approach could predict the incidence of various insect outbreaks or the PCA scores indicative of a particular combination of insects and fire. This takes us closer to a unified "risk analysis" of the factors threatening forest trees, stands, and landscapes. The mapping of risk and hazard classes is already the approach taken by geomorphologists in assessments of terrain stability, avalanche dangers, and flood return probabilities. We hope to incorporate these agents in descriptions and models (both statistical and simulation) of landscape disturbance regimes. Although some options may exist for disturbance risk reduction through forest management, we suspect that a more promising avenue to explore will be the repackaging of forest management units to reduce overall risk.

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Popular Summary

Is natural pattern emulation just a tool, or is it a new way of thinking?

David W. Andison[1]

Abstract

The attraction of the use of natural patterns as guides for sustainable forest management has generated vast amounts of new knowledge of disturbance patterns and processes. Although integration efforts are challenging, most have begun to include some basic pattern metrics as new decision-making filters within the existing planning system. An alternative way exists of taking advantage of natural patterns knowledge—that is, as a way of approaching how planning occurs. Using natural patterns as the foundation for both planning and monitoring creates several opportunities for advancing other important sustainable forest management issues that remain a challenge to integrate, such as cross-jurisdictional planning, integrated planning, streamlining monitoring and planning systems, and adopting an ecological foundation for planning.

KEYWORDS: *natural patterns, planning, sustainable forest management.*

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Introduction

The conceptual argument for adopting the use of natural disturbance patterns as guides for forest management decisions is convincing. Natural patterns offer a coarse, or generalized, filter through which all biodiversity values can be theoretically maintained (Hunter 1990)—thus the term "coarse filter." This claim is predicated on the assumption that by maintaining the historical range of natural patterns and processes on a landscape, all inherent historical functions and species will be maintained as well (Attiwill 1994).

In a perfect world, the first order of business would be to better understand exactly what we are dealing with: what are natural patterns, what scales do they occur at, how do they interact, how much variability is due to various influences, and so on. One cannot use natural patterns as management guides if those patterns cannot be quantified. This need spawned an explosion of disturbance research studies across Canada.

The challenge is beginning to shift to more practical questions of implementation and integration. Exactly how, to what degree, and when will natural pattern knowledge be used to plan, manage, and monitor our forest landscapes? Most would agree that, in general, agencies intend to use this information to help guide policy and management towards developing more ecologically sustainable land management practices; however, the specific answer is not nearly as straightforward. Two possibilities—natural patterns as decision filters and as the foundation for planning—are discussed here.

Natural Patterns as Decision Filters

The most obvious and common way of using knowledge of natural patterns is as simple ecological filters for decision making. For example, many forest management companies are now leaving residual stems and islands, disturbance sizes are increasing, and shapes are becoming more irregular—all of which represent more "natural" patterns. In addition, natural range of variation (NRV) targets for metrics, such as residual material, block size, and seral-stage distributions, are now being included in planning guidelines and monitoring systems. So management decisions are being made with the aid of natural pattern knowledge acting as a coarse (or general level) filter.

These efforts represent the progressive integration of a selection of NRV metrics into the existing policy, planning, and monitoring frameworks. In other words,

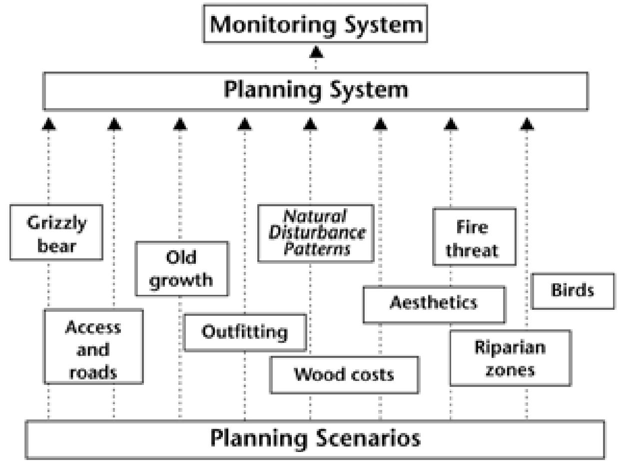

FIGURE 1. Traditional planning and monitoring system.

coarse-filter objectives based on natural patterns are being added to the list of values we manage for. The various management scenario options are delineated based on broad objectives (such as maximizing wood flow), and then each scenario is literally "filtered" through a set of values, such as habitat, aesthetics, access, and now also, natural patterns (Figure 1).

The assumption in this case is that natural patterns will drop into this planning framework as another series of (coarse) filters. Guidelines (e.g., for disturbance sizes and shapes, residual levels, old-forest retention levels, and so on) are by far the most obvious result of this thinking, but similar pattern metrics are now showing up as decision variables within sophisticated optimization computer planning models, planning manuals, and indicators within monitoring programs.

Natural Patterns as the Foundation for Decisions

Natural disturbance patterns may also be used as a conceptual framework, as the basis for planning and monitoring decisions. In other words, adopt natural pattern knowledge as an overarching philosophy about how to plan and monitor. By doing so, several fundamental changes occur.

- The natural patterns of a given landscape can be used as an ecologically robust starting point for all planning decisions. So natural patterns no longer function as filters, but rather as the base-case scenario(s) through which other filters are passed (Figure 2). This shift creates several advantages over the traditional

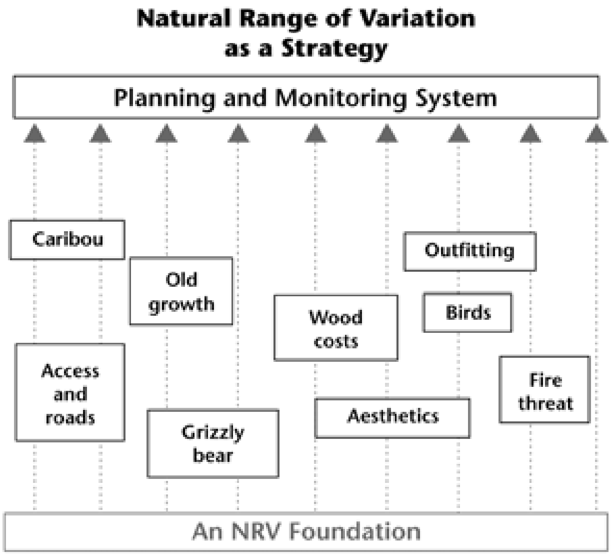

FIGURE 2. NRV-based planning and monitoring system.

system. First, it allows natural patterns to function as true guides for management as opposed to inflexible rules or accusations of trying to mimic nature. If and when a decision is made to deviate beyond NRV (e.g., to satisfy the need for economics, safety, cultural preferences, or specific ecological issues), this can be done with an objective awareness of the potential risks. Second, it offers a more defendable and transparent process. Starting with a neutral and "natural" disturbance pattern, and then layering the requirements of other objectives overtop is an excellent demonstration of the realities of forest management. Finally, it has the potential to create many win-win situations. The little we have seen so far suggests that many other ecological, social, and economic values are consistent with an NRV strategy. Simple logic models are often sufficient to demonstrate that the natural disturbance model is consistent with the habitat requirements of many species, minimizing access, mitigating wildfire and mountain pine beetle threats, providing economic benefits, and creating more pleasing landscapes aesthetically.

- Using natural patterns as a foundation for planning facilitates the combining and streamlining of planning and monitoring systems. Essentially, natural patterns now act both as testable hypotheses (testing the response of other values), and as targets for compliance monitoring (Rempel *et al.* 2004).
- Considering natural patterns first also compels us to consider all sources of disturbance simultaneously (i.e., natural and cultural). The systems we have inherited were designed to partition the various disturbance activities on forested landscapes—harvesting by long-term agreement holders, harvesting by small operators, harvesting by salvage operators, prescribed burning, road building, and oil and gas development all have distinct planning systems that were not designed to overlap or integrate. Recent efforts to integrate these and other activities into a single plan would be enhanced by the use of natural patterns as a neutral starting point.
- The last advantage of using natural patterns as the foundation for planning is that it emphasizes administrative boundaries as an artificial, and rarely beneficial, imposition. This is not to suggest that jurisdictional boundaries should be ignored. On the contrary, it suggests that planning across these boundaries, between neighbours and partners, can only result in greater ecological (and perhaps other) benefits.

Conclusions

It is not difficult to recognize elements of both strategies in many jurisdictions. The use of the more obvious natural pattern elements, such as disturbance size and residual levels, are becoming widespread planning filters and monitoring indicators. Less common, but still evident, are the beginnings of adopting natural patterns as a way of thinking. For example, both Yamasaki *et al.* (2001) and Andison *et al.* (2002) advocate using the natural range of disturbance patterns as one of the first steps in establishing desired future forest conditions. The natural-based planning commitment of West Fraser Mills, in Hinton, Alberta, began by identifying and conducting a gap analysis on 78 natural patterns (R. Bonar, pers. comm.). Finally, the Foothills Model Forest (Alberta) has also initiated a large-scale demonstration project that aims to generate a single long-term "disturbance plan" across four administrative jurisdictions, and that includes all possible land management partners using natural patterns as the foundation for planning decisions (for details, see *www.fmf.ca/Highway40north.htm*).

In the end, change will not happen easily or quickly because the shift from option 1 to option 2 is non-trivial. The first option simply adds to the list of filters within the existing planning and monitoring framework, and is thus quick and simple to implement. Knowledge of NRV is merely another tool in this scenario. The second option forces us to reassess, and to some degree redesign, the entire system(s); however, perhaps the exercise is a timely one. Consider that all of the benefits of adopting natural patterns as a way of thinking (e.g., planning across jurisdictional boundaries, integrated planning, robust and meaningful monitoring programs, and adopting an ecological foundation for planning decisions) are not particularly new goals for sustainable forest management, but they remain elusive ones in many cases. In other words, perhaps natural pattern knowledge can act as a trigger for change.

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Popular Summary

Clayoquot Sound 10 years after the Scientific Panel

Gordon Butt[1]

Abstract

Clayoquot Sound represents an experiment in forest management. In 1995, the Clayoquot Sound Scientific Panel recommended drastic changes forest management and practice. Could such changes be implemented while still maintaining an economically viable industry? In the 10 years since, licensees—working with government ministries—have adopted nearly all the recommendations, established a reserve system, implemented variable retention logging, and included First Nations and others into the planning process. The changes have improved the environmental sustainability of forest practices, although such improvement has not been confirmed through monitoring or research. This improvement, however, has had adverse social and economic ramifications. The increased cost of logging and the reduction in allowable annual cut has placed forest operations in Clayoquot Sound in a precarious economic position.

There is no doubt that forest management and practice since the Scientific Panel is much more environmentally sustainable than the model that preceded it. The question is, how much did it cost? To fully learn from the Clayoquot Experiment, we need to better understand both the environmental benefits and the economic and social costs.

KEYWORDS: *Clayoquot Sound, ecosystem-based management, natural disturbance, sustainability, variable retention.*

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Butt, G. 2005. Clayoquot Sound 10 years after the Scientific Panel. Popular Summary. *In* Forests and Natural Resources in the 22nd Century: Science Forum Proceedings, August 31–September 1, 2005. *BC Journal of Ecosystems and Management* 6(2):128–131. URL: ***www.forrex.org/jem/2005/vol6/no2/vol6_no2_scienceforum.pdf***

Introduction

Clayoquot Sound— an area of 260 000 ha on the west coast of Vancouver Island— is widely known for its scenic wilderness, biodiversity, and recreational values. Indeed it is a beautiful place, but its fame in forestry is due to its history of protest and dissent over forest practices and as one of the first examples of ecologically based forest management on public land in British Columbia.

Clayoquot's scenic prominence and accessibility, combined with the glaring visual impact of clearcuts, poorly built roads, and landslides, made it a focus of environmental protest by the early 1990s. By 1993, Clayoquot Sound had become the site of a show-down of international proportions, hosting the largest demonstration of civil disobedience in Canadian history.

Clayoquot Sound Scientific Panel

The New Democratic Party government of the day could not ignore the outcry and reacted by instituting several measures, including the Clayoquot Sound Land Use Plan, which accorded protection to roughly one third of the area in the Sound, and imposed special management restrictions on part of the remainder.

The most famous reaction, however, was the creation of the Clayoquot Sound Scientific Panel, consisting of 20 forest scientists and professionals. Their report, containing over 120 recommendations, was submitted in 1995, and was soon after accepted by government and industry.

In 1994, the Clayoquot Sound Scientific Panel recommended sweeping changes in the way the forests should be planned and managed. The announcement that the government would implement these changes brought worldwide attention and interest. Clayoquot Sound became a testing ground for ecologically based forest management.

Although many of the overarching principles in the report are familiar now, at that time their acceptance constituted a radical departure from conventional practice of coastal forestry. Although not explicitly using the term "ecosystem-based management," the Panel clearly had this idea in mind. Its report stated that: "ecosystem management must acknowledge the physical structures, processes and biological constituents of the ecosystem." It is notable that, although the Scientific Panel emphasized the inclusion of First Nations values in the process and the solution, relatively little attention was paid to the potential social and economic impact of the Panel's recommendations.

The New Way of Doing Business

In Clayoquot Sound, the whole focus of forest management changed. Instead of focussing on sustained timber flow, the new approach would focus on sustaining the productivity and natural diversity of the area. The emphasis would be on maintaining ecosystem processes, rather than on removal of wood products. To accomplish this objective, timber harvest planning changed in two main ways.

First, a priority was placed on the establishment of a network of reserves, including:

- hydro-riparian areas, sensitive soils, and unstable terrain,
- red- and blue-listed plant and animal species,
- forest-interior conditions in late successional forest, and
- areas with cultural values and scenic and recreation values.

In addition, reserves were established to ensure representation (at a minimum 30%) of all ecosystems, as well as to ensure linkages among watershed planning areas. The net result was at least 50% of the Sound was protected from timber harvest. This resulted, in part, in a 58% reduction in the allowable annual cut (AAC).

Second, the Scientific Panel recommended the phasing out of clearcutting in favour of variable retention in Clayoquot Sound. Variable retention was to provide a continuum of retention options, ranging from light (15%) in areas without significant non-timber resources, to high (70%) where visual, cultural, or wildlife resources were deemed significant. Opening sizes were to be limited in similar fashion (e.g., openings can be the equivalent of four tree lengths square with no point more than two tree lengths from standing timber).

The Scientific Panel stated that forest structure can be retained either by the retention of dispersed individual trees (dispersed retention), or by retaining small but relatively intact patches of standing timber (aggregate retention). Interfor has practised and perfected both methods. Dispersed retention maintains some forest cover over most of the area, thus maximizing the area under "forest influence"; however, this method also disperses the impact of harvesting throughout the block, and may render the retained stand more susceptible to blowdown. The Scientific Panel noted that aggregated retention allows more ecosystem components to be retained than with dispersed retention.

Emulating Natural Disturbance

Does the management regime in Clayoquot Sound meet modern objectives of ecosystem-based management?

Managing forest resources that mimic natural disturbance regimes was a key concept embraced by the Scientific Panel, and has also emerged as a paradigm for ecosystem management.

Modern precepts of ecosystem-based management suggest that forest practices that depart significantly from the range of natural variability are more likely to impair ecosystem functions than those that have impacts within the natural range. Large (40 ha) clearcuts were believed to lie well outside the range of natural variability, since such stand-level disturbances are rare, and in any case, have site-level effects that differ from, say, large-scale blowdown.

In the coastal forests of Clayoquot Sound, large stand-level disturbances are rare. The Coastal Western Hemlock (CWH) biogeoclimatic zone (covering most of Clayoquot) is predominantly located within Natural Disturbance Type (NDT) 1, in which stand-initiating events are rare. The moist and wet sub-maritime variants of the CWH (vm1 and vm2), however, are classed as NDT2, with infrequent stand-replacing events occurring at mean intervals of 200 years. Exposed parts of the Coast may be described as NDT3 with frequent stand-replacing windthrow events occurring at intervals of 100 years.

These are typically represented as even-aged hemlock–amabilis fir stands that originate from stand-level blowdown, and because they develop into a condition that renders them highly vulnerable to blowdown can be regarded as "wind-climax" stands. The more widespread forest type consists of uneven-aged redcedar-hemlock, with short and very open canopies that are relatively resistant to blowdown. In places, these stands have probably been continuously forested, without stand-level disturbance, for thousands of years. Of course, many stands are transitional between these two stand types, reflecting a complex history of partial blowdown.

In any case, the natural disturbance pattern is dominated by small openings, rather than the larger wildfire openings prevalent in much of the British Columbia interior (and in the rest of Canada).

Variable retention openings appeared on the surface to be more emulative of natural openings than the clearcuts they replaced. Pearson *et al.* (2002), investigating regeneration patterns in clearcut, variable retention, and natural openings in Clayoquot Sound, found that in many respects, variable retention openings showed patterns intermediate between clearcuts and natural openings. Nevertheless, these openings are substantially larger than natural openings, contain less decayed coarse woody debris, and are subject to more light and more exposure to desiccation.

True emulation of the natural disturbance patterns would require single-tree harvesting. This has been done on the Coast where high-value individual stems of Douglas-fir, spruce, redcedar, or yellow cypress are available, but it is only done on a very small scale to augment more conventional harvesting. It would not allow the achievement of even the smaller AACs in Clayoquot Sound.

Costs and Benefits of the Paradigm Shift

Switching from conventional clearcutting to variable retention posed a tough challenge for licensees in Clayoquot Sound. It entailed major changes in planning, engineering, and harvesting. Variable retention resulted in heightened problems of blowdown and mistletoe. It carried increased safety risks for falling and yarding crews. It necessitated higher road densities for a given level of harvest. Overall, it has resulted in substantially higher logging costs. This was recognized in the appraisal system through the "Clayoquot Additive," which reduced stumpage paid, but the Ministry of Forests has progressively reduced this amount, arguing that variable retention has become a more widespread—even conventional—form of logging on the Coast, and no longer unique to Clayoquot Sound. The higher costs, coupled with weak log prices, have resulted in a precarious economic situation. As this is being written, no logging is currently taking place in TFL 54.

The adoption of variable retention logging in Clayoquot Sound achieved, in part, the objectives set out by the Scientific Panel. Except in the relatively few cases where blowdown has damaged standing timber retention, variable retention has had the effect of lessening visual impact, especially in sensitive areas. It has probably lessened the ecological impact, although on a watershed and regional level, impact reduction has been achieved more through establishment of protected areas and reserves, and reduced AAC, than through the harvest method *per se*. Unfortunately, the lack of monitoring and research in Clayoquot Sound limits our assertions of impact reduction.

If the 1995 Clayoquot Sound Scientific Panel's recommendations have improved the environmental sustainability of forest practices, it has come at a substantial cost. Increased unemployment, reduced economic opportunities, and associated social costs have been felt in the local communities. Again, as for the environmental impact of the new forestry, sufficient monitoring and research into economic and social impacts has not taken place.

We still have a lot to learn from the Clayoquot Experiment. One of the lessons is that the zeal to achieve the environmental objectives within ecosystem-based management must be tempered with attention to the potential economic and social costs.

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Popular Summary

Disturbance, diversity, and resilience of forest communities and ecosystems

Sybille Haeussler[1]

Abstract

Evidence is accumulating that British Columbia's ecosystems are undergoing rapid, perhaps unprecedented, change due to interacting changes in climate, geochemical cycles, land use, and disturbance regimes, and in the distribution and abundance of native and non-native biota. Although such changes are not entirely unpredictable, they are extremely complex, and pose huge predictive and adaptive challenges for scientists, forest managers, and for society at large. Research findings demonstrate unequivocally that forest practices involving, among other things, road construction, dominantly clearcut logging, forest fragmentation, and active fire suppression, differ substantially from a natural wildfire-and insect-dominated disturbance regime across all spatial and temporal scales analyzed. Current, short-rotation forestry practices pose serious risks to organisms associated with old forest. Modified practices that increase retention of old forest, and retain and recruit old forest attributes such as large live, dead and downed trees will help to stem this loss of diversity. In field studies across a range of environments, ecological resilience is being measured in terms of the recovery of vegetation cover or biomass, the recovery of species diversity, and the recovery of species composition following a catastrophic disturbance or a gradient of silvicultural treatments. The intent of this research is to help sustain British Columbia's rich variety of ecosystems and the ecological services they provide into the 22nd century.

KEYWORDS: *biodiversity, ecological resilience, disturbance regimes.*

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Introduction

British Columbia is remarkable in the temperate world for its outstanding diversity of relatively intact forest ecosystems with functional food-webs that include top predators. What will these ecosystems look like in the year 2100? Will they provide a sustained supply of goods and services to human society? And how can science and technology be applied to ensure the maintenance of ecosystem services?

Evidence is accumulating that British Columbia's ecosystems are undergoing rapid, perhaps unprecedented, change due to interacting changes in climate, geochemical cycles, land use, and disturbance regimes, and in the distribution and abundance of native and non-native biota (e.g., Bradford and Irvine 2000; Woods *et al.* 2005). Humans intuitively expect such changes to be gradual and linear—to build incrementally upon our past experiences; however, science and observation increasingly show that ecological changes tend to be non-linear in nature. Abrupt regime shifts in climate, disturbance patterns, and ecosystem states may be the norm, rather than the exception (Rehfeldt *et al.* 1999, 2001; Chapin *et al*. 2004). Seemingly minor changes in ecosystem conditions can result in ecological effects that cascade across multiple trophic levels, spatial and temporal scales. Although such changes are not entirely unpredictable, they are extremely complex, and pose huge predictive and adaptive challenges for scientists, forest managers, and for society at large.

My work as a consultant and academic researcher, based in northwestern British Columbia, has focussed on understanding existing patterns of vegetation and ecosystems and on predicting how human disturbances, particularly in a silvicultural context, affect the structure, composition, and diversity of plant populations, communities, and ecosystems. Most of the detailed scientific research has taken place within short-term (1–3 years) and medium-term (10–20 years) stand-scale experiments. Various landscape, regional, and national scale projects, however, have helped to place these stand-scale observations within a larger-scale, longer-term context.

Disturbances

My own field research (e.g., Haeussler and Bergeron 2004) and the accumulated findings of other forest scientists (Haeussler and Kneeshaw 2003) demonstrate unequivocally that forest practices involving, among other things, road construction, dominantly clearcut logging, forest fragmentation, and active fire suppression, differ substantially from a natural wildfire-and insect-dominated disturbance regime across all spatial and temporal scales analyzed. Even subtle differences such as the range of variability in forest floor depth can have cascading effects on the structure, composition, and diversity of forest ecosystems. Major changes in ecosystems have already occurred and will continue to occur. Regional- to local-scale examples include:

- a loss of pine and black spruce-dominated ecosystems and corresponding expansion of aspen-dominated mixedwoods in southern boreal forests;
- loss of old forest attributes and species; and
- shifts in ruderal plant, bird, and soil communities from those dominated by pyrophilous, or fire-loving species (e.g., sedges and fire-mosses, woodpeckers, certain ectomycorrhizal fungi), to those dominated by species associated with cultivated fields (agronomic grasses and weeds, open habitat birds, earthworms).

These changes, while triggered by forestry-associated land-use practices, cannot be fully separated from accompanying climate change, species invasions, and other phenomena over which forest managers have little or no control. Modifying forest practices to reduce discrepancies between historical natural disturbance regimes and contemporary human-dominated regimes (Bergeron *et al.* 2002) will help to slow the rate of change, but cannot be expected to eliminate change entirely.

Diversity

But do such ecological changes, unstoppable as they may be, inevitably result in a loss of valuable ecosystem services? Initial research on this question focussed on measuring diversity. There is strong societal consensus that biological diversity, in and of itself, is a good thing, that diverse ecosystems are healthy and resilient ecosystems, and that forestry practices invariably result in forest simplification and the creation of monocultures. My research over the past decade, mainly in southern boreal/sub-boreal forests of northern British Columbia, Quebec, and Ontario, along with that of others (e.g., Betts *et al.* 2005), both confirms and challenges these widely held assumptions.

There is no doubt that current, short-rotation forestry practices pose serious risks to organisms associated with old forest and that modified practices that increase retention of old forest, and retain and recruit old forest attributes such as large live, dead and downed trees will help to stem this loss of diversity (Figure 1). Despite 10–15 years of unanimous scientific opinion on this topic, an

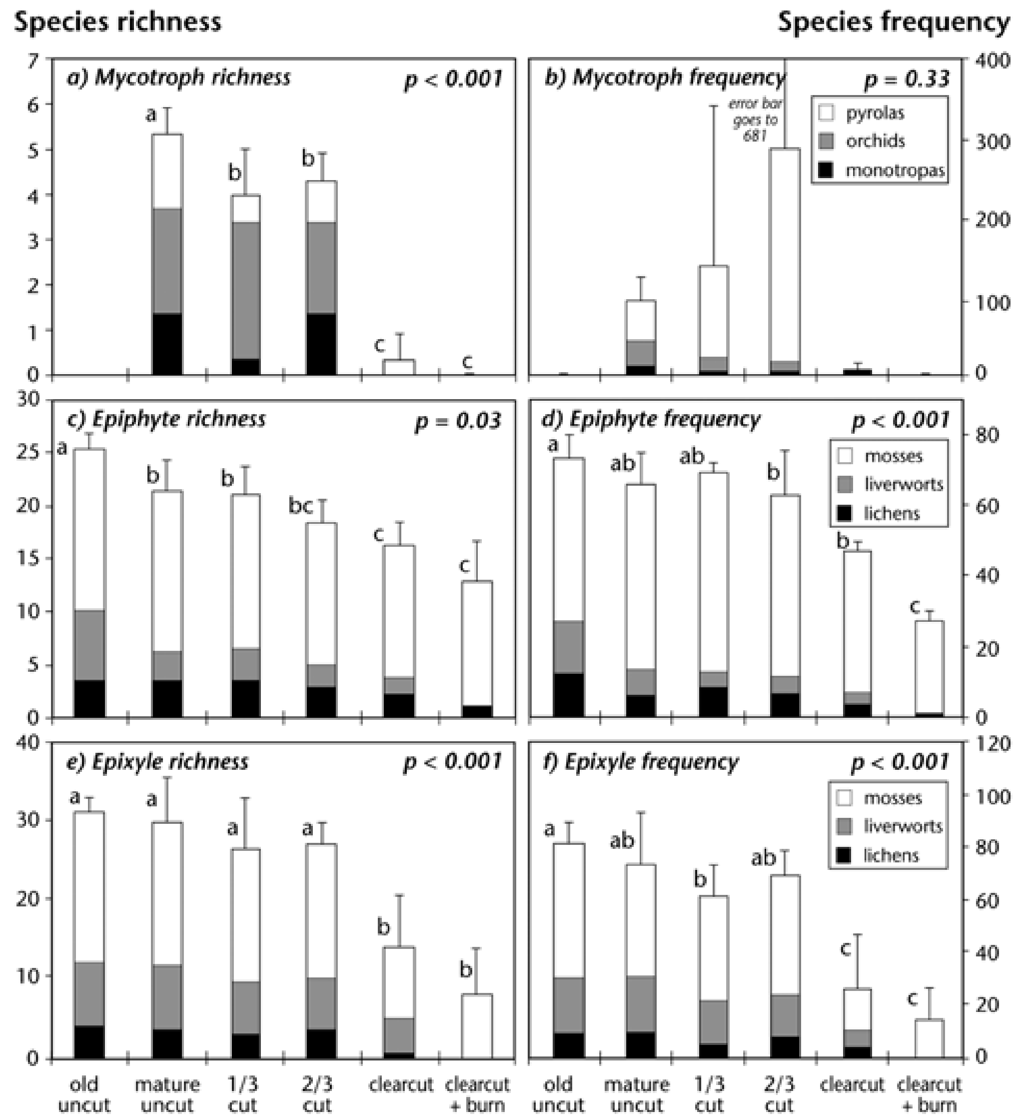

FIGURE 1. Effect of harvest severity on richness (number of taxa) and frequency of sensitive old forest-associated species in trembling aspen forests of the southern boreal mixedwood, Quebec: (a,b) mycotrophic herbs of the families Monotropaceae, Orchidaceae, and Pyrolaceae; (c,d) epiphytic mosses, liverworts, and macrolichens growing on trembling aspen trunks; and (e,f) epixylic mosses, liverworts, and macrolichens growing on decaying logs. Error bars are +1 standard deviation for all taxa combined. (From Haeussler 2004)

August 2005 flight over British Columbia suggests to me that we are still overwhelmingly clearcutting our forests (92% in 2002–03, Table 1) with mostly no more than a token amount of structural retention. This absolutely must change if we hope to retain the old growth-associated ecological services for which British Columbia is renowned into the 22nd century. The scientific evidence is clear, the technology surely exists, what is lacking is the political will to make the necessary changes.

For other organismal groups and ecosystem attributes, there is ample evidence that logging and associated silvicultural disturbances can either enhance or reduce structural and species diversity relative to untreated or naturally disturbed forest conditions depending on how they are applied, and for what species groups, successional stages, and spatial scales the diversity measurements are undertaken (Table 2). Generalization of results is difficult, but the following conclusions can be made.

TABLE 1. Area harvested in British Columbia by silvicultural system for 2002–2003, the most recent year for which statistics are available. (Source: B.C. Ministry of Forests and Range)

Silvicultural system	Crown land (ha)	Private land (ha)	Total (ha)	Total (%)
Clearcut	58 700	20 715	79 415	47
Clearcut with reserves	66 860	286	76 146	45
Intermediate cut	584	0	584	0.3
Patch cut	329	1	330	0.2
Retention	7 830	863	8 693	5
Seed tree	340	0	340	0.2
Shelterwood	3 131	3 980	7 111	4
Selection	4 155	0	4 155	2
Total	**141 929**	**25 845**	**167 774**	**100**

TABLE 2. Species richness and Shannon's diversity 10–15 years after silvicultural site preparation at the Inga Lake and Bednesti research sites. Where the trend is indicated in parentheses, treatment differences were not statistically significant at $p = 0.05$. Conclusions about how increasing silvicultural disturbance severity affects diversity depend upon the species group (vascular vs. non-vascular), the successional stage (10 vs. 15 years), the diversity index (richness vs. Shannon's), the spatial scale (quadrat vs. plot scale), and the type of ecosystem. (Adapted from Haeussler *et al.* [1999, 2004]).

	Increasing silvicultural disturbance severity →					
	Untreated	**Disk-trench**	**Plowed**	**Rotocleared**	**Burned windrow**	**Trend**
Inga Lake (mesic, boreal mixedwood ecosystem)						
Vascular richness 10 year	28	29	30	36	39	(increase)
Vascular richness 15 year	30	n/a	29	35	37	increase
Vascular diversity 10 year	2.5	2.6	2.7	2.8	2.5	(hump-shaped)
Vascular diversity 15 year quadrat	2.2	n/a	2.1	2.3	2.1	(no effect)
Vascular diversity 15 year plot	2.4	n/a	2.4	2.8	2.6	right-skewed hump
Non-vascular richness 10 year	5	9	11	7	6	(hump-shaped)
Non-vascular richness 15 year	10	n/a	11	13	16	increase
Non-vascular diversity 10 year	1.0	1.4	0.9	0.9	0.8	(left-skewed hump)
Non-vascular diversity 15 year quadrat	0.7	n/a	0.8	0.9	1.0	(increase)
Non-vascular diversity 15 year plot	1.2	n/a	1.3	1.5	1.4	(right-skewed hump)
Bednesti (nutrient-poor, sub-boreal lodgepole pine ecosystem)						
Vascular richness 10 year	27	30	26	24	25	(left-skewed hump)
Vascular diversity	2.7	2.6	2.1	2.2	2.1	decrease
Non-vascular richness 10 year	10	8	6	8	3	decrease
Non-vascular diversity 10-year	1.6	1.4	0.8	0.9	0.3	decrease

- For a given ecosystem or biotic functional group, no single treatment or set of treatments provides optimal diversity across all spatial scales and successional stages.
- Different ecosystems and different biotic functional groups respond in fundamentally differently ways to the same set of silvicultural disturbances.
- Many of the communities and ecosystems at highest risk in British Columbia have inherently low levels of diversity and may be placed at risk by disturbances that enhance diversity.
- There are no simple measures of diversity that can serve as universal, unambiguous measures of the success of forest operations in maintaining biodiversity.

Local-level indicators must be tailored to local ecological conditions and locally identified risk factors. Once again, many of these risks (e.g., invasive species) are reasonably well understood and technology exists to reduce expected losses in ecosystem services associated with losses in diversity, but perceived costs and societal inertia prevent us from taking action.

Resilience

My current research explores the concepts of ecological resilience and self-organization and their role in maintaining the composition, structure, and diversity of British Columbia ecosystems during a period of rapid and cumulative ecological change. Resilience refers to the magnitude of disturbance that a dynamical system can absorb without changing its structures, functions, and controls to an alternative state or stability domain (Gunderson 2000; Carpenter *et al.* 2001). In field studies across a range of environments, we are measuring resilience in terms of the recovery of vegetation cover or biomass, the recovery of species diversity, and the recovery of species composition following a catastrophic disturbance or a gradient of silvicultural treatments. Ecosystems differing in resource availability (moisture, nutrients, favourable temperatures) and their adaptation to disturbance regimes (e.g. fire, flooding, wildlife disturbance) demonstrate contrasting capacities to recover their biomass, their diversity and their composition (Figures 2 and 3). Mesic boreal and sub-boreal mixedwood ecosystems (moderate resource availability,

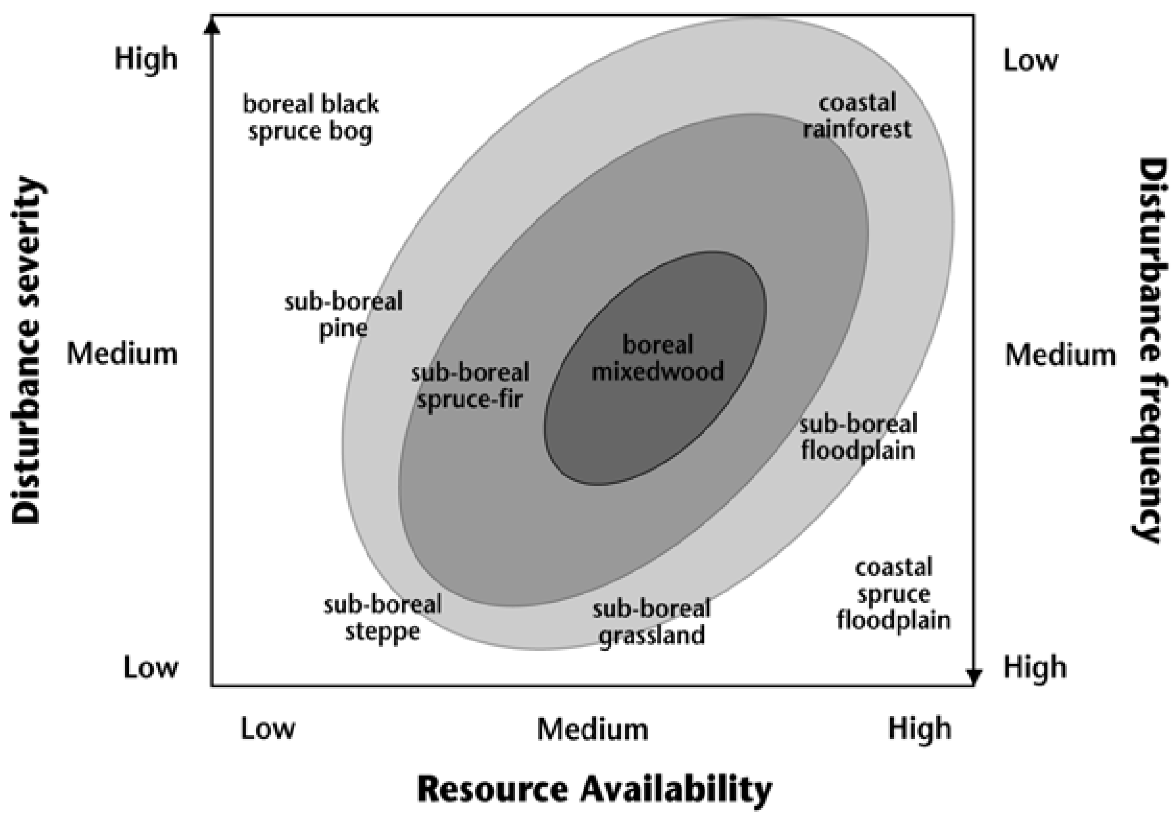

FIGURE 2. Hypothetical model of how ecosystem resilience may vary across gradients of resource availability and disturbance severity and frequency. Darker shading indicates higher overall resilience.

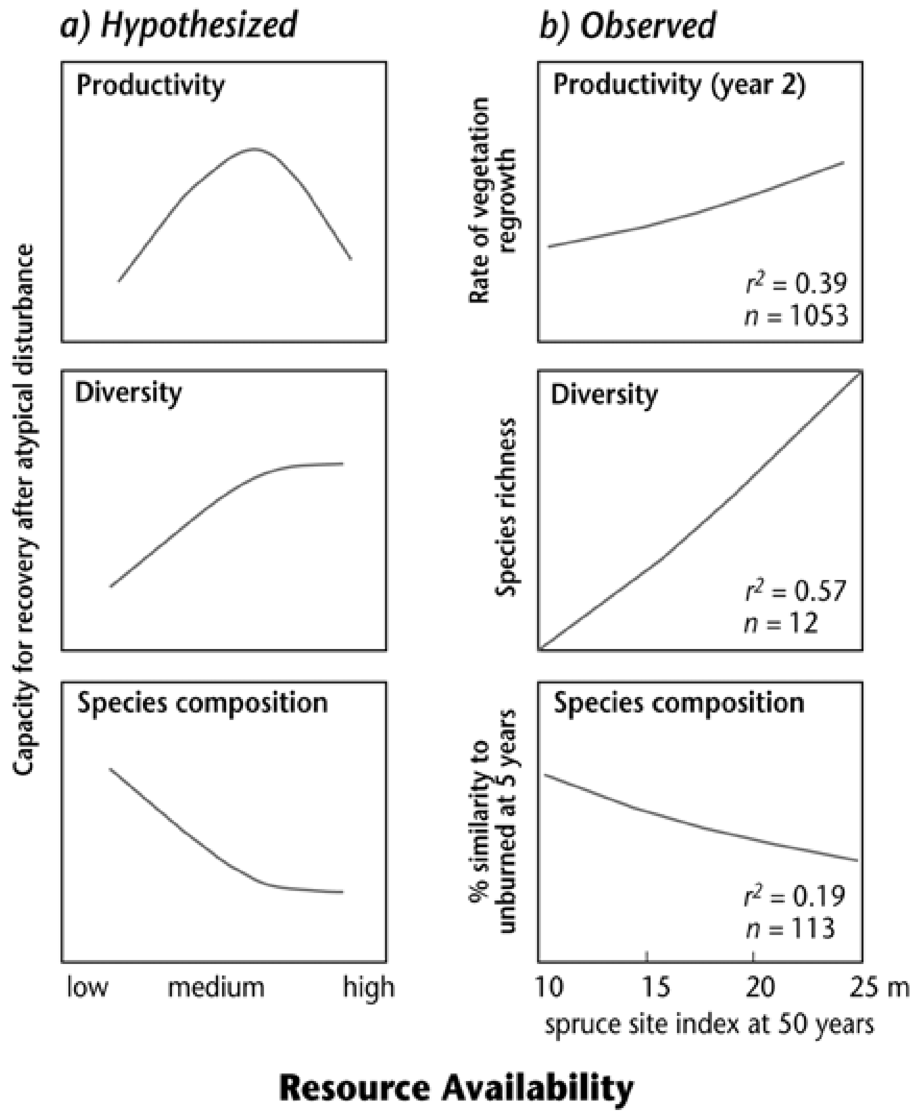

FIGURE 3. Variation in the three measures of resilience—recovery of productivity, recovery of diversity, recovery of species composition across a gradient in resource availability: (a) hypothesized relationships; (b) real data from clearcut and slashburned sites in central British Columbia (Hamilton and Haeussler [2005]), where the spruce site index at age 50 is used as an index of resource availability.

moderate/high disturbance frequency/severity) appear to have high resilience (Haeussler *et al.* 2004; Hamilton and Haeussler [2005]), whereas non-mesic ecosystems and those with either very active, or very infrequent disturbance regimes (e.g., coastal floodplains, nutrient-poor lodgepole pine, sub-boreal grasslands) express lower resilience in a variety of ways.

The intent of this scientific research is to help sustain the rich variety of ecosystems we have in British Columbia and the ecological services they provide into the 22nd century. To do so, our science and technology must:

- find ways to maintain and enhance the capacity of ecosystems to resist change;
- identify the range of acceptable disturbances and interventions within which recovery is possible;
- develop restoration strategies for degraded ecosystems; and
- improve the adaptive capacity of both ecosystems and human society where change to an alternative state is unavoidable or irreversible.

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Popular Summary

Protection forests: Keeping watershed reserves functioning

David Wilford[1] and Matt Sakals[2]

Abstract

Forested reserves are established in watersheds in British Columbia to protect and maintain physical and ecological functions in riparian zones and old-growth management areas and on unstable slopes and visually sensitive terrain. However, given a host of forest health issues, abiotic factors, and forest succession, the ability of these reserves to provide benefits for the long-term is questionable. In many situations, it is necessary to apply silvicultural interventions to maintain the qualities desired in forested reserves. This is referred to as "protection forestry." The occurrence of flooding, poor water quality, or lack of other services from watersheds leads land managers and the public to seek alternative management strategies, often resulting in protection forests. Internationally, some protection forests have been in place for over 100 years. Now is the time for resource managers in British Columbia to make a shift from reserving forests to managing protection forests.

KEYWORDS: *forest function, forest management, forest reserves, land management, protection forests, watershed management.*

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Wilford, D. and M. Sakals. 2005. Protection forests: Keeping watershed reserves functioning. Popular Summary. *In* Forests and Natural Resources in the 22nd Century: Science Forum Proceedings, August 31–September 1, 2005. *BC Journal of Ecosystems and Management* 6(2):139–142. URL: ***www.forrex.org/jem/2005/vol6/no2/vol6_no2_scienceforum.pdf***

Introduction

Until the mid-1970s, the whole forested land base in British Columbia contributed to the allowable annual cut (AAC)—all forested land was considered available for production forestry. This changed in 1975 with the environmentally sensitive area (ESA) initiative by Inventory Branch of the British Columbia Forest Service. The program identified forested areas that: were naturally unstable; presented high challenges for reforestation; had high visual values; or were key fish and wildlife habitats. The ESA program resulted in net downs to the AAC, and thus was a significant advancement for the recognition of multiple values in the forested landscape.

Recognition of the role played by logging and road-building in initiating landslides was also increasing in the 1970s. Research by Doug Swanston (1971) identified specific practices that were problematic, and this led to restrictions on logging terrain steeper than 36° in much of the American Pacific Northwest and Alaska. British Columbia took a different approach by identifying specific sites and practices that were linked to landslides (Wilford and Schwab 1982). This site-specific approach was used by Bill Bourgeois of the Land Use Planning Team of MacMillan Bloedel to develop a five-class terrain stability scheme. This scheme was adopted through the Forest Practices Code, and is applied province-wide. Now no logging is allowed on Class V terrain (naturally unstable), and constraints are placed on practices on Class IV terrain (marginally stable terrain). These uncut areas have thus become an important "reserve" in watersheds.

Until the mid-1970s, "primary firebreaks" were established within watersheds. These were reserves of timber, in blocks or strips that divided watersheds, with the objective of reducing the spread of forest fires. Primary firebreaks were not considered permanent, but were to be left for a considerable period of time (e.g., until the logged areas had sufficiently recovered from a fire perspective). With improvements in fire detection and aerial attack methods, however, the concept of primary firebreaks was discontinued, much to the worry of fisheries managers who saw that whole watersheds would be progressively clearcut. This concern led to the "hydrologic rate of cut" debate that resulted in the Watershed Assessment Procedures of the Forest Practices Code.

Also in the 1970s, more attention was paid to retaining riparian reserves, but the reality of windthrow became apparent, and research provided site-specific recommendations for designing riparian reserves that would remain functional (Moore and Archdekin 1980). Given the blowdown hazards in some locations such as the Queen Charlotte Islands, prescriptions were developed to log one side of a stream completely, with subsequent harvesting on the other bank once the regenerating stand had achieved a certain size and structure. With the Forest Practices Code, however, a province-wide blanket policy was implemented under which the presence and width of riparian reserves was dictated by channel width and presence of fish.

In addition to unstable terrain and riparian zones, reserves in watersheds have also been established for visual and old-growth management purposes. In some cases, these reserves also play important watershed protection roles.

On the surface, it appears that water and aquatic resources are fully protected with forested reserves in the watersheds of British Columbia. In many cases, however, closer inspection of the situation leads to a different conclusion.

How Permanent are Forested Reserves?

Forests are dynamic systems with individual trees going through their life cycles over periods of decades to centuries. In addition, forests are influenced by biotic and abiotic factors. Although forests as entities may be relatively permanent in some locations, the species mix, structure, and function may change significantly. These changes may affect the value, functions, and services of a forested reserve over time. There are many examples. The deciduous component of a riparian reserve may disappear over time because of lack of disturbance and successional processes that favour conifers. Dieback of cedar in southeast Alaska has led to an increase in landslides from old-growth reserves (Johnson and Wilcock 2002). Reserves have been prescribed for fans to limit the runout of debris flows, but the stands are sustaining attack from balsam bark beetles and regeneration and growth will take decades to replace the protective value of the stand (Wilford *et al.* 2004). Throughout the Interior of British Columbia, the mountain pine beetle infestation has reduced riparian reserves to standing snags. This has significantly reduced the shading of streams, which is required to moderate stream temperatures.

While some reserves may be in multi-aged mixed stands with a high likelihood of being reasonably "permanent," many reserves cannot be considered permanent. What, then, is the solution if we want to maintain the protective role of forest reserves in watersheds?

Towards A Solution: Protection Forests

Protection forests are defined as forests "managed primarily to regulate stream flow, maintain water quality, minimize erosion, stabilize drifting sand, conserve ecosystems, or provide other benefits via protection" (Helms 1998). The British Columbia Ministry of Forests and Range has a more narrow definition of protection forests: "forests maintained on steep, unstable slopes to prevent accelerated erosion" (British Columbia Ministry of Forests and Range 2005). The concept of protection forests has been developed over a considerable period of time throughout the world. Documents referring to protection forests in Italy date back to the 14th century (Motta and Haudemann 2000). Japanese land managers have been managing protection forests for the purpose of protecting railroads from landslides for over a century. In Taiwan, the designation of protection forests has been occurring for over a century (Cheng *et al.* 2002). In the United States, the *Organic Administration Act* of 1897 introduced national forests that were intended to be working forests with multiple objectives. Improving and protecting the forest, water flows and timber extraction were the primary concerns. Later in the United States, the Weeks Law of 1911 emphasized the regulation of flow in navigable streams and the function of forests in the associated watersheds. Protection forests have also been used in many other areas around the world.

The concept of forests offering protection is not new; a seemingly more recent idea is that of maintenance of the forest function through active management. For centuries, the only action in European protection forests was to ban wood-cutting. This resulted in a series of problems as the forests become over-mature because of the lack of disturbance (Motta and Haudemann 2000). Some Japanese forests are also experiencing reduced protective capacity as a result of stand conditions as well as other factors (Togari-Ohta *et al.* 2005). Despite these issues, protection forests in Malaysia are currently under a no-harvesting management strategy (Thang and Chappell 2004). Forests will continue to provide protection services regardless of their designation or management regimes; however, the protective service may be reduced. A balance is required between the protection level desired and the management intensity. Further, forests are more than a collection of trees. The awareness and management of specific features, such as downed logs and snags, within protection forest systems is increasing (Bebi *et al.* 2001; Dorren *et al.* 2004; Perret *et al.* 2004).

Optimal management of protection forest ecosystems will require an understanding of the components, structure, and interactions of these forest ecosystems. It is possible that some forest reserves will not need silvicultural interventions to maintain the target protective role; however, this situation may be rare. A multidisciplinary approach is required to assess risks to forest reserves, and management prescriptions must be developed that will be implemented over a long period of time. Continuity of management intent is a critical aspect if forested reserves are to continue to provide important roles in British Columbia's watersheds.

Conclusions

British Columbia has been a world leader in identifying erosion-prone sites and establishing reserves for multiple resource values in watersheds; however, reserves are but a first step because the majority of these forests may not continue to provide protective roles at an adequate level. It is necessary for British Columbia to adopt and apply the concept of protection forests. This will be a challenging new chapter in the evolution of natural resource management, one that will involve many disciplines and require a strong and long-term management commitment to succeed.

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Abstract

Watershed sensitivity to logging-induced changes in peak flow

Rob Hudson[1]

Watershed sensitivity to logging-induced changes in peak streamflow was examined by comparing results obtained from paired watershed experiments conducted in coastal British Columbia (Flume Creek, Roberts Creek study forest) and in Oregon (small watersheds at H.J. Andrews Experimental Watershed). The comparison suggested that watershed land slope, drainage area, initial forest cover type, and precipitation regime all play a role in watershed sensitivity such that any factor that tended to favour lower peak flows under the original forest condition also tended to make the watershed sensitive to increased peak flows after logging.

Most watershed experiments were conducted with old-growth forest as a starting condition. When second growth is the starting condition (e.g., at Flume Creek), the change in peak flow after logging is extreme when rain-on-snow conditions occur; however, this type of forest is over-recovered compared to old growth. Peak flows under the dense, single-species, even-aged canopy are already reduced relative to old growth. This suggests that management opportunities exist to convert advanced second growth to an old-growth-like structure by using group selection harvesting to restore streamflow to a more natural regime.

KEYWORDS: *logging-induced changes, peak flows, watershed sensitivity.*

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