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RESPONSE TO DISTURBANCE IN BOREAL MIXEDWOOD ECOSYSTEMS: THE BLACK STURGEON BOREAL MIXEDWOOD RESEARCH PROJECT

John B. Scarratt

INTRODUCTION

Although Rowe (1972) characterized the boreal forest as primarily coniferous, in reality the typical boreal landscape in Ontario is comprised of a complex mosaic of forest associations ranging from single-species stands to intimate mixtures of several species. Mixed stands of conifers and hardwoods—broadly classified as boreal mixedwoods—are an especially common feature in the southern parts of boreal Ontario (Fig. 1). Here, they are estimated to occupy at least 50 percent of the productive forest land. Because of their wide occurrence and typically high productivity, these forests have always been an important contributor to the economy of northern Ontario, and provide the economic foundation for many northern communities.

Figure 1. Extent of the "predominantly forested" Boreal Forest Region in Ontario (after Rowe 1972). The location of the Black Sturgeon Boreal Mixedwood Research Project is indicated by a ★.

Ontario's boreal mixedwoods are generally more species rich than those of regions to the east and west. Characterized by varying proportions of conifers (white spruce [*Picea glauca* (Moench) Voss], black spruce [*Picea mariana* (Mill.) B.S.P.], balsam fir [*Abies balsamea* (L.) Mill.], jack pine [*Pinus banksiana* Lamb.]) and hardwoods (trembling aspen [*Populus tremuloides* Michx.], white birch [*Betula papyrifera* Marsh]), these are complex and dynamic ecosystems, with broad spatial, temporal, and structural diversity. Both at the stand and landscape levels, there may be major species shifts over time, depending upon sometimes random circumstances. Thus, for an individual stand, current species composition and its future successional pathway are influenced by more than just local soil and site conditions. In particular, the nature and frequency of disturbance, predisturbance stand composition, and the time elapsed since the last major disturbance all have a major influence on forest development. Before European settlement, two natural forces—insect outbreaks and wildfire—were an integral part of the ecology of boreal mixedwoods, and played a fundamental role in their periodic renewal and in maintaining ecosystem diversity. While fire and the eastern spruce budworm (*Choristoneura fumiferana* Clem.) are still important factors to be considered in the management of these forests, the principal disturbance factors today are associated with timber harvesting and silvicultural activities.

Boreal mixedwoods occur on a broad range of well-drained, fertile, upland soils, often characterized by rich herb and shrub vegetation. Because they tend to occupy the most fertile sites, these are potentially the most productive forests

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in the boreal zone, whether in terms of species diversity, timber yields, or their ability to sustain high wildlife populations. It is this high potential productivity, coupled with the ecological complexity of boreal mixedwood ecosystems, that makes them such a challenge for the forest manager.

A CHANGING MANAGEMENT PARADIGM

Despite the extent and economic importance of boreal mixedwoods, traditional approaches to their management have generally been simplistic. Numerous factors contributed to this situation, *viz*: (i) a market-driven focus upon exploitation and management of the conifer (i.e., spruce [*Picea* spp.]) component; (ii) a past lack of markets for hardwoods; (iii) management constraints posed by the ecological complexities and fragmented nature of mixedwood forests; and (iv) spruce regeneration problems. In consequence, clear-cutting or selective harvesting (high-grading) followed by attempted conversion to conifers has long been the preferred management option. Current harvesting and silvicultural technologies are well adapted to this approach, but generally inhibit more sophisticated management strategies. Only in recent years, with changing social and market forces (environmental concerns, demands for sustainable management, increased utilization of hardwoods) and the availability of more adaptable harvesting machines, has the outlook begun to change.

The impact of changing public expectations about how forests should be managed will perhaps be greater for boreal mixedwoods than for any other forest type in northern Ontario. Added to environmental concerns over current forestry practices, mixedwoods also have important nontimber values. The diversity, aesthetic appeal, rich flora and fauna, and remoteness of these forests give them broad public appeal in terms of recreational and spiritual values. As a result, demands for the protection of nontimber values, such as wilderness, hunting and fishing, and wildlife, are likely to become an increasingly potent factor in decisions relating to mixedwood management. Resource managers will be challenged to manage for both timber and nontimber values, often on the same land base. If managers are to continue to practice economic forestry in mixedwood cover types, it must be integrated into a more holistic approach to forest management that ranks and accommodates the often divergent needs and goals of different interest groups. Clearly, integrated resource management (IRM) will be a critical goal in the future sustainable development of boreal mixedwoods. This in turn creates a need to develop ecologically and operationally sound alternatives for managing these forests; alternatives able to satisfy different resource-use demands.

THE BLACK STURGEON BOREAL MIXEDWOOD RESEARCH PROJECT

To establish a strong ecological foundation for the future management of boreal mixedwoods, and for the application of IRM in particular, a much better understanding of the component ecosystems is needed—their structure and dynamics, their response to disturbance and manipulation, and the interrelationships among different ecosystem elements (e.g., vegetation, nutrients, wildlife, pests and diseases, etc.). Such knowledge is crucial if managers are to implement an ecosystem-based approach to mixedwood management that will maintain or enhance biological diversity and ecological values, yet also meet society's demands for timber and other resource benefits.

The Black Sturgeon Boreal Mixedwood Research Project was established in 1993 to address this need through multidisciplinary research that focuses on long-term, stand-level ecosystem response to disturbance and silvicultural manipulation. It incorporates treatments that seek to evaluate the feasibility and impacts of adopting alternative management approaches that avoid clear-cutting. While the project is expected to provide answers to certain contemporary silvicultural and forest management questions, the emphasis is on understanding ecological processes and interrelationships rather than on the development of new technologies *per se*.

The project is situated in the Black Sturgeon Forest, approximately 120 km northeast of Thunder Bay, Ontario (Fig. 1). It is a cooperative project of the Canadian Forest Service–Sault Ste. Marie, the Ontario Ministry of Natural Resources, and Avenor Inc. of Thunder Bay. While the Black Sturgeon Project focuses on stand-level issues, a complementary project located at Rinker Lake, some 55 km to the northwest, deals with landscape-level issues in boreal mixedwood management (Sims and Mackey 1994).

Forest conditions in the project area and the management problems they pose are typical of mixedwoods throughout much of boreal Ontario. This includes extensive areas of second-growth forest characterized by greatly increased contents of trembling aspen and balsam fir as compared to the original forest. The high balsam fir content, and its high regenerative capacity in the absence of fire, greatly increases the difficulty of managing these forests. Thus, their susceptibility to periodic severe spruce budworm infestations can lead to a significant and premature reduction in the merchantable value of the forest, and can create a major fire hazard.

The project is located in an extensive area of second-growth mixedwood forest, first harvested between 1939 and 1942. For the most part the soils are fresh, well-drained, and fertile. These support stands that fall predominantly within the herb- and shrub-rich mixedwood vegetation types of the forest ecosystem classification for northwestern Ontario (V6, V7, V9, V11, and V16) (Sims et al. 1989). At the time of the most recent provincial forest resource inventory (1975), stand composition in the project area averaged 50 percent poplar, 30 percent balsam fir, 10 percent black spruce, and 10 percent white spruce, with local admixtures of white birch and/or jack pine. However, 1993 preharvest data indicated that a significant compositional shift had occurred since that inventory. This was largely due to a negative impact upon the balsam fir and white spruce by a 10-year spruce budworm infestation. Much of the balsam fir in the upper canopy is now either dead or moribund.

Despite their relatively young age (≈55 years), in the normal course of events these budworm-infested stands would have been clear-cut (full-tree logging with on-site chipping) in 1994–95 to salvage as much as possible of the conifer component. The increased market demand for the aspen component makes this a viable option. This situation presented an opportunity to explore the long-term ecological consequences of alternative harvesting and silvicultural strategies for second-growth stands within an operational context. The timing was especially serendipitous from an ecological perspective, for it coincides with the end of the current spruce budworm epidemic and the period of maximum fire hazard for this forest. As such, it clearly represents a natural milestone in the development of these stands—the culmination of a major natural disturbance and the beginning of a new cycle of forest succession.

The Black Sturgeon Project adds human disturbance to the events experienced by these stands in recent years. Currently, the project comprises three linked multidisciplinary components that seek to determine ecosystem impacts and responses to different harvesting regimes, fire (prescribed burning), and mechanical site preparation (Fig. 2). The **fire ecology component** is concerned principally with the impacts of large-scale prescribed fire on vegetation succession and soil nutrient dynamics. In a broader sense, however, it will also help to address the much-discussed question of how closely harvesting mimics the ecological impacts of natural disturbance on mixedwood sites. The **site preparation component**, established in 1993, examines the effects of intensive mechanical soil mixing and surface organic matter removal on soil processes, seedling survival, and the abundance and diversity of soil invertebrates and microflora.

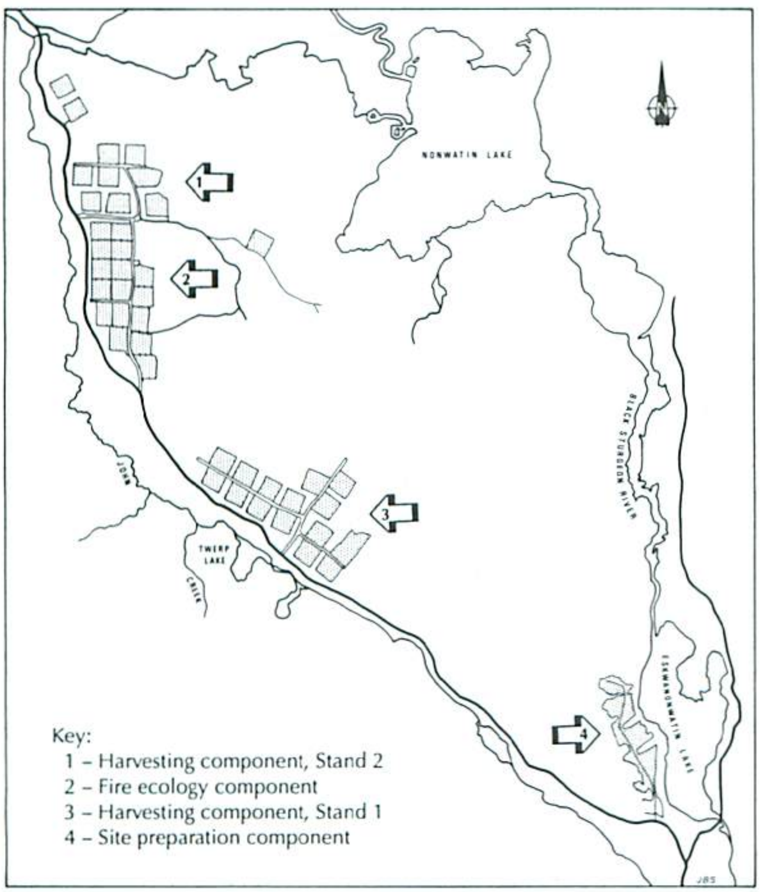

Figure 2. The Black Sturgeon Boreal Mixedwood Research Project, showing the configuration of the three project components.

The **harvesting component**, the subject of this note, examines shelterwood cutting as an alternative to clear-cutting in second-growth stands. While the emphasis is on ecosystem response (*see* Appendix 1), the project also addresses a number of basic silvicultural questions, *viz*:

- Is shelterwood cutting a biologically sound and viable management alternative to clear-cutting for second-growth mixedwood stands?
- Is logging damage a significant factor in partially cut stands?
- Can enhanced growth of the residual trees offset the additional costs of shelterwood cutting?
- How can the spruce content of partially cut stands be enhanced?
- How do silvicultural techniques (e.g., site preparation) need to be modified for use in shelterwood cuts?

Harvesting commenced in September 1993 and was completed by the end of the year. Six different harvesting treatments were applied, each replicated three times, *viz*:

- Uncut control
- Clear-cutting:
  1. Conventional feller-buncher and grapple skidder *(full-tree extraction)*
  2. Single-grip harvester (Ultimate 4500) and grapple skidder *(tree-length extraction)*
- High intensity shelterwood cut:
  3. Conventional feller-buncher and grapple skidder *(full-tree extraction)*
  4. Single-grip harvester (Timberjack 1270) and forwarder *(cut-to-length)*
  5. Manual felling and cable skidder *(partially delimbed full-tree extraction)*
- Patch cuts:
  6. Manual felling and cable skidder *(partially delimbed full-tree extraction)*

Both harvested and uncut control blocks have an area of 10 ha, with 100 m-wide uncut buffer strips between the blocks (Fig. 2). The shelterwood cuts aimed to remove about two-thirds of the merchantable volume from a block, including all merchantable balsam fir, while retaining a uniform canopy of good quality aspen with a scattering of potential white spruce seed trees (2–3 trees per hectare). In practice, it was frequently necessary to accept black spruce as a substitute seed tree because of extensive spruce budworm damage to the preferred white spruce.

The patch cuts were established as a link with related research into white spruce regeneration being conducted in the Chapleau area.[1] In this case, 21-m-diameter clear-cuts (equivalent to average stand height) were made at 50-m center-to-center spacing along 5-m-wide skid trails cut 50 m apart. All merchantable trees were harvested from the patches and skidways, thereby removing approximately 20 percent of the standing volume from each block.

Extensive preharvest sampling, to establish the baseline conditions for their particular area of interest, was carried out by participating scientists before harvesting commenced. In addition, general vegetation and soil surveys of the research area were conducted, together with forest inventories of blocks designated for harvest and further study. The results of such preharvest studies are important, both for judging the long-term impacts of harvesting, and for monitoring long-term changes in the undisturbed forest.

The harvesting operations were monitored by staff of the Forest Engineering Research Institute of Canada (Eastern Division) (Gingras 1995). Although the machine productivity data was less useful than hoped for because of operator inexperience and high turnover, a number of important lessons were learned. Foremost among these is the urgent need for operator training, both in appropriate machine operating techniques and basic forest biology, if mechanical shelterwood harvesting is to be successfully accomplished. Most harvester and skidder operators in northern Ontario clearly have a timber-oriented, clear-cutting mindset. While the availability of harvesting equipment adapted to partial cutting is increasing rapidly, this will be of little avail unless we are able to establish a pool of skilled and motivated operators who understand the silvicultural and biological goals of alternative harvesting strategies.

With harvesting completed, preharvest research plots were reestablished in the spring of 1994, together with a number of new studies. Current studies, listed in Appendix 1, focus upon site impacts, logging damage to residual trees and advance growth, pathological and entomological responses, seedbank dynamics, postharvest vegetation succession and structure, forest renewal, stand dynamics, growth and yield, soil nutrient dynamics, soil fauna, and wildlife relationships (songbirds, small mammals, amphibia). A number of these activities are illustrated in Figure 3. Many of the studies have a long-term outlook, and it is anticipated that the full story of how individual ecosystem elements respond to disturbance will take several years to emerge.

The second phase of research began in 1995 with the initiation of conifer regeneration studies. These aim to determine the fundamental conditions needed to successfully regenerate spruce from seed or planting stock under an aspen shelterwood. Selected partially cut and clear-cut blocks were divided to permit one-half of each to be site prepared (the other half will remain untreated). Site preparation treatments, including soil mixing, surface organic matter removal, mounding, and herbicide application, were applied to subplots in late summer. Planting and seeding of white spruce and black spruce is to follow in the spring of 1996. This phase of the work complements the site preparation component of the project, referred to earlier, and will encompass a similar suite of investigations, plus studies on conifer seedling ecophysiology. A parallel study to examine factors influencing white spruce establishment has been initiated in the patch cuts.

The Black Sturgeon Boreal Mixedwood Research Project exemplifies the long-term, multidisciplinary research approach that is essential if managers are to develop the knowledge needed for applying ecosystem-based forest management. Much of the research now under way is breaking new ground in the study of boreal mixedwood ecosystems and their response to disturbance. The results will provide a better understanding of the complex ecological relationships within these ecosystems and of the long-term ecological consequences of forestry practices. In these times of changing forest management policies and priorities, this will help managers to make scientifically based decisions on the sustainable management of boreal mixedwoods into the 21st century.

ACKNOWLEDGMENTS

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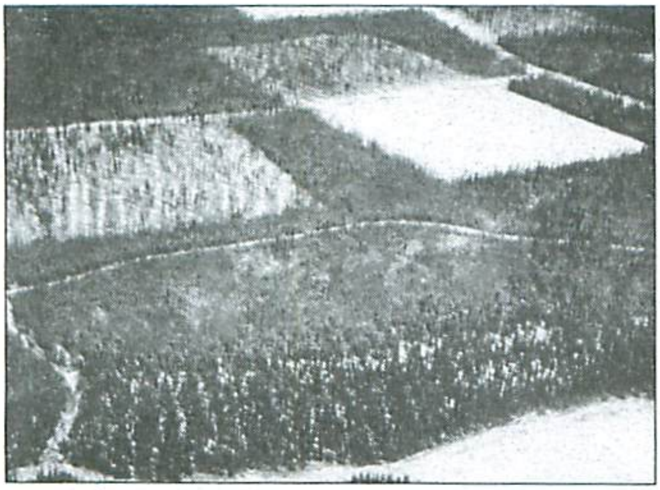
Partial cutting with Timberjack 1270.

J.-F. Gingras of FERIC conducting machine productivity studies.



Aerial view of harvest blocks at Stand 1 in February 1994.

Bruce Canning and Matthew Shaw collecting baseline inventory data.

Dr. Meiqin Qi and Hongshen Huang extracting soil cores for seedbank studies.

Dr. Chris Sanders conducting breeding bird population survey.

Figure 3. Activities in the Black Sturgeon Boreal Mixedwood Research Project.

APPENDIX 1. Harvesting Component – Current Studies.

Harvesting productivities and site impacts.
Jean-Francois Gingras (FERIC–East, Pointe Claire, QC)

Logging damage and pathological colonisation of residual trees.
Michael Dumas and John McLaughlin (CFS–Sault Ste. Marie, ON)

Logging damage and recovery of advance growth and regeneration.
Jean-Denis Leblanc (CFS–Sault Ste. Marie, ON)

Postharvest vegetation succession and dynamics.
John Scarratt (CFS–Sault Ste. Marie, ON)
(Steve Taylor was project leader until the time of his death in 1994.)

Effects of moose browsing on aspen sucker development and vegetation diversity.
John Scarratt (CFS–Sault Ste. Marie, ON)

Seed bank dynamics, seed rain, and tree seedling recruitment.
Meiqin Qi and John Scarratt (CFS–Sault Ste. Marie, ON)

Impacts of harvesting on distribution and cycling of organic matter and elements.
Ian Morrison (CFS–Sault Ste. Marie, ON) and Mark Johnston (OMNR, Centre for Northern Forest Ecosystem Research, Thunder Bay, ON)

Effects of harvest method on canopy development.
Arthur Groot (CFS–Sault Ste. Marie, ON)

Impacts of harvesting practices on boreal forest soil invertebrates.
Jan Addison and Kevin Barber (CFS–Sault Ste. Marie, ON)

Impacts of harvesting practices and fire on the red-backed salamander.
Raymond Guy (Collège Boréal, Sudbury, ON)

Impacts of harvesting practices on small mammal populations.
Arthur Rodgers (OMNR, Centre for Northern Forest Ecosystem Research, Thunder Bay, ON)

Impacts of harvesting practices on bird populations.
Ken Abraham (OMNR, Southern Terrestrial Ecosystems Research Section, Maple, ON)

Postharvest site preparation and regeneration studies.
Brad Sutherland, Michael Dumas, Ian Morrison, John Scarratt (CFS–Sault Ste. Marie, ON)

Effects of competition and shelter on establishment of white spruce.
Arthur Groot and Jim Wood (CFS–Sault Ste. Marie, ON)

Growth and yield monitoring in control blocks.
Jim Mackenzie and Mark Roddick (OMNR, Northwest Region Science & Technology, Thunder Bay, ON)

Impacts of spruce budworm and budworm spraying on conifer regeneration.
Chris Sanders (CFS–Sault Ste. Marie, ON)

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