

# INVERTEBRATE BIODIVERSITY, FORESTRY AND EMULATION OF NATURAL DISTURBANCE: A DOWN-TO-EARTH PERSPECTIVE

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## ABSTRACT

A fire-based conceptual model of forest spatial dynamics is widely embraced as the way to make boreal forest management more ecologically friendly and to conserve biodiversity. However, use of the term "ecosystem based management" does not automatically confer either wisdom or naturalness to resource management tactics. We examine the logical structure of recently invoked arguments and summarize recent work to determine whether this conceptual model is necessary, sufficient and adequately developed to generate specific tactics for management of the western boreal forest. In particular, we show that biotic elements involved in both the early phases of natural succession and in the breakdown of coarse woody material will be at risk if only landscape level processes like the large-scale spatial dynamics of wildfire are considered in management. Development of complex stand structure associated with gap dynamic processes that are characteristic of post-rotational age forest should be accommodated in extensive forest management to conserve the biota and the processes that ensure long-term maintenance of site productivity. We preview developing efforts under the Canadian EMEND project to understand how the situation might be improved.

Keywords: biodiversity, invertebrates, boreal, natural disturbance, wildfire, spatial patterns

## INTRODUCTION

Humans generally are impressed by big things, and trees are the biggest living things that most of us encounter day to day. Likewise large stands of trees, comprising primeval forests, intrigue us and provide comfort and solace to many. The Canadian boreal forest, as it presently exists in northern Alberta, is among the last of the Earth's large, wild forests, and this ecosystem is tightly linked to the identity of many Canadians. However, the western boreal forest is being cut at an unprecedented and accelerating rate (Pratt and Urqhart 1994). By the end of a projected 80 year rotation period started in the present decade, much of the remaining primeval timber will have fallen to the saw in Alberta. Never-cut forests of merchantable volume will remain only on inaccessible land or in a few scattered parks and reserves, but large tracts of regenerated forested land will remain to possibly satisfy our manifold non-timber interests. Nonetheless, natural dynamics on many scales, which

have heretofore patterned the Canadian boreal landscape, will be profoundly altered by human activity. Will it matter? How will we know? Should we do anything about it? Can we do anything to guarantee a more favourable outcome? Although we are not in a position to answer these questions confidently with respect to many components of unmanaged forests, including their invertebrate faunas, ongoing research suggests answers that can be built into adaptive forest management.

Western societies have started to feel uneasy about the depth of our imprint on the planet's forests. In developed countries we increasingly consider forests as more than a collection of harvestable trees — first as habitats for charismatic wildlife, and now after the Rio Summit, as repositories for 'biological diversity'. In fact, conservation of 'biodiversity' is now widely, and perhaps somewhat uncritically, accepted as representing whole forest values (fig. 1). Land-use policy makers are increasingly adopting biodiversity

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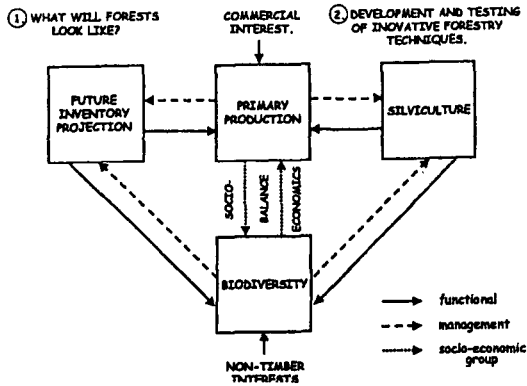
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**Figure 1**—Forces that guide development of forest management. Since the Rio Convention on Biodiversity, both long- and short-term effects on biodiversity have entered the forest planning domain.

measures to indicate whether ecosystems are being maintained in a 'functionally integrated state'. In many countries, some version of the biodiversity criterion is being explored as a possible addition to those of regeneration standards and future inventory projection that have been used to support a sustained yield approach to allocating harvests (Probst and Crow 1991, Franklin 1993, Angelstam 1997). The new suite of evolving protocols proposed to regulate harvest and evaluate forest management plans is termed "sustainable forest management". Incorporation of the biodiversity criterion broadens the focus beyond fiber yield.

The general rationale for the approach adopted under sustainable forest management is that "nature knows best". Simply put, forest communities with biodiversity measures in the range of natural variation, as established from undisturbed areas used for baseline studies, are judged to be "healthy", whether or not we understand the ecological functions of the component species. This approach to management of complex ecosystems acknowledges our ignorance. It prompts us to tread more gently with respect for the whole system, rather than insist on solid functional or economic evidence for retaining any particular component. Thus, more than a half century after it was penned, land use policies are being developed in the context of Aldo Leopold's famous, often-quoted metaphor: "If the biota, in the course of aeons, has built something we like but do not understand, then who but a fool would discard seemingly useless parts? To keep every cog and wheel is the first precaution of intelligent tinkering" (Leopold 1953). In this context, knowledge about non-pest forest invertebrate species becomes a necessary component of forest management.

## FOREST MANAGEMENT AND INVERTEBRATE POPULATIONS

Is there any evidence that invertebrates are being lost as a result of forestry activity? Such losses are generally accepted as being huge in the tropics (Erwin 1991, Wilson 1992), but undesirable side effects of forest management also have been revealed by research on invertebrate communities in northern forests (Mikkola 1991, Nilsson and others 1995, Niemelä 1997). For example, carabid beetle species abundant in primeval montane pine forests of western Canada have not re-established populations in the oldest available regenerated sites (*i.e.*, up to c. 30 years after harvesting) (Niemelä and others 1993, Spence and others 1996), suggesting that old-growth specialists will be disadvantaged in harvested landscapes. In a landmark paper, Siitonen and Martikainen (1994) compared the saproxylic beetles of areas in eastern Finland that have been subjected to intensive logging with those of similar areas of Russian Karelia exposed to minimal human disturbance for the past 40-50 years. With comparable effort, they collected 186 individuals of 15 red-listed species from aspen snags in Russia but found only one individual representing this same set of species in Finland.

The important point of the recent work on northern forest invertebrates is that large-scale changes in empirical patterns of species diversity and composition have apparently resulted from the way that humans have repeatedly altered the land through intensive forest management. Most current forestry practices homogenize the landscape, leaving regenerated stands ill-suited for maintenance of the full complement of species that once inhabited them (Angelstam 1997, Niemelä 1997). Large scale patterns of unplanned forest fragmentation and the resulting isolation of species with particular habitat requirements may also prevent recolonization of regenerating forests, even when suitable microhabitats develop over time. The recolonization process depends on spatial and temporal scales characterizing the metapopulation dynamics of particular taxa, and thus landscape level planning based primarily on requirements of vertebrates may be at the wrong scale to accommodate arthropods species with different dispersal ability. However, even for arthropods with excellent ability to seek out and colonize appropriate microhabitats, it remains critical to understand and optimize direct, stand-level habitat effects. If appropriate microhabitats are missing, the creatures that depend on them and the ecosystem services that these creatures provide are surely at risk.

Unfortunately, with respect to development of forest management prescriptions in western Canada, we are woefully ignorant of much of the biodiversity that we have agreed to protect as signatories of the Rio

Convention. Thus, we are caught on the two horns of a dilemma: we must conserve this biodiversity, while forests are being cut at an ever increasing rate. The rosy ideal of 'sustainable forest management' represents what we want, but do we have a rational strategy for attaining this state? Furthermore, we urgently need to define how such a strategy connects appropriately to operational measures of biodiversity. In the balance of this paper we discuss how knowledge about invertebrates can contribute to adoption of modern forest management models, and give examples of research about soil and litter-dwelling arthropods that can be applied toward this end.

## NATURAL DISTURBANCE AS A MANAGEMENT PARADIGM?

The currently advocated approach to sustainable management of the boreal forest promotes linkage between management regimes and natural disturbance. The boreal forest, like many ecosystems, is reset in fractal mosaics to earlier successional stages and has its successional courses altered and diversified by various natural disturbances (Haila and others 1994). In the forestry arena, a number of approaches to management, including "new forestry" (Franklin 1989) and "ecosystem management" (Kaufmann and others 1994), are converging on the same sort of rationale. Hunter (1993), for example, characterizes the approach as follows: "timber harvesting regimes should be designated to imitate the natural disturbance regimes, such as fire and windfall, which shape the structure of forest ecosystems".

In western Canada the forested landscape reflects a conspicuous influence of wildfire (Rowe 1972, Stelfox 1995). Analogues to fire are already being applied in management regimes for the mixedwood zone of western Canada (Stelfox 1995). From the premise that the boreal biota is well adapted to deal with the natural disturbance of periodic wildfire, it is inferred that imposing similar patterns of forest regeneration on the landscape through harvesting should only minimally disrupt natural processes and patterns of biodiversity. Proponents reason further, and probably correctly, that we cannot know enough to micro-manage our forestry activities for the benefit of every forest species and, even if we did, complete knowledge would doubtlessly paralyze us. The pragmatic approach to resource development in the light of uncertainty is to apply a coarse, general filter in forest management. Thus, we seek to develop and adopt policies for harvest that ensure existence of an appropriate mosaic of habitats on the landscape, as defined by natural disturbance patterns, to maintain our biota as a whole. Fine-filter management geared to the needs of particular biotic elements may be established under this approach, but

only for charismatic or exploitable species that are negatively influenced under the coarse filter approach. We tend to ignore small, unengaging or poorly known species, especially those that appear to be unimportant in socio-economic reasoning.

The above arguments ignore practical constraints and make significant leaps of faith. Although the approach seems rational and represents a stage in the process of improving forest management, it is critical that the approach not be canonized as a 'magic bullet', and thus, simply be defined as sustainable forestry. Magic bullets are simple but powerful prescriptions that seem to give exactly the results we want (Van Den Bosch 1978). Unfortunately, magic bullets, used to solve environmental problems, frequently fail when the temporal or spatial frame is expanded and unpleasant side effects are noticed. Scientists and research managers may stall recognition of side effects and development of alternative approaches. This comes from insisting on the sort of local focus guaranteed to deliver research dollars from magic bullet makers and those who want fixed truths on which to maximize efficiency of profit-oriented operations. A strictly fire-based natural disturbance model seems like a magic bullet to us. It has been most touted by those familiar with creatures that range widely over a landscape. For many birds and most larger mammals such as bears and ungulates, about which we already have considerable biological knowledge, such an approach has real appeal. Although our comparative ignorance of invertebrates may be blissful for a time, there is no guarantee that little known invertebrates, including those involved in the biotic engine that renews soil fertility and other ecosystem functions, will not be negatively affected by forest management directed at and monitored using the more charismatic fauna. Such negative effects could compromise sustainability of forestry operations in the long term. For this reason, it is imperative that we continue to study all aspects of forest systems brought into harvest rotation.

The strong focus on large-scale spatial patterns, ignores significant concerns from which probable side-effects may spring. Let us consider four rational counter arguments to a strict landscape approach. This is not to dismiss landscape level work but rather to amplify why it remains essential to study processes operating at both smaller and larger scales if we are going to manage them effectively. After all, it is the interaction of these processes that produces natural forests.

1) In current discussions about pre-eminence of landscape processes, generation of stand-level variation across successional scales meaningful for forestry is frequently ignored. The within-stand diversity of such harlequin environments is critical to ensure the persistence of species that might be favoured as

background conditions change. Within-stand homogenization resulting from forestry activities could move environmental conditions out of the range of today's levels of natural variation, causing extreme reductions or extirpations of some species dependent on rare microhabitats. If so, we would constrain the system's ability to respond and there would be little basis for assessing the long-term success of adopting a natural disturbance model. For example, the boreal biota is probably not in meaningful equilibrium (Boktin 1990), but is still recovering from the last glaciation (Prentice and others 1991) and probably responding to anthropogenic climate change (Lenihan and Neilson 1995). Biodiversity, including small, rare and/or cryptic species, is a key element in ecosystem response to change (Wilson 1992, Naeem and others 1994). We ignore these changes and the ecosystem features required to buffer them at our peril. Tomorrow need not be like yesterday.

2) Innovative managers are encouraged to emulate natural patterns of stand origin. Under a wildfire-driven natural disturbance model, these are those seen on fire maps. However, natural but erratic spatial-temporal patterns are unlikely to be either socially or economically acceptable for industrial forestry. Even if some vague approach to pattern matching is acceptable, what time-frame should be used to establish the base pattern? Fire frequency and patterns have clearly varied, even recently, both as an effect of active fire suppression and as a result of natural processes (Bergeron and Dansereau 1993, Gauthier and others 1995). Should we, for example, force landscapes to develop in the form defined by processes that operated in some limited past time window?

3) On occasion, practical implications are reduced to a worrisome short-cut stated as follows: if we don't cut more land annually than was scorched in former times, estimated to be in the range of 2-3% for the boreal mixed wood, the biota will be conserved. However, there is little hard scientific evidence to show that any wildfire-based model, applied strictly at the landscape scale, will be any better for biodiversity than the old "cut it and pray" model. Adopting an untested model does not automatically confer the mantra of sustainability on boreal forestry (Fanklin 1993). Models are tested most stringently by experiment and there are excellent but largely untapped opportunities to develop appropriate experiments in the context of adaptive management (Hilborn and others 1995). It is unlikely that we have inferred the optimal answer based on incomplete information.

4) The scenario depicted in figure 2 is generally accepted as a description of what happens to forested uplands in the western boreal region (Rowe 1972, Bonan and Shugart 1989; Stelfox 1995). Upland stands are initiated by wildfire and, after a very poorly

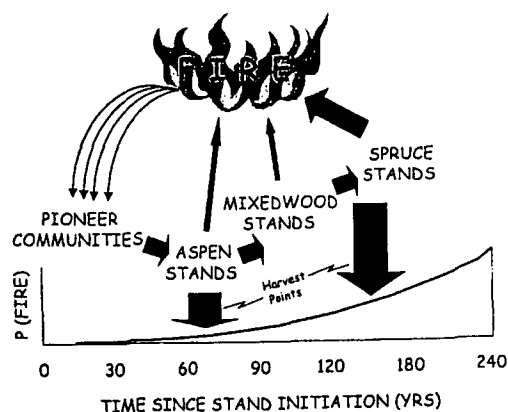


Figure 2—Schematic diagram indicating the general course of succession in the boreal mixedwood forest. The two major harvest points presently envisioned are indicated by the two dark vertical arrows.

understood early successional period, come to be initially dominated by trembling aspen. These may have a white spruce understory right away, or may be slowly colonized by spruce, depending on the distance to seed source (Liefers and others 1996). As a stand becomes more dominated by spruce, the probability of stand replacing fire goes up and eventually the stand burns again to reinitiate the cycle. Two main harvest points will be imposed as we come to a stable rotation in the boreal mixedwood forest. The earlier one, representing a major part of today's harvest in Alberta, is directed at an ecosystem that is rarely re-initialized by wildfire. It is not clear that we will allow natural processes to guide the intervening period to spruce harvest, but even if we do, the age distribution and variation of these spruce stands will surely be truncated. Thus, with respect to the ecological processes inherent in natural stand development, it is fair to ask whether a natural disturbance model is being followed at all. Should the wildfire analogue be used more deeply than as a weak justification for removal of fiber?

The natural disturbance approach is perpetrated mainly as an idea about risk management. As in a game of bingo, it is argued that "chance" will determine the winners and losers as in natural situations. If each species has a fair or "natural" chance to win (*i.e.*, to stay in the game) we might legitimately dodge responsibility for extinctions. However, we need to know if the rules of the game, under anthropogenic forest management, are really natural for all players. Thus, we prefer an approach that manages for the results we want to achieve over the long run, rather than rushing blindly to emulate selected aspects of natural process that fit into our socio-economic constraints. We will be responsible for the outcome either way because clearly we will not allow nature to take her own course, even under a natural disturbance model. This is not to claim that we will ever be able to

employ perfect knowledge, but we argue that testing and applying the limits of what we know is preferable to 'biodiversity bingo' when we can be sure that the probabilities of extinction will be affected however we manage the system.

A superficial, landscape-oriented approach to basing management on natural disturbance may encourage false security with respect to biodiversity. In the words of song-writer Joni Mitchell, it is common for humans to "pave paradise" as a result of focus on specific objectives. If our forestry practices homogenize forest stands, we might not even know what biodiversity "we've got 'til it's gone". Organizing the size, age and distribution of "parking lots" carefully according to some natural rhythm of land disturbance won't help much if the parking lots themselves are part of the problem.

## BEETLES AND SPIDERS OF BURNS AND HARVESTS

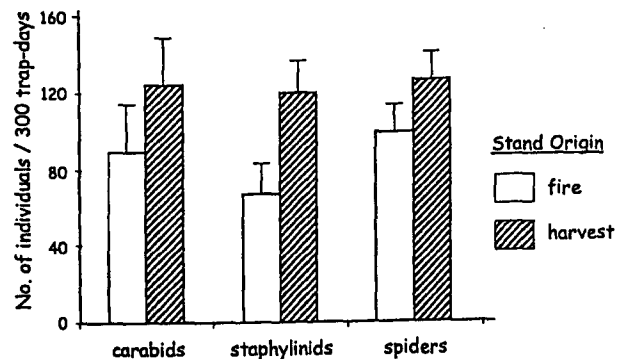
Recently burned and recently harvested stands are quite dissimilar to most observers. The question for those interested in managing in the context of sustainability criteria is whether such differences throw biotic succession onto different courses that might threaten some of the biota. As part of a team of forest ecologists, we set out to determine how close succession from burns and harvests might be in the aspen-dominated mixed wood. We asked whether harvest was a reasonable substitute for fire with respect to development of the litter-dwelling invertebrate fauna. If so, we reasoned that fire- and harvest-origin stands would develop increasingly similar faunas as they aged. If the fauna diverged significantly, however, the logic of using harvest as an analogue for fire may be flawed with respect to protection of biodiversity.

Finding suitable harvested and burned stands was a challenging matter, undertaken by P. Lee and his colleagues at the Alberta Research Council. Using forest inventories, aerial photography and ground truthing, they found aspen stands either harvested or burned in 1968, 1982 and 1995. These sites are spread out over a wide geographical area in northeastern Alberta, and thus interpretations of resulting data may be confounded by geographical variation. However, this is the best that can be done with a chronosequence study of aspen forest, given that harvest of aspen was rare in Alberta before the late 1980s.

We have focused our studies on two families of litter-dwelling beetles (Carabidae, Staphylinidae), and spiders (Araneae), using pitfall trapping (Spence and Niemelä 1994, Digweed and others 1995). The specific

sampling designs will be detailed in future papers. Here, it suffices to say that we ran trap lines of 6 traps, each separated by c. 50 m, in two stands of each origin-age combination during 1996 and 1997. More than 17,000 specimens were collected during the two year sampling period and the definitive taxonomic analysis is still in progress. However, our preliminary findings can be used to illustrate the general level of similarity between fire- and harvest-origin stands.

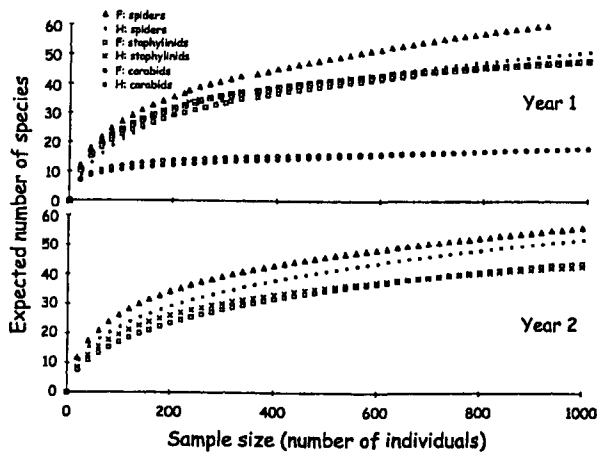
There were no great differences in overall abundance of these litter-dwelling taxa between harvest and wildfire-origin stands (fig. 3). There is a marginally significant trend for staphylinids to be less abundant in fire-origin stands, but the other taxa show no significant differences in overall abundance. Furthermore, the differences in the first year after fire appear to be much greater than in year 2. We used rarefaction (Simberloff 1978) as a measure of diversity, and the results show that overall diversity of litter dwelling arthropods did not differ dramatically between fire and harvest origin stands at any age (fig. 4). Although there were prominent differences in spider diversity between wildfire and harvest in the first year of the study, these had largely disappeared in the second year. However, analyses of diversity and abundance, however, do not provide much comfort about the fit of harvest effects to natural disturbance, if the species differ between harvested and pyrogenic stands.



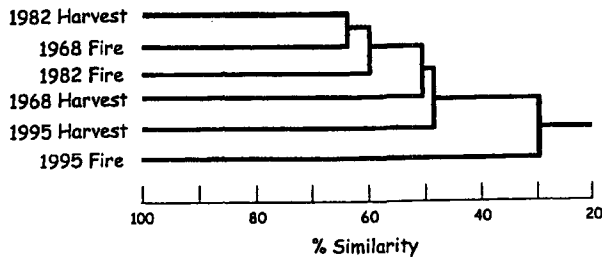
**Figure 3**—Least square mean abundance ( $\pm$  standard errors) by stand origin for beetles and spiders collected by pitfall traps during 1996.

We have just begun to tackle the problem of distribution of particular species on the chronosequence. As a start, we've used cluster analysis to ask questions about patterns of relative abundance of species. Results using all litter-dwelling taxa collected in year one, suggests that pyrogenic and harvested stands tend to converge on similar species associations. It appears that litter dwelling invertebrates recover faster from disturbance by harvesting than by wildfire as the stands harvested in

1982 are most similar to the 1968 fire-origin stands (fig. 5).

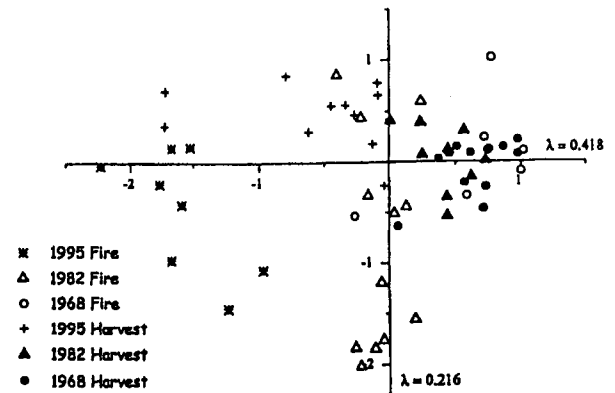


**Figure 4**—Rarefaction estimates of species richness in stands originating from fire (F) and harvest (H) for carabids, staphylinids and spiders sampled by pitfall traps in 1996 and 1997.



**Figure 5**—Cluster analysis of Bray-Curtis measures of percent similarity for carabids, staphylinids and spiders collected by pitfall trapping during 1996. Data were standardized to 800 trap-days.

We've used detrended correspondence analysis (DCA) (ter Braak 1987a,b) to further describe these assemblages. An example of this approach is provided by figure 6, in which individual trap data about three taxa are plotted in ordination space defined by the first two DCA axes. The first axis, which has a high eigenvalue, separates the stands quite clearly and consistently with respect to age. As would be expected from the results of the cluster analysis, the harvest-82 and harvest-68 stands are closer together in the ordination than are the comparable fire-origin stands. Although fire- and harvest-origin assemblages start off from quite different points in this ordination-space, they appear to converge in 30-year old stands. Thus, both cluster analysis and ordination support the claim that litter invertebrates converge with respect to general community structure of litter invertebrates by 28 years post-disturbance. However, given that the



**Figure 6**—Detrended correspondence analysis (DCA) of sample scores (pitfall traps) derived from 153 species of carabids, staphylinids and spiders collected in 1996.

two chronosequences followed quite different trajectories to reach the present positions in ordination space, it may be risky to predict that community development will be parallel in fire- and harvest-origin stands in the future.

From a biodiversity perspective we still must get down to the level of species. Some species of each taxon are collected only in stands of one age or origin (table 1). Many of these are records of only one or a few individuals and may thus be somewhat discounted. However, some records refer to more abundant species and the data about them are thus less comforting. As we replace fire with harvest, for example, is it possible that early successional species characteristic of pyrogenic stands could drop out of the system? The aspen-dominated mixedwood seems to have relatively few litter-dwelling species that specialize in old stands, but especially among saproxylic species, some may be at risk (Spence and others 1996, 1997).

## BEETLES OF FIRE SKIPS

We are studying the ecological significance of old-growth patches of residual forest nested within large burns by looking in detail at the actions of wildfire, and at what sorts of habitats it creates. Fire brings about profound changes in community structure, but it also creates patchiness and spatial heterogeneity on several scales. Today's foresters attempt to re-create some of this local structure by leaving patches of standing green trees in patch-retention logging systems. However there has been little research to characterize invertebrate assemblages of 'fire skips' and to assess whether they are significant for recolonization of the surrounding burned sites. We have set out to describe what happens in both unburned patches and the burned matrix of large burns by comparing the fauna

Table 1—Number of species unique to one type of stand origin (fire or harvest) or age (origin in 1995, 1982 or 1968) for two orders of beetles and for ground dwelling spiders. Data from pitfall traps run during 1996.

Taxon	Disturbance Type		Year of Stand Origin		
	Fire	Harvest	1995	1982	1968
Carabidae	4	12	5	1	3
Staphylinidae	4	12	5	3	4
Araneae	19	17	15	10	8

between two large sub-alpine burns, one 15 and another 30 yrs-old, in conifer-dominated forests on the east slope of the Rockies.

We studied the 15 yr-old burn intensively in 1997 and will do the same for the older burn in 1998. As above, pitfall traps have been used to sample and describe the carabid fauna of unburned patches of various sizes, of the burned matrix and of the surrounding old-growth forest, consisting mainly of Englemann spruce, lodgepole pine and sub-alpine fir. Transects of traps have been laid out to run across the boundaries of fire-skips and burned areas and of burned forest and the undisturbed forests at the edges of the burn. The details of the sampling design will be presented elsewhere.

Although definitive analyses must await completion of the second year of field work, some points of interest emerge from the first year's work. Several numerically dominant old-growth carabid species, including *Calathus advena* and *Nebria crassicornis*, were found in 15-year old fire-skips and the surrounding unburned forest, but were not taken in the burned areas except near skip edges. One interesting parthenogenetic species, *Pterostichus empetricola*, which is a predominantly northern species existing in relict populations southward along the Rockies, was collected exclusively from skips. We suggest that this species requires a narrow range of cool, wet habitat that is relatively rare in the forest at large, but which may be disproportionately represented in skips because of their resistance to burning.

The data suggest that beetles move more readily into the burns from the fire skips (fig. 7), perhaps because of population pressures in the smaller skip habitats. Clearly beetle activity-abundances are higher in fire-skips than in either burned or surrounding old-growth forest. Also, it appears that skips of different sizes may retain different mixes of beetle species, perhaps as a result of interspecific interactions intensified in

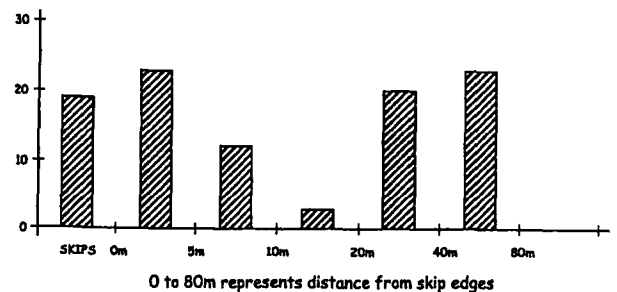
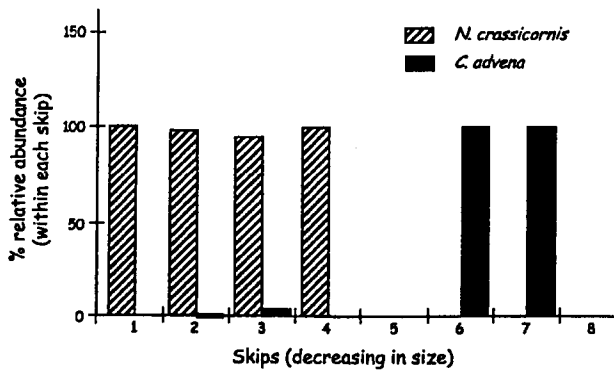


Figure 7—Evidence for recolonization of burned areas from fire skips by the carabid beetle, *Calathus advena*.

these small areas. For example, *Nebria crassicornis* was found only in larger skips, where it sometimes overlapped with small populations of *C. advena*. However, in smaller skips, *C. advena* was abundant (fig. 8).

Already this study provides several results with implications for the patch retention approach to harvesting. Fire skips do provide refuges for old-growth invertebrate assemblages and these species do re-colonize burned patches from the skips. Patches of different sizes vary in respect to carabid assemblage retained. Thus, distribution of patch size will be an important aspect of emulating natural process. Furthermore, it appears that the location of these skips is not random with respect to microtopographic features, and that especially the largest skips, which occupy wetter microsites, may have remained unburned through at least two fires. This is not the random pattern that proponents of the Natural Disturbance Paradigm have suggested. Thus, the spatial distribution of patches in a logged stand should be adjusted to aspects of intrastand variation that remain to be studied and defined.



**Figure 8**—Segregation of two carabid species in fire-skips of differing size.

## THE EMEND PROJECT: STAND STRUCTURE AND INVERTEBRATES

Unmanaged stands differ in structure from stands managed for fiber production, by generally having more coarse woody material (CWM) lying about in various stages of decay. This probably has little to do with differences in stand origin, but instead stand developing exclusively under natural processes vary conspicuously in size, age and spacing of trees and CWM as result of ongoing GAP dynamics (Botkin 1972; Shugart and West 1977; Solomon 1986). These smaller scale, within stand disturbances, which diversify stands as habitats for other organisms, kick into high gear as canopy trees begin to senesce, and thus, aspects of these processes are generally eliminated or truncated by harvest rotations. Although surely important components of insect habitats, the effects of complex and variable stand structure are not well studied.

We have recently launched a cooperative project that seeks to determine the significance of stand structure and to put it to work in management of the northern mixedwood forest system. The project goes by the acronym EMEND (Ecosystem Management by Emulating Natural Disturbance) and occupies > 1000 ha of mixed wood forest, c. 120 km northwest of Peace River Alberta. The project was developed through nearly 2 years of detailed consultation among research scientists, practicing industrial foresters and public land managers. EMEND has been designed both to meet the needs of industry and to satisfy the requirements for a rigorous scientific experiment. It has been linked to the operating plans of Canadian Forest Products LTD. (CANFOR) and Daishowa-Marubeni International LTD. (DMI) and has been envisioned from the start as a significant research component for adaptive management. The work involves a large, multi-disciplinary team, including biologists, foresters and social scientists.

Our general objectives are as follows: 1) to investigate how retention of forest structure on cut blocks affects forest renewal, including regeneration of biodiversity; 2) to compare a number of alternative harvest options to the effects of wildfire; and 3) to investigate the cost-benefit ratios of alternative prescriptions. The two main driving variables are the extent and type of disturbance and the original forest cover type (aspen dominated [> 70% of canopy], aspen dominated with strong spruce understory, mixed forest [white spruce and aspen both < 60% of canopy], and conifer dominated [> 70% of canopy]). Experimental burns are planned at several intensities and the impacts of these will be compared with those of several practical harvesting regimes. Integrated study of a wide range of response variables, including comprehensive work on invertebrate biodiversity, is planned. A central component of this project is an effort to connect studies of nutrient cycling and long-term site productivity to invertebrate assemblages characteristic of living trees, dead and dying wood, leaf litter and soil organic matter.

During 1997, we collected the ground-level baseline data required to lay out an effective experiment. Our main goal was to select blocks of relatively homogeneous stands for the experiment from a pool of candidate stands identified initially from the enhanced Alberta Vegetative Inventory. Data about the stands selected suggest that we are indeed dealing with rather distinct points along the successional pathway (fig. 9). Spruce volume increases over the sequence and that of aspen falls. There are clear differences in age among the oldest trees found on site. These are somewhat less different than might be expected from the standard successional model, adding support to recent ideas that the process is more complex than frequently envisioned. The various treatments have been laid out over three replicate stands representing each of the four cover types. During summer 1998, we will make pre-treatment measurements on all these stands, with burning and harvest scheduled to begin in the following fall and winter. Further information about the EMEND project, including experimental design, specific biodiversity projects and contacts for questions, can be found at <http://www.biology.ualberta.ca/emend/emend.html>. Proposals for additional work to take advantage of the unusual opportunities provided by the EMEND site are welcome.

## CONCLUSIONS

It is appropriate that reason and scientific study structures the way in which biodiversity is applied in forest management. However, at present we have too little sound information about the biota of northern



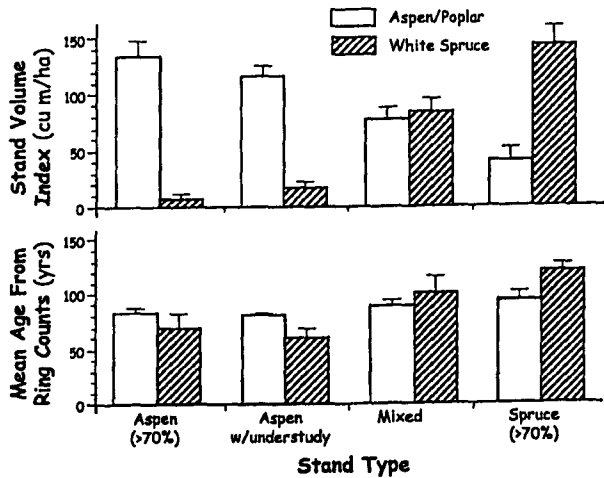


Figure 9—Characteristics of overstory vegetation in stands selected for the EMEND experiment.

forests to corroborate the hypothesized value of new management models based on natural disturbance. Perhaps more than ever before in northern forestry, adaptive management that wed research and operations is in order. Society is clear in the message that biodiversity is to be valued in the context of management of public lands (Kuusipalo and Kangas, 1994; Abramovitz, 1998). Thus, invertebrate biologists must clearly connect their studies of biodiversity to studies of consequences of particular land-use patterns, if concerns about invertebrates are to influence those making the management decisions. It is time for those involved in forest management to leave the value judgments about biodiversity alone and ask rigorous questions about the consequences of adopting any particular concept as a model for forestry development.

At this point we offer the following tentative answers to the questions posed at the end of our first paragraph about the possible influences of extensive forestry activity in the western boreal forest.

- Will it matter? Leopold's dictum about intelligent tinkering cautions us against throwing away things that we don't understand. Even if many forest species contribute little to the sustainability of the forest resource in human terms, many are concerned about the ethical aspects of human-caused extinction.
- How will we know? Forest health monitoring should incorporate some assessment of poorly understood taxa like invertebrates, otherwise we may understand what we have lost only when it is too late to reverse the process. Experiments that compare effects of real management prescriptions and follow these for significant periods of time will also increase our understanding.

- Should we do anything about it? In addition to monitoring, the fire-skip study suggests that refugia are important and that their locations could be critical. Thus, we should characterize the patterns of sub-landscape level structure that contribute to the function of these refuges and incorporate such information into cutting plans.
- Can we do something about it? This depends both on forestry policies, market pressures and land owners. Balancing study of and attention to biodiversity concerns against the need to generate revenues from a fully allocated forest resource will be tangible proof of commitment.

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## QUESTIONS FROM THE FLOOR

Q: I'm wondering if the "magic bullet" isn't stand dynamics and the focus on these scale processes. What about the relationship between biodiversity and landscape dynamics, the "neighborhood" effect on disturbance processes landscape structure?

A: Let me begin by saying that I have no faith in any sort of magic bullets. What we've tried to illuminate is how the present preoccupation with landscape-level processes leaves out concerns important to conservation of species with dynamics on smaller spatial, but perhaps longer temporal scales. I do not argue that work at the landscape scale is not important or that it should not be done, only that it isn't the be-all and end-all for sustainable forestry. We need to be concerned that our forestry practices, as applied at the stand-level, do not homogenize whole regions with respect to microhabitats critical for invertebrate species, like for example, in the case of the saproxylic beetles studied by Sittonen and Martikainen (1994).

Assuming that by "landscape dynamics" you mean changes in the the size and distribution of forest stands of various ages over time, then I think this is possibly important and we've commented on it to some degree in Spence and others (1996, 1997). Indeed colonists available to any isolated habitat unit come from the surrounding matrix. However, the surrounding matrix in forest land is composed of stands as well, and stands are the focus of how harvest technology affects the land, repeatedly across a landscape. The important point that I want to re-emphasize is that we don't know enough about how stand level processes like gap dynamics create habitat complexity that may be crucial for biodiversity. It is clear that short rotation forestry limits the action of these processes. Will there be undesirable consequences? The available evidence does not rule them out.

I cannot address the last part of the question because I just don't understand it.

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