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SOIL- AND LITTER-DWELLING INVERTEBRATES: EFFECTS OF FOREST HARVESTING AND IMPLICATIONS FOR SUSTAINABILITY AND BIODIVERSITY

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INTRODUCTION

A sustainable soil system forms the basis on which a sustainable forest develops (Maser 1994), and aboveground production is simply a reflection of the ability of the soil to grow that particular stand of trees—once. The soil productivity of an area is related to the ability of the soil to conserve water and nutrients, and to maintain structural and biological integrity. It cannot be assumed to remain constant over time. Practices that affect the integrity of the soil system will eventually be reflected in the ability of the soil to sustain the aboveground forest.

Today, professionals are required to manage forests as ecosystems, seeking to conserve a variety of different and often conflicting forest values by using practices that minimize environmental impacts and promote biodiversity. Most practices and regulations attempt only to manage a small number of large species (e.g., moose [*Alces alces* (L.)] or black spruce [*Picea mariana* (Mill.) B.S.P.]). However, the integrity of the system depends, to a great extent, on a large number of small species, predominantly insects and microbes (Pimentel et al. 1992). Many of these "little things that run the world" (Wilson 1987) live and function in the soil, out of sight and out of mind. Yet, current understanding of the living components of the soil system is woefully inadequate. Researchers do not know what species are present in the soil—many of them have not even been described in the scientific literature—and even less is known about their ecological roles, or how they respond to different forest management practices (Marshall 1993).

This study reports on the short-term response of two groups of soil fauna—ground-dwelling carabid (ground) beetles and soil-dwelling springtails (Collembola)—to clear-cut and partial cut harvesting regimes, and discusses implications for forest sustainability.

WHY SOIL INVERTEBRATES ARE IMPORTANT TO FOREST PRODUCTIVITY

Carabid beetles often occur at the top of the invertebrate food chain, and can be important predators of insect pest species (Weseloh 1985). Their abundance and diversity reflect the abundance and species composition of the prey populations on which they feed. Thus, carabids have often been used as bioindicators of environmental changes associated with forest management alternatives (Duschesne and McAlpine 1993).

Soil microarthropods, including springtails, play vital roles in decomposition and nutrient cycling by feeding directly on litter and organic matter, and by acting as catalysts of microbial decay. Grazing activities by springtails have been shown to increase plant growth rates by controlling pathogenic root fungi (Curl et al. 1988), promoting mycorrhizal fungi (Rabatin and Stinner 1988), and improving the efficiency of nutrient uptake from the soil to plant roots (Setälä and Huhta 1991).

MATERIALS AND METHODS

The present study was carried out at the Black Sturgeon Boreal Mixedwood Research Area, a 55-year-old spruce (*Picea* spp.)–fir (*Abies* spp.)–aspen (*Populus* spp.) mixedwood

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approximately 120 km northeast of Thunder Bay, Ontario. This area was harvested in 1993 using conventional and alternative technologies. Sampling was carried out in 1994 on three replicate blocks (~10 ha/block) each of uncut, partial cut (feller-buncher), and clear-cut (feller-buncher) forest. (*For project details see* Scarratt [1996].) Carabid beetles were collected in pitfall traps (12 traps/block; four 2-week collections), pinned, counted, and identified and capture rates were standardized to 100 trap-nights (some traps were lost or disturbed by mammals). Springtails were extracted from soil cores in a modified Macfadyen High Gradient Extractor, counted, and identified in the laboratory. Data presented are based on 18 soil cores/treatment (two cores x three blocks x three times). Additional cores were taken along transects that run across logging trails.

RESULTS

Effects of Harvesting Treatments on the Numbers of Individuals Collected

Data collected in the first year postharvest do not show that harvesting had any significant effects on either the capture rate of carabids, or on the abundance of springtails. For the carabid fauna, means of 22.0, 13.8, and 16.6 individuals/block per 100 trap-nights were recorded for the uncut, partial cut, and clear-cut blocks, respectively (ANOVA $F = 3.86$, $P = 0.08$). The mean number of springtails/m^2 was 68 400 on the uncut sites, 52 900 on the partial cuts, and 53 600 on the clear-cuts (ANOVA $F = 0.801$, $P = 0.492$).

In contrast, the abundance of springtails in cores from transects taken across logging trails was dramatically influenced by the type of harvesting machinery used. The Timberjack 1270 single-grip harvester and forwarder left the organic mat (and its resident fauna) virtually undamaged, whereas drastic reductions in abundance were obvious even 2 years post-harvest on the logging trail made by the conventional feller-buncher and grapple-skidder (Fig. 1).

Effects of Harvesting on Species Diversity

For carabids, there was no evidence of a decline in the number of species on harvested blocks as compared with controls.

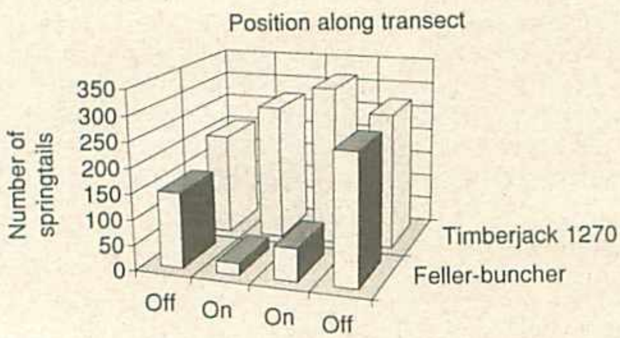

Figure 1. Abundance of springtails in soil cores taken in transects across logging trails in partial cuts, 2 years postharvest. Cores were taken at 2-m intervals, with the first and last cores obtained in the relatively undisturbed soil just off the trail.

If anything, there was a slight increase. Fewer species of springtails were recorded in cores taken from clear-cuts than in the uncut forest. There was an intermediate number in the partial cuts (Table 1).

Table 1. Effect of harvesting on the number of species of carabid beetles and springtails collected 1 year postharvest.

	Uncut control	Partial cut	Clear-cut
Carabid beetles	10	13	13
Springtails	37	34	28

The species diversity indices, N1 and N2 (Table 2), incorporate both the concept of species richness (number of species in the community) and that of species equitability (how the individuals are distributed among species). For both the carabids and the springtails (Table 2), there was a decline in the number of abundant species (N1), and in the number of very abundant species (N2) in the clear-cuts, as compared with the uncut controls. Values of these indices for carabids on partial cuts were intermediate between the uncut controls and the clear-cuts, but for springtails index values obtained for the partial cut fauna tended to approximate those of the uncut forest. Even though the total number of carabid species collected on the clear-cuts was higher than in the uncut forest, most of the species on the clear-cuts were not abundant and the fauna was dominated by a single species (*Pterostichus adstrictus* Eschscholtz). This change in the pattern of species abundance is shown clearly in the Evenness Index of species distribution (Table 2), which indicats a clear decline from the uncut forest, to the partial cut, to the clear-cut. This shift in the Evenness Index was not apparent in the springtail community.

DISCUSSION

While there were minimal (nonsignificant) effects of harvesting on either the numbers of carabids captured, or on the total numbers of springtails extracted, there were readily identifiable treatment effects on individual species and on community structure. The two groups of soil invertebrates responded somewhat differently to harvesting. The observed decline in the number of species of springtails inhabiting the clear-cuts, as compared with the partial cut or uncut stands, probably occurred because springtails, and other microfauna in general, are extremely sensitive to desiccation and have poorly developed dispersal capabilities. Thus, species unable to tolerate changed environmental conditions died out, and as immigration of replacement species is slow (Moldenke and Lattin 1990), the initial response to clear-cutting was a decrease in species richness. On the clear-cuts, even 2 years postharvest, there was still no evidence of the arrival of species adapted to clear-cut conditions.

Carabids are highly mobile, surface-active species with well developed dispersal capabilities. Therefore they are capable of a rapid response to changing environmental conditions, abandoning unfavorable habitats, and invading suitable locations. Overall, 1 year postharvest there were slightly

Table 2. Effect of harvesting on species diversity and evenness of carabid beetles and springtails, 1 year postharvest. Indices calculated after Ludwig and Reynolds (1988).

	Carabid beetles			Springtails		
	Uncut	Partial cut	Clear-cut	Uncut	Partial cut	Clear-cut
N1 ($e^{\text{Shannon's Index}}$)	7.25	5.88	5.02	11.53	11.03	7.78
N2 (1/Simpson's Index)	6.69	4.15	3.05	6.70	7.22	4.65
Evenness Index (N2-1)/(N1-1)	0.9106	0.6452	0.5098	0.5412	0.5649	0.5384

Shannon's Index:

$$\hat{H}' = -\sum_{i=1}^{s} [(\frac{n_i}{n}) \ln (\frac{n_i}{n})]$$

Simpson's Index:

$$\hat{\lambda} = \sum_{i=1}^{s} \frac{n_i(n_i - 1)}{n(n-1)}$$

where n_i is the number of individuals in the ith species and n is the total number of individuals for all S species in the sample.

more species collected on the harvested blocks than on the uncut controls. The partial cuts and clear-cuts each contained four species that were not captured on the controls, thereby suggesting that immigration was already taking place.

In both groups, an adjustment of the community is taking place as a result of harvesting. Changes are evident not only in the numbers of species occurring on the different treatments, but also in the evenness with which the individuals are distributed among these species. One year postharvest, species diversity of both carabids and springtails (as measured by N1 and N2) was lower in clear-cuts than in the uncut forest. In the carabid community a shift in dominance was already apparent 1 year postharvest. Values for partial cuts were generally intermediate between those of clear-cuts and the uncut forest blocks.

CONCLUSIONS

In designing forest management strategies in which consideration is given to conserving the natural diversity of the boreal mixedwood soil fauna, the following points should be considered.

Characteristics of the Soil Fauna of Boreal Mixedwoods

1. The soil fauna in the boreal mixedwood is very diverse. At present, because of a lack of understanding about the ways in which different species contribute to the functioning of the soil system, it is best to operate on the principle of retaining as much of the fauna as possible.

2. In boreal mixedwood soils, the overwhelming majority of the soil fauna is confined to the organic horizons. At the present study site, preharvest samples indicated only 2.3 percent of the Collembola were found below the organic/mineral soil interface.

3. Under natural conditions, the soil fauna of boreal forests must be able to adapt to major disturbances, such as drought and forest fires, so that some degree of tolerance to disturbance can be expected in the community.

4. Harvesting effects on soil invertebrates are expressed at the species level and may not be detected in studies that deal only at gross taxonomic levels.

MANAGEMENT IMPLICATIONS

1. *Use harvesting techniques that minimize damage to the soil.*

Although some degree of disturbance to the soil may be required during site preparation, soil compaction due to logging activities, and large-scale removal of the organic mat have been identified as major factors contributing to declines in forest productivity (Utzig and Walmsley 1988). In northern boreal forests, most of the nutrients and the bulk of the soil fauna are found in the organic mat.

2. *Regenerate boreal mixedwoods as mixed woods.*

There is growing scientific and political support for managing the boreal mixedwood resource as mixed species forests (MacDonald 1995). Mixed litters have been shown to increase invertebrate species diversity, enhance decomposition and nutrient release, and improve control of fungal diseases (Chapman et al.1988, Kessler 1990, Navratil et al.1991)

3. *Avoid creation of large areas with microclimatic extremes and provide refugia from which recolonisation of cut areas can occur.*

Many soil invertebrates are extremely sensitive to temperature and moisture extremes, conditions that are characteristic of large clear-cuts. Limiting the size of cut areas, use of partial cutting techniques, and the provision of refugia both at the landscape level (tracts of uncut forest) and within cut areas (coarse woody debris and areas of intact forest floor) will allow a diverse fauna of soil invertebrates to survive in managed forests.

LITERATURE CITED

Chapman, K.; Whittaker, J.B.; Heal, O.W. 1988. Metabolic and faunal activity in litters of tree mixtures compared with pure stands. Agric. Ecosystems Environ. 24:33–40.

Curl, E.A.; Lartey, R.; Peterson, C.M. 1988. Interactions between root pathogens and soil microarthropods. Agric. Ecosystems Environ. 24:249–261.

Duschesne, L.C.; McAlpine, R.S. 1993. Using carabid beetles (Coleoptera: Carabidae) as a means to investigate the effect of forestry practices on soil diversity. Forestry Canada, Petawawa National Forestry Institute, Chalk River, ON. Tech. Rep. 16. 10 p.

Kessler, K.J., Jr. 1990. Destruction of *Gnomia leptosyla* perithecia on *Juglans nigra* leaves by microarthropods associated with *Elagaenus umbellata* litter. Mycologia 82:387–390.

Ludwig, J.A.; Reynolds, J.F. 1988. Statistical ecology: A primer on methods and computing. John Wiley and Sons, Inc., New York, NY. 337 p.

MacDonald, G.B. 1995. The case for boreal mixedwood management: An Ontario perspective. For. Chron. 71:725–734.

Marshall, V.G. 1993. Sustainable forestry and soil fauna diversity. p. 239–248 *in* M.A. Fenger, E.H. Miller, J.A. Johnson and E.J.R. Williams, eds. Our Living Legacy. Royal British Columbia Museum, Victoria, BC. 392 p.

Maser, C. 1994. Sustainable forestry: Philosophy, science and economics. St. Lucie Press, Deleray Beach, FL. 373 p.

Moldenke, A.R.; Lattin, J.D. 1990. Dispersal characteristics of old-growth soil arthropods: The potential for loss of diversity and biological function. Northwest Env. J. 6:409–410.

Navratil, S.; Branter, K.; Zasada, J. 1991. Regeneration in the mixedwoods. p. 32–48 *in* A. Shortreid, ed. Northern Mixedwood '89. Proceedings of a Symposium. 12–14 September 1991, Fort John, British Columbia. For. Can., Victoria, BC. FRDA Report No. 164.

Pimentel, D.; Stachow, U.; Takacs, D.A.; Brubaker, H.W.; Dumas, A.R.; Meaney, J.J.; O'Neil, J.A.S.; Onsi, D.E.; Corzilius, D.B. 1992. Conserving biological diversity in agricultural/forestry systems. BioScience 42:354–362.

Rabatin, S.C.; Stinner, B.R. 1988. Indirect effects of interactions between VAM fungi and soil-inhabiting invertebrates in plant processes. Agric. Ecosystems Environ. 24:135–146.

Scarratt, J.B. 1996. Response to disturbance in boreal mixedwood ecosystems: The Black Sturgeon Boreal Mixedwood Project. Nat. Resour. Can., Canadian Forest Service–Sault Ste. Marie, Sault Ste. Marie, ON. NODA Note No. 19. 16 p.

Setälä, H.; Huhta, V. 1991. Soil fauna increase *Betula pendula* growth: Laboratory experiments with coniferous forest floor. Ecology 72:665–671.

Utzig, G.F.; Walmsley, M.E. 1988. Evaluation of soil degradation as a factor affecting forest productivity in British Columbia: A problem analysis. Can. For. Serv., Victoria, BC. FRDA Report No. 25.

Weseloh, R.M. 1985. Changes in population size, dispersal behavior, and reproduction of *Calosoma sycophanta* (Coleoptera: Carabidae), associated with changes in gypsy moth, *Lymantria dispar* (Lepidoptera: Lymantriidae), abundance. Environ. Entomol. 14:370–377.

Wilson, E.O. 1987. The little things that run the world. Conserv. Biol. 1(4):344–346.

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