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Edge effects and the responses of aerial insect assemblages to structural-retention harvesting in Canadian boreal peatland forests

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Abstract

Clear-cut harvesting can alter ecosystem conditions and dynamics drastically compared to natural disturbance regimes, hence alternative harvesting systems are being developed in an attempt to better mimic natural forest structure. A recent approach is to harvest trees at variable intensities and spatial configurations in what is known as variable retention harvesting. Our study examines the responses of aerial insect assemblages to a gradient of forest retention at the landscape scale, and provides an assessment of the conservation benefits of alternative versus traditional harvesting systems in lowland boreal forest. The experimental design consisted of six treatments representing decreasing levels of structural retention at the landscape scale (with four replicates per treatment): (1) unharvested forest interior; (2) unharvested forest edge; (3) high-structural retention (strip retention harvesting areas at the edge of adjacent areas of unharvested forest); (4) medium-structural retention (strip retention harvesting areas in the interior of contiguous retention harvesting areas); (5) low-structural retention (strip retention harvesting areas adjacent to clear-cutted areas); (6) clear-cut harvesting. Response variables were the abundances of selected families and trophic assemblages of aerial insects, which were sampled with Malaise traps at each site. Univariate and multivariate analyses showed that the structural-retention harvesting influenced the abundance of most families and trophic assemblages. Most insect families and assemblages were most abundant in the strip retention harvested areas, especially in the medium retention treatment. These increases in abundance reflected strong edge effects, as evidenced by the fact that significant treatment effects were observed even within the two major habitat types of the study (cleared or forested habitat). Increasing structural retention favoured some assemblages such as Diapriidae, herbivores, and parasitoids whereas other groups such as predators decreased in abundance. Results support the potential use of high-level taxonomic and trophic assemblages of aerial insects in monitoring the ecological sustainability of forest harvesting practices.

Keywords: Variable retention harvesting; Insects; Black spruce; Boreal forest; Clear-cutting

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1. Introduction

Although better understood for vertebrates than invertebrates, habitat fragmentation and change can strongly affect insect communities (Didham, 1997). Relative to most vertebrates, insects tend to utilize small areas and require narrow microhabitat conditions. Consequently, studies on changes within insect communities are of particular interest because of the potential influence of changes in microhabitat features, such as downed woody debris and canopy openings (Harris, 1984; Niemelä et al., 1993; Økland, 1994, 1996; Bader et al., 1995; Simard and Fryxell, 2003). In many recent approaches in insect conservation, the spatial arrangement of such microhabitats is a major consideration (Winchester and Ring, 1996; Didham, 1997; Tscharntke et al., 2002; Major et al., 2003; Bunnell and Huggard, 1999).

The effects of habitat alterations on insect communities also are of considerable interest given that insect functional assemblages, such as trophic groups, are involved in many of the critical processes that maintain forest ecosystems. Changes in these assemblages following habitat management may affect ecosystem function (Kruess and Tscharntke, 1994; see also Grime, 1997; Chapin et al., 2000; Loreau and Hector, 2001). An increasing number of studies have suggested that use of functional or/and higher-level taxonomic assemblages can aid in revealing information on the impacts of habitat change on insect taxa and functional groups and in directing future monitoring programs (Williams and Gaston, 1994; Malcolm, 1997; Katzourakis et al., 2001; Tscharntke et al., 2002; Bellocq and Smith, 2003). Although such studies will certainly benefit from research at the species level (Danks and Winchester, 2000), evidence of sensitivity to environmental perturbations at high taxonomic levels can define strategic directions with respect to ecological sustainability and serve as a focus for future assessment and monitoring without the time-consuming process of identifying insects to the species level (Williams and Gaston, 1994; Balmford et al., 1996a, 1996b). Here, we examine the responses of high-level taxa and trophic assemblages to different levels of forest retention in the boreal forests of northern Ontario.

The insect fauna of peatland boreal forests, one of Canada's most extensive forest types, has not yet been studied in detail (Danks and Foottit, 1989) and responses to logging are poorly understood. Most work examining the effects of forestry practices on arthropods in this ecosystem have focused on logging per se (Niemelä, 1997) rather than on comparisons of different harvesting techniques (Bird and Chatarpaul, 1986; Bellocq et al., 2001). Most of the Canadian boreal forest is managed using clear-cut silviculture, which initially results in the complete removal of the canopy over relatively large areas. Studies of the effects of clear-cut harvesting on arthropods have included studies of the soil and litter micro and macrofaunas (Bird and Chatarpaul, 1986; Niemelä et al., 1993; Paquin and Coderre, 1997; Duchesne et al., 1999; Bellocq et al., 2001). As yet, variable retention harvesting, which is an increasingly common harvesting method in the boreal forest (Bergeron and Harvey, 1997; Franklin et al., 1997), has received little attention.

After clear-cut logging at a site, certain microhabitat conditions of the original forest may take many decades or longer to re-appear. Thus, alternative harvesting systems are being developed in an attempt to maintain some of the existing natural structure of forests, especially the within-stand variability of boreal old-growth stands that show multi-cohort age structures (Bergeron and Harvey, 1997). A recent approach is to harvest trees at variable intensities and spatial configurations across the landscape in a technique known as Variable Retention Harvesting (Bergeron and Harvey, 1997; Franklin et al., 1997; Sullivan et al., 2001). For example, the Lake Abitibi Model Forest in northeastern Ontario has developed a variable retention harvesting method called harvesting with advance regeneration protection (HARP) that maintains the young trees (advanced regeneration) present in peatland black spruce forests (MacDonell and Groot, 1997). These operations clear trees in strips approximately 5–7 m wide, and remove trees from the adjacent retention rows (5–9 m wide) using a minimum diameter limit cut. The resulting harvested landscape contains retained strips of black spruce forest separated by cleared strips. Although the retention strips are thinned based on a tree diameter limit, which in some even-aged stands results in the removal of most canopy trees, the understory and substrate remain largely intact in the retention rows because of the lack of vehicular traffic and because