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Response of vegetation and birds to severe wind disturbance and salvage logging in a southern boreal forest

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ABSTRACT

Vegetation and birds were inventoried on the same plot before and after a severe windstorm in 1999 disturbed a mature black spruce (*Picea mariana*)–jack pine (*Pinus banksiana*) forest in northern Minnesota. Following the storm, another plot was established in an adjacent portion of the forest that was salvage-logged. Birds were inventoried on both plots through 2002. The original unsalvaged plot was prescribed-burned in 2004, but vegetation was surveyed through 2003, and through 2005 on the salvaged plot. We examined the effects of wind disturbance by comparing the pre-storm bird and vegetation communities with those developing afterwards through 2002 and 2003, respectively, and the effects of salvage logging by comparing vegetation and the bird community on the unsalvaged plot with those in the salvaged area. Wind reduced the canopy of the forest by over 90% with a temporary increase in the shrub layer, mostly resulting from tip-ups. Several plant species, including jack pine and beaked hazel (*Corylus americana*), appeared temporarily in the ground layer (<1 m height), but did not persist through 2003. Quaking aspen (*Populus tremuloides*) root sprouts were abundant in 2001, but decreased dramatically by 2003. Delayed mortality of tipped trees resulted in reduction of the shrub layer to pre-storm levels, and release of advanced regeneration black spruce and balsam fir (*Abies balsamea*). Bird species using the forest changed from dominance by canopy-foraging species to ground-brush foraging species, with an overall increase in bird diversity. Salvage logging resulted in significant reduction in coarse woody debris, and successful recruitment of jack pine seedlings. Quaking aspen sprouts were nearly 30 times more abundant in the salvage-logged area compared to the unsalvaged control. Ruderal species, especially red raspberry (*Rubus ideaus*), fringed bindweed (*Polygonum cilinode*), and several sedges (*Carex* spp.), were significantly more abundant after salvage logging. The bird community, on the other hand, was greatly diminished by salvage logging, with a reduction in diversity, density, and overall richness of species.

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1. Introduction

Recent controversy over the ecological effects of salvage logging (Donato et al., 2006; Stokstad, 2006), primarily concerning the effects on species composition of post-disturbance vegetation, suggests an incomplete understanding of how disturbances alter forest communities (Greene et al., 2006). There is, however, little disagreement that composition and structure in the southern boreal forest, where our study was conducted, reflect disturbance largely by fire, insect outbreaks, logging, and wind (Van Wagner and Methven, 1978; Bonan and Shugart, 1989; Bergeron, 1991; Heinselman, 1996; Drapeau et al., 2000; Burris and Haney, 2005). Although fire and spruce budworm (*Choristoneura fumiferana* Clemens) are the most prevalent natural disturbances in this region (Heinselman, 1996), large-scale wind events alter forest structure and composition at average return intervals of 1000 years or more (Frelich and Reich, 1996; Larson and Waldron, 2000; Schulte and Mladenoff, 2005). The risk of severe fire increases following wind disturbance, with a cumulative impact on the vegetation that may be greater than the independent effects of either fire or wind (Canham and Loucks, 1984). Timber salvage is often used to mitigate economic loss, and was widely assumed to reduce the risk of fire (Holtam, 1971), a generalization that was recently challenged (Donato et al., 2006).

During the past 100 years, disturbance from timber harvesting in northeastern Minnesota has equaled or exceeded natural

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disturbances (Heinselman, 1996). There have been several studies comparing effects of fire and logging disturbance on plant and avian communities (Reich et al., 2001; Schulte and Niemi, 1998), but we know of no studies that examined effects of salvage logging after severe wind disturbance in the region.

Infrequent, large-scale wind disturbance is an important factor in forests of the Upper Midwest (Canham and Loucks, 1984; Peterson, 2000; Lorimer, 2001) although little has been reported on the early stages of vegetation reorganization after such storms (Dyer and Baird, 1997; Cooper-Ellis et al., 1999; Frelich, 2002). Most studies of wind disturbance effects on vegetation are in tropical and temperate hardwood forests (Everham and Brokaw, 1996). Spurr (1956) and Merrens and Peart (1992) suggested that severe windthrow and clear-cutting had similar effects on vegetation in temperate hardwood forest communities. Although salvage logging after severe wind disturbance is arguably similar to clear-cutting, the effects of either in a conifer-dominated forest is likely different than in a hardwood forest. The only known comparison of the same forest before and after severe wind disturbance was Whitmore's (1989) study in the rain forest of the Solomon Islands and our studies in northeastern Minnesota (Burris and Haney, 2005, 2006). Our studies were unique in examining bird communities before and after wind disturbance in a southern boreal forest where we found that destruction of over 90% of the canopy resulted in little overall change in avian diversity, density, or energy consumption three years before the storm compared to three years afterwards, but there was a nearly complete change in species composition.

Disturbances can affect availability of many specific resources (Bazzaz, 1983), but also the balance or congruence of resources, all of which can favor different sets of species (Carlten, 1998; Bazzaz, 1996). Natural disturbances generally increase patchiness, which should favor diversity at a landscape scale even as small as a few hectares (gamma diversity) (Denslow, 1985; Drapeau et al., 2000), but not necessarily at a scale more comparable to passerine bird territories (alpha diversity) (Haney et al., unpublished data, Herrando et al., 2003). However, large changes in habitat structure result in nearly complete change in avian species composition (Burris and Haney, 2005, 2006). Recruitment of plant species following blowdown likely reflects microplot characteristics (Webb, 1988; Bazzaz, 1996; Carlten, 1998; Elliott et al., 2002), whereas responses of birds reflect both habitat structure and patchiness (Herrando et al., 2003; Burris and Haney, 2005, 2006). Severe wind disturbance alters both.

Cooper-Ellis et al. (1999) concluded that salvage logging of New England hardwoods following wind could have long-term effects on tree species composition. Greenburg et al. (1995) found that most native species in fire-maintained Florida scrub forests responded similarly to fire followed by salvage logging as they did to clear-cutting, and cautiously concluded that effects of clear-cutting in ecosystems adapted to frequent high intensity disturbance would be similar to natural disturbances. Greene et al. (2006) and Donato et al. (2006), however, reported poorer recruitment of conifer trees on post-fire salvaged plots.

Because vegetation structure as well as patchiness and microplot characteristics likely will be differently affected by different disturbances, including salvage logging (Elliott et al., 2002; Johnson et al., 2005), and vary according to pre-disturbance characteristics (Baker, 2002), it is not surprising that there have been contrasting conclusions. Moreover, response to disturbance is species specific (Greene et al., 2006; McIver and Starr, 2001; Dunn et al., 1983) and, therefore, would be expected to vary from one region or cover type to another.

In this paper, we document changes in the structure and composition of vegetation associated with wind disturbance and salvage logging in a northeastern Minnesota forest, and examine the response of the bird communities.

2. Methods

On 4 July 1999 a microburst swept across northeastern Minnesota, producing heavy rains and straight-line winds in excess of 90 miles (145 km) per hour, impacting approximately 200,000 ha (USDA Forest Service, 2002). Fortuitously, we had thoroughly inventoried vegetation and birds in spring 1997 in a permanent plot in a mature black spruce (*Picea mariana*) – jack pine (*Pinus banksiana*) forest near the middle of the storm track, and re-surveyed the birds on the same plot in 1998 and 1999, thereby providing an uncommon baseline from which to evaluate changes in structure and composition of the vegetation and associated birds (Burris and Haney, 2006). In 2001, when the plot was re-surveyed, we extended our study to include a permanent plot in an adjacent area that was salvaged-logged in 2000. We compared the structure and floristic composition and birds in 2001 in the unsalvaged plot to the pre-disturbance vegetation in 1997, and the average of birds using the forest plot in 1997, 1998 and 1999. We also compared the 2001 bird data to inventories the following year, and 2001 vegetation data to data from 2003 in both the unsalvaged and salvaged plots. The control area was prescribed-burned in 2004, thereby truncating our study, although we re-surveyed the vegetation on the salvaged plot again in 2005.

The study area was located in the Superior National Forest, Minnesota, USA, in a relatively homogeneous, mature, upland black spruce–jack pine forest that originated following a 1903 wildfire (Heinselman, 1977). We established the initial 6.25 ha permanent bird plot within the forest on a 10–20% west facing slope, with 25 m buffers between the spruce–pine forest and surrounding wetlands. Location was chosen to represent the cover type within the most homogeneous area we could find. Post-disturbance data from the unsalvaged plot were collected from the same plot as the pre-storm data. The salvage-logged plot was immediately adjacent, separated by a 100 m buffer. It had the same slope, aspect, and disturbance history, and qualitative examination of broken and tipped trees indicated that the cover type was the same as the unsalvaged plot prior to the storm.

For purposes of bird surveys, we divided the 6.25 ha plot into a 5×5 grid with 50 m $\times$ 50 m cells (Fig. 1). Flagging was hung at the corners of each cell so that we could easily determine our location within the plot. Birds were surveyed from dawn to mid-morning during the last week of May and first two weeks of June using the same methods previously reported (Apfelbaum and Haney, 1981; Burris and Haney, 2005, 2006; Haney et al., 2008). All birds seen or heard inside as well as within 25 m of the outside of the grid were plotted, providing a survey area of 9 ha. Each census averaged a minimum of 5–6 person hours. Inventory of birds involved censusing the area five times, usually spread over two or more weeks. Censuses were conducted only on days without significant wind or rain.

Vegetation sampling was done within the bird grid in order to relate bird and vegetation data. Samples consisted of 10, randomly located, 50 m transects within each treatment year. Permanent transects were not used, and random samples were taken each year. Tree and shrub cover for each species was estimated using the line intercept method. Trees were defined as stems standing $>45^{\circ}$ relative to the ground and diameter breast height (dbh) >5 cm. Shrubs/small trees were identified as stems >1 m in height and <5 cm dbh, or those trees that were still alive but tipped to $<45^{\circ}$ relative to the ground. Cover of each ground-layer (vegetation <1 m tall) species was estimated by five 1 m^2 quadrats centered at 5, 15, 25, 35, and 45 m along the transect line. Within the ground-