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Bioenergy or biodiversity? Woody debris structures and maintenance of red-backed voles on clearcuts

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ABSTRACT

Wood residues from forest harvesting or disturbance wood from wildfire and insect outbreaks may be viewed as biomass “feedstocks” for bioenergy production, to help reduce our dependence on fossil fuels. Biomass removals of woody debris may have potential impacts on forest biodiversity and ecosystem function. Forest-floor small mammals, such as the southern red-backed vole (*Myodes gapperi*) that typically disappear after clearcut harvesting, may serve as ecological indicators of significant change in forest structure and function. We tested the hypothesis that large piles and windrows of woody debris would enhance the population dynamics (abundance, reproduction, and survival) of *M. gapperi*, compared with a dispersed treatment on clearcut sites. We also investigated the trade-offs in values and functions between the apparently competing uses of bioenergy or biodiversity. Red-backed voles were intensively live-trapped from 2007 to 2009 in replicated woody debris treatments of dispersed, piles, windrows, and uncut mature forest at each of two study areas in south-central British Columbia, Canada. Our hypothesis was supported, at least on sites with substantial woody debris structures. Here we show, for the first time, that constructed piles and windrows of woody debris maintain habitat for red-backed voles, and presumably some components of biodiversity, on clearcuts. Woody debris from harvested sites can be used for bioenergy production, but this depends on the interplay between volume, transportation distance, plant capacity, and electricity price. These variables define the economic value of woody debris and we feel this is an indirect expression of the value of biodiversity. The response of policy makers will reflect how we prioritize the challenge of managing biodiversity as we develop new sources of renewable energy.

1. Introduction

Coarse woody debris (CWD) on the floor of coniferous forests provides many important components such as wildlife habitat [1], reserves of nutrients and water [2], as well as microsites and substrates for seedlings [3] and other organisms such as various saprobic and mycorrhizal fungi [4]. These attributes of woody debris have major roles in ecosystem function and are essential

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to maintenance of forest biodiversity and long-term productivity [2,5,6]. Woody debris is created by natural and anthropogenic disturbances and may affect ecosystem response to disturbance, particularly the timing and severity of wildfire and insect outbreaks [7]. It is this role in disturbance regimes, and our utilitarian outlook, that has generated a definition of woody debris as "wood waste," particularly the residue (slash) occurring after conventional and salvage harvesting of forests [8].

Wood residues from forest harvesting or disturbance wood from insect outbreaks, such as the mountain pine beetle (MPB), *Dendroctonus ponderosae* Hopkins, outbreak in British Columbia (BC), Canada, are viewed by some to be biomass "feedstocks" for bioenergy production in North American and European forestry sectors [9]. Indeed, bioethanol from lignocelluloses does not impinge on food production chains and could reduce our dependence on petroleum-based energy sources and their consequent release of greenhouse gases [9,10]. Most concern about forest biomass removals has concentrated on the impacts on site productivity, particularly soil nutrient reserves and tree nutrition and growth [10]. Potential impacts on biodiversity, and hence ecosystem function, from biomass removals of woody debris should be central to policy development but there is little quantitative information available [8,11,12]. Thus, there is a possible conflict between competing uses for woody debris for biodiversity conservation and energy generation.

On the forest floor, communities of small mammals may serve as ecological indicators of significant change in forest structure and function [13]. These terrestrial mammals are widespread across temperate and boreal forest ecosystems and have a variety of functions, including prey for many predators [14], distribution of beneficial mycorrhizal fungi [15], and consumers of plants, plant products [16], and invertebrates [17]. The southern red-backed vole (*Myodes gapperi*), in particular, is an important indicator species of "old forest conditions" [18,19]. This microtine commonly inhabits late successional coniferous and deciduous forests across temperate and boreal North America [20], and hence is a good candidate species for evaluation of the development of "old forest" structural attributes in young stands. The presence of red-backed vole populations at mature or old-growth "forest" levels of abundance suggests that networks of food sources and predators are also present as components of biodiversity.

Clearcutting of forests remains the dominant silvicultural system in much of North America and northern Europe. Studies in coniferous and mixed coniferous-deciduous forests reported dramatic declines of *M. gapperi* on clearcuts [21–23], but not necessarily in deciduous forests in the eastern part of the continent [24]. This pattern of red-backed vole responses might be related to the more humid microclimates associated with deciduous than coniferous forests, a likely requirement of red-backed voles [24]. Populations of *M. gapperi* have been maintained, up to 3 years post-harvest, in western coniferous forests that have partial cutting systems [23,25,26]. Although these partial cutting results are encouraging for maintenance of *M. gapperi*, clearcutting still dominates as a harvesting system, even with some degree of green-tree retention (GTR). Thus, is there a habitat management tool that might ameliorate the negative impact of clearcutting on *M. gapperi*? This is particularly relevant in those areas where large-scale salvage harvesting is done in response to wildfire and insect outbreaks [27].

Some studies indicate that red-backed voles seem to select forest sites with large amounts of woody debris that moderate moisture, temperature, and cover for foraging [28–30]. Enhancement of woody debris may help retain moisture on drier sites and perhaps mitigate micro-habitat changes resulting from clearcutting [14]. However, other studies did not support this relationship, reported mixed results, or were less clear about the role of factors such as vegetation cover, ecosystem, climate, seral stage, and scale of investigation that may interact with woody debris and small mammals [31–33]. In particular, experimental manipulations of woody debris at a real-world scale that includes extremes in amounts and configurations of debris are wholly absent. Such investigations are needed to determine the interaction between these two uses of post-harvest woody debris for forest biodiversity and the expanding bioenergy market. Thus, we tested the hypothesis that woody debris arranged in treatments of large piles and windrows, at a real-world scale, would enhance the population dynamics of *M. gapperi*, compared with a dispersed (conventional) treatment on clearcut sites. A second major objective was an economic analysis of woody debris removal for bioenergy to investigate the trade-offs in values and functions between these apparently competing forest uses of bioenergy or biodiversity.

2. Methods

2.1. Study areas

Two study areas were located in south-central BC, Canada: (i) the Aberdeen Plateau (50°09′ N; 119°12′W) 22 km southeast of Vernon; and (ii) Summerland (49°40′N; 119°53′W) in the Bald Range 25 km west of Summerland. Both areas are in the upper Interior Douglas-fir (IDF_{dk}) and Montane Spruce (MS_{dm}) biogeoclimatic subzones [34]. Topography in all areas was rolling hills at 1125–1520 m elevation. The upper IDF and MS have a cool, continental climate with cold winters and moderately short, warm summers. The average temperature is below 0 °C for 2–5 months, and above 10 °C for 2–5 months, with mean annual precipitation ranging from 30 to 90 cm. Open to closed mature forests of Douglas-fir (*Pseudotsuga menziesii*) cover much of the IDF zone, with even-aged post-fire lodgepole pine (*Pinus contorta* var. *latifolia*) stands at higher elevations. Hybrid interior spruce (*Picea glauca* × *Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) are the dominant shade-tolerant climax trees. Trembling aspen (*Populus tremuloides*) is a common seral species and black cottonwood (*Populus trichocarpa*) occurs on some moist sites [34].

Prior to harvesting, study stands were composed of a mixture of lodgepole pine with variable amounts of Douglas-fir, interior spruce, and subalpine fir. Average ages of lodgepole pine ranged from 80 to 120 years and for Douglas-fir and other conifers ranged from 120 to 220 years. Average tree heights ranged from 10.5 to 19.5 m for lodgepole pine and from 16.7 to 27.5 m for Douglas-fir and other conifer species.

2.2. Experimental design

Each study area had a randomized complete block design with 3 replicates each of: (i) CWD dispersed uniformly over each site (control); (ii) CWD distributed into several piles (average of