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Effects of even-aged and uneven-aged timber management on dung beetle community attributes in a Missouri Ozark forest

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ABSTRACT

The goal of this study was to estimate the effects of even-aged, uneven-aged and no-harvest forest management on dung beetle community attributes at both landscape and local (either closed or open canopy within treatments) scales. We collected a total 2579 individuals of Scarabaeoidea with 72 baited pitfall traps in the Missouri Ozark Forest Ecosystem Project throughout the summer of 2003. Six species accounted for 81% of all individuals collected, with community composition changing over the summer. At the landscape scale, the effects of treatments on overall abundance and abundance of individual species varied geographically, with forest thinning reducing abundance compared to clear-cutting forest stands and no harvest but in only one of the three blocks. The effects were also dung beetle species-specific, as there were unique responses of abundances of individual beetle species to the treatments. Five species (*Ateuchus histeroides*, *Deltochilum gibbosum*, *Onthophagus pennsylvanicus*, *O. taurus*, and *O. tuberculifrons*) were affected by forest thinning. In contrast, at the local scale, canopy opening (through timber harvesting and natural tree falls) increased expected (rarefied) species richness. Ordination showed that community composition was uniquely different among the six harvest treatments by canopy openness combinations. Together these results demonstrate that timber extraction from a temperate forest ecosystem influenced community composition of dung beetles at the landscape level, but this impact varied with cutting treatment, geographically, and by dung beetle species.

1. Introduction

Past forestry practices have decreased biodiversity and soil fertility, increased habitat loss and erosion, all ultimately compromising ecosystem functions. Resulting scientific and societal concerns have driven the current search for alternative timber management strategies (Alverson et al., 1994; Christensen et al., 1996; Loreau et al., 2001; Matveinen-Huju et al., 2006). In response, federal and local land management agencies have developed projects that investigate how different forestry techniques affect both long-term timber production and maintenance of biological diversity. The ultimate goal is to find an informed, contextual, and adaptive middle-ground between commodity production and maintenance of ecosystem integrity (Grumbine, 1997; Rauscher, 1999; Gram et al., 2001).

The Missouri Ozark Forest Ecosystem Project (MOFEP), a long-term (300 years), multi-investigator, landscape-level, manipulative experiment, is one such project. The goal of MOFEP is to compare the impact of three timber management strategies, uneven-aged cutting, even-aged cutting, and no harvest, on multiple taxa and multiple environmental variables, and in turn their effect on ecosystem functions and processes (Gram et al., 2001; Kabrick et al., 2004).

One as yet unstudied arthropod taxon in the MOFEP system in particular, and in temperate forest ecosystems in general, is the Scarabaeoidea (dung beetles). Despite numerous studies that document the natural history and ecology of dung beetles, particularly for Europe and the tropics, there are no published studies of the effects of forest management on these beetles in north temperate forests. This lack of knowledge is surprising given the important role of dung beetles in ecosystem functioning and integrity. By burying mammal dung and carrion, dung beetles increase the rate of decomposition of these materials, as well as enhance local nutrient cycling and soil aeration (Halffter and Mathews, 1966; Mittal, 1993). They also aid in the biological control of parasitic flies and nematodes that breed in dung (Bergstrom et al., 1976; Hanski and Cambefort, 1991; Gronvold et al., 1992). As alternative timber harvesting methods become more common, understanding how these harvesting approaches affect dung beetle community attributes (e.g., abundance,

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distribution and diversity) is warranted; dung beetles are strongly influenced by vegetation cover and soil characteristics, both of which are altered by tree removal (Nealis, 1977; Klein, 1989; Vessby, 2001).

The goal of the present study was to characterize the response of the Missouri Ozark dung beetle community to uneven and even-aged management strategies at both the landscape and local level. We assessed these impacts in terms of abundance, species richness, diversity, and community composition. We tested for effects at the landscape level by comparing response variables among landscapes subjected to different harvest regimes. In turn, we tested for a local effect of harvesting by comparing response variables for locations adjacent to harvest or not (and in the case of the no harvest treatment, to the disturbance of tree falls). We also sampled across the season to document seasonal changes in abundance of the individual species. We predicted that at the landscape level, uneven-aged management would cause a greater short-term reduction in dung beetle species richness and density in the remaining forest matrix than even-aged management. Uneven-aged management disturbs a greater amount of forest to harvest an equal amount of timber and it generates forest stands with less dense overstories. At the local level, however, we expected that clear-cuts in even-aged management would show the greatest decline in richness and density of dung beetles, and greatest change in community structure relative to unlogged stands than either single tree extractions (uneven-aged management) or treefall gaps (no harvest sites). Both hypotheses presume, in the absence of any published habitat preference data, that most or all species to be encountered would be closed canopy specialists.

2. Methods

2.1. Site description

The MOFEP study area (Fig. 1) is located in Shannon, Reynolds, and Carter Counties in southeastern Missouri within the Current River Hills Subsection of the Ozark Highlands (Kabrick et al., 2000b). Several rivers (Current, Jacks Fork, Eleven-Point, and Black) dissect the landscape creating a mix of broad and narrow ridges flanked by steep slopes (Loreau et al., 2001; Grabner and Zenner, 2002). The forests of this area are primarily oak–hickory and oak–pine communities (Kurzejeski et al., 1993), and the landscape is 84% forested (Brookshire et al., 1997). Prior to 1880 these forests were dominated by *Pinus echinata* and oak savannas (Batek et al., 1999; Gram et al., 2001). Changes in natural fire schedules (i.e., suppression) and fire intensity have contributed to the establishment of the relatively homogeneous oak–hickory community currently occurring at MOFEP (Grabner and Zenner, 2002; Guyette and Kabrick, 2002). Currently, there is limited cattle and horse grazing, both restricted to valleys of large watersheds.

2.2. MOFEP harvest treatments

The MOFEP experimental design consists of nine treatment sites ranging in size from 314 to 516 ha. Three timber management treatments were organized into three blocks, so that each block randomly received one each of the uneven-aged management, even-aged management, and no harvest management treatments (Fig. 1). Sites are divided into stands approximately 4 ha in area and defined by slope aspect, soil type, and vegetation composition. The number of stands per site ranged from 44 to 82. Sites 1–3 constitute block 1, sites 4–6 block 2, and sites 7–9 block 3.

In all uneven-aged management and even-aged management sites, 10% of the site was designated as old growth and not cut for the duration of the project. In the remaining stands, uneven-aged management and even-aged management harvests were applied to achieve the target size class distribution set by the MDC Forest Land Management Guidelines (10% seedlings, 20% trees 6–14 cm diameter at breast height (dbh), 30% Trees 14–29 cm dbh, and 40% saw timber >29 cm dbh) (Brookshire et al., 1997). The harvest treatments will be rotated among stands within the treatment sites every fifteen years (Kurzejeski et al., 1993). The first round of timber extraction in the MOFEP sites took place from May to October 1996.

Two harvest types were employed in the even-aged management sites, clear-cuts and intermediate-cuts. Clear-cut harvests completely remove canopy cover while an intermediate cut, also called thinning, removes some mature trees and undesirable immature saw timber and poles but does not completely clear-cut the stand. In the first round of timber extraction approximately 130 ha were harvested from clear-cut stands and 166 ha were thinned, with the size of each clear-cut stand averaging 5 ha, while the thinned stands averaged three hectares at each site. This schedule of harvests yielded a tree volume of 5.7×10^3 m^3 and a tree size class distribution consistent with the MDC Forest Land Management Guidelines described above (Kabrick et al., 2002).

Uneven-aged management also followed the MDC Forest Land Management Guidelines and included both single tree selection and group selection (21–43 m diameter cuts) for timber harvest and regeneration. The area treated with group selection was approximately 5% of the total area harvested in the uneven-aged management sites (Sheriff, 2002). Uneven-aged management removed greater timber volume overall, 8.0×10^3 m^3 board feet, than even-aged management (Kabrick et al., 2002).

2.3. Beetle sampling

The experimental design was a split-plot, repeated measures design, with canopy type (open vs. closed canopy) nested within harvest regime (no harvest, uneven-aged management, and even-aged management). We used 72 pitfall traps baited with approximately half a tablespoon of fresh human dung to assess dung beetle abundance. We established eight traps per site, with four in open canopy areas, and four in closed canopy forest. In even-aged management sites, we considered clear-cuts as open canopy sites; we placed traps 3–5 m into a clear-cut from its edge, where vegetation was the most open. Regrowth was extensive further into clear-cuts, so edges often had the most open canopy at the time of sampling. In uneven-aged management sites, open canopy traps were in areas thinned (single-tree selection). In no harvest sites, open canopy traps were placed in natural tree fall gaps. We placed closed canopy traps in untreated areas of even-aged management and uneven-aged management, or in the no harvest sites, in areas where no gaps were present. All closed canopy sites were a minimum of ca. 400 m from open canopy sites, and trap locations within a canopy type at a site were 100–200 m from each other. As a result, multiple light gaps were sampled in no harvest sites.

We randomly chose sampling locations from a list of MOFEP vegetation plots (Shifley et al., 2000) that were no more than a 30 min walk from the closest road access. For each vegetation plot selected, we took a random compass bearing from the middle of the plot and then set a single trap just outside the plot to avoid disturbing the permanent vegetation plot. We used a spherical densiometer (Lemmon, 1956) to estimate canopy cover above each trap.

Traps consisted of deli plastic containers (±10 cm deep and 11.5 cm in diameter filled with ca. 150 ml of 70% EtOH as a killing and preserving agent) set flush with the ground, a plastic spoon to hold the bait over the cup, and a plastic plate to prevent rain and debris