

Patterns in spatial extent of gap influence on understory plant communities

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Abstract

Gap formation in forests can have impacts on forest ecosystems beyond the physical boundary of the canopy opening. The extent of gap influence may affect responses of many components of forest ecosystems to gap formation on stand and landscape scales. In this study, spatial extent of gap influence on understory plant communities was investigated in and around 0.1 and 0.4 ha harvested canopy gaps in four young Douglas-fir (*Pseudotsuga menziesii*) dominated stands in western Oregon. In larger gaps, the influence of gap creation on understory plant communities in surrounding forests was minimal. The area showing evidence of gap influence extended a maximum of 2 m beyond the edge of the canopy opening, suggesting that the area affected by gap creation did not differ greatly from the area of physical canopy removal. In smaller gaps, influence of the gap did not extend to the edge of the canopy opening. In fact, the area in which understory vegetation was influenced by gap creation was smaller than the physical canopy opening. Gap influence appears to be limited to areas where ruderal or competitor species are able to replace stress-tolerator species, likely due to elimination or reduction of these species by physical disturbance or competition. The limited gap influence extent exhibited here indicates that gap creation may not have a significant effect on understory plant communities beyond the physical canopy opening. This suggests a limited effectiveness of gaps, especially smaller gaps, as a tool for management of understory plant diversity, and perhaps biodiversity in general, on a larger scale.

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1. Introduction

Canopy gaps have long been seen as an important component of forested ecosystems (Watt, 1925, 1947; Bormann and Likens, 1979; Spies et al., 1990). Recently, creation of gaps has become a focus of managers attempting to emulate natural disturbance regimes (Runkle, 1991; Coates and Burton, 1997; Franklin et al., 2002). Canopy gaps are often considered in silvicultural prescriptions designed to produce and maintain late-successional habitat features in young forests (Hunter, 1993; Cissel et al., 2006; Davis et al., 2007). As a management tool, gap creation is aimed at increasing habitat heterogeneity and stand structural complexity (Runkle, 1991; Coates and Burton, 1997; Davis et al., 2007), both of which are often

associated with late-successional habitat conditions (Franklin et al., 2002; Muir et al., 2002).

The effects of gap formation on forest processes within the gap area (*sensu* Runkle, 1982), such as tree regeneration, stand structural development, and dynamics of the understory layer have been well documented (Canham and Marks, 1985; Collins and Pickett, 1988b; Spies et al., 1990; York et al., 2004). However, gap influence is not always limited to the physical canopy opening (Canham et al., 1990; Van Pelt and Franklin, 1999, 2000; Gray et al., 2002), and the extent of gap influence on the surrounding forest is less well understood (Coates et al., 1997; Menard et al., 2002). Research aimed at quantifying gap influence extent has focused on overstory tree responses (Payette et al., 1990), regeneration responses (Kobe, 1999; York et al., 2003; York et al., 2004), and modeling of tree growth and regeneration (Dube et al., 2001; Menard et al., 2002). Gap influence extent may vary widely depending on the parameter measured (Dube et al., 2001). Therefore, delineating the areal extent of gap influence in relation to aspects of biodiversity requires an ecologically integrative measure.

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Variation in understory plant communities may be a useful tool in quantifying gap influence extent and may be a good indicator of overall response of biodiversity to gap creation. Gap responses in understory plant communities may differ greatly from those of the overstory, especially in temperate forests where the understory is much more diverse and exhibits greater niche specialization (Gilliam, 2007). Due to this disparity, small-scale responses of species composition to gap formation in temperate forests are easier to quantify in understories than overstories, and variation in understory species composition may be useful in delineating areas influenced by gap creation. The understory also provides important habitat for other taxa in forest ecosystems and may be a good indicator of biodiversity in general (Hayes et al., 1997).

Utilizing characteristics of understory plants, for example classifying the understory community into functional groups, may further aid in detection of gap influence. Functional groups based on plant strategies such as those of Grime (1977), may be especially informative in this type of analysis. Grime advocates three strategies that have evolved in response to combinations of stress and disturbance intensity: (1) competitor species (adapted to low stress and low levels of disturbance), (2) ruderal species (adapted to low stress and high levels of disturbance), and (3) stress-tolerator species (adapted to high stress and low levels of disturbance). In forest understory plants, stress is most likely to be manifested in low availability of light and other resources under a closed canopy (Grime, 1977), and high intensity natural disturbance in these forests is primarily related to wildfire (Franklin et al., 2002). These functional groups are likely to be useful in highlighting the mechanisms responsible for understory community response to gap creation. In addition, investigating distributions of individual species may be instructive, especially for species known to be indicative of disturbed conditions (Halpern, 1989).

One approach to quantifying gap influence extent based on biotic responses is to treat gap influence as an edge effect emanating from the gap edge into the surrounding forest. Determination of depth of edge influence (DEI) in forests has received a great deal of attention (Chen et al., 1992, 1995; Cadenasso et al., 2003; Harper et al., 2005), and has an established methodology (Harper and Macdonald, 2001; Toms

and Lesperance, 2003). Response parameters investigated in DEI studies include: microclimate (Chen et al., 1995), tree mortality (Chen et al., 1992), tree growth (Chen et al., 1992; Laurance et al., 1998; McDonald and Urban, 2004), tree species distributions (Wales, 1972), tree regeneration (Chen et al., 1992), and understory vegetation (Fraver, 1994; Euskirchen et al., 2001; Harper and Macdonald, 2002b; Honnay et al., 2002). Although studies of edge influence have generally focused on edges resulting from large, natural or anthropogenic disturbances (e.g., clearcuts, old fields), methods developed for these purposes are also applicable to investigation of edges resulting from smaller forest canopy gaps.

The objective of this study was to better understand mechanisms that drive understory vegetation response, and the spatial extent of this response, to gap formation in managed forests. To accomplish this objective we (1) investigated the impact of gap creation on various components of the understory plant community and (2) determined the spatial extent and patterns of gap influence on the same components. To achieve these goals, we quantified depth of gap influence (DGI) on understory plant species composition, species diversity, functional group abundance, and the abundance of gap-indicator species. We estimated DGI separately for north and south facing gap edges and compared between two gap sizes.

2. Methods

2.1. Site descriptions

This research was conducted as a component of the Density Management Study (DMS), an ongoing investigation of the effectiveness of thinning treatments in fostering development of late-successional habitat features in young Douglas-fir forests. We focused on four DMS sites located in western Oregon, three in the Coast Range ecoregion (Omernick, 1987): Bottomline (BL), OM Hubbard (OMH), and North Soup (NS), and one in the Cascade Foothills ecoregion: Keel Mountain (KM). All study stands were even-aged and dominated by 40–70-year-old Douglas-fir (*Pseudotsuga menziesii*) in a single canopy layer. One site (KM) had a minor western hemlock (*Tsuga heterophylla*) component. Sites spanned a variety of

Table 1
Characteristics of DMS sites used in gap influence study

	Bottomline	Keel Mountain	North Soup	OM Hubbard
Latitude (N)	43°46'20"	44°31'41"	43°33'57"	43°17'30"
Longitude (W)	123°14'11"	122°37'55"	123°46'38"	123°35'00"
Elevation (m)	236–369	659–768	159–411	394–783
Aspect	NW-NE	SW-NW	NW-N	NE-N
Slope (%)	0–30	0–30	0–60	30–60
Annual precipitation (cm)	127	165	216	178
Logging method	Cable yard	Cable/ground	Cable yard	Tractor/cable
Treatment date (month/year)	7–11/1997	7/1997–9/1998	8/1998–9/1999	7–11/1997
Soil texture	Clay loam	Loam	Clay loam	Loam/clay
Stand age (years)	~65	~50	>50	~45–50
Mineral soil cover (%)	1.1	0.9	3.0	4.9
Site index (50 year)	138	127	132	120

For more detail see (Cissel et al., 2006).

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