ECOLOGICAL IMPLICATIONS OF SNOW AVALANCHES

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Snow avalanches hold great importance for people who live and work in mountainous locations. Every winter, snow avalanches result in extensive property damage, interrupt transportation corridors and harm people (McClung and Shaerer 1993). As a consequence, much research has been devoted to understanding mountain weather and climate, properties of the mountain snowpack, terrain characteristics and avalanche mechanics and dynamics. This information has allowed snow scientists and avalanche professionals to develop and employ a variety of tools and strategies for avalanche forecasting, protection, land use planning, and education.

Because snow avalanches commonly disturb alpine and subalpine ecosystems, they also have broad ecological implications. Snow avalanche disturbance in conjunction with local topography often determines the distribution and assemblages and successional stage of plant species in avalanche paths (Smith 1974; Butler 1979; Malanson and Butler 1984; Butler 1985). Grasses, herbaceous plants and shrubs typically occupy the inner portion of avalanche paths frequently disturbed by small avalanches and where snow deposition retards plant growth (Smith 1974; Cushman 1976; Butler 1979; Malanson and Butler 1984). Deer, elk and other ungulates benefit from the diverse and nutritious forage these plant communities provide (Krajick 1998). Stands of small trees and shrubs become established toward the flanks of paths where avalanche return intervals average approximately 5 years (Malanson and Butler 1984). Increasingly older deciduous trees and conifers comprise the margins and trim lines of avalanche paths that experience less frequent avalanching (Malanson and Butler 1984).

Rarely, unique combinations of weather, terrain and the mountain snow pack result in major avalanches and/or widespread avalanche cycles. These events may be attributed to the development of unusually unstable snow structures when continental-like climate patterns prevail, or occur during winters characterized by heavy seasonal snowfall, or rain (Roch 1949; LaChapelle 1966; Armstrong and Armstrong 1987; Mock and Kay 1992; Changnon 1993; Mock and Birkland 2000; Birkland and Mock 2001; Hebertson and Jenkins 2004). Major avalanches often cause extensive damage to forests adjacent to avalanche paths. Stress caused by stem breakage, wounds and severe root system disruption predispose injured trees to attack by insects and decay fungi (Cobb 1989; Wargo and

Harrington 1991). Dead, broken and uprooted trees may contribute to local fuel loads and increased fire hazard (Taylor and Fonda 1990). The production of downed woody materials, however, also benefits many terrestrial animal species by providing food, shelter, hiding cover and breeding habitat (Dueser and Shugart 1978; Bartels et al. 1985; Hecnar 1994; Butts 1997; Krajick 1998; Ruggiero et al. 1998). Wounds on trees damaged by avalanches can serve as entry courts for decay fungi that over time create cavities important for nesting birds (Miller et al. 1979). The deposition of woody avalanche debris in streams stabilizes channels and creates pools that enhance habitat for fish and other water-dwelling species (Bilby and Likens 1980; Dudley and Anderson 1982; Sedell et al. 1988). Conversely, the rupture of debris jams can also scour stream channels destroying critical spawning habitat (Sedell et al. 1988). Downed woody material prevents erosion from wind, rain and melting snow and facilitates the regeneration of trees by trapping soil and litter and providing shade (Maser et al. 1988; Harmon and Franklin 1989). The decomposition of woody material contributes organic matter to the soil and is important for nutrient cycling (Maser et al. 1988; Arthur and Fahey 1990; Edmonds and Marra 1999). Avalanche paths also create discontinuities in otherwise contiguous forests that can influence the spread of fire (Veblen et al. 1994).

Perhaps one of the most important ecological consequences of major snow avalanches affecting subalpine forests is the production of large quantities of downed host material for bark beetles (Coleoptera: Scolytidae) such as the Engelmann spruce beetle (*Dendroctonus rufipennis* Kirby) and the Douglas-fir beetle (*D. pseudotsugae* Hopkins). Endemic populations of these beetles typically infest the inner bark of downed spruce to mate and lay eggs. After hatching, beetle larvae feed and develop within the inner bark until they have reached maturity. The life cycle of bark beetles commonly requires two years, although one and three-year populations often occur. With insufficient quantities of downed host material, newly emerged adults may attack and kill live trees. Local bark beetle mortality is often observed in forests adjacent to avalanche runout zones. Snow avalanches produce downed host material at a time and in an environment optimal for successful spruce beetle colonization and brood production (Hebertson 2004). Spruce beetle and Douglas-fir beetles begin flight in the spring just when melting debris exposes fresh host material. Avalanche debris covering host material helps prevent desiccation and deters competing insects and fungi from initial colonization. The deposition of host material typically coincides with lower slope positions in drainages and creek bottoms and on aspects sheltered from direct sun. These conditions provide an optimal environment for successful spruce beetle colonization and brood production. These beetles may also attack large trees within runout zones that have been seriously injured by avalanche debris.

Bark beetle outbreaks can cause extensive tree mortality. For example since the late 1980's, spruce beetle epidemics have resulted in the deaths of over one million mature and old growth spruce on the Manti-LaSal and Dixie National Forest in south-central and southern Utah (Dymerski et al. 2001; Matthews et al. 2005). Similar levels of spruce mortality were documented for historic epidemics in Utah, Colorado, Arizona and New Mexico during the mid 1800's, 1916-1928, 1940's, and the 1950's.

Extensive bark beetle tree mortality modifies stand structure and species composition in affected forests with reductions in average tree diameter, height, basal area and age (Baker and Veblen 1990; Veblen et al. 1991; Veblen et al. 1994). Heavy tree mortality can adversely affect watershed, timber, wildlife, aesthetics, and recreational resources (Bethlahmy 1974; Schmid and Frye 1977; Holsten et al. 1999). Tree mortality can also alter fuel loads and profile development potentially resulting in high fire hazard over time (Schmid and Frye 1977; Arno 1980, Jenkins et al. 1998). The lack of bare, mineral soil following beetle disturbance may deter the establishment of seedlings (White 1979). Stands affected by past beetle outbreaks generally have a scarcity of old trees and non-host species typically become stand dominants (Veblen et al. 1994; Jenkins et al. 1998).

Unprecedented large, widespread avalanche cycles during the winters of 1982 to 1986 may have contributed to the most recent spruce beetle epidemic on the Wasatch Plateau in south-central Utah (Hebertson and Jenkins 2004). Small pockets (1-10 trees) of spruce beetle mortality were first aerially detected on the Wasatch Plateau in 1986 in the vicinity of several large avalanche paths. The occurrence of avalanches dated in these paths fit within the time frame expected for spruce beetle populations to build in host material and initiate attacks on live trees.

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