39

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Restoration as a Mechanism to Manage Southwestern Dwarf Mistletoe in Ponderosa Pine Forests

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Intermountain West Frequent-Fire Forest Restoration

Ecological restoration is a practice that seeks to heal degraded ecosystems by reestablishing native species, structural characteristics, and ecological processes. The Society for Ecological Restoration International defines ecological restoration as "an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability….Restoration attempts to return an ecosystem to its historic trajectory" (Society for Ecological Restoration International Science and Policy Working Group 2004).

Most frequent-fire forests throughout the Intermountain West have been degraded during the last 150 years. Many of these forests are now dominated by unnaturally dense thickets of small trees, and lack their once diverse understory of grasses, sedges, and forbs. Forests in this condition are highly susceptible to damaging, stand-replacing fires and increased insect and disease epidemics. Restoration of these forests centers on reintroducing frequent, low-severity surface fires—often after thinning dense stands—and reestablishing productive understory plant communities.

The Ecological Restoration Institute at Northern Arizona University is a pioneer in researching, implementing, and monitoring ecological restoration of frequent-fire forests of the Intermountain West. By allowing natural processes, such as low-severity fire, to resume self-sustaining patterns, we hope to reestablish healthy forests that provide ecosystem services, wildlife habitat, and recreational opportunities.

ERI working papers are intended to deliver applicable science to land managers and practitioners in a concise, clear, non-technical format. These papers provide guidance on management decisions surrounding ecological restoration topics. This publication would not have been possible without funding from the USDA Forest Service and the Southwest Fire Science Consortium. The views and conclusions contained in this document are those of the author(s) and should not be interpreted as representing the opinions or policies of the United States Government. Mention of trade names or commercial products does not constitute their endorsement by the United States Government or the ERI.

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Cover photo: Southwestern dwarf mistletoe sprouts on a ponderosa pine branch. Dwarf mistletoe is an endemic species to southwestern ponderosa pine forests. It provides high ecological value and ecosystem function through wildlife habitat via food sources, nesting and hiding cover, and creates snags when older trees die from infestation. *Photo by Mary Lou Fairweather*

Table of Contents

Introduction

Forest conditions in the southwestern United States are often the legacy of past land use since Euro-American settlement, including historical fire suppression, livestock grazing, and logging practices (Cooper 1960, Covington and Moore 1994). These forests are often the focus of restoration and fuels reduction projects to address altered stand structure and dense forest conditions. Increased wildfire activity and a higher frequency and intensity of fire and wildfire risk has led to concerns about the effectiveness of current forest management practices across western landscapes. Dense stands with small-diameter trees are more likely to experience extreme fire behavior (Fulé et al. 2001, 2002), and these dense stands alter insect and pathogen/disease activity. For example, trees in dense stands are less resistant to bark beetle attack (Parker et al. 2006, Hoffman et al. 2007) and stands with severe dwarf mistletoe infestations have higher fuels (Hoffman et al. 2007) that may increase fire intensity (Harrington and Hawksworth 1990, Conklin and Geils 2008).

Dwarf mistletoes (*Arceuthobium spp*) have been recognized as forest pathogens since the late 1800s (Woolsey 1911, Hedgecock 1915). Dwarf mistletoes are endemic parasitic flowering plants that are host specific and depend entirely on their host for nutrients and water. Dwarf mistletoe causes direct damage to trees by reducing tree growth, causing branch deformity and witches' brooms, decreasing tree longevity and vigor, and increasing susceptibility to bark beetle attacks (Hawksworth and Weins 1996). Southwestern dwarf mistletoe (*Arceuthobium vaginatum* subsp. *cryptopodum*) is a common parasite of ponderosa pine (*Pinus ponderosa*) in the southwestern United States and northern Mexico (Hawksworth and Wiens 1996). Dwarf mistletoes spread primarily via ballistic seed, and spread occurs from tree to tree and within the crowns of previously infested trees (Conklin 2000). Spread is relatively slow, averaging 1–2 feet per year horizontally through a forest (Hawksworth and Gill 1960). Mistletoe infection is a dynamic process, where already infected areas tend to become more infected over time (Conklin 2003). However, historic levels of dwarf mistletoe were thought to be relatively high in the region (Woolsey 1911, Conklin and Fairweather 2010). Box 1 discusses historic and current levels of mistletoe infection.

At both the stand and landscape level the distribution and abundance of dwarf mistletoe is patchy and not uniform (Conklin and Fairweather 2010). Dwarf mistletoe is often characterized by infection centers of groups of trees surrounded by areas without the disease. This can range from just a few trees to a few acres of infected trees (Conklin and Fairweather 2010). The abundance and distribution of mistletoe varies widely across the landscape, and efforts should focus on reducing levels of infestations and not eradicating the pathogen (Conklin and Fairweather 2010).

It is thought that roughly one-third of the ponderosa pine acreage in Arizona and New Mexico has some level of mistletoe infestation (Andrews and Daniels 1960, Maffei and Beatty 1988), and up to one-half of the mixed conifer acreage in the Southwest has some dwarf mistletoe present (Conklin and Fairweather 2010), although intensity of infestation varies widely across the region.

Dwarf mistletoes can substantially influence forest structure by causing reduced growth and seed production and death of severely infected trees (Hawksworth and Geils 1990, Hawksworth and Wiens 1996, Geils and Hawksworth 2002). Tree growth and vigor decline when more than half the crown is parasitized. Hawksworth (1977) developed a standard six-class dwarf mistletoe rating (DMR) system to quantify infection severity that can be characterized at the individual tree or stand level. Lightly infected trees (DMR 1–2) can survive for several decades, and generally, smaller infected trees die more quickly than larger infected trees (Hawksworth and Geils 1990). It is important to take a holistic approach to mistletoe management in an ecological framework and in a landscape context, especially in forests where timber production is not a primary objective.

Box 1: Historic and current mistletoe levels

Dwarf mistletoes are endemic to forest ecosystems and have evolved in western North American forests for tens of thousands of years (Hawksworth and Wiens 1996). Current distribution of mistletoe is thought to be relatively similar to mistletoe distribution 150 years ago (Dahms and Geils 1997, Conklin and Fairweather 2010). However, mistletoe abundance is probably greater today than in the 1800s because the abundance of trees across the landscape is higher, and the density of trees is significantly higher in ponderosa pine forests (Conklin and Fairweather 2010). Historical grazing practices and fire exclusion have allowed natural openings to infill with regeneration and young established trees, thus facilitating the spread of mistletoe from infested stands to new areas. Within the landscape, dwarf mistletoe has spread into some previously un-infested stands, however, much of it is attributed to spreading into previously existing openings within already infested stands (Conklin and Fairweather 2010). Quantifying dwarf mistletoe abundance and distribution across the region should consider historic levels of infestation, the effects of past management efforts, and forest and landscape changes from historic conditions (Conklin and Fairweather 2010).

Dwarf mistletoe also provides high ecological value and ecosystem function. Mistletoe provides wildlife habitat via food sources, nesting and hiding cover, and creates snags when older trees die from infestation. Stand conditions have changed significantly since Euro-American settlement. Fire suppression, livestock grazing, and silvicultural practices have dramatically increased tree densities throughout many parts of the Southwest (Cooper 1960, Covington and Moore 1994, Saab et al. 1995, Mast et al. 1999, Grissino-Mayer and Swetnam 2000). Stands with dense thickets of young small-diameter trees are common where small groups of large-diameter trees once dominated the forest. Many ponderosa pine forests in the Southwest are managed primarily in an ecological framework, and not for timber products. Ecological based forest management includes multiple use management that should incorporate dwarf mistletoe as part of the ecosystem.

A dwarf mistletoe shoot extends from the branch of a ponderosa pine tree. *Photo by Robert L. Mathiasen*

Ecological restoration aims to return forest conditions to within the natural range of variation, including tree density, stand structure and composition, age and diameter distributions, and endemic species (Covington and Moore 1994). Prescriptions are based on site history, using evidence of historical stand conditions via stumps and dendroecology (Kaufmann et al. 1998, Moore et al. 1999). Managing for groups and openings of ponderosa pine trees that are characteristic of southwestern forests can help moderate the spread and intensification of dwarf mistletoe, helping to reduce impacts and promote ecological benefits.

The Legacy of Past Management

When dwarf mistletoe was recognized as a forest pathogen in the early 1900s the focus was on controlling the damage to timber production, not managing it as part of the ecosystem (Conklin and Fairweather 2010). Removal of all heavily infected trees was widely implemented across southwestern ponderosa pine forests. Early reports and historical photos provide evidence of dwarf mistletoe infestation (see MacDougal 1899, Woolsey 1911, Korstian and Long 1922); however, less is known about the abundance and distribution of mistletoe across the region before 1850 (Conklin and Fairweather 2010).

When timber production was a primary objective in the Southwest, severely infested stands were thought to require sanitation cuts, using overstory removal and seed tree cuts that reduced overall canopy cover and reduced the age distributions of trees (Herman 1961, Heidmann 1968, Conklin and Fairweather 2010). Overstory removal cuts were thought to eliminate major sources of infection, but actually stimulated infection already present in the understory (Conklin 2000). Hawksworth (1961) recommended removal of all infected trees with follow-up treatments 5 years later and a third entry within 5–10 years was needed to keep mistletoe levels at low, non-damaging levels. This management approach didn't work because the follow-up entries using mechanical means were not implemented in many areas, and therefore stimulated new infection in these areas. Research in New Mexico and Arizona has demonstrated that in stands managed for timber commodities where all or most of infested trees were removed, with one or more follow-up mechanical treatments at 5 year intervals, dwarf mistletoe levels were decreased but never eliminated, and repeated entries are necessary every 5 years to keep levels of infestation low. Latent infections are prevalent in areas where mechanical treatments were used without follow-up use of prescribed fire.

Throughout the 1960s–1980s, aggressive efforts were made across the Southwest to control mistletoe infestations where selective and partial cuts were implemented to thin the severely infected overstory trees. While temporary reduction in mistletoe was achieved by removing sources of infestation in the overstory, high levels of infection were left in the understory (Conklin and Fairweather 2010). Few treatments in the region involved final sanitation entries and complete stand replacement, instead, the dominant overstory was removed and replaced by younger infested stands (Conklin and

Fairweather 2010). Even-aged management was then widely implemented on federal lands (Beatty 1982, USDAFS 1985), and through the 1990s overstory removal and seed tree cuts were implemented across the region (Conklin and Fairweather 2010). However, final entries often were never completed and therefore left an infested understory within the stand.

Mistletoe infection levels today are a result of previous management practices across the West, especially selection cutting (Conklin and Fairweather 2010). The majority of stand entries in the region have been selective and partial cuts that tended to favor mistletoe spread and release, as it persists and tends to increase after harvest and mechanical thinning (Conklin 2003, Bickford et al. 2005). Following treatment, mistletoe shoot growth is greater on trees with high uptake of water and carbon (Bickford et al. 2005), so mistletoe tends to appear to increase at a faster rate following thinning (Conklin 2003, Bickford et al. 2005) due to latent infections that thrive and produce more shoots and seeds (Hawksworth 1978, Parmeter 1978). Monitoring of ponderosa pine stands in Arizona and New Mexico, where all or most of visibly infected trees were removed, demonstrated that stand infestation levels return to pre-treatment levels within 20 years without retreatment and re-entry or use of prescribed fire (Hessburg et al. 2008, Geils unpub data).

Eventually, management focus moved toward ecological management (Dahms and Geils 1997, Conklin and Fairweather 2010) that incorporated dwarf mistletoe into the stand and landscape as having ecological function and value. Management efforts should be based on the specific needs and objectives for each area, within a framework that considers the overall landscape and forest conditions (Conklin 2000). While the number of infected trees has likely substantially increased across the landscape, the actual proportion of the landscape with mistletoe infection has likely increased only modestly from historic levels because of the relatively slow rate of mistletoe spread (Conklin and Fairweather 2010).

Ecological and Wildlife Value of Southwestern Dwarf Mistletoe in Southwestern Forests

Dwarf mistletoe is part of the forest ecosystem and increases biodiversity within the forest (Tinnin 1984, Bennetts and Hawksworth 1991, Mathiasen 1996, Watson 2001) (Box 2). Dwarf mistletoe is beneficial to a multitude of species including insects, birds, and mammals by providing food sources, storage sites, resting areas, and nesting sites (Hawksworth and Geils 1990, Hawksworth and Wiens 1996, Mathiasen 1996).

Squirrels, porcupines, and deer eat dwarf mistletoe shoots and cambium (Hawksworth and Weins 1966, Hedwall et. al. 2006). Ungulates and grouse eat fruits and shoots of dwarf mistletoe (Severson 1986). Abert's squirrels (*Sciurus aberti*) use mistletoe infested trees for caching, foraging, and nesting (Garnett et al. 2006), and as the number of branches within a broom and tree height increase so does the probability of use by Abert's squirrels (Garnett et al. 2006). Mexican spotted owls (*Strix occidentalis lucida*) and other raptors use witches' brooms as nesting structures (Seamans and Gutiérrez 1995, Hawksworth and Wiens 1996 (see table 8.3), May et al. 2004, Ganey et al. 2013).

Box 2: Dwarf mistletoe infestation has unique ecological features

Stands infested with dwarf mistletoe have positive attributes such as edible fruit and shoots, witches' brooms, and altered forest structure (Mathiasen 1996). Large infested trees with witches' brooms have high ecological and biodiversity value for birds and mammals. Witches' brooms and snags create and enhance wildlife habitat by providing structural diversity (Tinnin et al. 1984, Bennets et al. 1996, Mathiasen 1996, Hedwall et al. 2006). Infested areas have tree mortality, witches' brooms, and deformed branches. Over time, severe infection creates snags that multiple species of wildlife use to meet their life history needs. Infection centers are often hundreds of years old. Over time, these areas become more open with lower canopy cover and basal area than the surrounding forest. Some older, severely infested stands should be managed as long-term wildlife habitat (Conklin 2000, Conklin and Fairweather 2010, Parker et al. 2017).

Conservation of owl nesting habitat in the Southwest now includes retaining large trees with dwarf mistletoe witches' brooms (Hedwall et al. 2006, Ganey et al. 2013).

Several species of songbirds nest and forage for insects in witches' brooms (Hudler et al. 1979, Bennetts 1991, Bennetts et al. 1996, Parker et al. 2017). Insect abundance and richness was greater in witches' brooms than non-broomed branches in Douglas fir (Smith et al. 2013). Birds use heterogeneous tree and canopy structures resulting from mistletoe infestation (Reich et al. 2000). Cavity-nesting birds nest in snags created by mistletoe infection, and bird abundance was higher in ponderosa pine stands that were severely infested by mistletoe in Colorado (Bennetts et al. 1996).

Dwarf mistletoe can cause deformities in ponderosa pine trees, like this witches' broom. Witches' brooms create ideal nesting sites, like this robin's nest. *Photo by Robert L. Mathiasen*

Increased Wildfire Intensity in Mistletoe Infested Stands

While there is ecological benefit of dwarf mistletoe, forests with severe dwarf mistletoe infestations have a higher wildfire risk and can experience more intense and severe fire events (Harrington and Hawksworth 1990). Fuel loadings are higher in mistletoe infected stands (Koonce and Roth 1985, Harrington and Hawksworth 1990, Hoffman et al. 2007, Stanton and Hadley 2010, Klutsch et al. 2014), and stand-replacing fires are more likely in severely infested pine forests (Alexander and Hawksworth 1975, Koonce and Roth 1985, Harrington and Hawksworth 1990, Parker et al. 2006, Stanton and Hadley 2010). Branching patterns, resin accumulation, and increased tree mortality are factors contributing to increased flammability (Conklin and Fairweather 2010). Witches' brooms affect stand structure and tree flammability by increasing the amount of tree resin and lowering crown base heights (Hoffman et al. 2007). Tree mortality from mistletoe infestation creates snags and enhances snag density that can increase fuel loads as dead trees fall to the forest floor (Hoffman et al. 2007). Natural fires can help maintain lower levels of mistletoe on the landscape, and some heavily infested stands may warrant being deferred to mechanical treatment and be allowed to burn via prescribed fire or natural fire events.

Stands with insect outbreaks and dwarf mistletoe may be more susceptible to experience extreme fire behavior (Fulé et al. 2001, 2002), and the interactions of stands impacted by bark beetles and other insects with pathogens such as mistletoe are thought to intensify fire behavior and spread (Parker et al. 2006, Hoffman et al. 2007). Dense stands with small-diameter trees that have also been exposed to insect and disease outbreaks are believed to be more likely to experience extreme fire behavior (Fulé et al. 2001, 2002).

Ecological Restoration and Mistletoe Management

The goal of ecological restoration is to return forests to pre Euro-American settlement forest conditions in terms of stand structure, density, groups and openings, and forest fuels (Covington et al. 1997). Variability across the landscape exists in terms of these factors, and the goal of restoration is to capture this system variability using historical site evidences. Treatments are designed to emulate forest structure, composition, and function characteristic of the natural evolutionary environment (Covington et al. 1994, Moore et al. 1999). Additionally, all trees alive at the time of fire exclusion (presettlement) are retained within the stand. Today's forests are deficient in large, old trees, which have unique structural characteristics and represent centuries of genetic diversity (DeWald and Mahalovich 1997, DeWald 2008). Old trees have greater genetic diversity than even-aged groups of young trees, the majority of which established post fire-exclusion (DeWald and Mahalovich 1997). Trees that establish outside of their evolutionary envelope may lack key adaptive traits to survive natural disturbances. Additionally, trees 200+ years old have survived large climatic fluctuations and may provide forests a better chance of adapting to changing climatic conditions and other environmental factors (DeWald and Mahalovich 1997). More than a century of fire suppression and exclusion and an increased density of young trees has favored dwarf mistletoe abundance and distribution (Parker et al. 2006).

In northern Arizona, past management and lack of fire have allowed presettlement stumps, snags, and logs to persist on the landscape. These legacy structures can serve as a guide for the design of restoration treatments. Reconstructions using historic evidence are around 91 percent accurate in blind comparisons to historic stem-maps (Moore et al. 2004). Restoration treatments retain all presettlement trees and use mechanical thinning followed by prescribed fire to reduce post-settlement stem densities and fuel loads. Restoration treatments that significantly reduce tree density within a stand can be used to manage dwarf mistletoe abundance and spread (Conklin and Fairweather 2010).

Ecological restoration treatments using mechanical thinning and prescribed burning treatments offer tools to mitigate mistletoe spread and intensification. Dwarf mistletoe spreads mainly via ballistic seed; lateral tree-to-tree spread is common (Conklin 2000) and spread from overstory to understory trees is rapid (Hawksworth 1961). Some old presettlement trees with mistletoe infestation are often targeted in traditional silvicultural techniques for the management of mistletoe. However, some of these trees should be retained for ecological value and because infection growth is slower in these larger old trees. Maintaining the distance between neighboring groups of trees and infection centers, tree crowns and infested trees, and reducing stand density are some restoration practices that can aid in the mitigation of dwarf mistletoe spread (Parker et al. 2006, Conklin and Fairweather 2010). Facilitating regeneration is not a primary goal of ecological restoration. The goal is to reduce stand densities that are uncharacteristic of the site, and return the stand to presettletment tree densities and characteristic tree groups and openings.

Mistletoe spreads more quickly in dense stands of evenly spaced trees than in groups of trees and openings that were more common in this area before 1870 (Hawksworth 1961). Creating and maintaining more openings and interspaces on the landscape would tend to reduce overall spread (Conklin 2000). Creating openings and interspace of 40–60 feet (or larger depending on the site) by thinning trees beyond margins of visible infections can help mitigate the effects of latent infections (Conklin and Fairweather 2010). In some cases, these openings can be used to isolate infestations, and distance between groups of trees can be used to prevent spread when groups of infested trees are far enough away from healthy groups of trees. Openings and interspaces without host trees can help prevent the spread of mistletoe if they are wider than the distance seeds can be disseminated (~ 40 ft) (Conklin 2000, Conklin and Fairweather 2010). In all cases, prescribed fire will need to be used in these openings and interspaces either pre or post-treatment to prevent infected regeneration within these newly created openings. Multiple re-entries with prescribed fire are necessary to inhibit new regeneration from infection in these sites for many years.

Data on mistletoe abundance and distribution are limited to research studies, often written in non-peer reviewed publications, and often do not exist on a stand or at the landscape level. Most studies on restoration treatments have little data on long-term monitoring, and have used models to simulate the spread of mistletoe over time. Some recent studies used the forest vegetation simulator (FVS) to model projected spread of dwarf mistletoe post fuels reduction and restoration treatments (Maloney et al. 2008, Hessburg 2008). According to model projections, thinning and burning treatments used together did provide a sanitation effect by lowering levels of dwarf mistletoe, and larger residual trees had lower levels of dwarf mistletoe infestation (Maloney et al. 2008, Hessburg 2008). However, one entry is never enough to achieve desired conditions to keep dwarf mistletoe infestation at desired levels, and multiple follow-up treatments are needed. Dwarf mistletoe infestation returned to pre-treatment levels within 20–50 years in both on-the-ground and model projected experiments (Geils unpublished data, Maloney et al. 2008, Hessburg 2008).

Full ecological restoration treatments can be a viable tool for addressing dwarf mistletoe spread and intensification in ponderosa pine forests. For example, treatment plots at Fort Valley Experimental Forest in Flagstaff, AZ were examined for pre and post-treatment differences in dwarf mistletoe spread and intensification, and mortality rate of infected ponderosa pine trees 10 years post-treatment (Kralicek and Mathiasen unpublished data 2012). Treatment blocks incorporated thinning followed by a low-intensity prescribed fire 1–2 years after they were thinned. Plots examined DMR pre and post-treatment. Restoration treatments were full restoration (1.5/3), modified restoration (2/4), and minimal restoration (3/6) (See Box 3 for description). The full restoration thinning (1.5/3 replacement) was the most effective at reducing the intensification of dwarf mistletoe. The 2/4 replacement also reduced mistletoe intensification moderately over 10 years, but the 3/6 replacement essentially had no effect on reducing dwarf mistletoe intensification treatment (Kralicek and Mathiasen unpublished data 2012). Dense stands of young small-diameter trees have less distance between trees, therefore there is no spacing to impede the spread of dwarf mistletoe within the stand. Ecological restoration treatments based on historical site evidences characterized by groups and openings where trees are spaced beyond the maximum distance of seed dispersal were effective in slowing mistletoe spread (Kralicek and Mathiasen unpublished data 2012).

Thinning treatments that focus on creating characteristic openings and interspaces based on historical evidence within the stand could be effective in mistletoe management and reduction. Reducing the density of trees, creating openings and interspaces between groups of trees, and using frequent prescribed fire to maintain openings are effective tools in addressing mistletoe spread and intensification in southwestern ponderosa pine forests (Conklin and Fairweather 2010). Ecological restoration treatments can be flexible and can retain presettlement large-diameter ponderosa pines that are severely infected for ecological value, and thinning and burning treatments can help prolong the life of large infected trees, which can persist on the landscape for years or turn in to large-diameter snags (Parker et al. 2006, Conklin and Fairweather 2010). Maintaining less dense and more open and park-like forest conditions characteristic of southwestern ponderosa pine forests, composed of scattered groups of ponderosa pine trees with native grasses, forbs, and shrubs can aid in keeping southwestern dwarf mistletoe at acceptable levels. Some heavily infected stands may warrant being deferred from treatment and allowed to become wildlife habitat or burn in a fire event.

Box 3: Treatment descriptions for restoration at Fort Valley Experimental Forest

1.5/3 (full restoration): All presettlement trees retained. Replacement trees left for each presettlement evidence dependent on size: if the replacement trees are more than 16 inches in diameter, 1.5 trees are left standing for each presettlement indicator. If they are smaller, 3 trees are left standing for each indicator.

2/4 (modified restoration): All presettlement trees retained. If the replacement trees are more than 16 inches in diameter, 2 trees are left standing for each presettlement indicator. If they are smaller, 4 trees are left standing for each indicator.

3/6 (minimal restoration): All presettlement trees retained. If the replacement trees are more than 16 inches in diameter, 3 trees are left standing for each presettlement indicator. If they are smaller, 6 trees are left standing for each indicator.

Frequent Fire and Natural Density of Tree Groups and Openings

Fire history is an important driver of dwarf mistletoe distribution across western forests (Alexander and Hawksworth 1975, Koonce and Roth 1985, Hawksworth and Wiens 1996, Conklin and Fairweather 2010). The historical fire regime in ponderosa pine forests in the Southwest was frequent, low-intensity fires (Covington and Moore 1994b, Swetnam and Baisan1996). Frequent fires characteristic of the historical fire regime often reduced mistletoe infection levels, provided natural control of mistletoe, and would have kept forests more open, limiting tree-to-tree spread. (Alexander and Hawksworth 1975, Harrington and Hawksworth 1990, Hoffman et al. 2007). Disruption of the natural fire regime has increased the severity and distribution of dwarf mistletoe (Maffei and Beaty 1988, Hawksworth and Wiens 1996, Conklin 2000, Conklin and Fairweather 2010). More than a century of fire suppression has been favorable to dwarf mistletoe abundance, as the increased density of trees facilitates spread of the pathogen (Parker et al. 2006, Conklin and Fairweather 2010).

Prescribed fire is a tool to directly manage and reduce potential spread of dwarf mistletoe (Alexander and Hawksworth 1975, Conklin and Armstrong 2001, Conklin and Geils 2008). Prescribed fires are effective at reducing the spread of mistletoe, especially when implemented together with thinning treatments (Parker et al. 2006, Hessburg et al. 2008). Periodic, moderate intensity fires can inhibit new regeneration in a stand, eliminate infected regeneration, and maintain openings (Alexander and Hawksworth 1975). Fire can prune

A young, local infection of southwestern dwarf mistletoe causes a ponderosa pine branch to swell. *Photo by Mary Lou Fairweather*

infected trees by scorching infected branches and witches' brooms, inflict mortality on severely infested trees, and reduce seed crops of mistletoe plants via smoke and heat (Koonce and Roth 1980, Conklin and Armstrong 2001). Prescribed fires are necessary in severely infested stands where surface fuel levels are higher due to resinous witches' brooms, dead branches, and snags (Conklin and Armstrong 2001, Koonce and Roth 1985).

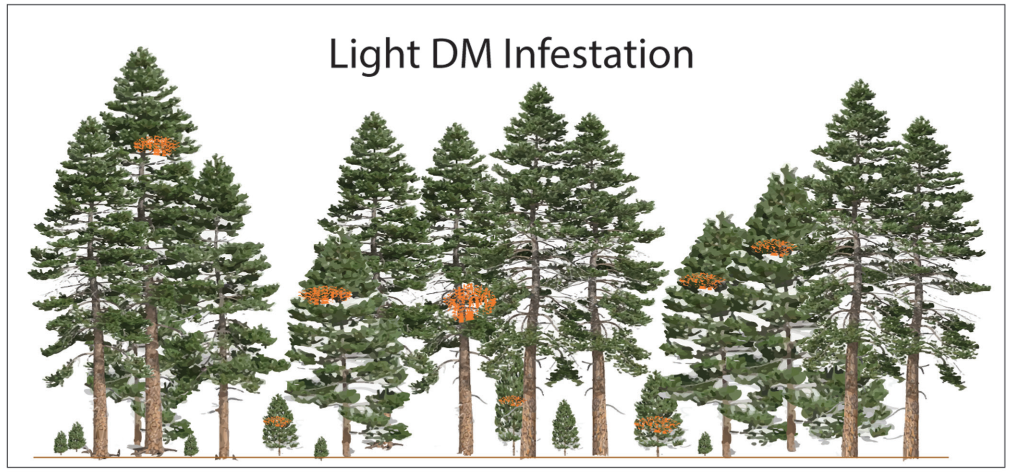
Thinning and burning have proved to be effective tools toward achieving management goals and addressing mistletoe infection levels (Harrington and Hawksworth 1990, Conklin and Armstrong 2001, Conklin and Geils 2008); and repeated entries are needed to achieve these goals. The return of fire to the landscape is a necessary management tool in addressing mistletoe spread and intensity. Moderate severity fire, underburning, and torching of the lower branches has proven effective in reducing southwestern dwarf mistletoe in ponderosa pine forests (Alexander and Hawksworth 1975, Conklin and Geils 2008). Underburning and scorching of infected trees can help keep the disease in check if sufficient torch levels are achieved without killing the tree. For example, underburning, where an average of 50 percent crown scorch is achieved, can set back dwarf mistletoe infection levels 10 years (Conklin and Geils 2008). In ponderosa pine forests, stand level DMR declined 0.3–1.6 percent 3–8 years following prescribed burns, and the proportion of infected trees declined 5–18 percent (Conklin and Armstrong 2001).

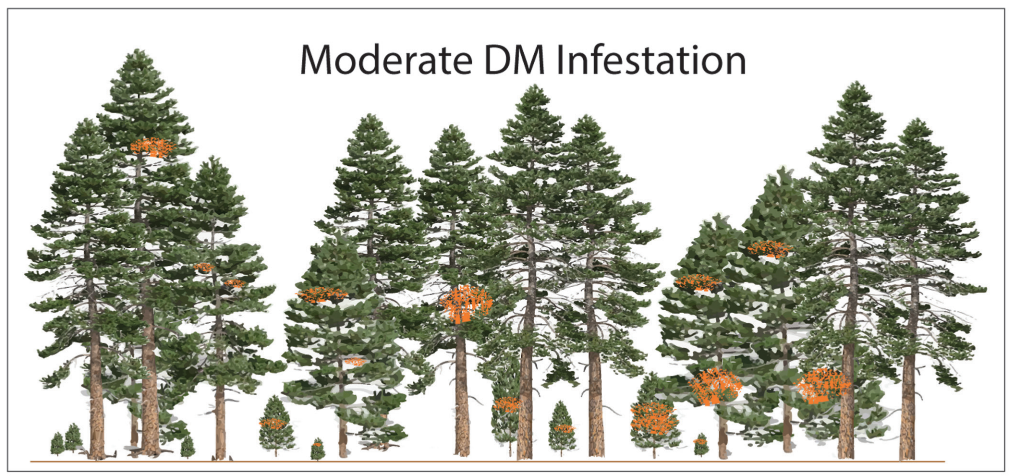
In recent years, managers recognize the need to restore the natural fire regime to our forests by implementing fuels reduction and forest restoration programs in the western United States. The Healthy Forest Initiative (2002) and the Healthy Forests Restoration Act of 2003 aim to reduce wildfire risk across western forests using thinning and prescribed fire treatments. Fuels treatments (mechanical thinning and burning) are common in many western forests to reduce wildfire risk and return forests to the natural range of variability in terms of tree density, size and age classes, and fuel loads. Thinning and burning treatments used together can reduce mistletoe severity in all size classes and show a modeled trend of reduced dwarf mistletoe spread and intensification over time for actively treated areas (Hessburg et al. 2008). Treatment effects diminish after 20 years, so re-treatment is necessary via multiple follow-up entries. Many southwestern ponderosa pine forests are currently identified to be actively managed in order to decrease the risk of catastrophic wildfire, therefore allowing an opportunity to effectively manage southwestern dwarf mistletoe and enhance wildlife habitat.

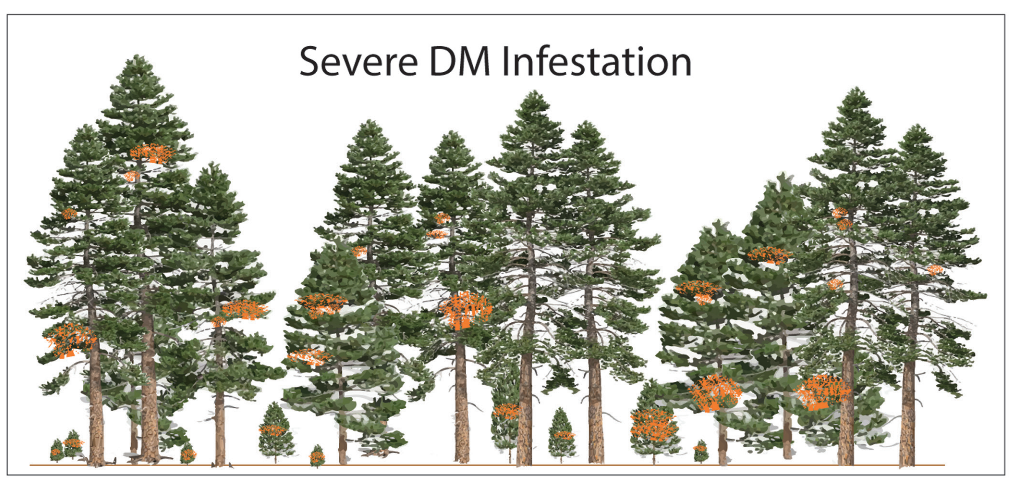
Management Prescriptions

Here we describe ecological restoration prescriptions and compatible silvicultural prescriptions for dwarf mistletoe in southwestern ponderosa pine stands (Figure 1). Prescriptions should be based on stand infestation level, site productivity, and management objectives. A walk-through of the stand to determine infestation levels is always necessary before making prescription decisions or marking trees. Flexibility is key, as mistletoe infestation can be a gradient within the stand with severe infestation in some areas and light infestation within others. Management should be flexible and based on improving forest health and achieving desired forest conditions while providing ecological value across the landscape. The presence of dwarf mistletoe in a stand should not influence treatment priorities (Conklin and Fairweather 2010). Use of prescribed fire and thinning can be beneficial to reduce fuels and fire risk, provide wildlife habitat, and improve the growth of remaining trees and vegetation (Conklin and Fairweather 2010). On productive sites with effective tree spacing, tree growth will outpace the spread and intensification of dwarf mistletoe. Larger infected trees can survive for decades, as mistletoe infection intensifies at a slower rate in these large trees, and prescriptions can include retaining some large, severely infected presettlement trees within some groups. Severely infested stands may be deferred from management. Use of prescribed fire and re-treatment is necessary.

Figure 1. Describes ecological restoration prescription and provides compatible silvicultural prescriptions to address southwestern dwarf mistletoe on a stand-by-stand basis.



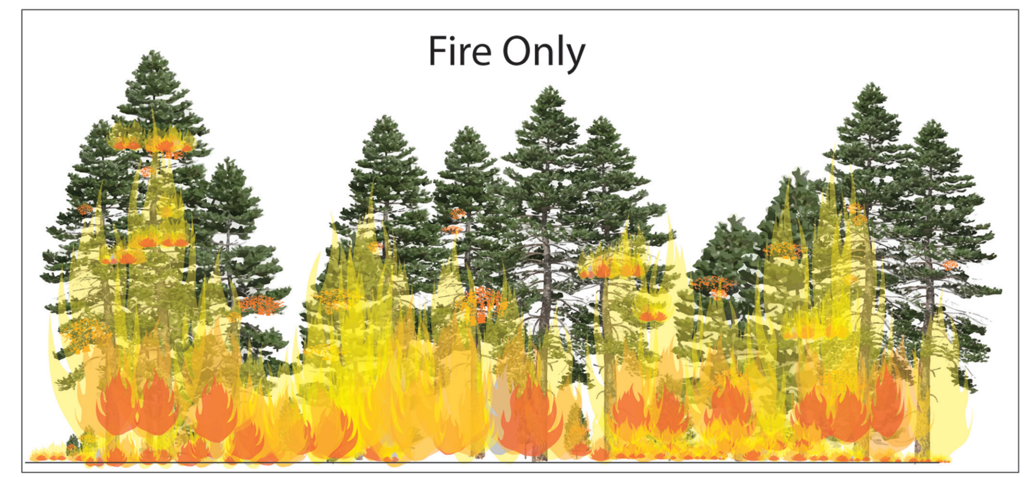




This figure portrays southwestern dwarf mistletoe within a landscape context. Prescriptions are at the stand level, but management goals and overall landscape objectives will need to be taken in to account. For example, if near the WUI, use of fire only may not be feasible. Prescriptions are flexible, and a stand walk through and assessment of DM infestation and DMR rating is always necessary.

Presettlement trees means all trees that established when natural disturbance processes were intact.

Use historic site evidences to inform stand density and presettlement leave trees. Maintain groups of presettlement trees with openings and interspaces. Thinning of infested understory and dense trees complements management. Regeneration maintained at historic levels with fire. Repeated entries with prescribed fire are necessary.



Compatible Silvicultural Prescription

Light to Moderate DM infestation:

- Uneven-aged prescriptions that are relatively open, maintaining groups of presettlement trees (old trees) with interspaces and openings (40-80 ft between groups).
- Group selection with thinning in the matrix; Retain all presettlement trees and use interspaces and openings with intergroup spacing of 40-80 ft.
- Be flexible and take advantage of opportunities to leave size/age class diversity.
- Repeated entries with prescribed fire are necessary to maintain openings.

Moderate to Severe DM infestation:

- Even-aged management maintaining groups of presettlement trees and openings (40-80 ft between groups).
- Group selection with thinning between groups. Retain all presettlement trees and remove all blackjacks. Maintain openings and interspaces (40-80 ft between groups).
- Be flexible. If DM infestation is patchy, may need to divide up stand at treat accordingly. Take advantage of opportunities to leave size/age class diversity.
- Repeated entries with prescribed fire are necessary to maintain openings.

Severe DM infestation:

- Use of fire only. Severely infested stands may be deferred and allowed to burn or left as wildfire habitat.

Summary

Southwestern dwarf mistletoe is part of the ponderosa pine ecosystem and should managed accordingly — whether it is to provide wildlife habitat, reduce fire risk, or improve timber resources. The management objectives will determine the levels of dwarf mistletoe left within a stand. Dwarf mistletoe stand level infestation increases relatively slowly, allowing time to plan management activities and re-entries. Infested trees can live for decades and provide snags that promote structural diversity within a stand. Southwestern dwarf mistletoe affects all sizes and ages of trees. Lightly infected trees can survive for several decades, and smaller, severely infected trees die more quickly than larger infected trees (Hawksworth and Geils 1990).

The overall distribution of dwarf mistletoe and the percentage of the landscape affected by dwarf mistletoe is thought to have only modestly increased from historic conditions; however, the overall intensity and abundance of mistletoe is thought to have increased (Conklin and Fairweather 2010), likely due to the increased density of trees. Dwarf mistletoe is part of the forest ecosystem and increases biodiversity within the forest (Tinnin 1984, Bennetts and Hawksworth 1991, Mathiasen 1996, Watson 2001). Dwarf mistletoe is beneficial to a multitude of species including insects, birds, and mammals by providing food sources, storage sites, resting areas, and nesting sites (Hawksworth and Geils 1990, Hawksworth and Wiens 1996, Mathiasen 1996).

Mistletoe infection levels today are a result of previous management practices across the West, especially selection cutting (Conklin and Fairweather 2010), where selective and partial cuts tend to favor mistletoe spread and release after thinning (Conklin 2003, Bickford et al. 2005). Selection cuts should be avoided, and prescriptions should be based on a stand exam of mistletoe infestation levels, site productivity, and management objectives. Fire suppression and selection cutting have been important drivers of dwarf mistletoe intensification and distribution across western forests (Alexander and Hawksworth 1975, Koonce and Roth 1985, Hawksworth and Weins 1996, Conklin 2000). Disruption of natural fire regimes has increased the severity and distribution of dwarf mistletoe across the landscape (Maffei and Beaty 1988, Hawksworth and Weins 1996, Conklin 2000, Conklin and Fairweather 2010).

Using ecological restoration principles, managers can design treatments that restore groups of presettlement trees and openings where overall stand health is improved to address mistletoe spread and intensification. Reducing the density of trees, creating openings and interspace between groups of trees, and using prescribed fire of sufficient intensity to maintain openings are all effective tools in addressing mistletoe spread and intensification in southwestern ponderosa pine forests (Conklin and Fairweather 2010). Healthy stands can have a manageable amount of mistletoe within them. Use of prescribed fire can reduce the incidence of mistletoe, especially when used in tandem with mechanical thinning treatments (Parker et al. 2006, Hessburg et al. 2008). Periodic low-intensity fires can inhibit new regeneration in a stand, eliminate infected regeneration, and maintain openings (Alexander and Hawksworth 1975). Use of moderate intensity fire can prune infected trees by scorching lower infected branches and witches' brooms, inflict mortality on severely infested trees, and reduce seed dispersal from mistletoe plants via smoke and heat (Koonce and Roth 1980, Conklin and Armstrong 2001).

Management should focus on improving the health of remaining trees, forest health, maintaining biological diversity, stand dynamics, and reducing fire risk by reducing uncharacteristic tree densities. Management should be based on the specific needs and objectives for each area, within a framework that considers the overall landscape and forest conditions (Conklin 2000). Silvicultural prescriptions should incorporate mistletoe as an important wildlife habitat component, and management should focus on managing dwarf mistletoe as part of the stand, not controlling or eradicating it.

Climate, site microclimates, past management efforts, and fire history are all important drivers of current dwarf mistletoe abundance and distribution (Parker et al. 2006, Conklin and Fairweather 2010). The interaction between climate, fire, insects, and disease can have large effects on western forests and are likely to become more pronounced in the future, especially during drought years and climate oscillations. Trees that are stressed and weakened by insects and/or pathogens are more susceptible to mortality during fire events (Harrington and Hawksworth 1990, Conklin and Armstrong 2001). Genetics of host and pathogen and the interactions in the environment will also be important variables in future dwarf mistletoe abundance and distribution.

Management Recommendations

- Forest restoration treatments that return and maintain ponderosa pine forests within their evolutionary envelope of forest structure and natural disturbances is an effective tool to address mistletoe spread and intensification in southwestern ponderosa pine forests.
- In lightly and moderately infested stands, restoration treatments that thin uncharacteristically dense stands can be effective in addressing dwarf mistletoe intensity.
- Retain presettlement trees, even if dwarf mistletoe is present.
- Prescribed fire at sufficient intensity can manage dwarf mistletoe levels; however one entry is rarely enough to achieve desired conditions. Multiple entries are needed and should be planned for.
- Some severely infested stands should be deferred from treatment and allowed to burn or be managed for wildlife habitat.
- Be flexible. If dwarf mistletoe infestation is patchy, managers should divide up the stand and treat accordingly. Take advantage of opportunities to leave size and age class diversity.

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